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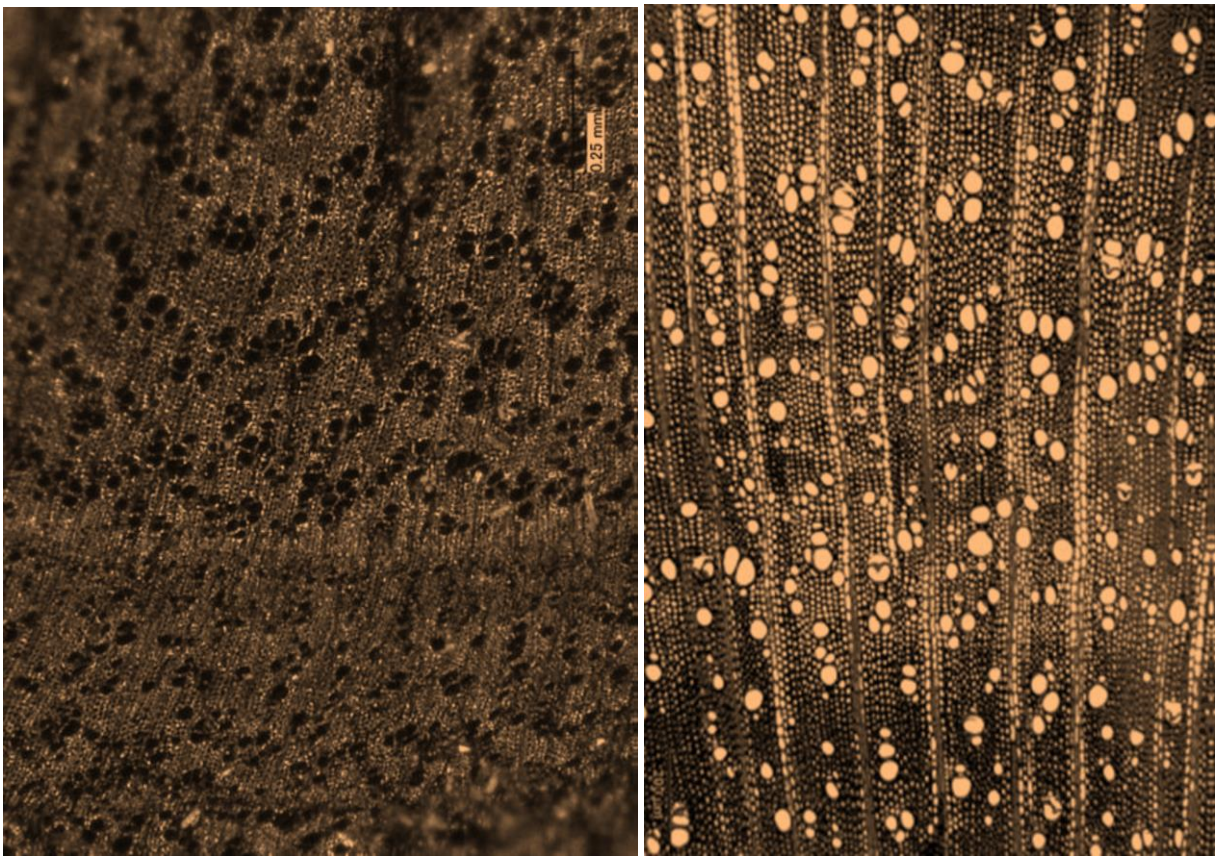

Human-Environment Interactions in the Bale Mountains During the Late Pleistocene and Holocene Epochs: Anthracological Study

By
Tefera Tarekegn

August 2021

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Human-Environment Interactions in the Bale Mountains During the Late Pleistocene and Holocene Epochs: Anthracological Study

A Thesis Submitted to the College of Social Sciences in Partial Fulfillment of the Requirements for the Degree of Master of Arts in Archaeology Department of Archaeology and Heritage Management

By

Tefera Tarekegn

Advisor: Alemseged Beldados (Ph. D)

Co-advisor: Götz Ossendorf (Ph. D)

Addis Ababa University

Addis Ababa, Ethiopia

August 2021

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

This is to certify that the thesis prepared by **Tefera Tarekegn Bayu**, entitled **"Human-Environment Interactions in the Bale Mountains during the Late Pleistocene and Holocene Epochs: Anthracological Study",** submitted in partial fulfillment of the requirements for the degree of Master of Arts in Archaeology compiles with the regulations of the university and meets the accepted standard with respect to originality and quality.

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Acronyms

AHP	African Humid Period
ARCCH	Authority for Research and Conservation of Cultural Heritage
BMNP	Bale Mountain National Park
BMs	Bale Mountains
BO	Black Organic
BOG	Black organic with Gravel
Cal	Calibrated Age
CSA	Central Statistics Agency of Ethiopia
CWD	Compact Wet Dung
EWCA	Ethiopia Wildlife Conservation Authority
FDD	Fine Dry Dung
FHL	Fincha Habera Layers
IAWA	International Association for Wood Anatomists
LB	Loamy Belts
LGM	Last Glacial Maximum
LSA	Late Stone Age
MEH	Mountains Exile Hypothesis
MIS	Marine Isotope Stage
MSA	Middle Stone Age
PLE	Principles of Least Effort
UNESCO	United Nation Educational Scientific and Cultural Organization

Abstract

This thesis presents results of the analysis of the anthracological remains excavated from 10 archaeological sites located in the Bale Mountains. These sites yielded hundreds of anthracological remains collected from the early LSA occupation phase to the early arrival of pastoral phase in the BM covering a period between ~15-0ka cal. BP. The aims of the present study are: to reconstruct firewood collection strategies used by the prehistoric group in the Bale Mountains, to investigate the nature of vegetation history, to shed new light on the poorly understood environmental conditions during human occupation phases in the Bale Mountains, and to understand interactions between past humans and their environment in African high-altitude ecozones.

The anthracological investigation was conducted on a total of 565 charcoal macro-remains obtained from various excavated sites. From the samples, a total of 366 anthracological samples were identified in their respective taxa from which seven different plant spices were documented. The recorded taxa include Erica arborea (n=90), Myrsine africana (n=82), Solanum giganteum (n=51), Artemisia afra (n=47), Hagenia abyssinica (n=44), Hypericum revolutum (N=31) and Juniperus procera (n=21)

The results of antrhacological analysis show the presence of varied vegetation cover and environmental conditions in the sites located along the plateau and northern escarpments of the BMs. The finding of this study also demonstrates that prehistoric hunter-gatherers used different ecological zones very variably; the aforementioned plant types namely, Erica arborea, Myrsine africana, Solanum giganteum, Artemisia afra, Hagenia abyssinica, Hypericum revolutum, and Juniperus procera were also available as fire woods.

Key words: Anthracology, Bale Mountain, ecological adaptations, palaeoenvironment, vegetation history

CHAPTER ONE

INTRODUCTION

1.1.Background of the Study

Archaeologists working in different parts of the world have associate ancient human settlements only with lower-altitude and river valleys environments. Scholars, for instance, Ilardo & Nielsen (2018); and Zhang *et al*., (2020) argued that prehistoric hunter-gatherers preferred lower-altitude and river valleys regions as suitable settlement sites for survival owing to the wealth of resources required for human survival. Ancient civilizations as those in Mesopotamia, Egypt, India, and China support the above statement as these civilizations flourished either in river valleys or lower altitude environments. Such assumptions proposed that mountains and plateaus were among the last places to be occupied by ancient humans (Ossendorf *et al*., 2019; Vogelsang *et al.*, 2018; Zimmer, 2019).

However, recent studies in the Tibetan Plateau of Asia, the Andes of South America, and the Rocky Mountains of North America have shown high-altitude human adaptations since early times. The Tibetan Plateau, situated at an altitude of 4600 meters above sea level (m asl), was occupied sometimes about 40,000–30,000 years and the high Andes (altitudes 3000–4000 m asl) for up to 12,000 years) (Moore *et al*., 1998, Bigham & Lee, 2014; Lu, 2016; Zhang *et al*, 2020). Furthermore, an ongoing archaeological investigation under the "Mountain Exile Hypothesis [1]"(MEH)" project at the Bale Mountains (BM, henceforth) in Ethiopia is shedding new light on

[1] The 'Mountain Exile Hypothesis' is interdisciplinary research project currently working on a new perception of the Alpine Anthropocene, to understand the Quaternary abiotic, biotic and cultural changes in the African model highland environments of southern Ethiopia.

the human adaptation of high-altitude environments in Africa (Ossendorf *et al.*, 2019). In the BM, several sites including Fincha Habera, Mararo, Fish Shelter, and Simbiro Rock Shelters with an altitude of 3469, 3779, 3423, and 3519 m asl respectively have been the focus of archaeological investigations. A range of material remains such as stone tools, pottery, faunal, and floral remains were uncovered. The archaeological remains coming from BM suggest that the African high-altitude ecozones were occupied by Hunter-gatherers during late Pleistocene due to its environmental stability at times of environmental uncertainties in lowlands. Chronologically, the sites are dated between the late-Pleistocene to Holocene epochs based on C^{14} (Ossendorf *et al*., 2019; Vogelsang *et al*.; 2018). According to Ossendorf *et al*. (2019), hunter-gatherers occupied most sites in the BM in times when resources were depleted in the lowland either as a result of rapid population increases or ecological changes.

Several studies such as Moore *et al*, (1998,), Ilardo & Nielsen (2018), and Zhang *et al*, (2020), have found out that humans have till today conquered inhospitably high altitudes with technological innovations including fire, clothing, dwellings, advances in hunting equipment, and methods for food and water storage, biological adaptations, where humans have undergone genetic and physiological changes to survive the conditions of the environment. This is because life in high-altitude climates is full of challenges due to scarce resources, extreme weather, and low levels of oxygen. Humans have also undergone physiological and genetic changes to develop natural adaptations to survive extreme conditions of the environment, including extreme heat in low-lying regions such as the Afar.

On the other hand, archaeological studies revealed that high-altitude environments, such as the BM, experienced a long history of repeated and extensive occupation in the human past. Based

on previous studies, the site Fincha Habera has been intermittently, occupied by humans. This has been confirmed through the evidence of hearth that was used repeatedly until about the last 15,000 years BP (Ossendorf *et al*., 2019).

Among other environmental data, archaeobotanical data are one of the significant sources of information to study the above-stated inconsistency hypothesis regarding human occupation and their environmental adaptations. Archaeobotany deals with environmental remains that can provide generous information to understand the interactions that human communities had with their ecosystem, from Prehistory to the contemporary period (Popper and Hastorf 1988; Lucas L. 2014). Depending on the nature, type, and size of the remnants to be studied, archaeobotanical data can be classified as macrofossils, microfossils, and molecular data (Campbell, 2011; Reitz and Shackley, 2012; Day, 2013).

In most archaeological sites, that have been investigated; macro-remains of plants are preserved by carbonization. Anthracological data are among the most ubiquitous of these remains that can provide sufficient information for the reconstruction of environmental history, plant resource utilization, vegetation dynamism, human impacts on the landscape, and C^{14} dating of suitable samples among many others. Within the wide spectrum of archaeobotany, charcoal analysis is a reliable tool and a widely used method for palaeoenvironmental reconstruction. The interpretation of complex past ecological adaptations and attendant events are mostly deciphered through anthracology data analysis (Veal, 2015; Carlos & Melo, 2017; Kabukcu, 2018).

A bulk of anthracological assemblages have been collected from various sites in the BM. Analysis of anthracological data from this area allows a better understanding of the dynamics of vegetation history through the identification of the wood taxa category. Identifying wood into the

taxa category helps us to capture information about the vegetation pattern and its relation with humans. In this study, therefore, the anthracology samples were used to strengthen and further elucidate the 'Mountain Exile Hypothesis'. Specifically, the analysis helps to understand the interactions between past humans and their environment in African high-altitude ecozones.

1.2.Statement of the Problems

The BM is one of the few geographical locations in the world where humans were able to settle and adapt to the high-altitude environments during the Late Pleistocene to Holocene. As indicated by many scholars such as Moore (2001), Vogelsang *et al* (2018), Ossendorf *et al*., (2019), and Zhang *et al* (2019), hunter-gatherers had occupied such kind of extreme environments including the BM as a result of decreasing resources from environmentally preferable residence areas (lower-altitude locations) either as a result of rapid population increase or ecological changes. Archaeological evidence from diverse rock shelters of BM provides typical evidence to test how Middle Stone Age (MSA) and Late Stone Age (LSA) hunters-gatherers colonized and benefited from the afro-alpine environments of Africa.

Since 2015, the BM are being under investigation by the Mountain Exile Hypothesis project under the direction of Dr. Götz Ossendorf. The main objectives of the project are to give public attention to the world's oldest residential site in high altitudes and to identify more additional sites to examine the landscape use of its prehistoric inhabitants through time (Ossendorf, *et al* 2020). Since the discovery of archaeological sites in the BM, different scholars have contributed to the understanding of patterns, processes, and occupational history of the region from various points of view based on material cultures recovered from those sites.

According to Ossendorf *et al*., (2019), the analysis of anthrosols, lithics, and faunal remains from the Bale Mountains has been completed**.** Anthrosol analysis was conducted to understand the burning of organic material (i.e., fire pits), food preparation, storage of organic materials, and disposal of organic waste (plant and animal tissue). Lithics analysis also played a significant role to recognize cultural, technological, and functional decisions of past hunter-gatherers by analyzing basic attributes recorded on all artifacts including data on raw material, coverage, position and nature of cortical surfaces, completeness, and thermal damage. The study on some faunal remains is also completed and indicates breakdown and resulted in the identification of human (cut marks, fire marks) and animal (gnawing marks) agents of the accumulation of faunal remains.

Understanding past human adaptation to a certain type of environment is also a key and significant precondition for conceptualizing patterns, processes, and natural selection pressures that may affect the course of human biological and cultural evolution (Ambrose, 1984). Among more than a few archaeological remains, anthracological assemblages are the other significant collections of these sites that need to be analyzed. Investigating these anthracological data will help to establish nomenclature to family, genus, and species levels. This, in turn, helps to understand the interactions between humans and their environments in settlement contexts. At the BM sites, though there are other material culture remains for human cultural activities, the environmental context is not yet properly defined and understood. A well-defined environmental context will help us to understand the cultural changes that occurred during the Late Pleistocene and Holocene. The present research is; thus, design to fill this crucial gap.

1.3.Research Questions

This study will address the following four basic questions:

1. What was the palaeoenvironmental conditions of the study area during the Late Pleistocene and Holocene?
2. What types of vegetation existed in the region during the period under investigation?
3. Which plants were selected and used for fire in the study area?
4. What are the impacts of the prevailing environment for changing human adaptation strategies?

1.4. Objectives of the Study

1.4.1. General Objective of the Study

The main objective of this study is the contextual analysis of anthracological data collected from archaeological excavations in the Bale Mountains and to use this information to reconstruct human-plant interactions in the past.

1.4.2. Specific Objectives of the Study

- To understand the nature of the past environment and its effect on hunter-gatherer ways of life.
- To establish nomenclatures for anthracological samples collected from the study area to family, genus, and species levels.
- To reconstruct the vegetation pattern of the Bale Mountains.
- To describe the firewood use history of the study area.
- To understand late Pleistocene-Holocene cultural changes.

1.5. Materials and Methods

1.5.1. Materials

The choice and use of materials and methods are determined by the research questions and objectives. To achieve the objectives of this research work, the following materials were used.

- KEYENCE electro-microscope (to see the anatomical differences of the samples in 3D-views)
- Voltcaft weighing machine (to weigh the samples)
- Razor blade (to expose the fresh sections of the charcoals)
- Sieving mesh (to separate the charcoals samples from sediment by sieving).

Data for this study was also collected through pre-field, field, and post-field methods.

1.5.2. Pre-field

Published and unpublished secondary sources such as books, articles, journals, and research reports acquired from Addis Ababa University libraries and the libraries of the Institute of Ethiopian Studies, Ethiopia Wildlife Conservation Authority (EWCA), and Authority for Research and Conservation of Cultural Heritage (ARCCH) as well as online archives of the MEH project was referred.

1.5.3. Fieldwork

The fieldwork data acquisition method encompasses the collection of modern wood samples for comparative studies, interviewing local communities, and actual observations of the main archaeological site in the BM.

1.5.3.1.Interviews

To understand current vegetation exploitation elders, officers, and knowledgeable members of the local community in and around the study area were interviewed. This qualitative study depends upon the purposive sampling technique. The researcher purposefully selected the interviewees who have the required knowledge in the area of vegetation.

1.5.3.2. Ethno-botanical survey

An ethnobotanical survey was also another source of information for this study that was conducted through field observation. Ethno-botanical observation of current vegetation set up and its exploitation by the local community was investigated to define change and continuity in the environmental condition that prevailed in the study area. Observing current vegetation patterns and their geographical distribution in the study area provides a better understanding of the past environmental history of the region in due consideration of the principle of uniformitarianism. Consequently, observation of the modern vegetation distribution and exploitation of available plant resources within the belief systems of the study area and its environs were made.

1.5.4. Post-field

Post-field examinations involve activities mostly dealt in the processing of selected samples in the laboratory. These include sorting, documentation of anatomic features, classifications of similar types, and identifications. All the post-field activities were conducted in the laboratory room of ARCCH.

1.5.4.1. Sorting

The selected anthracological samples at this stage were checked for mixed occurrences of artifacts such as ceramic sherds, lithics, and bones. This activity is quite simple and was accomplished by the use of naked eye. Some samples were stored with sediments. Here the charcoals have to be separated from sediment by sieving. In this stage, samples were weighed using a digital weighing machine called 'Voltcraft' and weighed with and without sediments in the laboratory.

1.5.4.2. Documentations of Anatomical Features

Before documentation, the fresh sections of the charcoals were exposed by fracturing either by using hand pressures or steel razor blade based on the size and physical features of the sample. This produces a fresh section of the charcoals in all three anatomical planes (cross-section, radial, and tangential). This was followed by taking microscopic images through cross-sectional, radial, and tangential views. To do this, a KEYENCE electron microscope with a magnification level of 100X, 150X, and 200X was used to see the anatomical differences in 3D-views and to capture microscope images of all samples. In this way, the anatomic features of all samples selected for this study were examined and its microscope images were documented.

A B **C** D

Figure 1. Photos that show (A) sorting of the sample, (B) weighing of the sample, (C) exposing a fresh section of the charcoal by using hand pressure, (D) taking microscopic images through cross-sectional, radial, and tangential views (Photo by Biruk Jifar and Yared Asefa, 2020).

1.5.3.3.Identification of similar wood anatomy

After documenting the anatomical features of each sample, they were categorized into the same group based on their anatomic similarities. Based on their defined characteristics they were categorized from type "A" to type "K". While defining the anatomic features of each sample the IAWA, Wood Anatomy Identification Guideline was used. In this way, the anatomic features of all samples were categorized into the respective types based on their anatomic similarities. Table 1 summarizes IAWA defining characteristics of wood anatomy used in this study to classify the anthracological samples into their categories.

Table.1. a table that summarizes IAWA wood anatomy defining characteristics and their definitions.

Characteristics	**Definition**
1. GROWTH RINGS	1.1. Growth ring boundaries distinct 1.2. Growth ring boundaries indistinct or absent
2. POROSITY	2.1. Wood ring-porous 2.2. Wood ring semi-porous 2.3. Wood diffuse-porous
3. VESSEL ARRANGEMENT	3.1. Vessels in tangential bands 3.2. Vessels in diagonal and/or radial pattern 3.3. Vessels in dendritic pattern
4. VESSEL GROUPINGS	4.1. Vessels exclusively solitary 4.2. Radial multiples of 4 or more common 4.3. Vessel clusters common
5. PARATRACHEAL	5.1. Aliform 5.2. Confluent 5.3. Vasicentric
6. RAYS CELL ARRENGEMENT	6.1. Procumbent ray cell 6.2. Square ray cell 6.3. Upright ray cell
7. RAY CELL WIDTH	7.1. Rays exclusively uniseriate 7.2. Rays biseriate 7.3. Rays multi-seriate
8. MINERAL INCLUSIONS	

1.5.3.3. Identifications

One way to identify archaeological charcoals is based on comparison with modern wood anatomy. In this study, modern wood samples were employed as a comparison to identify the anthracology samples into their family, genus, and species levels. Previous palaeoenvironment, ethnobotanical, and ethnoarchaeological study in the study area indicates that woods like *Erica arborea, Hagenia abyssinica, Hypericum revolutum, Juniperus procera, Solanum gigantum, Myrsine africana,* and *Artimessia afra* dominated the study area. Additionally, interviewing the local community and observation of the actual site also played a significant role while deciding wood collections for comparison. This suggests that the above-mentioned wood types are most probably used as firewood for cooking and/or for warming up at times when the temperature becomes low during the period under investigation.

Unknown archaeological charcoals collected from the study area were identified into family, genus, and species levels by comparing them with known reference woods. Reference wood of the known species that grown in the study area collected earlier by Alemseged Beldados for comparison (*Alemseged, Pers. Comm., Addis Ababa, 22/09/2020).*

The comparison process was done in two different ways. The first way of comparison was looking for the descriptions and anatomic images of the comparison collections on the inside wood dataset. For most species there are descriptions and anatomic images on the inside wood dataset that have the same features as our comparative collections, thus, we have used that as a reference for comparison. The modern comparative slides obtained from teaching references of Alemeseged Beldadods were also used as a reference for comparison. These teaching reference

collections were used for species such as *M. africana* whose anatomic feature and description is not available on “inside wood dataset”.

1.6. Significance of the Study

The findings of this study will help to: -

- Improve our understanding of how to reconstruct vegetation history and the environmental setup of the study area by using anthracological data as a major source of information.
- Provide a significant source of data in terms of early high-altitudes settlement and vegetation history.
- Better understand the type, extent, and timing of vegetation cover in the past to find out the nature of the relationship between human occupation and the nature of the environment.
- Provide comparative material for future research works pertaining to the palaeoenvironment, anthracological study, and early high-altitude human occupations.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1.Anthracology: a theoretical and conceptual framework

Since their very existence, humans have produced tools that can range from small artifacts to large buildings from various types of materials for purposeful objectives. These material remains encompass stone tools, potteries, and structures that were deliberately made to achieve specific objectives. Evidently ancient people were dependent highly on their environment for resource exploitations. Evidence of all human activities in the past has been left behind for us, archaeologists. The analysis of these remnants provides an understanding of all aspects of past human behaviors and cultures (Renfrew and Bahn, 2016).

There are other archaeological records including organic and environmental remains which were unconsciously made but, deposited in archaeological records with many indications of past human activity including substantial information to understand the interactions that human communities had with their environments in the past (Campbell, 2011; Reitz and Shackley, 2012). These interactions studied under environmental archaeology through specific fields of studies such as Zooarchaeology (study both vertebrate and invertebrate animal remains from archaeological records), Archaeobotany (study of all plant remains preserved at archaeological sites), Bioarchaeology (study of human anatomy from archaeological sites) and Geoarchaeology(examine a wide range of data including the analysis of global climate, resource distribution, global and local topography, and soil) (Campbell, 2011; Reitz and Shackley, 2012).

Archaeobotanical remains are among the various environmental and organic evidence that can provide insights into the past human-environmental interactions. Archaeobotanical materials are

divided into macrofossils (charcoal, carbonized or charred seeds, shells, grains, root casts, impressions on clay, mineralized and petrified remains, and coprolites), microfossils (phytoliths and pollen), and molecular (compounds and residues that could survive in human and animal osteological remains, sediments, remnants of plants and ceramic vessels) (Reitz & Shackley, 2012; Cambell and Moffett, 2013).

Anthracology is an emerging archaeobotanical approach used for tackling archaeological problems related to human-environment interaction. It is a multi-disciplinary science encompassing archaeology, palaeoecology, palaeobotany, botany, forestry, and geology, among others. It deals with the study of interactions between humans and their environment in the past through the identification of wood anatomy. It has been playing a crucial role since its development as a discipline. Its application for archaeology is, however, found to be a recent phenomenon. In archaeology, anthracology has importance for understanding the past landscape, dwelling space, site catchment area, fuel economy, use of wood in domestic and ritual contexts, among others (Asouti, 2001; Kabukcu, 2015; Scheel -Ybert, 2016)

The analysis of charcoal as a methodological approach emerged in the 19th century in Europe. Investigation of charcoal is also known as anthracology. According to Scheel-Ybert (2018), the term anthracology is applied for any fields of study associated with the analysis of charcoal remains. The analysis of archaeological charcoals is also included with this viewpoint. In some earlier scholarly works, however, the study of charcoal in archaeology has been described as "archaeoanthracology" to indicate the significance of charcoal for archaeological investigation. Similarly, other fields of studies such as the analysis and identification of charcoal of sedimentary origin (soils, paleosoils, and sedimentary deposits) stated their work as "pedoanthracology" or "geoanthracology" to differentiate from another similar field of study in

the area of charcoal analysis. In the same way, the application of dendrological techniques through the analysis of charcoals is described as “dendroanthracology”, indicating the study of charcoal for dendrology. The analysis of pre-Quaternary charcoals is also presented as “Pre-Quaternary Anthracology”.

The term “anthracology” and “charcoal analysis” also exhibited a difference in their contextual meaning. While the former one is assigned for the analysis of macro-charcoals based on wood anatomical features, the latter one is associated with the analysis of microcharcoal analysis in a sedimentary context (Scheel-Ybert, 2018). In a broad sense, the term “anthracology” is a globally recognized term by many scholars, when it comes to the analysis of charcoals through anatomical identification of woods (Austin, 2005; Scheel-Ybert, 2018).

The beginning of charcoal analysis to understand the relationship between people and their environment has a long history. The first attempt at charcoal analysis was made in 1849 by the German scholar; D. F. Unger. Following his work, other scholars such as the Italian G.Passerini in 1864, the Swiss O. Heer in 1866 studied the prehistoric charcoals recovered from their respective study areas (Austin, 2005; Kabukcu, 2018; Scheel-Ybert, 2018).

In the subsequent decades from the beginning to the 1st half of the 20th century with the work of Henri Breuil, Maby (1932), and Grimes and Hyde (1935) the concept of anthracology witnessed increased attention. Maby (1932); and Grimes and Hyde (1935) had rejected thin section preparation from resin which was a time-consuming method and introduced the hand-sectioned technique in which fresh clean breaks were examined with a hand lens or under low power, binocular microscope. The introduction of this technique reduced the cost of analysis and enabled the identification of several fragments in comfortable ways. Breuil conducted his active

analysis of charcoals retrieved from Paleolithic sites in France and he had used the charcoals as a means to understand the nature of wood selection for fire by pre-historic groups rather than palaeoenvironmental reconstruction (Maby, 1932; Grimes and Hyde; 1935).

The development of systematic study on past ecology through the interpretations of anthracological data emerged in Britain in 1940 with the work of E. J. Salisbury and F. W. Jane. To understand the prehistoric vegetation pattern and climatic conditions of the Dorset area, Salisbury and Jane (1941), examined anthracological remains retrieved from Maiden Castle in England. The site was identified as Neolithic, Early, and Late Iron Age and stated to date to ca. 2500-2000 B.C., ca. 400-200 B.C., and ca. 50 B.C. respectively, based on results obtained from the charcoal analysis. To understand the range of vegetation variation through time, pre-historic charcoals from the Maiden Castle were correlated with charcoal remains of the Roman period, obtained from the Verulamium site. Additionally, modern charcoals were prepared from the study area and used as a comparison. Attempts to understand the climatic conditions of the study area were conducted by using the information retrieved from the ring width of pre-historic charcoals. Based on this, the result of their study indicates the Neolithic times of the Dorset area perhaps dominated with a closed plant community of woodland of the oak-hazel type. The evidence from the annual increments of the growth ring of vegetation indicates that a climatic condition throughout the period under investigation shows similar characteristics to that of the modern day's climate.

Finally, they concluded that a change in vegetation from the earliest to the latest period was caused by climatic changes due to increased human forest clearance. However, the work of Salisbury and Jane received strong criticism from scholars such as Godwin and Tansley (1941).

Their work was critiqued for the reason that, their woods sample selections techniques, and their use of tree ring data as the basis for comparison between trees grown in different regions.

The second half of the 20th century showed increased progress in the area of anthracology for the following four reasons. Firstly, the increased interest of French scholars from botany, ecology, and forestry in the analysis of anthracology records. In this context, French scholars such as J. Momot, M. Couvert, and S. Santa contributed a greater role in the development of anthracology. Momot (1955) studied the Saint-Saturnin charcoal deposit of the late Quaternary period. Through the aid of a binocular magnifying glass and an ordinary microscope, Momot examined the internal structures of charcoals in three-dimensional views (cross-section, radial, and tangential). He used animal biology (inclusion with paraffin) and, geology (polishing of sample) as a methodological approach. Based on the internal structure arrangements of the samples, the charcoals fragments belonged to the genera Betula and Quercus showing a fairly cold climate.

Another French scholar Couvert (1968), was the first to recognize the anthracological analysis as a source for more reliable palaeoenvironmental data compared to others including pollen analysis. In 1969, he also analyzed charcoals in Algeria from the cave sites of Khanguet Si Mohamed Tahar and Tamar Hat. This study of charcoals provides the first solid evidence for the existence of non-analog vegetation types in the study area during prehistoric times. This was interpreted as indicating different climate regimes in the past. In 1976, he also conducted other investigations of charcoals from the sixth-millennium site of Relilaï in Algeria. In this work, he reconstructed the vegetation cover of the study area based on modern rainfall values from wooded areas and topographic relief. Based on the axiom that "the same floristic stock will generate identical vegetation groups" (i.e., if vegetation communities are defined as essentially a

group of species, then the same range of species will give rise to identical floristic associations, now or in the past).

Another French botanist, Santa (1961), analyzed charcoals obtained from North Africa. To reconstruct past vegetation grown in the study area, he used qualitative data specifically the list of archaeological charcoal taxa, and tried to compare them with the current vegetation in the same area. His work also introduced a new concept in the study of anthracology which is called the concept of the "probability" of preservation and the "possibility" of taxon recovery. The concept dealt with the cultural and natural factors and different preservation issues that might affect the samples, and after all their possibility to be categorized into their respective taxonomical classifications. Based on his investigation, Santa concludes that vegetation types that are poorly collected in the archaeological record either because of their poor fire value or due to preservation issues. Some plant types were poorly selected as firewood by the pre-historic group due to their poor fire value and also natural factors such as their size, hinder them to preserve in archaeological sites.

Secondly, the establishment of archaeobotanical reference collections in Europe was the other achievement of the 1960s that laid the foundation for the discipline of anthracology. Cecilia A. Western's wood collections in the UK Institute of Archaeology, was one of the best archaeobotanical collections. It contains a large amount of wood, charcoal, and archaeological specimens of wood collected and established by Cecilia A. Western in the late 1960s. Following this, Greguss (1955 & 1959) published the first comparative wood anatomy atlases that drew the attention of other scholars toward wood anatomy, anthracology, and pollen analysis.

Thirdly, the scientific advancement of the 1960s saw the introduction of heavy land clearing machinery, new aerial and geophysical surveying techniques, computer technologies, and scientific methods enabling the ability to accurately date archaeological finds, such as C^{14} and dendrochronology (Clarke, 1973). The adaption of the C^{14} technique in the area of archaeology brought great and continuing change within archaeology in general and anthracology in particular. Following this, charcoal became the preferred dating material due to its high carbon content. This enables archaeologists to give great attention to charcoal assemblages in archaeological records more than before to define the age of their context.

Lastly, the development of more standardized techniques such as the use of reflected light microscopy in charcoal analysis also played a significant role in the development of the discipline. This signified the development of more standardized techniques in charcoal analysis. As indicated in scholar works before 1960, such as Momot (1955), Salisbury and Jane (1941), Grimes and Hyde (1935), the method of charcoal analysis (wax, resins, or paraffin embedment, microtome cutting, and thin sections mounting) was extremely laborious, with poor and limited thin sections preparation. Similarly, such method requires a long time to analysis small numbers of sample and the outcome of the analysis limit the general interpretation of a given environmental setup. At the end of the 1960s, light microscopy was used for charcoal study by scholars such as Western (1969, 1971), Leney and Casteel (1975). This enabled the development of Anthracology as a discipline with the establishment of a proper methodological approach in which charcoal samples were studied under incident light microscopes. This method not only provides scientific and more advanced ways for the study of charcoals but also allowed for the identification of a large number of samples in a much shorter time.

At the same time, systematic and more organized studies on charcoals were introduced in France following the establishment of the University of Montpellier under Louis Vernet with particular interests in research bearing on the origin and dynamics of biodiversity (Asouti, 2001; Scheel-Ybert, 2018).

The 1980s witnessed a sudden upsurge of anthracology interest among scholars following the adaption of the applicable sampling system and methodological approaches. These enabled the charcoal analysis to be the essential and reliable source of information for paaleoecological reconstructions regardless of the cultural and natural factors and different preservation issues that might have affected the samples. At the same time, the discipline called pedoanthracology was born in France under the guidance of Michel Thinon, allowing the reconstruction of ligneous ecosystems. Pedoanthracology deals with the analysis (anatomical identification) of charcoal pieces sampled not from archaeological (anthracology), but natural contexts (soils). This field of study enabled the study of Quaternary and pre-Quaternary sediments throughout Europe and North America, aiming essentially at the reconstruction of palaeoenvironmental and palaeoclimatic changes (Austin, 2005; Kabukcu, 2018; Scheel-Ybert, 2018).

From the 1990s, concurrently new opportunities were introduced in the area of anthracology. In France and Germany, new branches of the study of anthracology were established with new methodological approaches in the area of charcoal study including wood combustion experiments, ethnographic research, and wood anatomical studies. Furthermore, during this period the study of anthracology expanded to Portugal, Spain, and Italy, in the rest of Europe, in Africa, the Near East, North and South America. The subsequent events from 1990-2000, played a great role in the foundation of anthracology as a robust discipline. Nowadays, anthracology has a great number of publications in different parts of the world that confirm the robustness and

advancement of the discipline in its different approaches (Chabal *et al*. 1999; Scheel-Ybert, 2018).

2.2. Human-Environment Interaction in the Past

Archaeological evidence from different parts of the world shows that humans have started settlements, tool making, food production, and civilizations within favorable environmental conditions. Prehistoric occupation both in lower-altitude or river valley environments has been identified and reported by archaeologists since the beginning of the discipline. Ancient civilizations such as the Mesopotamian, Egyptian, Indian and Chinese based their civilizations on Tigris and Euphrates, Nile, Indus, and Huang He Rivers, respectively. Settlement in such kind of river valley regions is common from prehistory to the contemporary period for the reason that such kind of environment provides fertile soil and irrigation waters for agriculture, Protection from invasion, and due to its favorable climate, that could be easily adaptable.

However, recent studies provide evidence for human adaptation in high altitudes since the Stone Age. Himalayas (Tibetan) of Asia, the Andes of South America, and the Rocky Mountains of North America are the three major parts of the world associated with early high-altitude early human settlements with clear archaeological signatures (Moore *et al*., 1998).

The Tibetan Plateau is more important than the Andes and Rocky Mountains of North America because (1) it is the largest high-altitude plateau in the world, (2) geographically remote, and (3) likely to have been occupied by humans for a longer period. It approximately lies 2,400 km east to west and 1,100 km along its north-south direction covering over 200 million hectares. This plateau is a concern of researchers from different disciplines including archaeology, anthropology, biology, geography, and others to understand cultural and natural driving factors

that forced humans to struggle with such kind of challenging environments and to define geographical distributions of the plateau (Moore *et al.*, 1998; Zhang, *et al.*, 2020).

The archaeological record makes available evidence for the presence of hominid in Asia associated with Palaeolithic and microlithic tool technologies dated back to the Upper Palaeolithic sometime between 25,000–50,000 years BP, with an altitude of 4,500–5,200m on the northern Tibetan Plateau; (Zhang, *et al.*, 2020). The archaeological record also provided evidence for the presence of hominids in Asia associated with the Paleolithic and varies from site to site. The available archaeological evidence revealed that the northwestern part of the Tibetan Plateau for the first time was colonized 15,000 years before the present (YBP). The southeast of the Plateau is believed to have been occupied around 36,000 YBP, and the central part was occupied at about 30,000 YBP (Lu, 2016; Zhang *et al.* 2020). Other significant sites at Tibet Plateau remain undated. Rather, their age was defined by correlation with other dating sites based on technological similarities (Lu, 2011, Yuan *et al*., 2007). In general, based on archaeological and recent genetics investigations scholars believe that the first human presence at Tibetan Plateau goes back to the late Pleistocene sometime between 40,00-30,000 BP (Qi et al., 2013; Zhang et al., 2020).

Regarding the development of permanent settlements at the Tibet plateau, many researchers have revealed their findings based on the available archaeological evidence. As indicated by the researchers (Chen *et al*., 2015; Zhan*g et al.*, 2016), three phases of prehistoric occupations were recorded at Tibetan Plateau. Accordingly, the first phase of human occupation of the northeastern part of the Tibetan Plateau is believed to have been started before 5,200 YBP with hunting activities. The second phase falls sometimes between 5,200-3,600 YPB, associated with

millet farming, and the last phase of human settlement at the Tibetan Plateau is dated back to 3,600 YBP following the cultivations of cereals like barley and wheat.

The advent of agriculture at the Tibetan Plateau is an area of debate among scholars. Some archaeological evidence from particular sites such as Chamdo Karoo, Lasa Qugong, and Changguogou make available solid evidence regarding the introduction of cultivation in the region. Based on evidence from the above-mentioned sites, the advent of agriculture in the Tibetan Plateau occurred between 5,200–3,500 BP with the cultivation of foxtail, millet, and broomcorn millet (d'Alpoim *et al*, 2018; and 2020).

In addition to archaeological investigations, genetic and linguistic studies are also significant in the history of Tibet providing information regarding sources of origins of the people. Dental morphology and mitochondrial and nuclear genetic signs associated the origin of Tibetans with Korean, Siberian, Mongolian, Chinese, and other Southeast Asian communities (Matsumoto, 1987; Lee *et al*., 1988).

As discussed above, bulks of vital findings have been collected from the settlement area of the Tibetan Plateau that made the region be an ideal area that constitutes the vast field of investigation on early human settlement in alpine environments to understand human physiological, genetic, and cultural adaptation potentials (Bigham & Lee, 2014; d'Alpoim *et al*, 2020; d'Alpoim *et a.* 2018; Li *et al*., 2020).

2.3.Survey of Palaeoenvironment Studies in the Bale Mountains

The Bale Mountains is the subject of an array of investigation from multiple ranges of studies because (1) it is the principal alpine ecosystem in Africa, (2) it is home to a high number of both endemic animals and plants, (3) it is under nature protection due to its perception as little and

lately changed by humans, and (4) it is a high-altitude ecosystem in close vicinity to the earliest records of humans culture (3.3 Ma) and the earliest use of fire in the landscape level (1.9 Ma) in East Africa (MEH online data base, *https://www.uni-marburg)*.

The presence of conventional data sources for palaeoenvironments such as hyrax dung deposits, lake deposits, preserved peatland, and zoogenic deposits played a significant role in the reconstruction of vegetation and climate history of the Bale Maintains. Based on this, the Bale Mountains have received much attention from palaeoenvironment and palaeovegetation studies to recognize the impact of natural and anthropogenic actions on ecosystems, to reconstruct the climate and vegetation history of the mountains (Bonnefille and Mohammed, 1991; Mohammed & Bonnefille, 1998; Umer *et al.*, 2007; Kuzmicheva *et al*., 2014; Kuzmicheva *et al*., 2018; Gil Romera *et al., 2019*; Bittner *et al*., 2020).

Mohammed and Bonnefille (1996) had conducted a pollen record analysis from the highland peat of the Bale Mountains to establish the vegetation history of the Bale Mountains and its subsequent modifications. They analyzed pollen of core of 1.80 m length taken from Tamsaa swamp at 3000 m and dated to ca. 13,000–10,000 years BP. They identified 44 taxa from the proposed sample and three pollen zones designated as phase III (1m-80 cm), phase II (1 m-50 cm), and phase I (50 cm to top) were established.

Their findings indicate from 13,000 to 10,000 BP the study area was dominated by *Apiaceae* indicating drier climatic conditions in the Bale Mountains, particularly in its northern part. The pollen diagram at 10,000 BP indicates the domination of vegetation like *Chenopodiaceae/Amaranthaceae* that also indicates the continuation of the drier period. The early-mid Holocene (7–8000 years) is recorded as a hiatus in the sediment accumulation of

Tamsaa. This is also true for sediment cores obtained from other areas such as Mt. Badda from Arsi and Kaisungor swamp from Chernangi hills, Mt. Kenya lacking sediment deposition from early to mid-Holocene which indicates a possible regional cause. Peat accumulations after 2,500 years BP designate that the late Holocene period was characterized by humid climatic conditions.

Other similar work by Umer and his colleagues (Umer *et al.*, 2007) played a significant role to understand the palaeovegetation and palaeoenvironment of the Bale Mountains during the terminal Pleistocene and Holocene. Their analysis was based on a sediment core retrieved from Lake Garba Guracha, an important palaeoclimatic archive in the region. The contribution of this research is substantial in providing comprehensive information about the geology, ontogeny, and vegetation of the Bale Mountains. By analyzing a total of 86 pollen samples they identified four pollen zones and their climatic implications of the study area.

The pollen zones designated as Zone GG-1, Zone GG-2 (sub divided into Zone GG-2a and GG-2b), Zone GG-3, and Zone GG4 (also divided into Zone GG-4a and GG-4b). Zone GG-1 represents a sediment length from 1582–1350 cm and deposited from 16,700–13,400 years cal BP. This period is dominated by *Amaranthaceae/ Chenopodiaceae, Poaceae, Cyperacea*, and *Artemisia* representing an arid and semi-arid environment. Zone GG-2a (1350–1070 cm) dated 13,400–12,550 cal BP and is characterized by a low concentration of *Amaranthaceae/ Chenopodiaceae* and a high concentration of *Cyperaceae* and *Botryococcus* in the pollen record, which indicate wetter climatic conditions. Zone GG-2b (1070–790 cm); goes back to 12,550–11,200 cal BP) shows a declining *Cyperaceae* tree, an increase of *Artemisia,* and a maximum of *Poaceae,* indicative for the re-occurrence of drier climatic conditions. Zone GG-3 (790–320 cm); the deposits date back to 11,200–4500 cal BP) and are characterized by the domination of *Ericaceae* and *Anthospermum, Poaceae,* and *Cyperaceae.* The environmental conditions of this

period are interpreted as warmer. Zone GG-4a represents a sediment length from 320 to 97 cm that deposited from 4500–1300 cal BP indicates a decrease in *Ericaceae* and *Poaceae* and an increase in *Podocarpus, Juniperus, Olea,* and *H. abyssinica* that specify a drier climatic condition. Zone GG-4b (97–0 cm; dated from 1300 cal BP to present) shows a decline in *Podocarpus* and with increase in *Juniperus, abyssinica,* and *Dodonaea viscosa.*

Kuzmicheva and her colleagues (Kuzmicheva *et al.,* 2013) undertook a research project entitled "Holocene hyrax dung deposits in the afro-alpine belt of the Bale Mountains (Ethiopia) and their palaeoclimatic implication". This research is resulted in the production of the most vivid articles on palaeoenvironmental reconstruction of the Bale Mountains.They analyzed two pollen hyrax dung middens, dating back to from about 15,000 to 1,500 years BP at Konteh (Sanetti Plateau, 4,100 masl) and Fincha Habera (upper Web Valley, 3500 masl).

They identified a total of 14 pollen and spore samples from the Konteh deposits. Based on these samples, they defined two pollen zones for Konteh, represented as Zone I and Zone II. Zone I, designated for sediment length from 20–10 cm; was deposited from 6900–3000 years BP. The record indicates a low amount of *Podocarpus*, and *arboreal* species were not indicated in the record. Zone II represents sediment with a length of 10–0 cm, deposited at about 3000 years BP–present. The record indicates an increased amount of *arboreal* pollen including *Hagenia abyssinica, Juniperus procera* and *Podocarpus falcatus*. It is also characterized by the high amount of *Ericaceae* and *Urticaceae* plants.

The pollen deposits of Fincha Habera II provided much better evidence than those of Konteh, as 22 taxa could be identified, seven tree and shrubs, and fifteen *herbaceous* plants and ferns. Five consecutive pollen zones were identified from this deposit. Zone I (represents a sediment length

from 57–48 cm, deposited before 15,000 (years BP) represents a high distribution of the *Asteroideae* subfamily (indicating a shift of the Afroalpine belt) and low distribution of *Podocarpus* and *Juniperus* indicate drier climatic conditions of this period. Zone II represents sediment formed from 15,000–10,000 years BP with a sediment length of 48–36 cm. Sediment deposition of this zone recorded *Apiaceae, Lactucoideae, Caryophyllaceae, Juniperus, Fabaceae,* and *Rubiaceae,* and high amounts of *Podocarpus* and *Ericaceae* (indicating both drier and more humid climates). Zone III represents the sediment deposited between 10,000–8200 years BP, with a length of 35–26 cm. This zone is characterized by the high amount of Podocarpus, *Juniperus, Poaceae, Apiaceae, Lactucoideae, Fabaceae Chenopodiaceous/ Amaranthaceae,* characteristic for an increasing humid period. Zone IV was deposited from 8200–5000 yrs ago, with a length of 26–15 cm. This zone shows a decline in *Podocarpus, Apiaceae,* and *Poaceae* while *Juniperus* and *Caryophyllaceae* increased which were typical characteristics of dry climate. A deposition formed from 5000–1500 with a length of 15–11 and 11–10 cm was designated as zone V. This zone shows a complete decline of *Juniperus* and *Urticaceae.*

Similar work at the same sites (Konteh and Fincha Habera rock shelters) was also published by Kuzmicheva *et al* (2014) with a title of "Vegetation and Climate Reconstruction for the Bale Mountains (Ethiopia) in the Holocene According to the Pollen Analysis and Radiocarbon Dating of Zoogenic Deposits". Unlike their previous work, the objectives of this publication focus on the cause of environmental changes and vegetation dynamism which was absent either in their or other's previous publications. They also attempt to assess the anthropogenic impact on the Bale Maintains ecosystems.

The results of their findings provide information for vegetation dynamism and climatic change in the Bale Mountains during the Holocene epoch. Humid Africa period recorded from 15 000–4600 years BP in the sediment deposition. This period was characterized by the dry and cold environment at about 12 500–10 000 years BP, which resembles the period of Younger Dry of the temperate latitudes of the Northern Hemisphere. Their data indicate 4600 years BP to be the end of the African Humid Period and the beginning of climate aridity which is also true for the entire East Africa.

Finally, based on their data they marked the presence of human settlement on the high altitude of Bale Mountains 10,000 years BP, whereas the land use at Senatti Plateau goes back to 600 years BP associated with pasturing activities. But they don't tell us why exactly at this date humans appear in the BM. Probably the presence of charcoal is used as an indicator for human presence, but then human presence should be dated back to 15,000 years BP. Based on the appearance of *Urticaceae*., they also conclude that the intensity of human presence increases in the last 2000/2500 years BP

To understand the Holocene vegetation and environmental history of Bale Mountains, Kuzmicheva *et al* (2018) conducted a spore-pollen analysis based on zoogenic obtained from sediment deposited for the last 6500 years at Katcha. Unlike their previous works, this publication is focused on the southern parts of Bale Mountains (Harenna Forest) which makes it probably the only research that dealt with past environment and vegetation in the southern part of the park. The objective of this publication is to understand whether monodominant *bamboo* vegetation existed in the Bale Mountains during the Holocene period or whether it represents a secondary type of vegetation that developed only after disturbances of the natural vegetation cover. To achieve the objective of the study, they conducted a spore-pollen analysis of the

Katcha zoogenic deposit, located in the bamboo vegetation belt in the Harenna Forest. The analysis of non-pollen palynomorphs (remains of plants, fungi, invertebrates, and algae) was also considered to supplement the results of the spore-pollen analysis.

The results of their study revealed that dense monodominant thickets of East African *bamboo* developed on the southern part of the Bale Mountains at altitudes of 2,700–2,800 m.asl from 6,500–5,000 years ago. Climatic and anthropogenic factors are recognized as responsible factors for the continuous decline of the bamboo trees of the Harenna Forest. At about 5,000 years ago, a drier climate and severe soil erosion enabled bamboo trees to decline from this area. The increased drier climate that appeared about 2500 years ago also led to the reduction of bamboo trees to an even higher degree. However, their results also attested that fewer human impacts were recorded on the environment of Harenna Forest compared to other parts of the BMNP.

Another publication that discussed the vegetation and environmental history of the study area was conducted by Gil Romera *et al* (2019), entitled "Long-term fire resilience of the Ericaceous Belt, Bale Mountains, Ethiopia". This publication differs by its nature of data from other similar publications from the Bale Mountains in general and Lake *Garba Guracha* in particular. In this research, sediment deposits of charcoals from Lake *Garba Guracha* are considered a source of data to reconstruct the environmental history of the region. To achieve their objectives, they analyzed a 15 m core obtained from Lake *Garba Guracha* that dated back to 14,000 years BP. From this core, they acquired 1118 macroscopic charcoals and 275 fossil pollen samples. The charcoals are used as data sources for past fire use and biomass burning, whereas the pollen fossil samples are used to document *Erica's* response to fire.

The findings of their research testified that fire has been extensively concentrated in the Bale Mountains from early Holocene (10,000) and mid-Holocene (6,000) to 2,000 years BP in its *Ericaceous* Belt landscape. Erica's accumulation rate and high concentration of charcoals that appeared in the Garba Guracha core are the results of high distributions of extensive wildfires/natural associated with the extent of *Erica* that dominated the region between 11,000- and 6,000-years BP. This is also supported by a synchronous supplementary model which shows positive relations between fire and *Erica* resprouting. Based on this, they indicated that a positive relation between *Erica* richness and fire existence was common during the Late Glacial and the Holocene. They interpret the *Ericaceous* Belt of the Bale Mountains as a lasting fire-resilient ecosystem. Finally, they recommended that controlled burning activities had better be considered as essential management parts of the Bale Mountains.

2.4.Settlement History of Bale Mountains

The early known hominid occupation in the vicinity of BM goes back to the Plio-Pleistocene period sometime between 1.5M- 700ka years that have been reported from Gadeb site at an elevation of 2300masl (Clark and Kurashina, 1979). As indicated by Clark and Kurashina (1979), the archaeological evidence from Gadeb site indicates hominids left out the drier and warmer climates of the Rift valley regions and started to occupy the nearby plateau at about 1Mya. This period marked the beginning of hominid occupation of varied ecological regions including high plains located close to BM (Clark and Kurashina, 1979).

Among all the Parts of the southwestern highlands of Ethiopia including BM are acknowledged for providing environmental shelter to Quaternary climatic changes (Foerster *et al*., 2015). As indicated by many scholars (Brandt *et al., 2012*; Ossendorf *et al.,* 2019), the extreme

environmental change that happened during the Pleistocene might have forced humans to occupy the highland of Ethiopia in general, and the Bale Mountains in particular.

Before the discoveries of the archaeological sites in the Bale Mountains, the settlement history of the region was supported by other archaeological evidence from the adjacent parts of the southwestern highlands of Ethiopia. Prominent evidence supporting this assumption comes from Mochena Borago rock shelter, situated on Mount Damota, only 220 km from the Bale Mountains. As indicated by Brandt *et al*. (2012, 2017), the settlement site at Mochena Borago is dated back to >53 ka BP. Other archaeological sites dating to the same period were also discovered in the Amhara Mountains, less than 400 km from the Bale Mountains, which were characterized by distinct stone tools dating back to the Middle Stone Age (Pleurdeau, 2003). Archaeological survey and excavation at ten caves and rock shelters in the highlands of the Kaffa region also indicate the development of settlement activity from the middle Holocene onwards (Hildebrand *et al,* 2010).

Furthermore, an extensive archaeological survey from 2015-2018 by the "MEH project" accompanied in the Bale Mountains. The objectives of the survey were to (1) consider when human beings occupied the high Mountains of Africa and (2) The age and evolution of the making of a tropical alpine human environment. Among all, a survey of the rock shelters in the Bale Mountains laid a foundation for further archaeological excavations and other related investigations in the region to conceptualize high altitude settlement history of Africa. David Reber and his colleagues (Reber *et al*, 2018) conducted the first extensive survey of rock shelters in the Bale Mountains entitled "High-Altitude Rock Shelters and Settlements in an African Alpine Ecosystem: The Bale Mountains National Park, Ethiopia". Based on GPS-assisted surveys and interviews with residents they documented a total of 331 rock shelters. Among those

rock shelters, 4 of them are permanently inhabited, 51 seasonally inhabited, and 276 currently uninhabited.

In the subsequent years, several archaeological research work on the analysis of lithic artifacts, faunal remains, and archaeobotany analysis) have been conducted. The archaeological investigation together with other investigations such as anthrosol and palaeoecological studies provided solid evidence to appreciate the nature of past human settlements in high elevations and adaptive responses such as site functions, subsistence, and long-distance networks by hunter-gatherers during the MSA and Late Stone Age (LSA) (Ossendorf *et al*., 2019).

The study on faunal remains retrieved from the BM also played a significant role to understand the trace of human activities on the bone, dietary system, cooking methods, and hunting activities in the study area. A total of 3,655 bones were recovered from Fincha Habera site and were analyzed at the National Museum of Ethiopia. The bones were found to be in good prservatin conditions, from whuch 66% of them were identified into their respective taxa.

Accordingly, the dietary system inferred as they were consuming a fresh meal which is identified from large mammal's limb bones that were broken in spiral shape indicating the breakage occurred on fresh bones. Based on well-preserved surfaces of the bone ample information was retrieved regarding human traces. Two kinds of humans trace mainly breakdown and gnawing appeared on the bones marked by a large carnivore and burn marks suggesting human processing.

High concentration of burnt bone of giant mole-rat (*Tachyoryctes macrocephalus*) was identified. This indicates the human exploitation of giant mole rats. The intensive cut marks that commonly appeared on the bones of large mammals are absent or scant on the mole rats which might be due

to their small size. The method of cooking and eating has been found similar to Sibudu Cave (South Africa).

On the other hand, the lithic collection from the Bale Mountains was also analyzed by recording attributes on all artifacts (Ossendorf *et al*., 2019). In this way, all 1019 lithic artifacts, except angular waste and chips were analyzed by following lithic terminology used by Inizan in general and lithic studies of Ethiopian late MSA assemblages in particular.

The results of the lithic analysis indicate basic human records on all assemblages including data on raw material, coverage, position and nature of patinated/cortical surfaces, completeness, and thermal damage, and many other technological attributes. Different raw materials such as obsidian, chert, basalt, and quartz were used to produce the stone artifacts. The analysis of reduction structure that ranges from the acquisition of raw materials to discard, show that the obsidian artifacts were mostly obtained from the nearby obsidian outcrop at Wasama Ridge (4,200 m asl). The decortification and the reduction processes took place on-site with unipolar exploitation of cores with two, either opposing or perpendicular platforms.

In addition to archaeological investigation, the information retrieved from the analysis of anthrosol, provided significant sources of evidence to understand burning of organic material (i.e., fire pits), food preparation, storage of organic materials, and disposal of organic waste (plant and animal tissue). The analysis showed high amounts of organic carbon, black carbon, and nitrogen but low amounts of phosphorus and calcium, which shows intensive burning activities and a high input of organic material with the only limited bone contribution.

With the objectives of understanding vegetation, environment, and hunter-gatherer interaction, the project has also been managed to collect botanical remains from the very beginning.

However, these botanical data more specifically anthracological data are not well studied yet. This research is, therefore, designed with the objective of an extensive investigation of the anthracological remains obtained from the site.

As discussed above, during the past few years, the Bale Mountains showed considerable progress in the study of environmental and vegetation history. Especially Bonnefille and Umer, (1998) based on preserved peat land, Kuzmicheva and her colleagues (2013,2014, and 2018) on pollen and hyrax deposits, Umer and his colleagues (2007) on sedimentary record of Garba Guracha, and Gil-Romera *et al*. (2019) on pollen and charcoal samples have conducted extensive research works by focusing on the natures of past environment and vegetation of the study area. However, their work dealt only with the reconstruction of plant communities and climatic conditions of the Bale highlands from the Late Pleistocene to the Holocene. The interactions between humans, vegetation, and the environment are scanty or absent. Since we have evidence for the occupations of hunter-gatherers on the BMs during the period under investigation, the existed interactions with their environment should be properly defined and understood. This enables us to conceptualize the cultural changes that have occurred during the Late Pleistocene to Holocene at the BMs.

Moreover, as agreed by many scholars such as (Couvert, 1968; Chabal *et al*., 1999; Austin, 2005), analysis of anthracological data provides more accurate and dependable pictures of past vegetation and environment than other sources of environmental data including pollen analysis. The previous attempts to reconstruct the palaeoenvironments of the region were based on the poorly preserved peat-land deposits and palynological remains obtained from a seasonally fluctuating lake in this region that makes the study very limited in understanding the environment of the region in a broader spectrum. Therefore, the results of the above-reviewed

articles had better be supported by more additional reliable and supplementary environmental data like anthracological analysis. This is for the reason that pollen and other samples retrieved from such kinds of circumstances may hinder the reliability of the regional vegetation and climate history.

This research is, therefore, trying to reconstruct the environmental history of the Bale Mountains focusing on hunter-gatherer ways of life during the late Pleistocene and Holocene based on archaeo-botanical data, more specifically on archaeological charcoals. All charcoal samples were retrieved after ongoing archaeological research from the Bale Mountains, indicating various occupational periods in the study area.

CHAPTER THREE

BACKGROUND OF THE STUDY AREA

3.1. Location

The study area, the Bale Mountains National Park (BMNP), is located in Bale Zone of Oromia Regional State. Bale Zone is one of the 21 administrative zones of the Oromia Regional State. It is located in the southeastern parts of Ethiopia 400 km from Addis Ababa. Based on current administration structure, the zone has 18 *Woreda*, 2 urban administrative centers, 20 urban, and 351 rural *kebeles*. The Bale zone is bordered by the Genale River in the south, the West Arsi Zone in the west, the Arsi Zone in the north, the Shebele River in the northeast, and the Somali Regional State in the east (Richman and Biniam, 2013; Kuzmichev *et al*, 2017).

BMNP is located in the Dinsho *Woreda* of the Bale Zone covering a total area of 2,200 km2. It is located roughly between 6º30'N and 7º00'N and 39º30'E and 39º55'E2. Geographically, the park is bordered by five woredas of the Bale Administrative Zone: Adaba, to the west, Dinsho, to the north, Robe town and Menna Angetu to the south, Goba to the northeast and Haro to the east (Kuzmicheva1et al., 2017; Lodge, 2020). The Park ranges in altitude from 1,500 to 4,377 m asl at Tullu Dimtu which is the second-highest peak in Ethiopia and the highest peak in the park. The Bale Mountains are Africa's biggest elevated area, rich in biodiversity and home to a large number of endemic plants and animals. The Park is also a source of origin for five major rivers that make these mountains one of the foremost important areas within the Ethiopian highlands. The park was established in 1970 to protect plants and animal diversity in an area of 2,400 km^2 (Miehe & Miehe,1994; Biniam and Richman, 2013; Lodge, 2020).

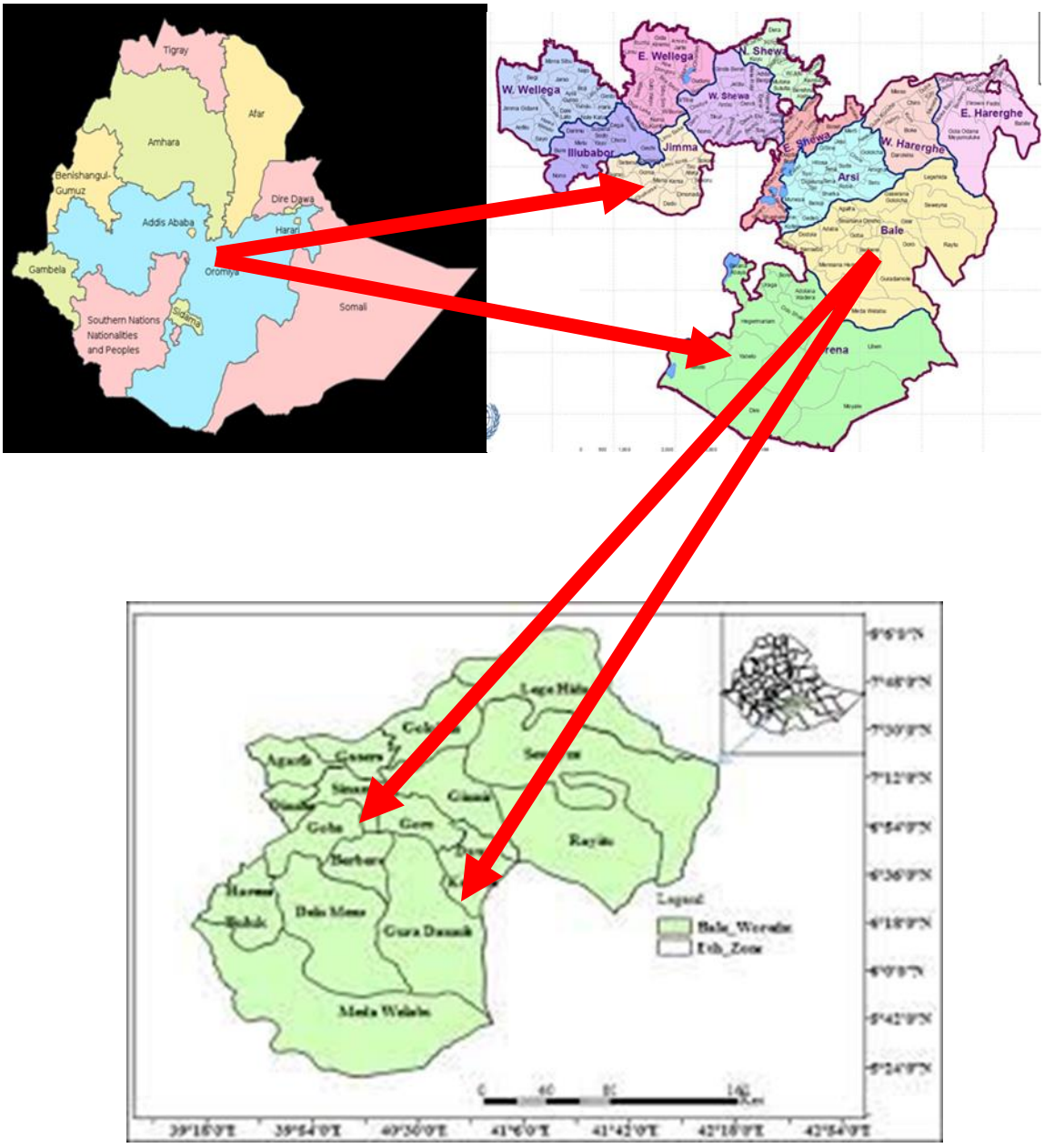


Figure.2. Location map of study Area modified from different sources

3.2. Population, Religion, and Language

Based on the national census of 2007, conducted by the central statistics agency of Ethiopia (CSA), the Zone has a total population of 1,402,492 of whom 713,517, are men and the

remaining 688,975 are women. A total of 297,081 households are counted in the Bale zone, which resulted in an average of 4.72 persons to household and 287,188 housing units.

The CSA 2007 report also indicates the three largest ethnic groups from this zone are Oromo Amhara, and Somali accounting, 91.2%, 5.7%, and 1.4% respectively of the total population. And all other ethnic groups made up only 1.7% of the population. Afaan Oromo is spoken as the first language by 90.5% of the inhabitants and Amharic by 7.1% and Somali by 1.1%; the remaining 1.4% spoke all other primary languages.

Regarding their belief system, the majority of the people are Muslims. According to the 2007 national statistics agency, it was reported that the majority of Bale Zone inhabitants are followers of Muslims which account for 81.8% of the population, 16.9 % of the population practice Ethiopian Orthodox Christianity 4.9%, and 1.04% of the population embraced Protestantism.

3.3.The Socio-economic Activities of the Society

The economy of the Bale zone is based on mixed agro-pastoralists economic activities. Most residents of highland practice integrated agriculture of animal husbandry and crop production. Both economic activities are mostly dependent on the ecosystems of the park, in which forests and natural resources of the park provide fertile soil and seasonal rainfall for cultivation, and grassland, fodder, and mineralized water for their cattle. Cattle keeping are considered as a measure of wealth among the Oromo peoples in general and the Bale peoples in particular. In addition to cattle, they herd sheep, goats, horses, mules, and donkeys. Crop production includes growing barley at higher elevations (Fiona *et al* 2017).

3.4. Vegetation

Due to its altitudinal variation, the Bale Mountains contain a huge variety of plant species. The species richness of the region consists of low to high altitude vegetation. Lower altitudes vegetation area located in the southern parts of the park with an altitude ranging from 1.500 masl (dominated by open canopy dry forest) to 2,400 masl (characterized by very moist, often cloud/mist-covered forest). The high-altitude vegetation is characterized by high concentrations of epiphytes and woody climbers and, a rich herb layer, and a low density of canopy species. Wood-like tree-heathers, *Erica arborea* and *Erica trimera*, and *Juniperus procera* dominate at 3200 m altitude. The peak of the mountains (above 4000m) is characterized by high concentrations of moorland including *Giant Lobelia* spp and cushions of everlasting flowers *Helicllysum* spp., particularly *Helicllysum citrispinwll* and *Helicllysum splendidum*. The high-altitude part of the park contains 30 % of the extremely rich endemic plants of the park (Miehe & Miehe, 1994; Biniam and Richman, 2013). In general, based on geographical distributions of modern vegetation cover, the BMNP is classified into the following five major zones.

3.4.1. Northern Grasslands

The Northern Grasslands are also called Gaysay Grasslands, located on both sides of the Web and Danka Rivers. The elevation of this zone ranges from 3,000 to 3,500 m asl. Geographically, this part of the park is flat and mostly dominated by overwhelming grasses and sedges, particularly of the *Cyperus* and *Scirpus* genera, and gets to be muddy during the rainy season. The northern grasslands at their higher elevation are dominated by plant such as *Artemisia afra* and *Helichrysum splendidum* (Gozalbez and Cerbian, 2002; Getu, 2010; Richman and Biniam, 2013).

3.4.2. The Juniper Woodlands

Juniper woodlands are found around the head quarter of the park, stretching from the northern slopes of the Bale massif and reaching from Dodola to Dinsho. It is called Juniper Woodlands because the zone is dominated by Abyssinia and African juniper (*Juniperus procera*), additionally, the area is also dominated by *Hagenia abyssinica* and is the only indigenous rose to Africa (*Rosa abyssinica*) (Binian and Richman, 2013).

3.4.3. Afro-alpine Meadows

The afro-alpine vegetation belt is generally situated above the Erica belt (from ca. 3800 to 4377) masl. Due to human impact (deforestation), the afro-alpine belt is nowadays extending further down the slope, especially in the northern Bale Mts. Due to its high elevation; plant diversity here is too low. Vegetation like *Juniperus, Hagenia, and Hypercum* dominated in the central part. One of the notable plant species in the highest elevation is the giant lobelia (*Lobelia rhynchopetalum*) that grows at high altitudes. Moreover, tussock grasses (*Festucca sp*.) and dwarf shrubs/cushion plants are also characteristic of the afro-alpine. This zone is also an area that holds Tullu Dimtu peak the highest peak in the park at 4,377m asl (Gozalbez and Cerbian2002; Biniam and Richman 2013).

3.4.4. Erica Belt

The Erica belt is located at an altitude that lies between 3,400 to 3,800 m asl. This zone is designated as Erica belt for the fact it is dominated by species of the *Erica* and *Phillippa* genera, specifically by *Erica arborea* (tree heath), a shrub grows to staggering proportions in Bale – up to 5m on the edge of the tree line (Miehe & Miehe, 1994; Abel, 2012; Biniam and Richman, 2013).

3.4.5. Harenna Forest

The Harenna Forest is located in the southern part of the park and is the moistest and extensive natural forest remaining in Ethiopia. Geographically, it contrasts with elevations that range from 1450 to 3200 masl. Based on altitude variation and tree composition, the Harenna Forest is further divided into the following five zones (Miehe & Miehe, 1994; Gozalbez and Cerbian, 2002; Biniam and Richman 2013).

The lower altitudinal zone lies between 1450 and 1500 masl and is dominated by *Filicium-Warburgia, Podocarpus-Celtis* forest concentration. This zone is exactly located in the transitional zone between the moist montane forest and the dry woodland. Due to this, it is characterized by both woodland taxa like *Combretum molle* and *Terminalia brownii*, and forest species like *Warburgia ugandensis*, *Celtis africana*, and *Podocarpus falcatus*, among others (Miehe & Miehe, 1994; Biniam and Richman, 2013).

The dry evergreen forest zone rises from 1500 to 1700 masl. This zone of the park is dominated by a scattered tree-like *Podocarpus falcatus* and an understory of wild coffee (*Coffea arabica*). The vegetation zone between 1700 and 2100 masl forms another section of Harenna forest. This zone is dominated by tree species such as *Syzygium guineense, Polyscias fulva, Allophylus abyssinicus, Erythrina brucei, Croton macrostachyus*, and *Canthium oligocarpum*. It also contains one of the dominant trees, *Erythrina brucei*, and a shrub, *Vepris dainellii*, which are endemic to Ethiopia (Miehe & Miehe, 1994).

The fourth classification of the Harenna forest is found between 2100 and 2700 masl. The dominant trees type of this zone includes *Hagenia abyssinica*, *Schefflera volkensii*, *Erythrina brucei, Galiniera saxifraga, Allophylus abyssinicus, Dombeya torrida, Ficus ovata, Prunus*

africana, Croton macrostachyus, Maytenus addat (endemic to Ethiopia), and *Canthium oligocarpum (*Miehe & Miehe, 1994; Biniam and Richman, 2013).

The last zone in the Herrenna Harenna Forest rises from 2700 and 3000 masl. This zone is characterized by species such as *Hypericum revolutum*, *Schefflera volkensii*, *Hagenia abyssinica*, *Myrsine melanophloeos*, *Galiniera saxifraga*, and *Erica arborea*. The area below the escarpment, between (2700-3400 m asl) is also dominated by a high concentration and a patchy distribution of Bamboo trees (Biniam and Richman, 2013).

3.5. Geology

The early formation of BM goes back to Miocene and Oligocene periods some times between 38 and 25 million years ago. BM were separated from the western Ethiopian highlands by the subsequent formation of the Rift Valley. Onward its formation, successive outpourings of lava that took place in the area, was responsible for formations of diversified land escapes and rock types in the BMs. The rocks of the volcanic Outpourings include trachytes, rhyolites, basalts and agglomerates, and tuffs. Among all trachytes is predominantly found rock type in the BMs (Biniam and Richman, 2013).

The main Bale highlands consist of different plateaus which were formed by lava outpourings. These created more than six volcanic cones, each of them has a length more than 4200 m high, which have been considerably flattened by repeated glaciations. The crust of the Bale Mountains originated as a result of volcanic activities. Due to this, the soils, which are consequent from the basaltic and trachytic parent rock, were found to be fairly fertile silty loams of reddish-brown to black color (Richman and Biniam, 2013).

The other considerable impact on the volcanic landscape of the Bale Mountains is the glacial period. Varied glacial events have been recorded in the Bale Mountains which makes the region one of the most extensively glaciated areas in Ethiopia (Biniam and Richman, 2013).

Glacial geomorphological and chronological study results from the Bale and Arsi Mountains indicate the plateau and valley of southern Ethiopian Highlands extensive glaciated during the mid and late Pleistocene. In the Ethiopia Highlands including BMs, glaciers reached their maximum from 42 to 28 ka before the global Last Glacial Maximum(LGM) indicating regional differences in the timing and extent (Groos *et al*., 2021).

Based on Glacial geomorphological and chronological evidence Groos *et al*., (2021) established the glaciers chronology for Ethiopian highlands in general and BMs in particular. Accordingly in BMs, the glaciers reached their local glacial maxima from 42 to 28ka, between 19 to 17ka the glaciers started to retreat back either because of decreased precipitation or increasingly wetter climatic conditions that happened afterward ~20 ka in the region. The deglaciation process started in the BMs from ~18 to 17 ka caused by regularly increasing temperatures in the area starting from 20 ka, and rapid deglaciation started after 15,000.

3.6. Climate

Climate conditions such as temperature, precipitation, wind, and other elements of BMNP are determined by the geographical features of the park. These features include the vicinity of the park to the equator and the high altitudes above the sea. Accordingly, significant changes in altitude notably resulted in great variations of climate in the northern and southern parts of the park (Getu, 2010).

3.6.1. Rainfall

Factors such as the north-easterlies trade winds originating from the Indian Ocean, the inter-tropical convergence, altitude, and topography intensely determine the levels of rainfall at BMNP. The annual total rainfall varies from 600-2000 mm. It has eight months of the rainy season, extending from March to October, while the remaining four months are characterized by a dry climate. With increased altitude levels, rainfall also increases (Fiona, *et al* 2008). Bale Massif is also acknowledged for controlling the overall climatic condition of the region by attracting large amounts of orographic rainfall, which has notable significance for agriculture (Biniam and Richman, 2013).

3.6.2. Temperatures

The meteorological data from Bale Zone indicate that the minimum temperature varies from -15 ^{0}C to -6 ^{0}C that has been recorded at the highest plateau of Bale (Sanetti) and Dinsho, respectively. Whereas the average minimum and maximum range of temperature recorded are 0.7 ^{0}C and 18.3 °C.

3.7. Hydrology

BMNP is an important source of water for over 12 million people living in the Bale zone and the adjacent lowland area. From the Bale massif, more than forty streams are emerging. These join together and form four major rivers (Wabe Shebele, Web, Dumal, and Genale). These Rivers give lives for a million people living in the surrounding low lands area. These rivers provide a significant source of water for extreme rainwater shortage areas particularly for lowlands of the southeast and eastern Ethiopia, reaching up to the Ogaden area (Wallelign, 2007). Major Rivers and their tributaries originating from the Bale Mountains are summarized in the following table.

Table.2. Major rivers and their tributaries originating from the Bale Mountains (after Walellegn 2007:14).

No	Major River	Tributaries
1	Wabe Shebele	Abasa, Arba, Baranda, Boko, Furuna, Gondedoh, Layleeso, And Solay,Wachekora, Mararo, Malka Segel
2	Weyib	Albabo, Dalcha, Danka, Dimbeba, Gareno, Gesse, Kebesha, Kaficho, Keyrensa, Lolla, Micha, Shaya, Shaya-Gugesa,Teynta, Tegona, Toroshoma, Wolla, Wasama, Web, and Zetegn melka
3	Dumal	Six unnamed tributaries
4	Genale	Geremba, Rira, Shawe, Shisha Yadot Welmel, Weyib, Dumale, Doya, Hawas, and Hambala.

3.8. Short History of Archaeological Research at the BMs and overview of sites selected for this study

3.8.1. History of Archaeological Research

Since its establishment in 1971, BMNP is considered as a fascinating destination for its rich wildlife, culture and nature fanatics, and bird-watchers (UNESCO 2008). Extensive archeological surveys undertaken in the main mountains of Bale from 2015 to 2018, led to a series of discoveries of archaeological sites coupled with evidence of repeated human settlement in the region since the late Pleistocene. Following these discoveries, BMNP has become an ideal study area for early human settlement in an alpine environment to have a better understanding of human physiological, genetic, and cultural adaptation potentials (Ossendorf *et al*., 2019).

Since 2015, the area has been under an ongoing archaeological investigation for two main objectives. Firstly, to look into the survey results that suggested the area as one the oldest repeated settlement site in high altitude never confirmed elsewhere in human prehistory. Secondly, to identify settlement patterns, tempo-spatial distribution, and landscape use of the inhabitants (Ossendorf, *et al* 2020). Bulks of paramount findings have been collected from the settlement area that made the sites promising in achieving research objectives. The rock shelters are endowed with rich archaeological materials including lithic artifacts (obsidian and chert), faunal remains (including bovids, carnivores, micro-mammals, and fish), and a huge concentration of botanical remains, ceramics, charcoal, and ochre (Ossendorf, 2016; Ossendorf *et al.*, 2017).

The archaeological remains coming from diverse rock shelters in the BMNP are one of the typical pieces of evidence to test how MSA and LSA hunter-gatherers colonized and benefited from the Afro-alpine environment of the region. The occupation chronology of the sites varied from year to year as the excavation went deeper down to the older strata and from site to site as well. According to radiocarbon dates published in the 2019 report from Fincha Habera site, the earliest levels suggest that the occupation began during the Late Pleistocene, sometime between 47,000 and 31,000 years ago (Ossendorf *et al*., 2019; Reber *et al*., 2018; Zimmer, 2019).

3.8.2. Overview of the sites selected for this study.

Previous studies have recorded a total of 331 rock shelters in the Bale Mountains (Reber *et al*., 2018). Among these, ten sites Fincha Habera, Mararo, Simbiro, Fish shelter, Gata I, Gata II, Umburi, Garba Guracha, Wela, and Dimtu were selected for this study, based on the following criteria that have direct relations with the objectives of this study.

The traces of human presence are one of very important criteria considered here while selecting the site. One of the main objectives of this study is to reconstruct the interactions between humans and environments during the periods under investigation. Consequently, it is important to consider here the presence of humans at each rock shelter while selecting the sites. Since this study is dealing with afro-alpine environment adaptations, the altitude of the sites is also another point that was considered while selecting sites. The concentration of charcoal at each site is also used as criteria to select those sites. This study aimed to reconstruct humans and their interaction with the plant community by using anthracological data as sources of information. Thus, it is very vital to consider the numbers of charcoal while selecting sites.

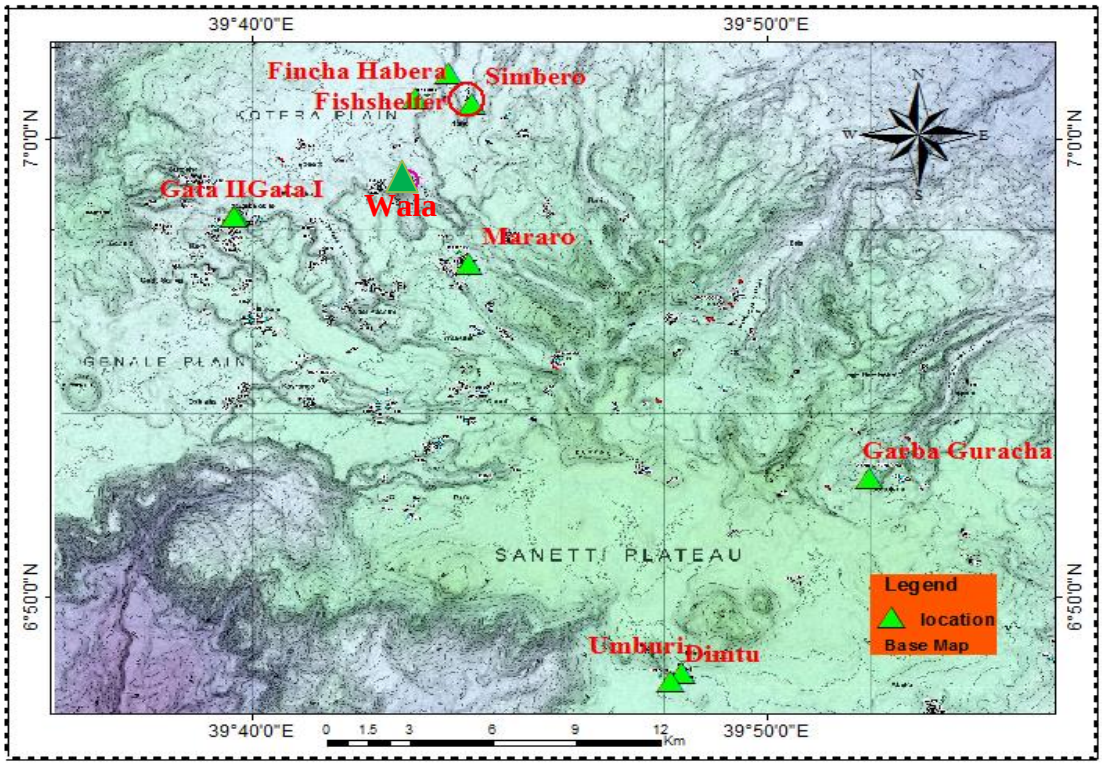


Figure.3. Map showing the location of sites in the Bale Mountains selected for the present study (developed by Ayele Akirso 2021).

1. Fincha Habera

Fincha Habera rock shelter lies at 7.014556° N, 39.720036° E, with an elevation of 3469 m asl. It is located in the Weyib River valley along a small stream called Wella. It is more important than others because, it is the world's oldest high-altitude residential site, so a "base camp" of prehistoric hunter-gatherers. While there are higher and older sites elsewhere, there we know only about the presence of humans at a certain altitude, at a certain time. But at Fincha Habera we have direct evidence and many aspects of how humans used the landscape around the site repeatedly over a long-time span. The site is also important because it lacks modern pastoral activities and also contains relatively undisturbed sediments (Ossendorf *et al*., 2019; Zimmer, 2019).

Excavations at Fincha Habera revealed thousands of Middle Stone Age artifacts that occurred in shallow sediments, including lithic tools, burnt animal bones, and hearths of frequent use. Radiocarbon dates from the site's earliest levels suggest that the occupation began during the Late Pleistocene, lasting between 47,000 and 31,000 years ago (Ossendorf, 2017; Ossendorf *et al*., 2019).

As indicated by Ossendorf, (Ossendorf, *Pers. Comm., May 31, 2021*) the occupations at Fincha Habera are classified into two broad phases. The earliest occupation phase corresponds to Middle Stone Age occupations that happened within the time span ranging from 46.5 to 31.4 ka cal. BP. Based on the vertical distribution of radiocarbon dating results, MSA layers at Fincha Habera can further be grouped into three broad horizons (46 to 42 ka, 39-34 ka, and 32-31 k a).

Based on the available dating and sedimentological results, the first MSA horizon at Fincha Habera is dated to 46 to 42 ka cal. BP in layer FHL-09, corresponding to the findings/samples of levels L12 and L13 of the H11 square, and also includes sample #726 from square F13, and

#1300 and #1301 from square F15. The second MSA horizon dates between 39 to 34 ka cal. BP in layer FHL-08 lower, and this corresponds to the findings/samples of levels L11, L12 of square E8, L10 of square H11, and samples #492, #567, #587, #617, #637, #640, #658, #738, #763, and #764 from square F16, and samples #1253 and #1265 from square F15. The last MSA layer at Fincha Habera is dated from 32 to 31 ka cal. BP in layer FHL-08 upper, corresponding to L9 and L10 from square E8, L8, and L9 from square H11, and samples #1181 and #1186 from square F15.

The second occupation phase at Fincha Habera was recorded after a long hiatus of 30,000 years after the end of the MSA period. The only visible re-settlement with archaeological signatures took place in the $12^{th}/13^{th}$ century AD. The second occupation phase is also classified further into two different layers. For the first layer (FHL-07) there are no secure dates with clear archaeological markers. Very few MSA artifacts were collected from this layer; however, the charcoals probably must have been trickled down from layer FHL-06. This layer corresponds to the findings/samples of levels L5-9 in square E8, samples #468, #852, #856, #863, #988 of square F15, and samples #183, #191, #211, #212, #430, #453, #454, and "F15 L6 N" from square F16.

The second horizon is predominantly associated with layers FHL-02/-03/-04/-05/-06/PIT, which correspond to levels L2-4 in square E8, and samples "F13 L2 SE", "F12 L4 SE", #338, #339, #278 from square F13, sample #468 from square F15, and samples "A45 F16 PIT1", #28, #45, #141, #320, #328, and #346 from F16 square. Charcoal samples obtained from five different occupational phases were examined in this study.

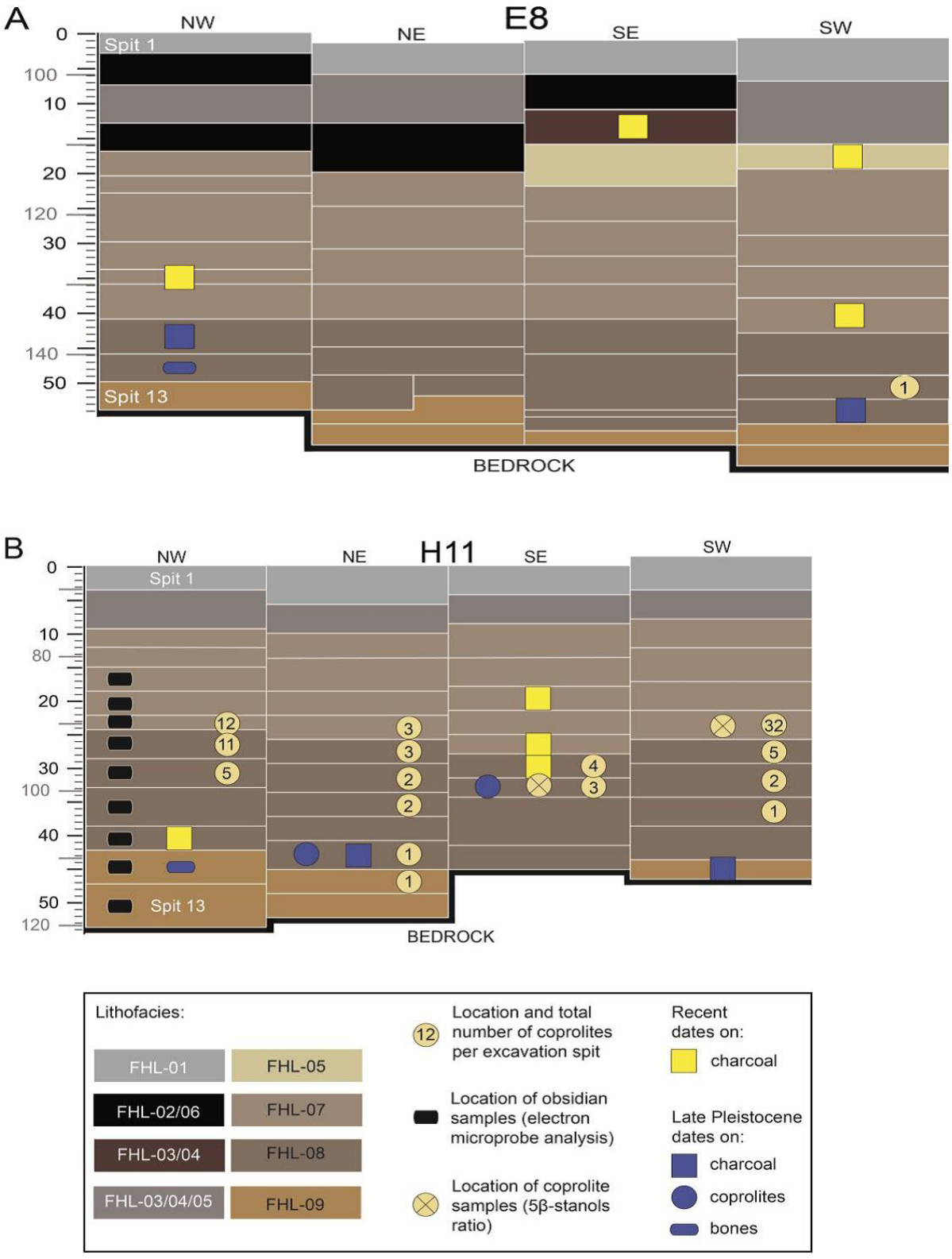


Figure.4. Schematic representations at Fincha Habera; "A" showing excavation levels "E8" square and "B" H11 square (After Ossendorf, 2019)

2. Simbero

According to C^{14} dating results, the stratigraphic sequence at Simbero comprises a considerable time depth, from 14,600 cal. BP up to recent times. The stratigraphic layers do not indicate specific occupational phases. However, based on the type of material cultures retrieved from each layer and C^{14} dating results, four different occupation events with clear archaeological signatures have been reconstructed. As indicated in the following schematic representation, the first occupation at Simbiro (LSA I) took place during the terminal Pleistocene around 14,600 yrs cal BP associated with retouched obsidian tools and corresponds to levels L8-10.

The second occupation phase (LSA II) happened during the early-to-mid-Holocene period between 8,100-5,000 yrs cal BP, characterized by a variety of geometric microliths which are the specific tool types of this period. In the schematic representations attached below, this occupation phase corresponds to level 7. At simbero on the deposition of Late Holocene layers, a high degree of burning events was recorded. Due to this, a relatively high number of charcoals was collected from this layer. A late Holocene occupation (LSA III) which occurred between 3,600-2,200 yrs cal BP is the third occupation phase associated with an even higher degree of a microlithic toolkit and an abundant amount of faunal remains (reflecting especially small game-hunting). This period corresponds to levels 3, 4, 5, and 6. The fourth and last occupation phase is a very late pastoral phase associated with ceramics and corresponds to level 1 and 2 (Ossendorf, *Pers. Comm., May 31, 2021).*

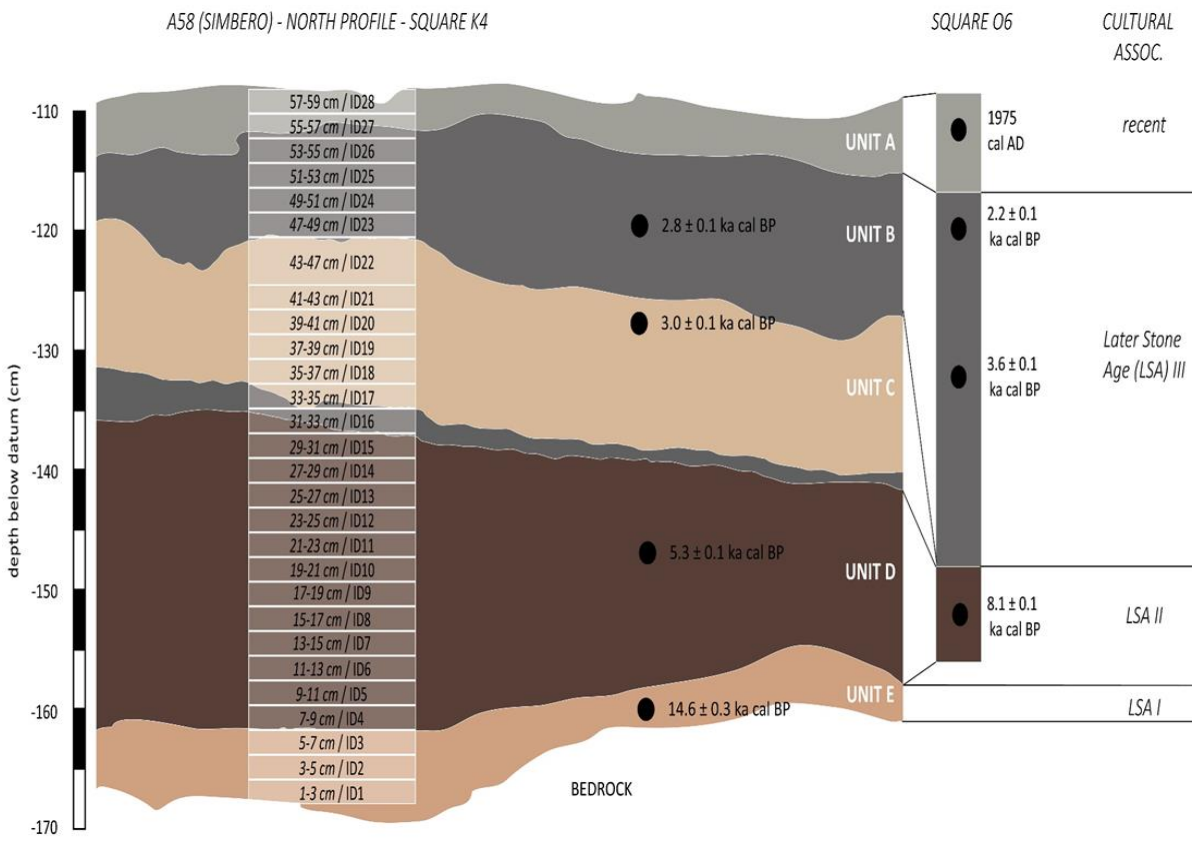


Figure .5. Schematic representation showing the allocation of levels to layers and the dates at Simbero (After Ossendorf, 2019)

As indicated on the below schematic representation, at Simbero a high degree of burning events was recorded on the deposition of Middle and Late Holocene layers. There are masses of charcoal here, or better, the charcoal has colored the sediments to such an extent that almost no layering is visible. Additionally, many obsidian artifacts show (different degrees of) burning and 99.8% of all faunal remains are burnt. Given its long sequence with repeated human occupations, the masses of faunal remains, the abundance and diversity of obsidian tools as well as the important role that fire played, this site forms a very relevant source of information (Ossendorf, *Pers. Comm., Nov 19, 2020*).

Figure .6. A photo showing charcoal concentration at Simbero site (after Ossendorf)

Some specialist studies including lithic technological & typological analyses, obsidian electron microprobe analysis, and faunal analysis) have already been completed and others, including lithic use wear and residue analysis, environmental DNA, geo-biochemical markers are currently underway *(*Ossendorf, *Pers. Comm., Nov 19, 2020*). In addition to the above-mentioned studies, the analysis and taxa identification of the charcoal is expected to constitute an essential contribution to understanding the human-environmental interactions that happened during the four occupation phases at simbero.

3. Fish Shelter

At the Fish shelter, two major occupation phases were reconstructed based on the material culture and the dating results obtained from both excavations units A61/A88. A61 refers to square F3 in the attached drawing. This is an old test excavation from 2017 where 50 cm of deposits were excavated up to the bedrock. A88 refers to square I4 in the attached drawing. This was re-excavated in the 2020 field season. For both excavation units at the Fish shelter, the

allocation of levels to layers and the dates is clearly described and very easy to understand (Ossendorf*, Pers. Comm., and May 31, 2021).*

Based on C^{14} dating results, the first occupation phase dated to be 14.0 to 14.8 ka cal. BP in layers D and E, corresponding to levels 8-15. The second occupation dated to be c. 6.3-6.5 ka calBP in layers B and C, corresponding to levels 3- 6. Here the sequence was excavated up to 70 cm, clearly showing two artifact horizons with much charcoal (layers B and D in the drawing). As suggested by Ossendorf *(*Ossendorf*, Pers. Comm., May 31, 2021)* the concentrations of artifact in these layers reflect the major depositions for each occupation, some charcoal pieces might then have trickled/trampled downwards into lower layers. This also shows that for some levels (e.g., level 7) it was difficult to allocate this level to a specific occupation phase because the samples were belonging to an interface between layers C and D. Also, the top levels do not reflect a prehistoric phase and are of comparably recent origin.

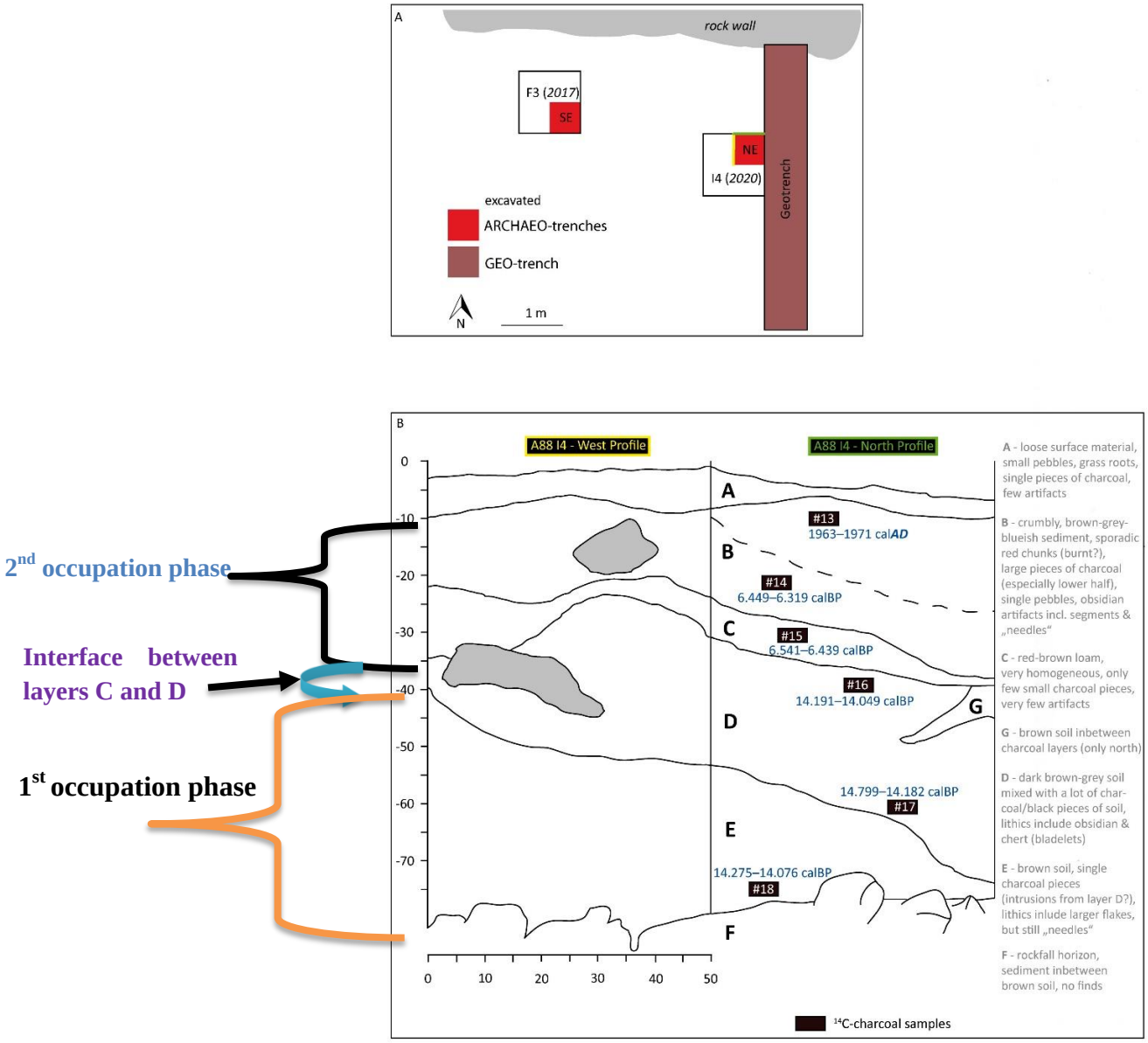


Figure.7. Schematic representations showing the allocation of levels to layers and the dates at Fish Shelter (After Ossendorf)

As indicated by Ossendorf (Ossendorf, *Pers. Comm., May 31, 2021)* the project members from the soil sciences have also worked at the same site and opened a geological trench. They obtained dates of around ~13,000 and 23,000 cal BP from their trench, showing the preservation of even older deposits, yet without clear signs of human presence.

The relevance of the Fish shelter consists of the fact that it might have obtained a rare human and environmental archive for Marine Isotope Stage (MIS) 2, approximately between 29-12 ka cal. BP. This period includes the global Last Glacial Maximum as well as the beginning of the African Humid Period. Very little is known about this phase in terms of human settlement; in fact, there are very few reliably dated archaeological sites in Ethiopia belonging to this period.

Additionally, the environmental conditions of the Bale Mountains during this time were not clear. The glaciers had their maximum advance already around 40,000 years ago and retreated after 17,000 years ago, and rapid deglaciation that started after 15,000 enabled the area to be ice-free, which corresponds to the early human re-settlement at ~ 14,000 (Groos *et al*. 2021).

The charcoal analysis would be a highly relevant contribution to understanding the human-environment interaction at that time. From the archaeological point of view, the human occupation has produced very unusual lithic artifacts (needle-like bladelets) which might indicate that prehistoric people spent much time fishing here at this site. Interestingly, both at the Plateau site of Dimtu as well as at the nearby site of Simbero, people have also settled at the same time (~14,000 BP) and fish bones were also recovered at the latter site *(Ossendorf, Pers. Comm., May 31, 2021)*. The charcoals from this settlement phase correspond to square K4, levels 9 and 10.

4. Mararo

As indicated by Ossendorf (Ossendorf, *Pers. Comm., May 31, 2021)*, the stratigraphic sequence at Mararo comprises two major occupation events. At the bottom, a late Holocene LSA occupation probably corresponds to the last hunter-gatherers in the Bale Mountains. The lithic assemblage is very rich in terms of numbers of artifacts and is moreover characterized by a very versatile LSA toolkit. Noteworthy, the production of borers is the most characteristic feature of this lithic assemblage, alongside other microlithic tools, such as retouched (scrapers, laterally

retouched bladelets) and backed (segments, crescents, straight-backed) tools. No faunal remains were recovered. Radiocarbon dating results place the onset of this settlement phase around the termination of the African Humid Period (4.7 ka cal. BP). The end of the LSA occupation probably occurred after 2.6 ka cal. BP, mirroring the results of A-58 Simbero. While this reflects a rather short occupation phase, there is a high degree of chronological control for the respective lithic and charcoal assemblages. The deposits of this phase feature a high number of charcoal pieces, burnt obsidian and sediments occur regularly, and the charcoal has colored the latter to a high degree.

At the top, a late pastoral occupation phase with very few and undiagnostic lithic artifacts and few pottery sherds were recovered from interfingering layers consisting of loamy deposits (with ash) and fine wet and dry dung. A single date points to 1.2 ka cal. BP (Ossendorf, *Pers. Comm., May 31, 2021).*

As at almost all sites, younger charcoal has been moved into deeper deposits, however, the charcoal assemblage of the LSA-deposits (black organic & black organic with gravel) seems to have rarely been affected by post-depositional disturbances and seems to reflect past burning activities similar to those at Simbero (anthrosol analysis still ongoing). Some specialist studies have already been completed (lithic technological & typological analysis, obsidian electron microprobe analysis) or are currently in process (lithic use wear and residue analysis, geo-biochemical markers). Analysis and taxa identification of the charcoal would be an essential contribution (Ossendorf, *Pers. Comm., May 31, 2021).*

The lithic material of this site is very similar to those of the late Holocene phase of Simbero, as well as from other sites in the Bale Mountains. The electron microprobe analysis has already

evidenced contacts to the Rift Valley; obsidian from the Chebe/Korbeti volcanoes was transported to the Bale Mountains.

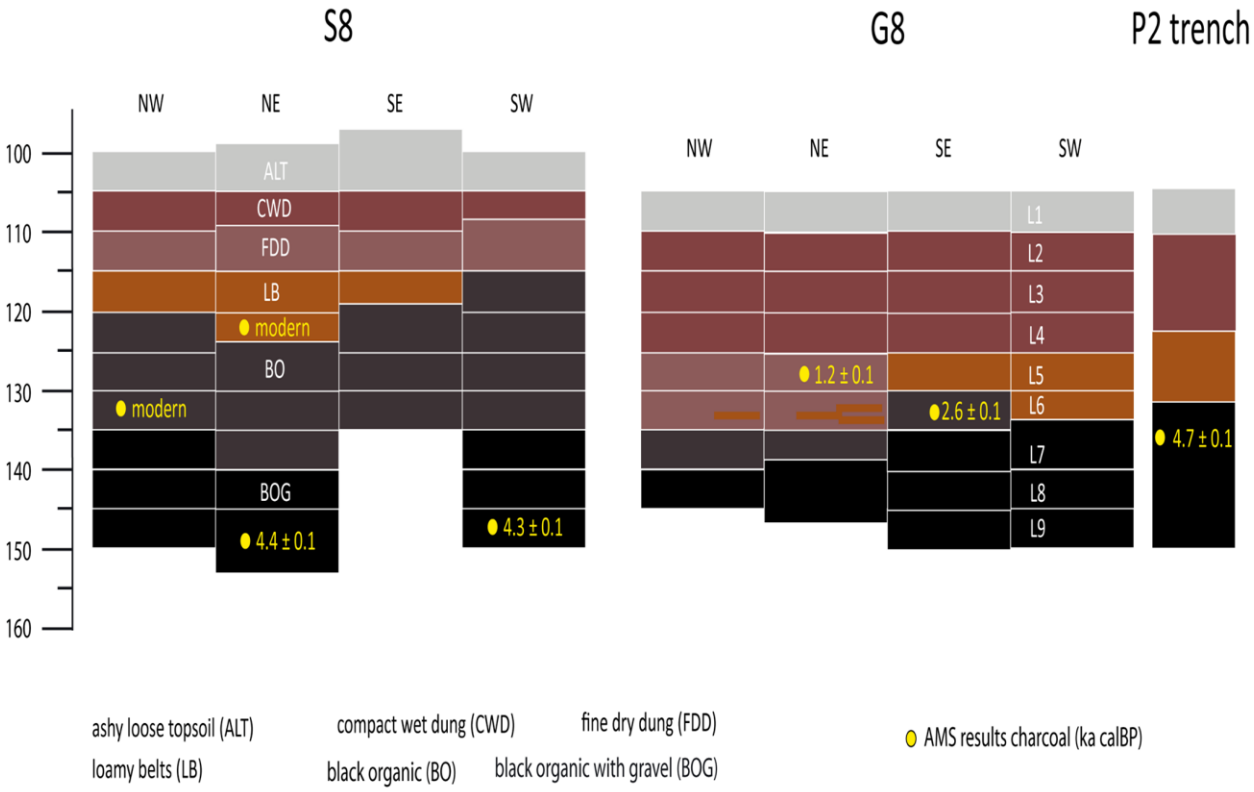


Figure.8. A plan Views showing excavation levels and units at Mararo Shelter (After Ossendorf)

5. Dimtu

Dimtu site lies at approximately 6.802389° N, 39.8025° E, and 4123 masl. This site has the highest altitude (4,123 masl) of all investigated sites. It is located on the Central Plateau of the Bale Mountains at the foot of its highest peak (Tullu Dimtu). It is probably the most relevant of the "diverse" sites, as here where found very unusual and unparalleled cultural remains *(Ossendorf, Pers. Comm., May 31, 2021*).

As with all sites on the Afro-alpine Plateau, this site is very interesting in the type of woods that were used by prehistoric people, and whether the afro-alpine vegetation is the result of human

fire management in the past. There is also the hypothesis that at times the vegetation belts in the Bale Mountains have shifted. Charcoal samples were recovered from four different depths of a single excavation square.

6. Garba Guracha

Garba Guracha rock shelter is situated roughly at 6.876133° N, 39.866533° E, 4019 m asl (Reber *et al*., 2018). The site is located next to the high-altitude Lake Garba Guracha, an important paleoclimatic archive. However, a single date of 950 YBP recovered here at the base associated with dark soil does probably not correspond to the Later Stone Age (LSA) lithic artifacts found here (Ossendorf, *Pers. Comm., May 31, 2021*). Charcoal samples were retrieved from the base of a test pit.

7. Umburi

Umburi site is located at 6.80585° N, 39.800725° E, with an altitude of 3973 m asl). As indicated by Ossendorf, only a single charcoal concentration was found at a test pit in this rock shelter. However, the charcoal was closely associated with a hyena skull (yet updated). The shallow deposits of the test excavation conducted here have yielded a homogeneous microlithic LSA assemblage. A single date places it to 8,900 YBP, which is not only the oldest date so far on the Plateau but also does correspond to the dating results for similar cultural material at Simbero. Charcoal samples were retrieved from 30-40 cm of depth beneath the ground, within a single, charcoal-rich archaeological horizon *(*Ossendorf, *Pers. Comm., May 31, 2021).*

8. Gata I

Gata I site is of the northwestern escarpment situated at 6, 9716649° N, 39, 66134401° E, and at the height of 3,566 m asl. As described in the field report, there was no expectation of any meaningful results for this site, as it was heavily disturbed by recent pastoral activities. It is the

largest rock shelter in the Bale Mountains. Based on some intact materials, the radiocarbon dates obtained indicate various settlements within at least the last 10,000 years. However, all investigated sediments were re-deposited and it cannot assign any archaeological material to a certain time phase. Charcoal samples were recovered from four different test pits, with a maximum distance of 30 m to each other *(*Ossendorf, *Pers. Comm., May 31, 2021).*

9. Gata II

Gata II lies at approximately 6.9716389° N, 39.661222° E, with an altitude of 3582 m asl. In contrast, a shelter in the immediate vicinity has a clear stratigraphy, albeit within shallow deposits: the lower deposits can be assigned to a late LSA hunter-gatherer occupation (3,000 to 2,000 YBP, the upper deposits show signs of a younger pastoral settlement. Charcoal samples were recovered from various depths along with one single geological profile *(*Ossendorf, *Pers. Comm., May 31, 2021*).

10. Wela

Wela lies at 6.9837222° N, 39.709° E, and the height of 3,559 m asl. At Wela, the research group has recovered a very homogeneous LSA assemblage from a highly protected situation (basalt block resting on three others). Dates are pending, but it belongs to the highly visible late Holocene settlement phase, comparable to Gata II, Mararo, and the upper deposits at Simbero. Charcoal samples were taken from different levels of a quarter square inside (C/D2) and a quarter square outside (E2W) the shelter (Ossendorf, *Pers. Comm., May 31, 2021*).

The present study is based on a sample of 565 specimens of archaeological charcoals collected from various unit levels of excavation sites at the Bale Mountains. The total sample includes charcoal from Fincha Habera (n=159), Mararo (n=74), Simbero (n=106), Fish shelter (n=146), Gata I (n=8), Gata II (n=8), Wela (n=20), Umburi (n=15), Garba Guracha (n=10), and Dimtu

(n=19). Therefore, this study tried to investigate the archaeological charcoals collected from the aforementioned 10 sites situated in the BMNP to address questions relating to vegetation history, fire use, and environmental setup of the study area.

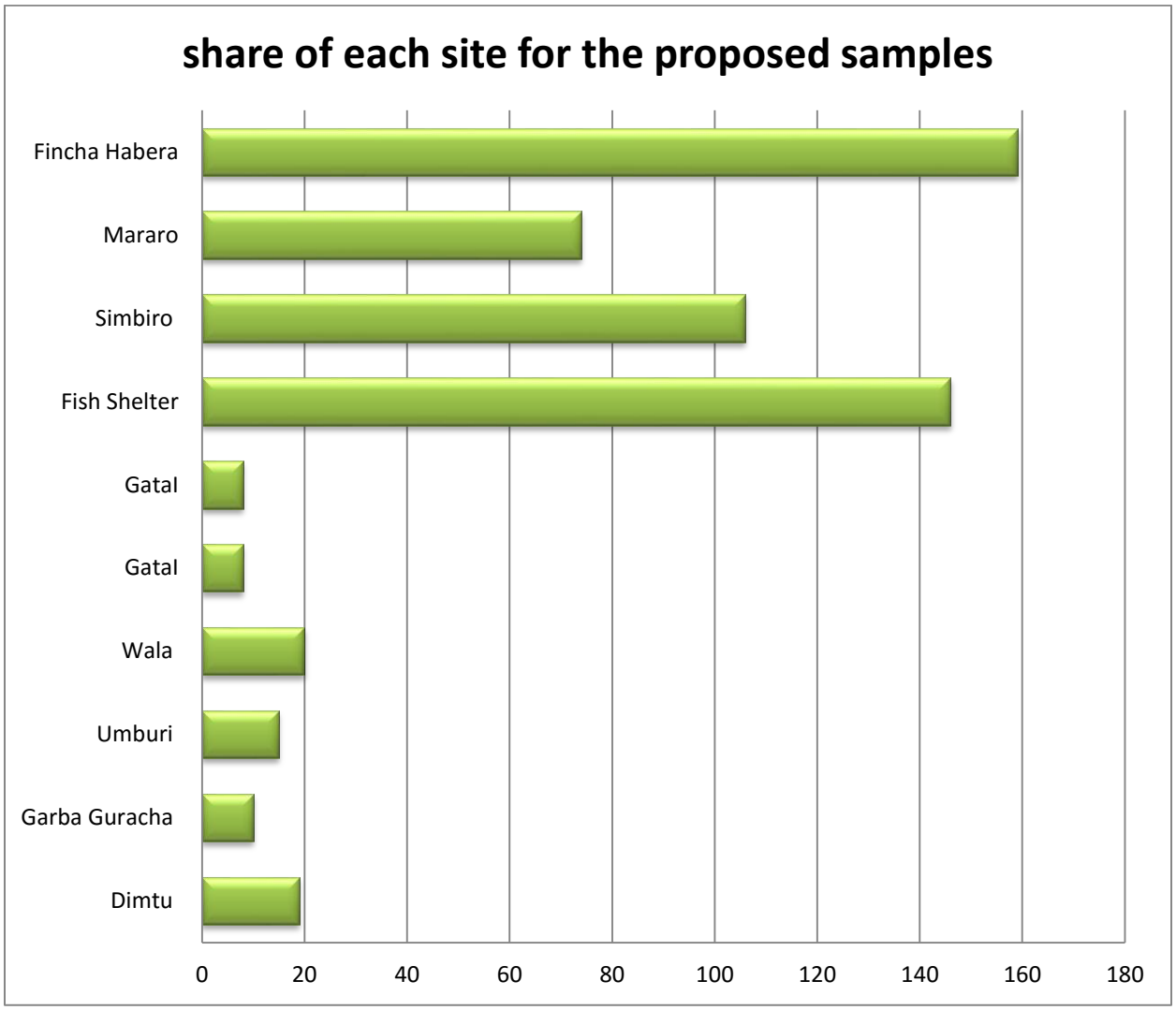


Chart 1. Graph that summarizes the share of each site for the proposed total samples

CHAPTER FOUR

DATA PRESENTATION

4.1. Charcoal samples, Recovery Techniques, and Preservation Conditions.

A total of 565 charcoal fragments were collected from 10 different sites of BM namely, Fincha Habera, Fish Shelter, Simbiro, Mararo Garba Guracha, Dimtu, Umburi, Wela, Gata I, and Gata II were examined in this study. In terms of sample recovery, all charcoals were individually picked from *in-situ* contexts during excavation. Among the samples selected for this study, there is no charcoal recovered either through sieving or floating. The excavation sequences of all ten sites are relatively free from any major disturbance factors like infill except at Fincha Habere where slight disturbances were observed.

As described by Ossendorf (Ossendorf, *Pers. Comm., May 31, 2021),* a recent pit which were cut into older Pleistocene layers was observed at Fincha Habera site. However, charcoal from these features was clearly labeled as ("pit 1"/"pit 2"). Two very small animal burrows (one with backfill, one without), and one large animal burrow spanning over several levels (square F16, profile wall of SE corner, from Level 6 to Level 12) were also observed. Though any charcoal from these contexts has been labeled accordingly because it was found associated with coprolites in these burrows and they are designated as originating from these burrows. The charcoals collected *in-situ* provide significant information to address research questions related to the type of wood selected and used for fire through time.

The preservation conditions of all samples are relatively good. The consistency of the charcoal samples ranges from large, firm chunks to powdery residues. Charcoals from Fincha Habera, Simbero, Mararo, and Fishshelter were relatively containing the most relevant charcoal

fragments. All minimum sizes of the charcoals are selected here for reliable identification. The powdery residues were not helpful for identification and therefore excluded. Attention was given to charcoal pieces with the appropriate size of 8-4 mm which enabled to break the charcoals into several pieces to see transverse, radial, and tangential anatomical lines. At most sites, recovered charcoal fragments have a size of >4 mm and could thus be examined. However, sites like Simbiro, Gata I, Umburi, and Wela yielded some charcoal fragments less than 4 mm and in some instances, we were forced to look at charcoal fragments >2 mm.

Attempts were done to allocate all charcoal samples into their respective occupational phases based on the chronostratigraphical information provided by the project. However, these attempts were not equally applicable for all sites. This is because in some sites like Fincha Habera and Mararo, the interrelations between levels, layers, and dating results were not always corresponding to each other. In all cases to reconstruct vegetation history diachronically across time, a minimum of 6 charcoal fragments was identified from each occupational phase.

4.2. Distributions of charcoal fragments along with the ten sampling sites

All possibly identified pieces were obtained from the ten sampling sites identified in their respective categories. From the total sample of 565 charcoal fragments selected for this study, 366 (65%) were identified into their respective taxa, whereas the remaining 199 fragments (35%) remain unidentified due to poor preservation, the absence of a sufficient number of comparative collections, and small sizes of the pieces (less than the actual standard).

Table .3. A table that shows the total samples selected for this study, total identified, and unidentified samples.

Sites	**Total samples selected for this study**	**Total identified pieces**	**Total unidentified pieces**
Fincha Habera	159	101	58
Fish shelter	146	87	59
Simbiro	106	82	24
Mararo	74	58	16
Wala	20	10	10
Dimtu	19	6	13
Umburi	15	6	9
Garba Guracha	10	6	4
Gata I	8	6	2
Gata II	8	5	3
Total	565	366	199

As illustrated in table 3, the largest charcoal fragments were obtained and identified from Fincha Habera site, represented by 159 charcoal fragments from which 101 of them were identified into

taxa, and the remaining 58 pieces remained unidentified. Fish shelter contains the second-largest samples and identified a piece which is represented by 146 charcoal fragments from which 88 of them identified into their respective taxa whereas the remaining 57 charcoal fragments remain unidentified. A total of 106 charcoals fragment were selected from Simbero, from these 82 of them were identified into their respective taxa and 24 remain unidentified. From a total sample of 74 charcoal fragments from Mararo, 58 of them were identified into their respective taxa whereas the remaining 16 samples remain unidentified. From Wala, Dimtu, Umburi, Garba Guracha, Gata I, and Gata II a total of 80 charcoal fragments were selected for this study. Out of these, 39 pieces were identified into their respective taxa and 41 pieces remained unidentified.

4.3. Identified taxa and their anatomical descriptions

Attempts were made to categorize all charcoal fragments into genus, family, and species levels. Before doing this, all samples of charcoal were classified into angiosperm or gymnosperm. KEYENCE electron microscope with a magnification level of 100X, 150X, and 200X was used to identifying charcoal fragments into angiosperm or gymnosperm by identifying the anatomical differences (the presence and absence of vessels, the size of rays, and abundance of tracheid). From the total charcoal fragments identified, 84% of them were classified as angiosperm/hardwood/ and 14% were classified as gymnosperm/softwood/.

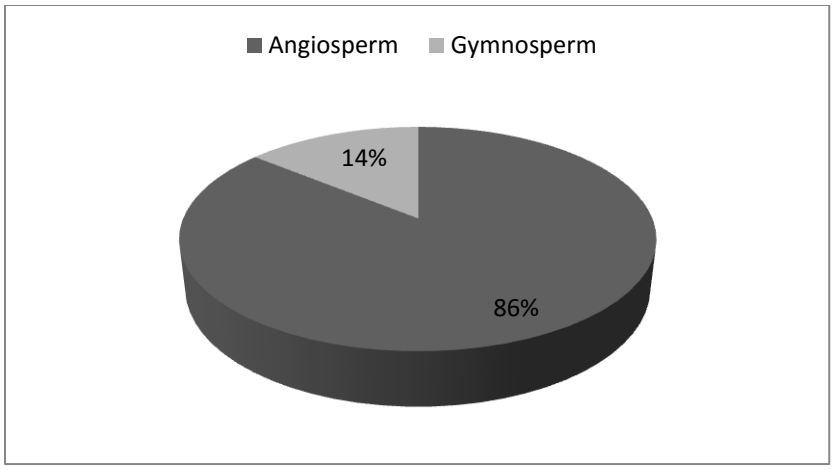
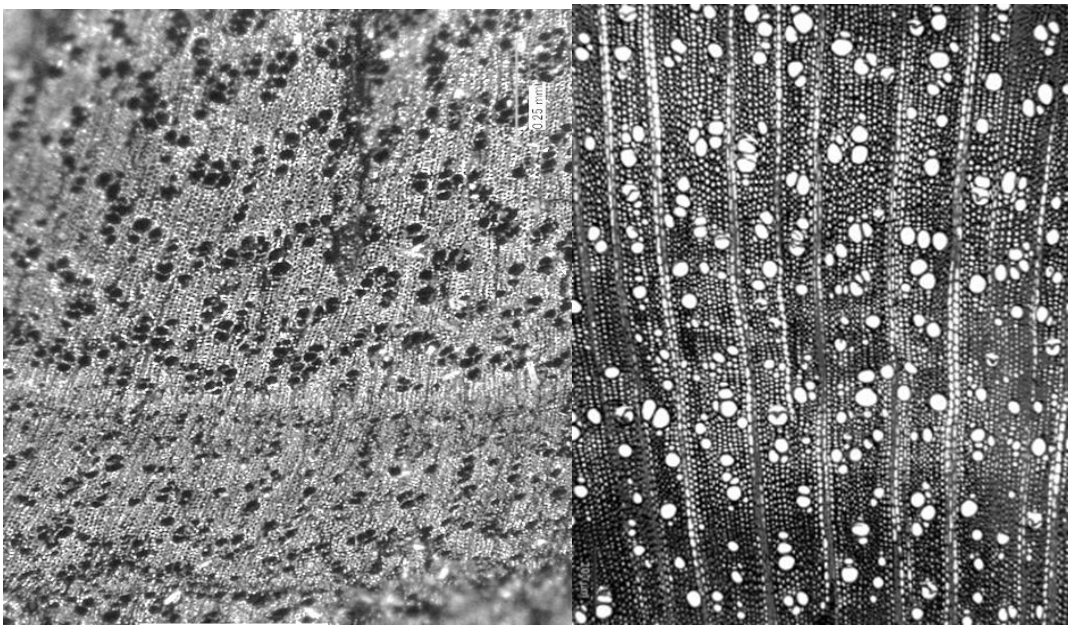


Chart 2. Summary of classifications of samples into Angiosperm and Gymnosperm in percentage.

After classifying charcoal fragments as angiosperm and gymnosperm through the aid of an electron microscope, an attempt was also made to identify those charcoals at the species level. Identifying types of trees at the species level is a very difficult task, and modern wood collections from the study area were used as a comparison to group the unknown charcoal fragments into species levels.

In this way, a total of seven different taxa were identified from all ten sites. The structure of the fossilized charcoal and its anatomic characteristics were carefully compared with modern ones retrieved from inside wood data base and Alemseged Beldados teaching references to find similar structure and descriptions. Some of identified taxa through close correlation of charcoal samples from the BM and modern anatomy from inside wood data set are shown in (Figure 12, 13, 14, and 13) and some additional will be present in appendix part.



A **B**

Figure .9. Identification of archaeological charcoals by comparisons with modern anatomy of *Artemisia afra* in cross-sectional view. (A) Anthracology sample from Fincha Habera site (FH17 E8 L2 SE) (B) Modern anatomy of *Artemisia afra* retrieved from InsideWood database. Published on the Internet. http://insidewood.lib.ncsu.edu/ contributed by Elisabeth Wheeler [accessed 2020-2021].

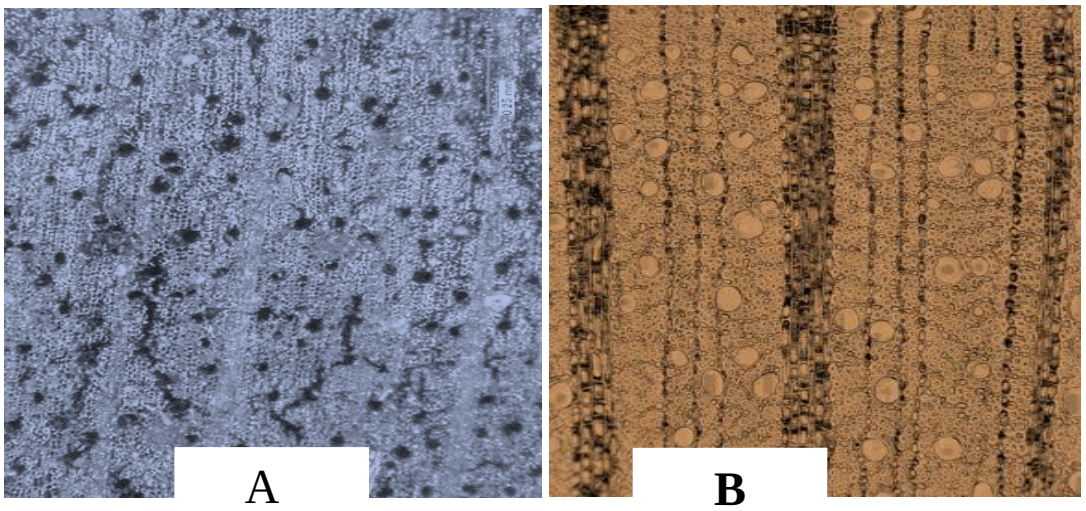
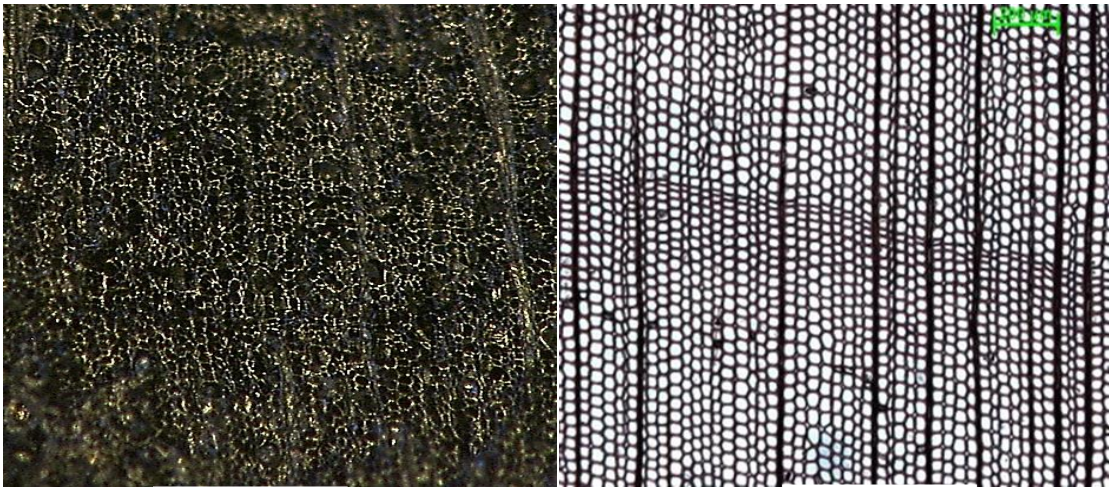


Figure.10. Identification of archaeological charcoals by comparisons with modern anatomy of *Erica arborea* in cross-sectional view. (A) Anthracology sample from Fincha Habera site (FH17 E8 L6 NW) (B) Modern anatomy of *Erica arborea* retrieved from InsideWood database. Published on the Internet. http://insidewood.lib.ncsu.edu/ contributed by Elisabeth Wheeler [accessed 2020-2021].



A **B**

Figure. 11. Identification of archaeological charcoals by comparisons with modern anatomy of *Juniperus procera* in cross-sectional view. (A) Anthracology sample from Mararo site (MAR A05S8 SW1-130, (B) Modern anatomy of *Juniperus procera* retrieved from Inside Wood database. Published on the Internet. http://insidewood.lib.ncsu.edu/ contributed by Elisabeth Wheeler [accessed 2020-2021].

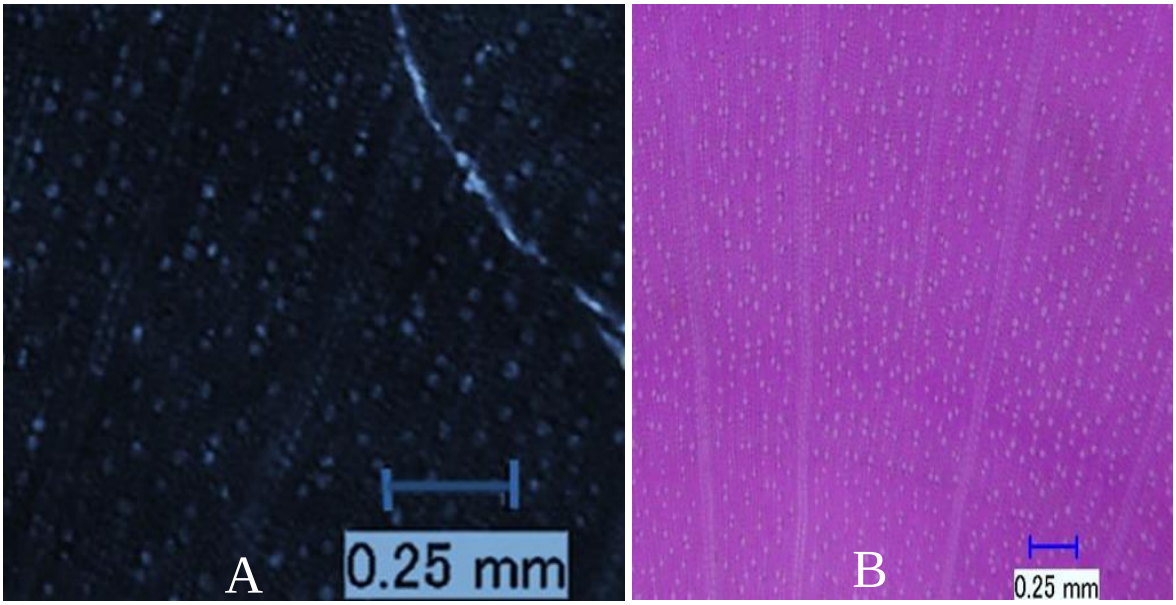


Figure. 12. Identification of archaeological charcoals by comparisons with modern anatomy of *Myrsine africana* in cross-sectional view. (A) anthracology data from Simbiro (E18 1 A58 K4 L9 NE (B) Modern anatomy of *Myrsine africana* obtained from Alemseged.B teaching collections.

In addition to image correlations, the anatomic descriptions were also considered while working with identifications. In the following part, the seven identified taxa and their anatomical descriptions will be presented.

1. *Artemisia afra*

Defining Characteristics	Definitions
Growth ring	Growth ring not clearly visible
Vessel porosity	Wood semi-ring-porous
Vessel arrangement	Vessels in tangential by making wavy bands
Vessel grouping	Vessel clusters common
Parenchyma cells	Fusiform parenchyma
Rays cell arrangement	procumbent, square, and upright cells found mixed throughout the ray
Ray cell width	1 to 3 cells

2. *Myrsine africana*

Defining Characteristics	Definitions
Growth ring	Indistinct or absent
Vessel porosity	Wood diffuse-porous
Vessel arrangement	Vessels in diagonal and/or radial pattern
Vessel grouping	Vessels partly solitary, partly in radial multiples of 2-4, or small clusters.
Parenchyma cells	scanty paratracheal
Rays cell arrangement	All ray cells upright and/or square
Ray cell width	1 to 3 cells

3. Hypericum revolutum

Defining Characteristics	Definitions
Growth ring	Indistinct or absent
Vessel porosity	Wood diffuse-porous
Vessel arrangement	Vessels in diagonal and/or radial pattern
Vessel grouping	Vessels partly solitary, partly in radial multiples of 2-4, or small clusters.
Parenchyma cells	absent or extremely rare
Rays cell arrangement	Rays with procumbent, square, and upright cells mixed throughout the ray
Ray cell width	exclusively uniseriate

4. Juniperus procera

Defining Characteristics	**Definitions**
Growth ring	Indistinct or absent
Transition from earlywood to latewood	Gradual transition
Parenchyma cells	Present
Arrangement of axial parenchyma	Diffuse (evenly scattered throughout the entire growth increment)
Ray tracheids	absent or very rare
Average ray height (number of cells)	medium (5 to 15 cells)
Ray cell width	Rays exclusively uniseriate

5. Hagenia abyssinica

Defining Characteristics	Definitions
Growth ring	Indistinct or absent
Vessel porosity	Wood diffuse-porous
Vessel arrangement	Vessels in diagonal and/or radial pattern
Vessel grouping	Vessel clusters in common
Parenchyma cells	vasicentric tracheids present
Rays cell arrangement	All ray cells procumbent
	Larger rays commonly 4 - to 10 seriate

6. Erica arborea

Defining Characteristics	Definitions
Growth ring	Distinct
Vessel porosity	Wood diffuse-porous
Vessel grouping	Vessels exclusively solitary
Parenchyma cells	scanty paratracheal
Rays cell arrangement	procumbent with mostly 2-4 rows of upright and/or square marginal cells
Ray cell width	Larger rays commonly 4 - to 10 seriate

7. Solanum giganteum

Defining Characteristics	Definitions
Growth ring	Indistinct or absent
Vessel porosity	Wood diffuse-porous
Vessel grouping	Vessels partly solitary, partly in radial multiples of 2-4, or small clusters.
Parenchyma cells	scanty paratracheal
Rays cell arrangement	Body ray cells procumbent with over 4 rows of upright and/or square marginal cells Sheath cells
Ray cell width	Ray width 1 to 3 cells

As indicated in the table below, out of total identified 366 samples, 47 pieces (13%) were identified as *Artemisia afra*, 82(22%) pieces defined as *Myrsine africana*, 31(8%) as *Hypercum revolutum*, 21(6%) as *Juniperus procera*, 44 pieces (12%) *Hagenia abyssinica*, 90 pieces (25%) *as Erica arborea*, and 51 pieces (14%) as *Solanum giganteum.*

Table .4. summarizes major identified taxa and their amount in number and %, obtained from all sampling sites

No	Types of identified taxa	Amount in number	%
1	*Erica arborea*	90	25%
2	*Myrsine africana*	82	22%
3	*Solanum giganteum*	51	14%
4	*Artemisia afra*	47	13%
5	*Hagenia abyssinica*	44	12%
6	*Hypericum revolutum*	31	8%
7	*Juniperus procera*	21	6%
	Total	366	100%

4.4. Individual share of each site for a total identified charcoal samples.

As indicated above, the identifiable 366 charcoal fragments were collected from 10 sites of BMs and identified into 7 different taxa. All 10 sites have the following individual share of the total identified taxa.

Table .5. Summarizes the share of each site for "*Erica arborea*" wood.

	Site	No charcoal fragments
Erica arborea	Fincha Habera	19
	Fish shelter	21
	Mararo	14
	Simbiro	21
	Dimtu	4
	Gata I	3
	Garba Guracha	2
	Umburi	4
	Gata II	2
	Total	90

As indicated in table 5, *Erica arborea* was the most dominant taxon by both abundance and representations from most sites (9), which represented 90 pieces, collected from nine different sites. From the total identified pieces, the largest amount was obtained from Fish Shelter, Simbero, Fincha Habera, and Mararo represented by 21, 21, 19, and 14 pieces respectively, whereas the smallest amount was obtained from Dimtu, Umburi, Gata I, Garba Guracha, and Gata II represented by 4, 4, 3, 2, and 2 pieces of charcoals respectively.

Myrsine africana is the second most abundant species by containing a total of 82 pieces of charcoal collected from nine different sites. From a total identified sample of *Myrsine africana*, 17 pieces were obtained from Fincha Habera, 20 from Fish shelter, 19 from Simbero, 13 from Mararo, 2 from Dimtu, 6 from Wela, 2 from Umburi, and 3 from Garba Guracha.

Table .6. summarizes the share of each site for "Myrsine africana" fragments.

	Site	No charcoal fragments
Myrsine africana	Fincha Habera	17
	Fish shelter	20
	Simbiro	19
	Dimtu	2
	Mararo	13
	Garba Guracha	3
	Wela	6
	Umburi	2
	Total	82

A total of 51 pieces of charcoal were collected from five sites identified as *Solanum giganteum*. From a total amount of this taxon, 14 pieces were obtained from Fincha Habera, 15 from Fish shelter, 13 from Simbero, 5 from Mararo, and 4 from Geta II.

Table .7. Share of each site for "*Solanum giganteum*" taxon

	Site	No charcoal fragments
Solanum giganteum	Fincha Habera	14
	Fish shelter	15
	Mararo	5
	Simbero	13
	Gata II	4
	Total	51

Out of identified charcoal fragments, 47 pieces were collected from six different sites identified as *Artemisia afra.* Out of total pieces identified as *Artemisia afra* 19, 11, 6, 8, 1, and 2, pieces were collected from Fincha Habera, Fish shelter, Simbero, Mararo, Garba Guracha, and Wela respectively.

Table .8. Share of each site for samples identified as *Artemisia afra* taxa.

	Site	No charcoal fragments
Artemisia afra	Fincha Habera	19
	Fish shelter	11
	Simbero	6
	Mararo	8
	Garba Guracha	1
	Wela	2
	Total	47

A total of 44 charcoal fragments were obtained from different five sites identified as *Hagenia abyssinica*. Among these, 15, 10, 8, 9, and 3, of them, were obtained from Fincha Habera, Fish shelter, Mararo, Simbiro, and Gata II respectively.

Table.9. Share of each site for "Hagenia abyssinica" fragments.

	Site	No charcoal fragments
Hagenia abyssinica	Fincha Habera	15
	Fish shelter	10
	Mararo	8
	Simbero	9
	Geta I	2
	Total	44

Out of the total of identified samples, 31 pieces were collected from four sites and identified as *Hypericum revolutum* out of these 11, 8, 7, and 3, were collected from Fincha Habera, Fish shelter, Mararo, and Simbero respectively.

Table .10. Share of each site for "*Hypericum revolutum*" fragments.

	Site	No charcoal fragments
hypericum revolutum	Fincha Habera	11
	Fish shelter	8
	Simbero	7
	Mararo	3
	Wela	2
	Total	31

Juniperus procera is the other identified taxon that contains the smallest number of charcoal pieces among all identified types. A total of 21 charcoal fragments obtained from four sites of BMs are categorized under this taxon. Out of these, 6 pieces were obtained from Fincha Habera, 2 from Fish shelter, 6 from Mararo, and 7 from Simbiro.

Table. 11. Share of each site for "*Juniperus procera*"

	Site	No charcoal fragments
Juniperus procera	Fincha Habera	6
	Fish shelter	2
	Mararo	6
	Simbero	7
	Total	21

4.5. The results of charcoal analysis from all contexts at each site

In the following part, the distribution of charcoal in the present analysis from all contexts at each site will be discussed. Before going to a detailed discussion on contextual analysis of all sites in respective to their charcoal fragments, it is also very important to talk about the chronostratigraphical information of the study area in general.

As reported by the project team, the term "level" was used to describe an artificial excavation removal (usually a 5 cm-thick, horizontal spit), and the term "layer" was used to describe macroscopically visible characteristics of the sediments (color, composition, texture, inclusions) during excavation and in the profiles.

As the rock shelter sediments in the Bale Mts., there are no sealed deposits, it is difficult to know whether a radiocarbon date (usually on charcoal) reflects the age of the level/layer, or whether the charcoal was re-deposited. To solve this problem, the project is looking to different options including (1) additional sedimentological and micromorphological studies to test for integrity (but this is time-consuming and expensive), (2) obtain a large number of radiocarbon dates (this is expensive), and (3) excavating in artificial spits allows to retain the general vertical control of the stratigraphy, and it can enable to check whether changes in artifact density and nature roughly corresponds to occupational horizons.

1. Fincha Habera

As indicated in chapter 3, Fincha Habera yielded two occupation phases. Attempts were made to analyze charcoal samples from all occupational phases of MSA and recent periods. However, the attempts to identify charcoal samples from the MSA occupation phase were unsuccessful. The samples from the three MSA occupation periods in Fincha Habera remained unidentified because of the absence of a sufficient number of comparative collections for most samples, and poor preservation, and small sizes of the pieces less than the actual standard for some samples. Therefore, at Fincha Habera site charcoal samples retrieved only from later occupation phases (layers FHL-02/-03/-04/-05/-06/PIT1 and FHL-07) were analyzed.

A total of 159 charcoal fragments were examined from Fincha Habera site among which 101 fragments of charcoal from FHL-02/-03/-04/-05/-06/PIT1 and FHL-07 layers have been identified whereas 59 pieces remained unidentified.

As indicated on the graph below, *Erica arborea* was the most dominant taxon by frequency and ubiquity, which was represented by 25 charcoal fragments and present in 24% from Fincha Habera site. *Artemisia afra* and *Myrsine africana* were the second most dominant taxa by

representing 18 and 17 charcoal fragments and cover 18% and 17 % of the samples respectively. *Solanum giganteum*, *Hagenia abyssinica*, and *Hypericum revolutum* were identified as the third most abundant taxa by containing 13, 12, and 11 charcoal fragments and present 13%, 12%, and 11 respectively. *Juniperus procera* identified as the least dominant taxa at Fincha Habera represented by only 5 pieces of charcoal fragments (5%).

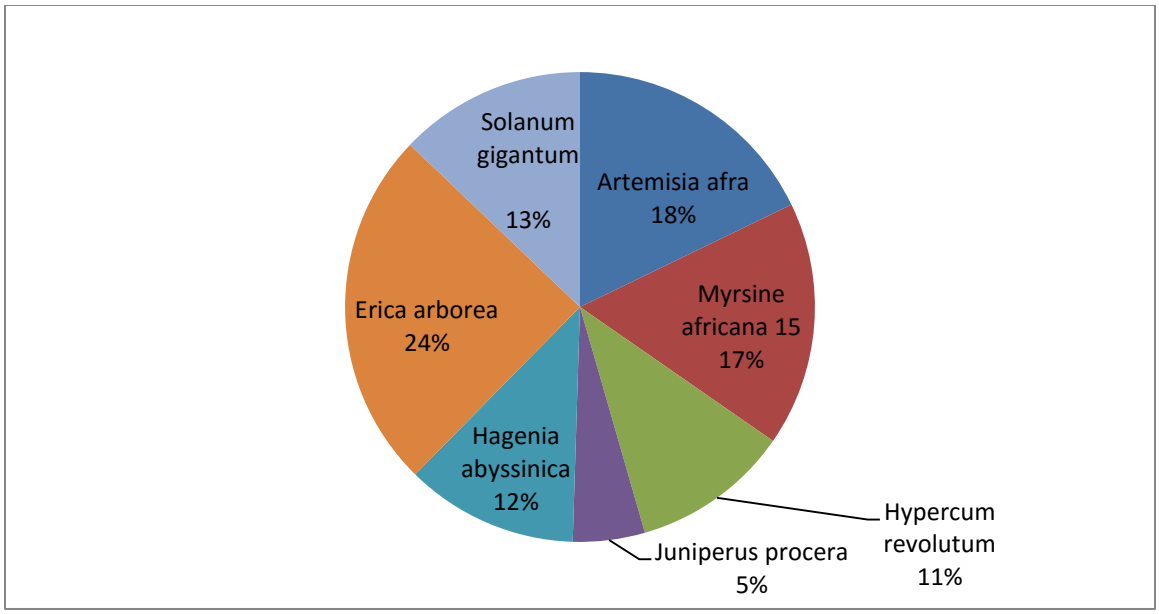


Chart 3. Graph that summarized percentiles of identified taxa from Fincha Habera

As indicated on the above chart, charcoal fragments obtained from later occupation phases (FHL-02/-03/-04/-05/-06/PIT1, and FHL-07) were analyzed from Fincha Habera site. FHL-07 and FHL-02/-03/-04/-05/-06/PIT1 layers relatively yielded an almost equal amount of identified charcoal fragments by containing, 52 and 49 charcoals fragments respectively.

FHL-07 layer has no secure dates corresponding to archaeological materials even though it contains few MSA artifacts. For this layer, many younger charcoals were also discovered indicating they have been trickled down from layer FHL-06. Due to high concentrations of charcoal fragments observed in this layer, the samples from this layer were identified apart from FHL-02/-03/-04/-05/-06/PIT1 layer.

From the total of charcoal fragments identified from this FHL-07 layer, *Erica arborea* is the most dominant taxon represented by 12 pieces of charcoals. *Artemisia afra*, *Solanum giganteum*, *Myrsine africana*, *Hypericum revolutum*, and *Hagenia abyssinica* constitute the second most abundant taxa by representing 9, 8, 7, 6, and 6 charcoal fragments respectively. *Juniperus procera* represents the least dominant taxa from this layer by representing only 4 pieces of charcoal.

In FHL-02/-03/-04/-05/-06/PIT1 layers *Erica arborea*, *Myrsine africana*, *Artemisia afra*, and *Hagenia abyssinica* were identified as the most dominant taxa by representing 12, 10, 9, and 8 charcoal fragments respectively. The reaming two taxa *Solanum giganteum* and *Hypericum revolutum* identified as the second most dominant taxon from this layer by comprising 6 and 4 charcoals fragments respectively.

2. Simbero

Based on the contextual information discussed in chapter three, the stratigraphic sequence at A58-Simbero comprises four occupation phases that are clearly correspondent with archaeological remains. The allocation of layers, levels, and dates is quite clear in this site due to corresponding interrelations of artifact distribution, stratigraphic sequence, and dating results. Apart from recent levels, three distinct Later Stone Age-occupations were identified. Based on the comparably few radiocarbon dates, each LSA occupation might be of longer duration than currently known. Only in level 3, there are two-quarter squares that are difficult to sort into the correct layer.

Charcoal samples collected from all occupational phases were analyzed at simbero site. From a total of 106 charcoal fragments collected from all stratigraphic units, 82 charcoal fragments were identified to species level. The 24 fragments remain unidentified because none of them were

large enough to be identified by available equipment due to their poor preservation, size below the standard, and the absence of a sufficient number of comparative collections.

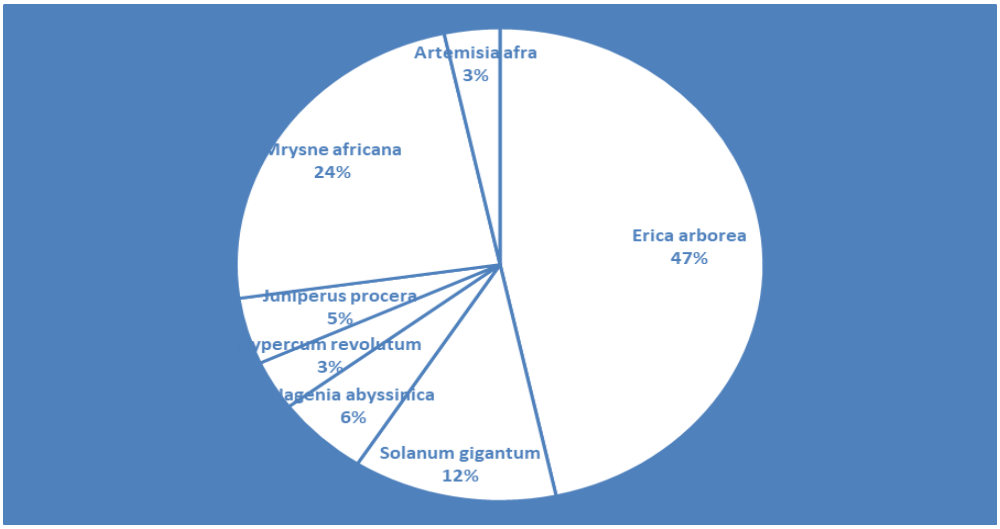


Chart.4. percentiles of identified taxa from Simbero site

As chart 4, illustrates, *Erica arborea* was a dominant taxon by both frequency and ubiquity, which represented 39 fragments and present 47% of the samples. *Myrsne africana* is the 2nd most dominant taxa by representing 19 fragments and covering 24% of the samples. *Solanum giganteum* was the 3rd dominant taxon by containing 10 charcoal fragments and representing 12% of the samples from Simbero site. *Hagenia abyssinica, Juniperus procera, Hypericum revolutum,* and *Artemisia afra* are identified as the least taxa from simbero by representing only 6%, 5%, 3%, and 3% respectively.

The largest concentration of identified charcoal samples observed in the late Holocene occupation phase is represented by nearly half (41) of fragments from a total of 82 identified sample fragments. From this context, Erica arborea was a dominant taxon represented by half of charcoal fragments (20) followed by *Myrsine africana, Solanum gigantum, Hagenia abyssinica, Juniperus procera, Artemisia afra,* and *Hypercum revolutum* represented by 10, 5, 3, 1, 1, and 1 respectively.

The terminal Pleistocene occupation phase comprises the 2nd concentration of charcoal samples by containing 16 fragments from the total identified samples from this site. *Erica arborea* is also the dominant taxa, identified from this context by containing 8 fragments. *Myrsine africana, Solanum giganteum, Artemisia afra,* and *Hypericum revolutum* ranked from the 2nd to 4th place according to their respective list by representing 5, 2, 1, 1, and 1 piece respectively.

Middle Holocene and pastoral occupation phases encompass the lowest charcoal concentrations by representing 13 and 10 pieces identified charcoal fragments respectively. At the middle occupation phase, *Erica arborea* is also the dominant taxa by containing 8 fragments. This was followed by *Myrsine africana* and *Juniperus procera* identified as the 2nd most dominant taxa, each of them representing 2 pieces, and *Solanum giganteum* represented the lowest fragments by containing 1 piece of each taxon. Pastoral occupation phases contain the lowest charcoals concentration but contain the biggest taxa identified of all occupational phases at Simbero. From this occupational phase, a total of 11 charcoal fragments were identified into 7 different taxa. From this context, *Solanum giganteum* contains the most dominant taxa by representing 3 pieces and followed by *Myrsine africana, Erica arborea, Hagenia abyssinica, Juniperus procera, Hypericum revolutum,* and *Artemisia afra* by representing 2, 2, 1, 1, 1, and 1 piece respectively.

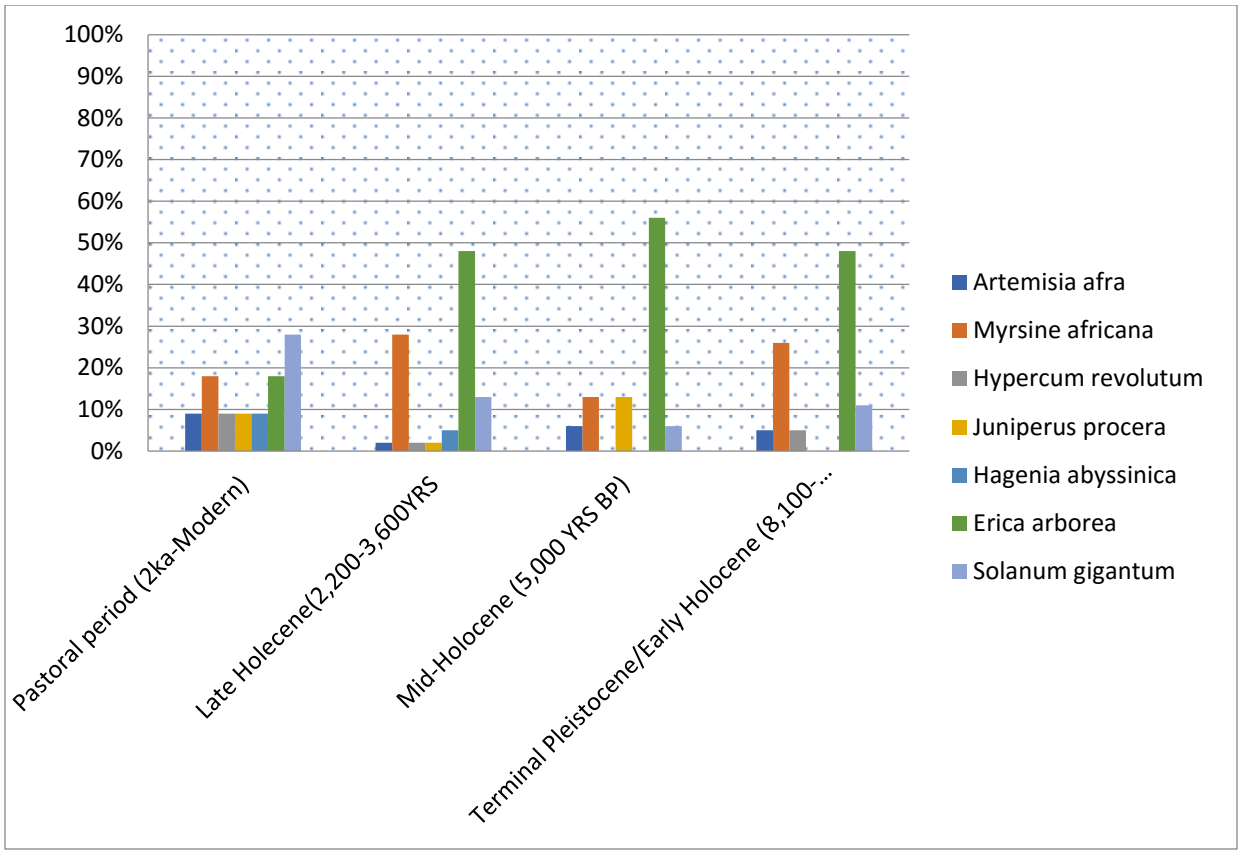


Chart.5. Percentiles of all identified taxa from each occupation phase at Simbero site

3. Fish shelter

Based on contextual information discussed in chapter three, at the Fish shelter, two major occupation phases were reconstructed based on material cultures obtained from this site. charcoal samples from two occupation phases and interface layers (level 7) were analyzed. From the early occupation phase, two charcoal fragments from the fireplace and two from red loam were identified at the species level.

From a total sample, 87 charcoal fragments obtained from both occupational phases were identified in their respective taxa category. High concentrations of charcoals were obtained from the first and second occupation phases by representing 44 and 32 charcoal fragments respectively. In the first occupation phase, *Erica arborea* was identified as the most dominant

taxon by representing 14 charcoal pieces from the total sample from this context. *Myrsine africana* was identified as the second most dominant taxon from the first occupation phase by containing 11 charcoal fragments. *Artemisia afra* is identified as the third most abundant taxa in this context, represented by 8 charcoal fragments. *Hypericum revolutum,* identified in lower abundance by representing 6 pieces of charcoal fragments whereas *Solanum gigantum* and *Juniperus procera* were identified in less much lower abundance by encompassing 2 pieces of charcoal from the early occupation phase of the Fish shelter site.

During the second occupation phase at the Fish shelter, *Erica arborea* was also identified as the most dominant taxon by both frequency and ubiquity, represented with 13 charcoal fragments. *Solanum gigantum* and *Myrsine africana* were the second most abundant and ubiquitous taxon in this context with 8 and 7 fragments respectively. *Hagenia abyssinica, Artemisia afra, Juniperus procera,* and *Hypericum revolutum* were identified as fewer dominant taxa only one piece of each taxon identified from this occupation phase.

Apart from both occupation phases, level 7 was analyzed under the separated category as the interface between layers C and D. This is for the reason that charcoal pieces under this level may not indicate a specific occupation phase rather the charcoals trickled from the upper levels into the lower one. In this way level, 7 was analyzed separately and contained both the smallest number of charcoal concentrations and taxa type. Only three taxa namely *Artemisia afra, Myrsine Africana*, and *Hypericum revolutum* identified in relatively equal distributions (4, 3, and 4 respectively).

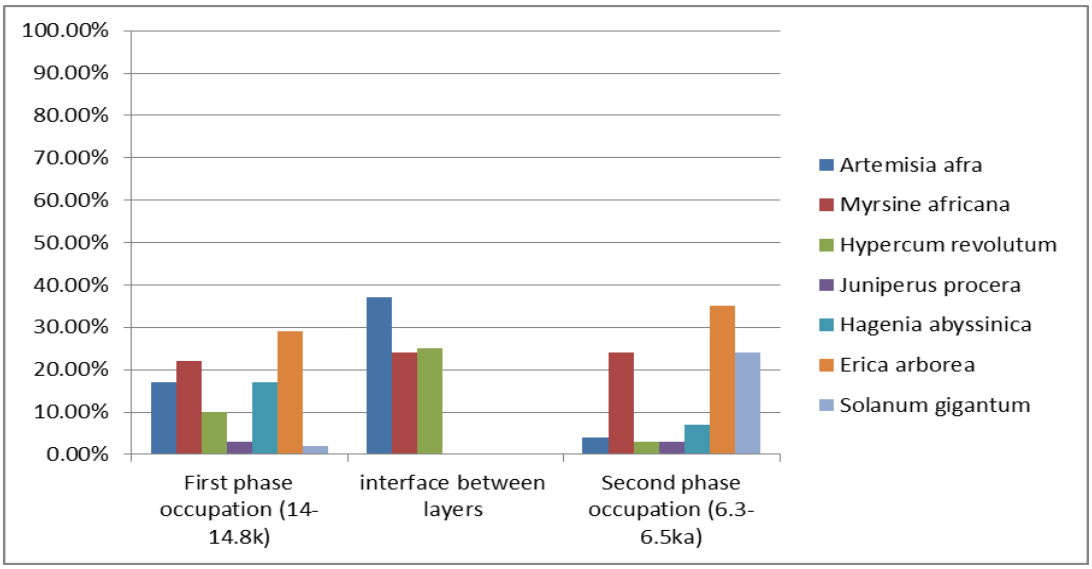


Chart.6. % of all identified taxa from each occupation phase at Fish Shelter site

4. Mararo

The stratigraphic sequence at Mararo comprises two major occupation events. (See chapter three). Unlike simbiro and Fish shelter, the allocation of layers, levels, and dating results at Mararo site, are unevenly distributed. The dating samples sometimes do not correspond to the levels of charcoal samples, the stratigraphy is very complicated with many interfingering layers, and charcoal pieces have been moved. However, based on the found distribution of lithic materials, LSA occupation between 4.8 and 2.4 ka cal BP (layers BO and BOG) can be identified mainly in square S8. The younger layers (FDD, CWD, and LB) are difficult to date and probably contain mixed charcoals. Due to this, the charcoal assemblages from Mararo were analyzed according to their respective layers rather than classifying them into different occupation phases.

Accordingly, five different layers Compact Wet Dung (CWD), Fine Dry Dung (FDD), Loamy Belts (LB), Black Organic (BO), and Black organic with Gravel (BOG) were identified from the S8 excavation unit at Mararo sites. Charcoal samples were collected from all layers except the

CWD layer. From a total of 74 samples of charcoals collected from all layers, 57 fragments were identified to species level. The remaining 17 fragments remain unidentified.

Mrysine africana and *Erica arborea* were the most dominant taxa by frequency and ubiquity, which represented by 16 and 15 fragments and present in 28% and 26% respectively. *Artemisia afra* and *Solanum giganteum* are the second most dominant taxa by representing 8 and 7 pieces of charcoals and cover 13% and 11 % of the samples respectively. *Hagenia abyssinica*, *Hypericum revolutum*, and *Juniperus procera* were identified as the least dominant taxa from Mararo represented by 4, 4, and 3 pieces of charcoals respectively, and these three taxa collectively cover only 22% of the total samples identified from this site.

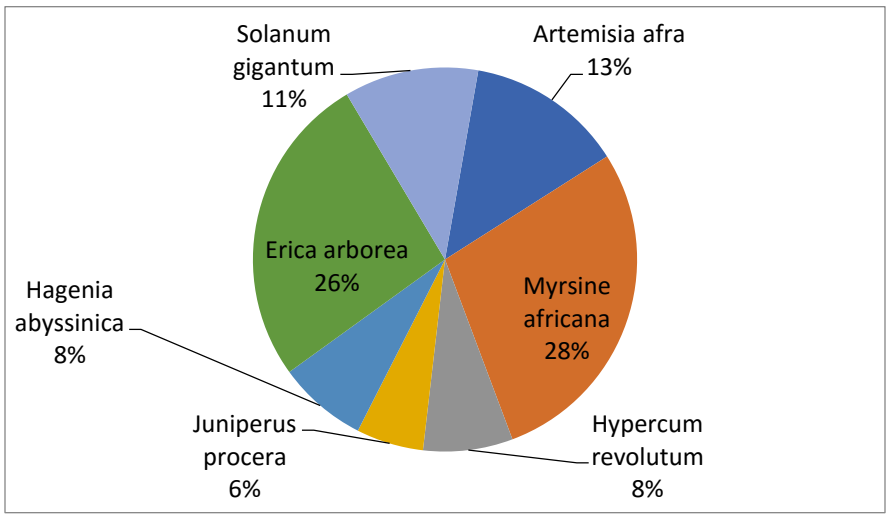


Chart.7. % of all identified taxa from Mararo site.

From all layers at Mararo, the largest concentration of charcoal samples was observed at layers BOG and BO which correspond to the major LSA occupation, represented by 22 and 17 charcoal fragments respectively out of a total of identified 57 charcoal pieces. In layer BOG *Myrsine*

africana was a dominant taxon, represented by 8 charcoal fragments. This is followed by *Artemisia afra* and *Erica arborea* each of which is represented by 5 pieces. The remaining taxa such as *Solanum giganteum, Hypericum revolutum,* and *Juniperus procera*, are presented in lower abundances, represented by only 2, 1, and 1 piece of charcoals.

Erica arborea is the dominant taxa identified from layer BO by containing 8 charcoal fragments. *Myrsine africana*, yielded the second fragments from this layer by containing 4 fragments. *Juniperus procera, Solanum giganteum,* and *Hypericum revolutum,* are the lowest abundant taxa from this layer by presenting 2, 2, and 1 piece of charcoals respectively.

FDD and LB layers encompass the lowest charcoal concentrations, represented with 11 and 7 charcoal fragments respectively. At FDD layer *Solanum giganteum, Myrsine africana*, and *Artemisia afra* are the dominant taxa in this layer. Both *Solanum giganteum* and *Myrsine africana* presented with equal proportion represented by (3 pieces), whereas *Artemisia afra* by 2 pieces. The remaining four taxa namely *Hagenia abyssinica, Hypercum revolutum*, and *Erica arborea,* occurred as single pieces only.

Layer LB contains the smallest charcoals concentration of all layers at Mararo site. From this layer, a total of 7 charcoal fragments were identified into taxa. *Hagenia abyssinica* contains the dominant taxa by representing 3 pieces, and this is followed by *Myrsine africana*, *Erica arborea*, *Hypericum revolutum*, and *Artemisia afra* by which each of them represented by single piece of charcoal fragment.

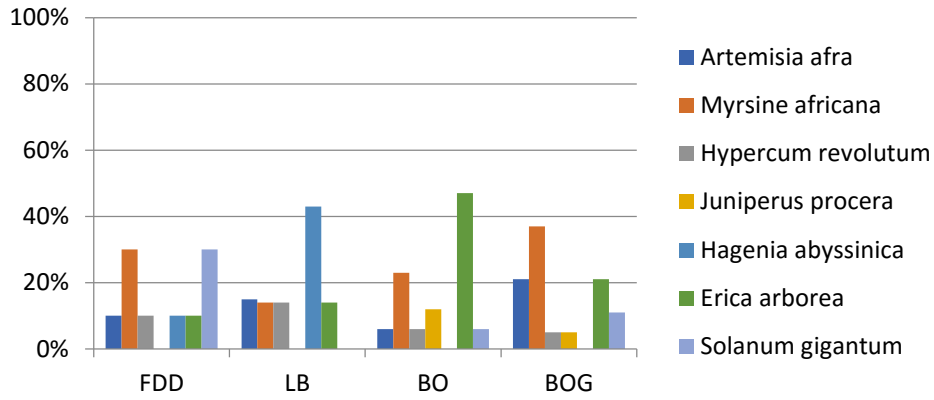


Chart 8. % of all identified taxa from each layer at Mararo site.

5. **Diverse sites**

A total of 80 charcoal fragments obtained from Wala, Dimtu, Umburi, Garba Guracha, Gata I, and Gata II were analyzed. Out of the total samples 39 pieces of charcoals were identified in their respective taxa categories, whereas the remaining 41 fragments remain unidentified.

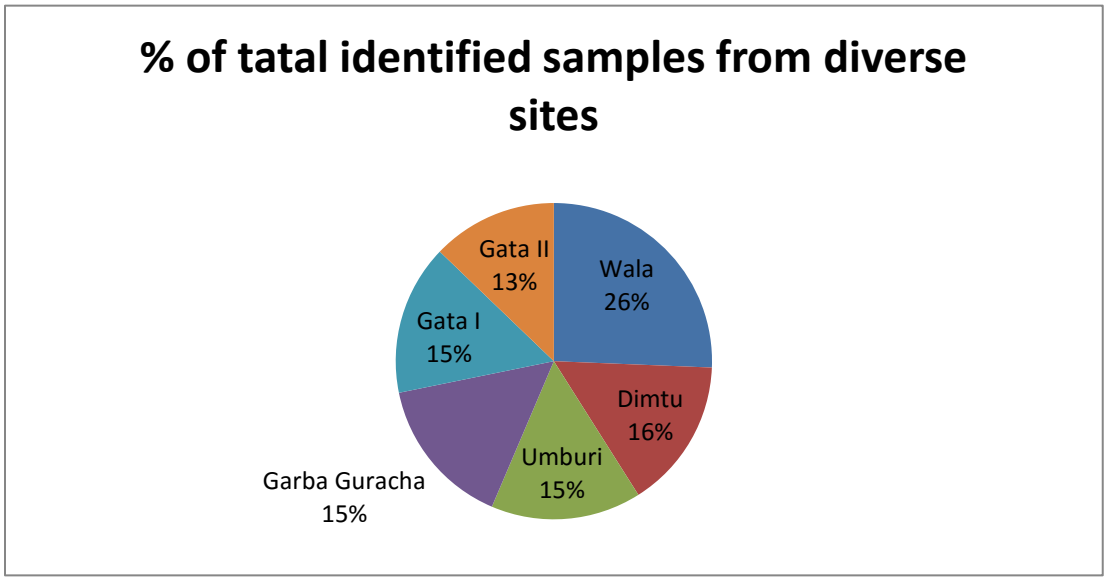


Chart. 9. % of total identified samples from diverse sites

As indicated in the above graph from the total identified taxa, 10 fragments (26%) identified from Wala, 6 (15%) Dimtu, 6 (15%0 Umburi, 6 (15) Garba Guracha, 6 (15%) Gata I, and 5 (13%) Gata II.

Based on the contextual information from Dimtu site, two occupation phases during terminal Pleistocene (14.8 – 14.2ka), and 14.1ka – 14ka) were recorded, and two different and separate occupations of late LSA were recorded.

All charcoal samples from the LSA layer were powdery and were not identified. From total samples of 19 fragments of charcoal from Dimtu, only 6 of them were obtained from terminal Pleistocene occupation phases identified. From the total identified taxa from Dimtu site only two taxa (*Erica arborea* and *M. africana* were identified. *Erica arborea* is the dominant taxon represented by 4 fragments and the *M. africana* is represented by the remaining two fragments.

From other diverse sites (Gata II and Wela) charcoal fragments of Late Holocene LSA layers (5-2ka Cal. BP) were analyzed. From Gata II site a total of 6 charcoal fragments possibly older than 2.7 ka Cal. BP identified into species level. Only two taxa (*S. gigantum* and *E. arborea*) were identified. *S.gigantum* is the dominant taxa from Gata II by representing in 4 pieces and the remaining 2 fragments identified as E. arborea. No radiocarbon dates are available from Wala site, but based on the lithics assemblages, all samples were identified as the late Holocene LSA period, so approximately 5-2 ka cal. BP. A total of 10 charcoals were identified from this site. Three different taxa namely *M. africana* dominant taxa represented by 6 pieces, and the remaining 4 fragments were identified as *A. afra* (2) and *H.revoltanum* (2).

In the remaining sites, the charcoal samples identified were small and undiagnostic; the age of the charcoal is difficult to assess (Umburi), or mixed and disturbed deposits; no reliable

statement of the age of the charcoals is possible (Gata I) or young radiocarbon date does not fit to the lithics, which point again to the late Holocene lithics (5-2 ka cal. BP). Despite these limitations, the identification of charcoal samples from these sites is important for the reasons discussed in chapter 3.

A total of 17 charcoal fragments were identified from these three sites representing 4 different taxa. Erica arborea is the dominant taxon from all these three sites by representing 7 fragments, whereas M. africana is the second most abundant taxon presented by 5 fragments. The remaining two taxa H. abyssinica and A. afra presented in the least amount represented by 2 and 1 fragments of charcoals respective

4.6. The compositional spectrum of identified charcoal taxa according to settlement phases in the BMs

Based on charcoal evidence retrieved from the above discussed 10 sites, attempts were made to reconstruct the environmental condition of BMs from terminal Pleistocene to Holocene.

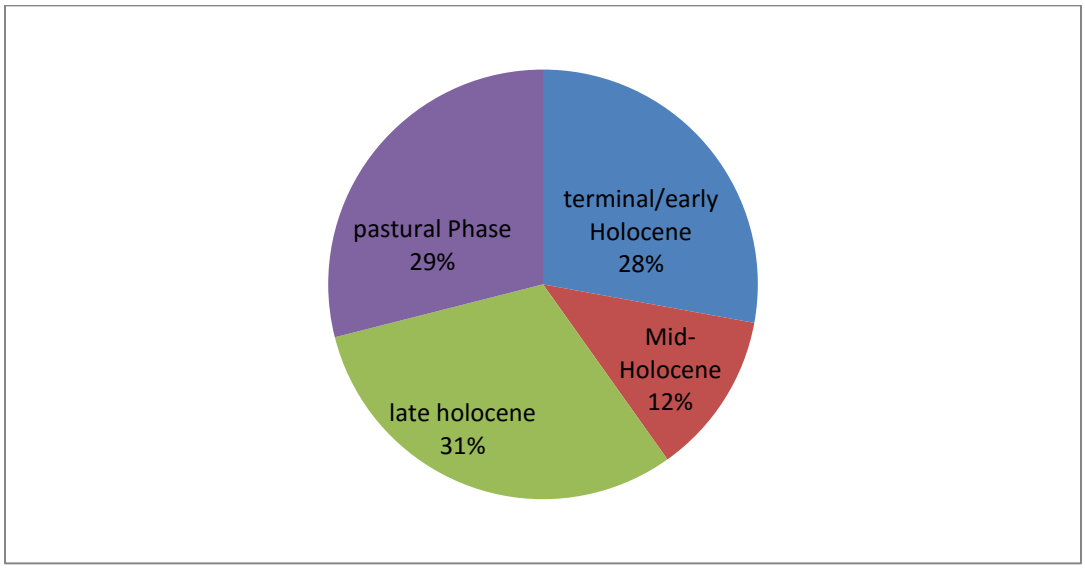


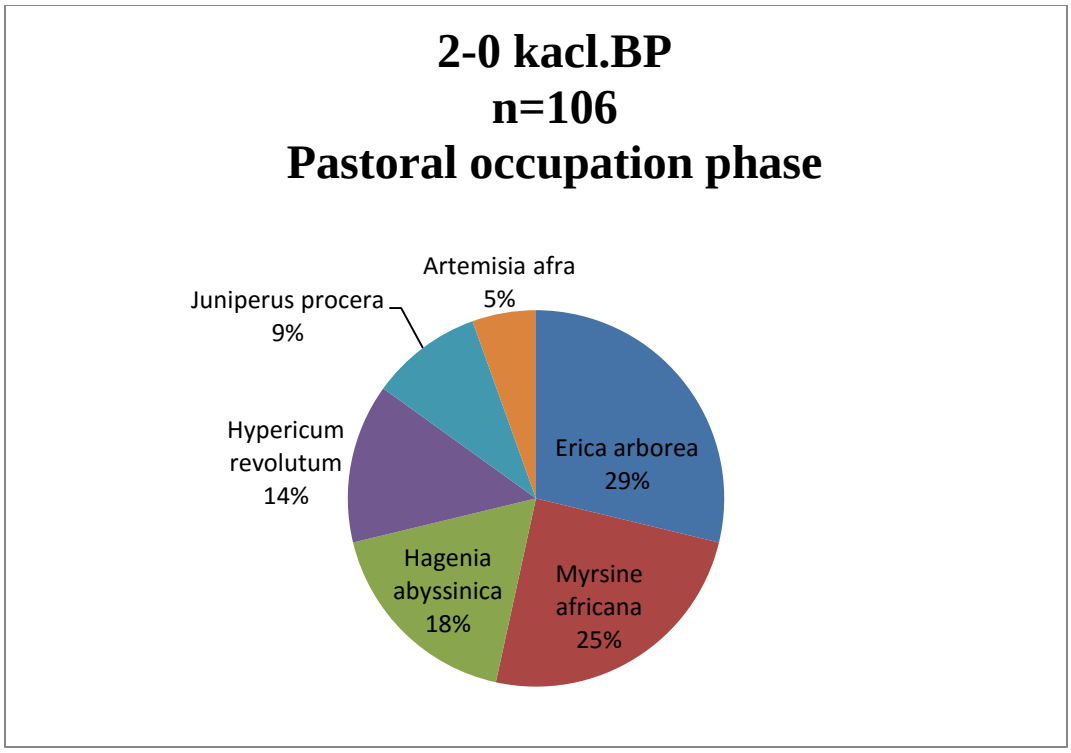
Chart. 10. % of identified charcoal pieces from each occupational phase of BM

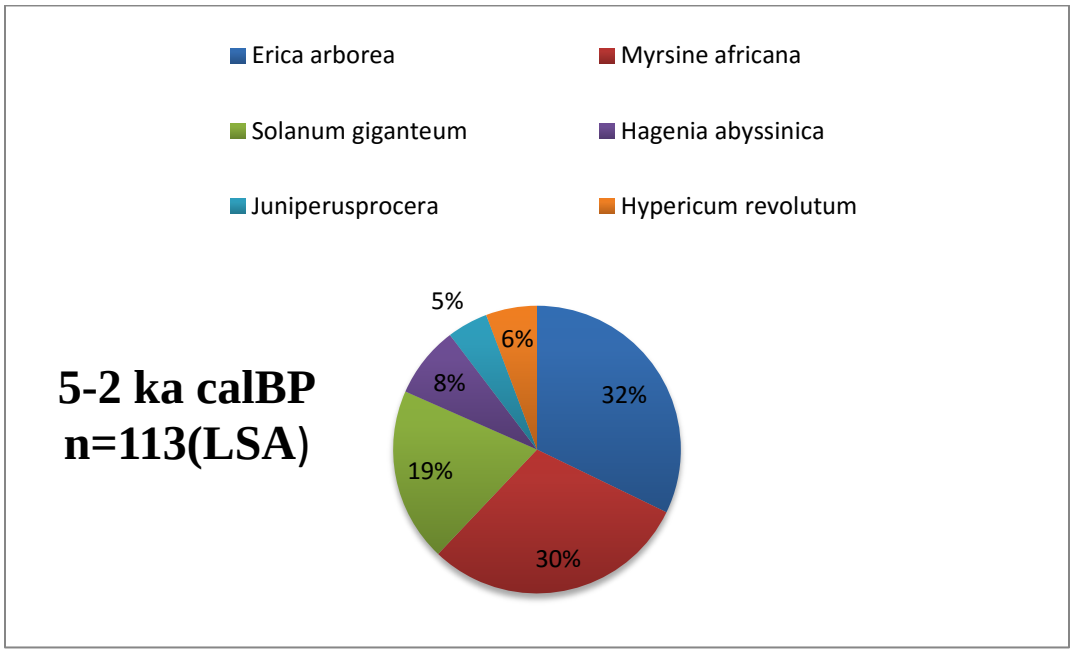
Terminal Pleistocene /early Holocene/ occupation in the Bale Mountains represented by charcoal samples obtained from Simbiro (14.3 -15.0 Ka. Cal. BP), Fish shelter (14.0-14.7ka cal. BP), and Dimtu (displayed two different occupation phases terminal Pleistocene/ early Holocene/ the 1st phase dated 14.8 – 14.2 and the 2nd phase 14.1– 14.032). Terminal Pleistocene/ early Holocene/ layer yielded the second-largest amount of identified charcoal pieces. From this layer a total of 102 fragments (28%) wereidentified into their respective taxa categories.

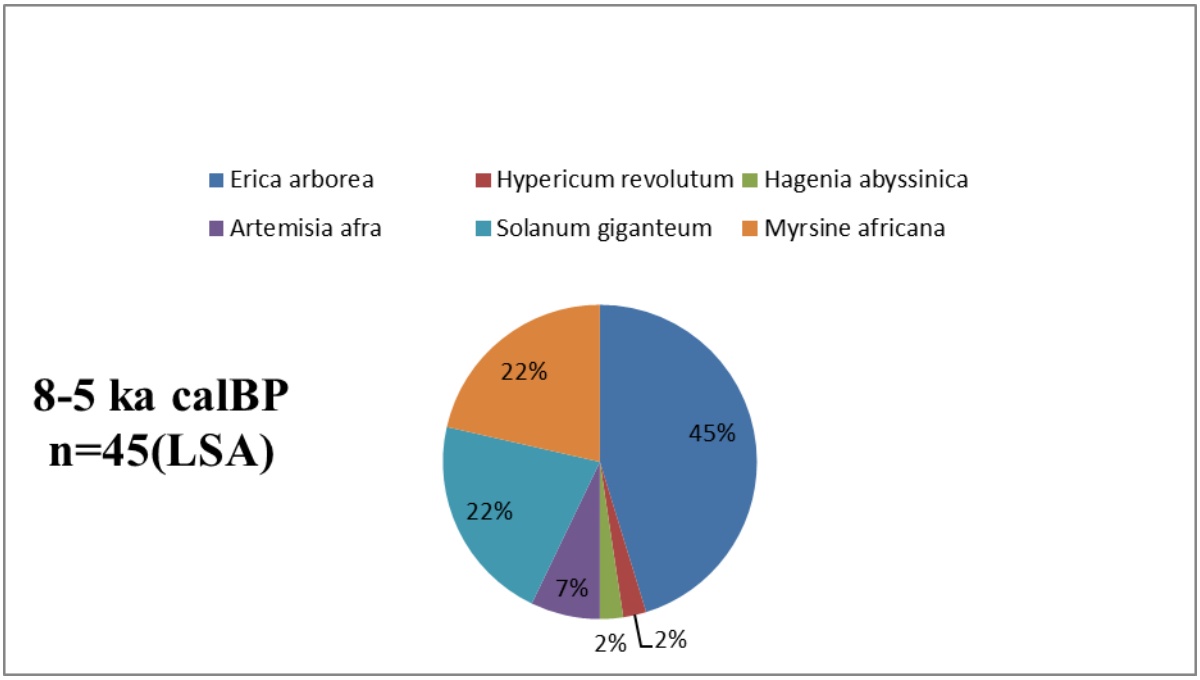
As summarized inthe above chart, the mid-Holocene layer showed the smallest number both in terms of site representation and the number of identified charcoals. This layer is represented by charcoal fragments obtained from only Simbero (8.2-5.2 Ka Cal. BP) and Fish from (6.5- 6.4 Ka Cal. BP). The occupation period also yielded relatively the smallest number of all identified charcoal fragments, from which only a total of 45 pieces (12%) of charcoals were identified in their respective taxa.

Late- Holocene and pastoral occupation phases were represented by charcoal fragments obtained from all 10 sites and the largest amount (more than half) of the total identified of charcoals fragments was also identified from these two occupations phases. From a total of identified charcoal samples, 219 (60%) pieces were identified from the late-Holocene layer, from which 113(31%) were identified from the last LSA occupation phase of BMs and 106 (29%) identified from the pastoral occupation phase.

The following graph summarizes the compositional spectrum of identified charcoal taxa according to settlement phases in the Bale Mountains.


2-0 kacl.BP
n=106
Pastoral occupation phase
Artemisia afra
5%
Juniperus procera
9%
Hypericum
revolutum
14%
Erica arborea
29%
Hagenia
abyssinica
18%
Myrsine
africana
25%


Erica arborea
Myrsine africana
Solanum giganteum
Hagenia abyssinica
Juniperusprocera
Hypericum revolutum
5-2 ka calBP
n=113(LSA)
5%
6%
8%
32%
19%
30%



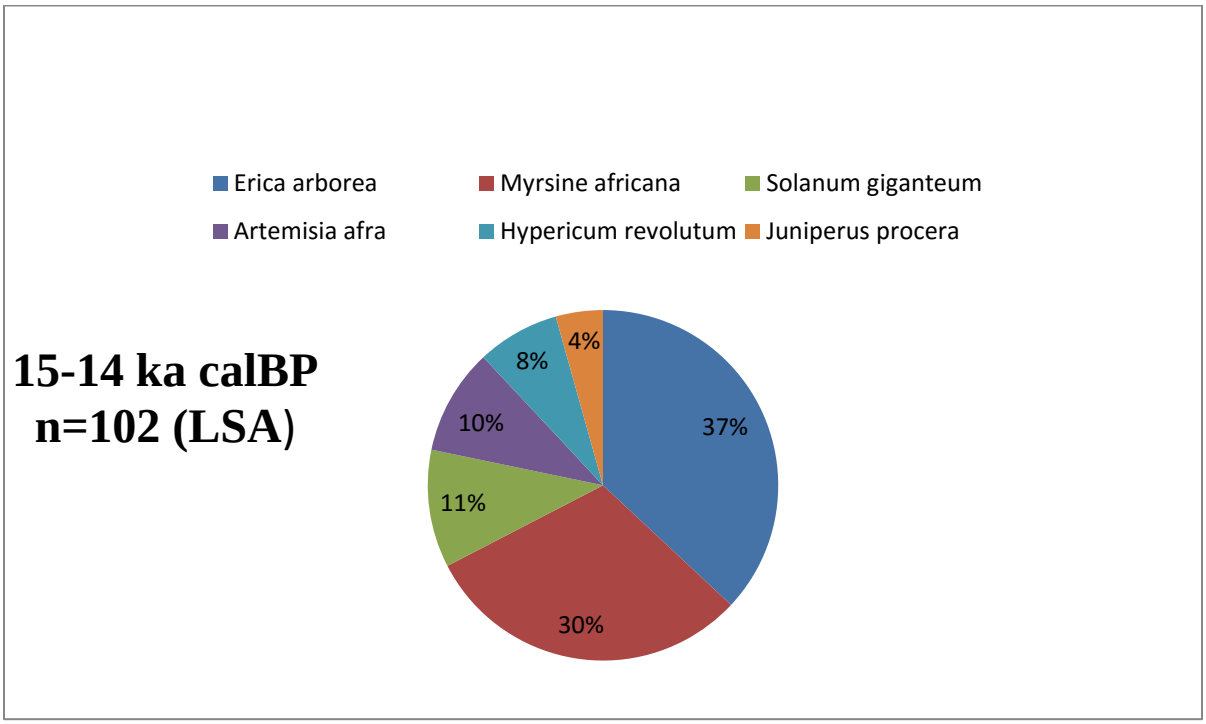


Chart 11. Graphs that summarize the compositional spectrum of identified charcoal taxa according to settlement phases in the Bale Mountains.

CHAPTER FIVE

DISCUSSION

5.1.Origin, Ecological Preference (Phyto-geography), and other Characteristics of Identified Species

The main objective of this study was the contextual analysis of anthracological data collected from the Bale Mountains and to use its information to reconstruct human-plant interactions during the Late Pleistocene and Holocene Epochs. To achieve the objectives of the study, anthracological samples retrieved from different sites of BMs were analyzed and seven different species were identified. To develop reasonable interpretations of the identified plant, in the following section, the general characteristics such as origin, ecological preference (Phyto-geography), and other related characteristics of each identified taxa will be discussed.

5.1.1. Erica arborea

Erica arborea is commonly known as the tree hearth/Giant hearth/ (English), Adale/Asta/ (Amharic), and Wadadi (Afaan Oromo) (Azene *et al,* 1993). It is one of a species of flowering plant (angiosperms) in the heather family Ericaceae. It is a shrub or small tree which sometimes grows up to 4-8m but infrequently it grows up to 20m. It covers a wide range of geographical distributions which encompassing from east Africa (Ethiopia, Kenya, and Tanzania) to the Mediterranean Basin and Macaronesia (De´samore *et al*, 2011, Azene *et al*, 1993).

Regarding its origin different ancestral reconstruction indicates different origins for the tree of Erica. Phylogenetic analysis on African and European Erica by (McGuire and Kron, 2005) indicates the African taxa were derived from the European one, and this species was dispersed from its origin across northern Africa to East Africa during the late Miocene/Pliocene,

Other ancestral reconstructions by De´samore *et al*, 2011, indicate that eastern Africa /Arabia is the center of origin for *Erica arborea*. Based on evidence retrieved from patterns of molecular diversity and palaeobotanical this study provides possible pathways for the expansion of *Erica arborea* out of its origin. Accordingly, it suggests a rapid expansion of *Erica arborea* westwards from Eastern Africa/Arabia/to Europe during the Pleistocene epoch.

The largest species of this family is confined in the south and East Africa highlands dominating geographical regions with elevations range between 2500 and 3300 m a.s.l. indicating a sub-alpine environment. But in Mediterranean Basin and Macaronesia regions, it can grow in the dry Rocky Mountains area. *E. arborea* tree can be used for different purposes. In Mediterranean Basin and Macaronesia regions, it can use primarily for smoking pipes whereas in east Africa particularly in Ethiopia its uses are limited to fire wood, charcoal, fodder (leaves and shoots) bee forage, and fence (Azene *et al* 1993; Miehe & Miehe, 1994; Désamoré *et al*., 2011).

E. arborea trees are distributed in the BM along the ericaceous zone on the Afromontane Forest zone co-occurring with Erica and Phillippa genera. *E. arborea* in the BMs mostly grown in the altitudinal range between 3,400m to 3,800m and co-dominated together with plant-like *Hypericum revolutum*, and *E. trimera* (Abel, 2012; Biniam and Richman, 2013). Strangely adequate, small Erica outposts are also found even in the afro-alpine zone on the central Sanetti Plateau ((Miehe & Miehe, 1994).

5.1.2. Artemisia Afra

Artemisia afra is commonly known as African wormwood (English), 'Chigugn' (Amharic), Kapani (Afaan Oromo), which is an evergreen perennial herb that belongs to the family of *Compositae (Asteraceae*). It is a deciduous subshrub that grows to reach a height of 2 meters, in

geographical locations with an altitude range of 3070 and 3600 m (Mesfin and Sebsebe 1992). There are 400 species of Artemisia and from this Artemisia afra is the only species indigenous to the African continent.

Artemisia afra is Common in South Africa, central and eastern Africa, and widespread as far north as Ethiopia. In Ethiopia, this plant is dominantly distributed in Bale, Sidamo, Arba Minch, and Keffa (Mesfin and Sebsebe, 1992). It dominantly grows naturally in wild mostly rocky mountainous areas along forest margins and stream sides. Its natural distribution extends from Bale Mountains National Park (Dinsho) southeastern Ethiopia to northern parts of Ethiopia (Dawit, 1986).

Artemisia afra is widely used for medicinal purposes to treat both internal (treatment of cough, croup, whooping cough, influenza, fever, diabetes, gastro-intestinal disorders, and intestinal worms and external (for a treat of headache and nasal congestion or a lotion to treat hemorrhoids) simply by smearing on the alimented part of the body by the fresh leaf of Artemisia (Dawit and Ahadu, 1993; Abiyselassie, 2007).

In the BM, this plant is confined in Northern Grasslands /Gaysay Grasslands/ zone with altitude ranges from 3,000m to 3,500m. In the BMs, *Artemesia afra* is commonly grown together with plant-like *Helichrysum splendidum* and *Hagenia abyssinica* (Binian and Richman, 2013).

4.5.3. Juniperus procera

Juniperus procera is commonly known as African pencil cedar, *Tid*, and Gatira/Hindessa/ in English, Amharic, and Afaan Oromo respectively. It is indigenous to Ethiopia and eastern Africa belongs to the family *Cupressaceous* (the cypress family) which is most commonly grown up to

30-35m, the Ethiopia *Juniperus procera* type can reach up to 50m which makes it the largest tree of its genus (Azene 1993; Negash, 2010).

Under the genius of Junipers, there are over 50 species of trees and shrubs occurring in regions extending from Arabia to Zimbabwe and from which *Juniperus procera* is the only species of the genus native to Africa dominated mountainous areas and on the rocky ground of eastern Africa (Negash, 2019)

Juniperus procera is dominantly found in the highland area of Ethiopia usually grows within altitudes range from 1500-3000Mm in moist and wet Dega and Dega agro-climatic zones. This plant is a high rain tree but it can survive under dry areas once it is established (Azene *et al* 1993; Negash, 2010). In the BM, *J. Procera* dominated the Headquarters of Park in *Juniper* Woodlands zone covering a wide range of the park extending as far as the northern slopes of the Bale massif, reaching from Dodola to Dinsho. *J. procera* tree in the BMs found dominantly together with plant-like *Hagenia abyssinica, Hypericum revolutum,* and *Rosa abyssinica* (Biniam and Richman, 2013).

The tree of *Juniperus procera* has a wide range of uses in Ethiopia. It is one of the most preferable types of trees for timber specifically to make the floor, roofing, pencil, and joinery. Additionally, it is also used as firewood, medicine, and ornaments making (Azene *et al* 1993).

4.5.4. Hagenia abyssinica

Hagenia abyssinica commonly called Africa Red wood/Rosewood/ *Kosso,* and *Heto,* in English, Amharic and Afana Oromo respectively. It is a dioecious tree native to Africa, belonging to the *Rosaceae* family which mostly can grow up to 35m. The largest distributions of *Hagenia abyssinica* in Africa are confined in Eritrea, Zimbabwe, Burundi, Congo, Ethiopia Kenya,

Malawi, Rwanda, Uganda, and Sudan. It is a high rain forest tree that is dominantly grown with elevations between 2300-3300M, in moist and wet Woyna Dega and Dega agro-climatic regions (Azene *et al* 1993; Negash, 1995).

Pollen evidence retrieved from Burundi indicates the earliest colorizations of *H. abyssinica* in Africa go back to 34,000 years BP, and introduced to Ethiopian from this region during Pleistocene sometimes around 16700 years ago BP. The introduction of the *H. abyssinica* tree to southern parts of Ethiopia including the Bale Mountains relatively short time ago compared to other parts of Ethiopia. As indicated by Mohammed & Bonnefille (1998), southern Ethiopia including Bale Mountains dominantly occupied by *H. abyssinica* tree at about 2500 BP.

In the BM, this plant dominantly found Juniper Woodlands, Gaysay Grasslands, and Erica Belt zones. In Juniper Woodlands it grows together with *H. revolutum*, *J. procera,* and *H. revolutum* in Gaysay Grasslands it grows together with *A. afra* and *H. splendidum*, and in *Erica* Belt commonly found together with *Erica* families (Binian and Richman, 2013).

H. abyssinica tree is one of multiuse plant in Ethiopia which widely used for timber, furniture, medicine (to treat tapeworm), fuel wood, pole and for conservation of soils (Azene *et al* 1993).

4.5.5. Hypercum revolutum

H. revolutum is the family of *Hypericaceae* which is native to Arabia and Africa. It is commonly called Curry bush, Amija, Edera/Garamba/Hendi/ in English, Amharic, and Afaan Oromo respectively. It is a shrub or tree which can grow up to 4 m but rarely can it grow as high as 10 m (Azene *et al*, 1994).

H. revolutum is characteristic of the *Afromontane* vegetation, often distributed in a geographical region with an elevation range from 1400 – 2593 M that ranges from southwest Arabia through the *Afromontane* zones of eastern Africa to the Cape. It is also found in the Cameroon Highlands, and on Madagascar, the Comoros Islands with decreased distributions. In Ethiopia, this species confined in Montane Forest/high altitude regions with elevations ranges between 2600-3600 M in moist and wet Dega agro-climatic zone mostly co-occurred with *E. arborea* and/or H. Abyssinica. H. revolutum tree widely used for medicine, commercial (timber) fire wood, bee, and soil conservation among (Azene *et al* 1994).

4.5.6. Myrsine africana

M. africana is species of shrubs in the family of *primulaceae* also commonly known as African boxwood/cape myrtle/ in English, and Kechimo in Amharic. This dioecious, evergreen, tree can grow from 1.5-5 m tall. This plant is native to Africa confined from the west coast (Azores) to east Africa (Angola, Ethiopia, Kenya, Malawi, Mozambique, Namibia, Somalia, Tanzania, Zambia, and Zimbabwe) through Arabian Peninsula (Yemen) to Asia (Afghanistan, China, India, Pakistan, and Yemen) (https://www.monaconatureencyclopedia.com).

Its distribution in Ethiopia is high confined to mountainous, shrubby grassland forest border and along (small) mountain rivers or gullies areas with an elevation ranging between 1750-3800 m. This plant is not cultivated; it grows in wild and is significantly preferred by many African peoples in general and Ethiopian in particular for its medicinal value. It is a widely used traditional medicine in Ethiopia (fruit) to treat tapeworm, ring warm, and other skin diseases. Sometimes its fruits are used together with *H.abyssinica* to treat against tapeworm. Besides its medicinal value, the fruit of *M. africana* is also used as food for donkeys and mules mixed with

barley or maize. This tree is also one of the preferable plant types for house construction and firewood due to its hard characteristics and good burning properties (Jansen, 1981).

5.1.7. Solanum gigantum

S. gigantum is a semi-evergreen and moist deciduous forests tree or shrub which can grow up to 5 m. It is commonly known as Red Bitter Berry, healing-leaf tree, giant bitter-apple, and red bitter. This plant is mostly the characteristics of montane species native to Africa (all sub-Sahara countries) and Asia (south India). Its distribution in sub-Saharan countries is high, dominantly found in high rainfall regions, up to 2000 mm annual rainfall. This plant is widely distributed in Grassland, thickets, moist and riverine forest and -margins, bushland, evergreen thickets, and bamboo zone (http://pza.sanbi.org/solanum-giganteum).

4.6. Reconstructing Fire Wood Collection, Vegetation Cover, and Environmental Conditions of the Study Area Based on Information Retrieved from the Analysis of Anthracological Remains.

Understanding the interactions that human beings have with their environment in the past is a critical point that has been an important concern in the study of the human past. Analysis of anthracological data is one approach among various environmental data which wildly used to understand overall interactions between human and their environments including the past landscape, dwelling space, site catchment area, fuel economy, use of wood in domestic and ritual contexts (Scheel -Ybert, 2018, Kabukcu, 2015; Asouti, 2001).

Since the development of anthracology as a discipline, various approaches and models were introduced by different scholars dealing with how to use and interpret anthracological results.

The Principle of Least Effort (PLE) and the Heuristic model are the two basic models widely used in the interpretation of anthracologic data.

The PLE model first proposed and used by George K. Zipf (1949), states that fuel wood collection would take place in a relatively small area, close to the location of the settlement and all available woody species universally collected in direct proportion to their availability in the past vegetation. According to this model, in a high-density woodland environment, the nature of firewood collections is characterized by selection toward a specific species based on different criteria such as burning property and deadwood. On the other hand, in the area with limited vegetation cover either because of extreme cold (Mountainous/ Tundra) or extreme arid (Desert) the collection of fire wood is characterized by non-selective. In both cases, any wood type available close to the campsite was collected regardless of the above-mentioned wood properties.

The other model called the heuristic model first proposed and used by Asouti and Austin (2005). This model states that fuel wood collection in a certain community is mostly influenced by some parameters that shape the decision-making toward fire wood collection. According to this model, while dealing with charcoal analysis, it is important to consider all parameters affecting firewood collection among societies which tend to be economy (pastoral, agro-pastoral, or settled agriculturalists), way of life (mobile hunter-gatherer or permanent settlements), technology (metallurgy or wood making production), and rituals (collection of special wood types for ritual purposes).

As hypothesized by this model a fire wood collection between hunter-gatherers and settled communities take different forms. In the first case fire wood collection characterized by opportunistic in nature (they collect what available in their surrounding), which make it the same

statement with the non-selective fuel collection proposed by the PLE. In the latter case, firewood collection is mostly affected by the above-mentioned factors.

Based on both models it is possible to suggest that in the course of terminal Pleistocene –early Holocene firewood was randomly gathered in the BM from the immediate surroundings and brought to the campsite. The PLE model suggests that in an area with low-density of vegetation cover, the wood collection tends to be characterized by non-selective/random/ collections. This is quite true for BMs regions where characterized by low-density of vegetation cover specifically in its high altitude part where most of the sites selected for this study are situated.

Mode of life is also another determining factor for firewood collections as proposed by the heuristic model. According to this model, fuel wood collection among group of mobile hunter-gatherers is characterized by random gathering. This is also true for the occupants who settled in the BMs specifically along the plateau where hunter-gatherers visited the region for a shorter period (Ossendorf *et al*., 2019).

Firewood collections strategy in the BM may also have different form. In the BM the hunter-gatherers probably collected firewood by "*embedded procurement*" strategy, so during hunting expeditions, or when returning, they collected firewood. Most resources (obsidian, chert, giant mole-rats, other prey, water, etc.) were available within a day's walking distance, so there was no need for "*direct procurement*" or search for firewood only. This in turn means that the charcoal assemblages are a reflection of the past vegetation conditions.

On the contrary, most (90%) of the woody taxa identified from the study area were potential fuel woods. As indicated by some scholars (Allott, 2006; Lennox *et al*., 2019) the identification of suitable fire woods in archaeological sites implies selection of specific wood type for particular

purpose. However, in the case of BM where the settlement sites are located in low-density woodland, it is possible to conclude that the identified taxa were collected randomly as firewood not because of their burning property rather because of their availability close to the camp. But this statement is only true for charcoal assemblages found on the layers of terminal Pleistocene and early Holocene. In the later period, starting from the mid-Holocene the charcoal assemblages displayed some characteristics that look like the firewood selection rather than random collection.

Based on this, the change in the relative abundance of fossil charcoal in archaeological sites is a direct indicator of vegetation cover that had been grown nearby in the past. To address the questions of this research both above discussed models were incorporated in this study. In this sense, the anthracological remains obtained from BM intend to shed light on the poorly understood environmental conditions during human occupation phases in the Bale Mountains. It is also aimed to diachronically reconstruct interactions between past humans and their environment in African high-altitude ecozones.

5.2.1. Firewood Collection and Use in the Bale Mountains

As discussed in chapter three, this study covers a timespan from the terminal Pleistocene (14ka cal. BP) to late Holocene. Attempts were also made to include charcoal samples dated to the MSA occupation phase recorded from Fincha Habera. Unfortunately, the MSA occupation site was only recorded from Fincha Habera site and there was no MSA layer identified on the remaining sites. Contrary to this, the LSA layer are represented at all sites. The last LSA occupation in the BMs is dated back to 2.6, 2.2, and 1.9ka recorded from Mararo, Simbero, and Gata I respectively.

The MSA occupation layers were well-recorded from Fincha Habera site and also yielded several identifiable charcoal pieces. However, none of the charcoals from MSA layers have been identified even to the family level. The identification from this layer was difficult because most of the charcoal pieces obtained from the MSA layer did not belong to one of the seven taxa which were actually identified, and the fragments were also too small to show diagnostic features in detail.

The mismatch between MSA charcoal assemblages and the modern comparative collection was probably caused by a change in firewood collection that happened after MSA. This change might be caused by environmental change that happened during the Last Glacial Maximum (LGM) in southern Ethiopia from 42 to 17ka. As indicated by Groos et al., 2021, the glacial-interglacial oscillations of the Pleistocene have a great impact on the alpine habitations of species in the Bale Mountains. This impact of the glacial-interglacial oscillations of the Pleistocene period, might be responsible for the recorded vegetation change. However, this assumption must be tested in light of further investigations by examining the unidentified charcoals of the MSA period from *Fincha Habera*.

Many LSA layers display evidence for burning events and relatively higher numbers of charcoals identified in their respective taxa from these layers. In most LSA sites at the BM (examples Simbero and Fish shelter), 99.8% of the faunal remains are burnt, and many obsidian artifacts show different degrees of burning *(Ossendorf Pers. Comm., May 31, 2021)*. This is one of the very important evidence that indicates wood was brought to camps to assist in the deliberate destruction of bone. The collections of firewood were not only limited to cooking. Since all sites in the BM are characterized by high altitude environments firewood was also collected for warming up at times when the temperature got decrease.

Firewood collecting in the BM during the period under investigation was characterized by collecting of firewood with good burning properties (*Erica aroborea, Myrsine africana Hagenia abyssinica, Hypercum revolutum, and Juniperus procera*) and woods with poor burning properties (*Artemisia afra and Solanum gigantum*). Dominantly identified taxa such as charcoal *of Erica aroborea and Myrsine Africana*) considered as the most preferred wood type for fire. Woods like *Hagenia abyssinica* and *Hypercum revolutum* were the second most preferred fuel wood in the study are whereas *Junipers procera* was also collected as firewood in the slightest amount.

Terminal Pleistocene layers (>10ka) in the BM recorded from Simbero, Fish Shelter, and Dimtu, sites. The charcoal analysis from these sites indicates that *E. arborea* and *M. africana* were used as the most dominant firewood in the Bale Mountains whereas wood-like *A. afra, S. gigantum,* and *H. revolutum*, recorded in fewer amounts less than 2 % of the total samples indicating the slightest use of these species as firewood.

The onset of the Holocene period (10-7 ka) in the BM was recorded from Simbero sites. From this site, *E.aborea* and *M. africana* were identified as dominant firewood. During early-Holocene collecting of *E. arborea* tree as firewood was frequently increased indicating this shrub existed in the catchment dominantly whereas the use of *M. africana* as firewood slightly decreased compared to the terminal Pleistocene period. Rare taxa such as *H. revoltanum*, *A. afra*, and *S. gigantum* remained constant (fewer amounts) indicating the slightest use of these species as firewood in the BM during the early Holocene.

Charcoal samples from Simbiro and Fish Shelter indicate during the mid-Holocene (7-5 ka) *E. arborea, M. africana, S. gigantum, and H. revoltunum* were identified as dominantly collected

firewood. Comparatively from the earlier period during Mid-Holocene the use of *E. arborea* diminished in high amount and was replaced by another wood such as *S. gigantum and H. revoltunum* which were presented in fewer amounts in earlier phases. Other taxa such as J. procera which was absent in the earlier phases began to appear here in fewer amount.

The late- Holocene (5 ka – recent) firewood collection in the Bale Mountains was reconstructed based on charcoal samples retrieved from all sites selected for this study. The anthracological materials correspond to the late- Holocene investigated after classifying them into two (5-2 ka corresponds to the LSA phase in the BM), and (2-0 ka corresponds to the pastoral occupation phase). The result of the charcoal analysis indicates the nature of firewood collections during last LSA occupation characterized by the continuous decline of *E. arboreal* trees in most sites. Reversely new wood types either completely unknown in bottom layers (*H. abyssinica*,), or infrequently collected (*A. afra, and J. procera*) started to dominantly collected as fuelwood during this period.

Firewood collection after 2 ka (associated with pastoral occupation phase) is characterized by the selection of specific taxa based on burning properties. Wood with good burning property such as *E. arborea, M. africana, H. abyssinica, H. revoltanum, and J. procera* constitute 95% of total identified taxa indicating the firewood selection of specific taxa based on burning properties.

In terms of total firewood coverage in the BM during the period under investigation *E. arborea* is the only dominant firewood in all sites. However, charcoals of *E. arborea* showed dramatical decline through time. In terminal Pleistocene and early-Holocene layers, *E. arborea* was the dominant taxa and *M. africana* is the second most dominant taxon. Other taxa such as *A. afra, H. revoltanum J. procera* were presented in fewer amounts in all sites where terminal Pleistocene

and early Holocene layers were represented. Afterward, on the mid-late Holocene layers there is a considerable increase in the occurrence of *H. abyssinica, A. afra,* and *J. procera* and corresponding to decrease of *E. arborea* charcoal. The gradual decline of the *E. arborea* charcoals towards the top layers reflects the continuous destruction of the *Erica arborea* tree in the catchment area.

Interestingly, in late Holocene layers specifically in Fincha Habera, Mararo, and Simbiro sites woods with poor burning properties (*A.afra and S. gigantum*) co-occurred with wood with good burning properties (*H. abyssinica, J. procera,* and *H. revoltanuem*) indicating awareness toward specific taxa selection based on burning properties.

An ethnoarchaeological survey also indicates that E. arborea and M. africana are the most preferred types of firewood in the study area. Local communities who are dwelling in and around BMs use these two wood types frequently as firewood because of their good burning property. M. africana is more preferable to fuel wood than E. arborea because it burns quickly, even when green.

Based on the relative abundance of charcoal fragments, it is possible to conclude that people changed their wood-collecting behavior from the mid-to-late Holocene period. From some sites such as Simbero and Fish Shelter where located along northern escarpments, long-term occupations were recorded. In these sites burning properties characterized by long-period burning by relying mainly on *E. arborea* shrub which was dominantly grown in the surrounding area whereas for some sites located alongside plateau such as *Dimtu and Umburi* visited for a short period and burning trend characterized by burning wood for short period mainly relying on small woody taxa. The co-occurrence of wood with poor burning and quick-burning properties

afterward the mid-Holocene is one of the very important indications for the beginning of fuel wood selections culture in the BM.

The change in fuelwood collection culture might be caused either because of increased awareness of fuel-wood burning property, environmental factors, or changes in the dietary system. As indicated above the only evidence associated with firewood selection in BM was observed after the mid-Holocene. Probably increased awareness toward the wood-burning property that happened after the mid-Holocene may have resulted in the identified change in fuelwood collection.

The change in some taxa may also be caused due to environmental change that happened during the mid-Holocene. As indicated by (Addis, 2017), the increasingly warmer climate that happened immediately after the end of LGM enabled the Erica tree to expand surrounding the BM. And after the mid-Holocene, the climate showed some changes, and this was responsible for the continued reduction of *Erica* tree in charcoals assemblage.

5.2.2. Reconstructing Vegetation and Environmental History

As discussed above the result of charcoal identifications in the BM shows some vegetation changed that happened from terminal Pleistocene to late Holocene. This vegetation shift was possibly caused by environmental change that happened throughout this period and had a direct effect on the diversity and composition of vegetation types in the study area.

The terminal Pleistocene period is represented by charcoal samples obtained from three sites (Simbero, Fishelter, and Dimtu) that are situated in very different locations and environments. But in all these sites we have defined occupation events recorded between 14.9 to 14.0 ka cal.

BP. Simbero and Fishshelter are located in the northern escarpment in a side valley of the Web Valley whereas Dimtu is on the Plateau at the foot of Mt. Tullu.

The result of the charcoal analysis shows that at Simbero and Fish shelter both *E. arborea* and *M. africana* co-dominated together whereas at Dimtu *E. arborea* was documented as the only dominant taxa. The recorded difference in taxa abundance between the two different geographical locations (plateau and northern escarpments) is good evidence indicating the presence of varied vegetation cover along with the two geographical locations. Accordingly, the plateau areas were dominantly covered by Ericaceous vegetation whereas in the northern escarpment Primulaceae and Ericaceous vegetation co-dominated together.

The result of charcoal identifications from these three sites suggests that the woody taxa in both geographical locations displayed relatively similar vegetation cover during the terminal Pleistocene. This is for the fact that in both cases vegetation covers specifying the presence of evergreen forest and also both taxa can prefer the same environmental condition. There are, however, a few ecological differences between the northern escarpment and the plateau geographical locations that have been indicated by the results of the charcoal analysis.

In the first case, the co-dominance of both plant families in the layers of terminal Pleistocene may result from the increased warmer climatic condition of BM that happened at the end of LGM. This can be understood as almost immediately after the ice cap/the valley glaciers had retreated, the Bale Mountains experienced warmer climatic conditions. The increased warmer climate of this period gave rise to expand of *Ericaceae* and *Myrsinaceae* plant families to dominantly surrounded northwestern escarpment and this gave good conditions to prehistoric people continuously settle in the Web Valley starting from around 15ka cal. BP.

In the latter case, the dominance of *E. arborea* during the terminal Pleistocene implies the presence of different environmental conditions such as humidity and moisture that creates a favorable condition for the expansion of the *Ericaceae* plant family. The identifications result suggests that, at the plateau sites climatic condition during the terminal Pleistocene was also warmer but available moisture was necessarily higher than northern escarpment.

Previous palaeoenvironmental researches such as Addis, (2017); Kuzmicheva *et al* (2013), and Mohammed & Bonnefille, (1998) in the study area also support the result of the charcoal analysis. Addis (2017) indicated that the increased warmer that happened onward 16 ka has given a significant condition to Erica tree dominantly grow surrounding the Sanetti Plataea. This is possibly true for other similar sites located along Plateau sites selected for this study (Dimtu, Garba, Guracha, and Umburi) which are dominated by *Erica arborea* charcoals. Similarly, sediment core analysis from Garba Guracha Lake by Umer *et al* 2007 and Fincha Habera site by Kuzmicheva *et al* 2013 also indicates an arid and semi-arid environment of BMs during the same period. Accordingly, after the end of LGM, the BM were dominated by *Amaranthaceae/ Chenopodiaceae, Poaceae, Cyperaceae, Ericaceae, Primulaceae*, and *Artemisia* representing an arid and semi-arid environment which is true for northwestern escarpment sites selected for this study. Interestingly all plant families identified by previous environmental studies, also co-occur with plant families identified by charcoal analysis (*Ericaceae and Myrsinaceae*) due to the same ecological preferences among these plant families. The other interesting thing some plant families such as *Artemisia afra* and *Ericaceae* that were common in sediment records of the previous studies are also common in charcoal assemblages during the same period (terminal Pleistocene).

Among all these three sites did not only showed difference in terms of location and environment but also have yielded quite distinct archaeological materials. The northern escarpment is characterized by unusual lithic production including very thin, needle-like blade-lets tool production which might indicate exploitation of fish at the BM during terminal Pleistocene. Remarkably at the Simbero site, fish bones dated to the same period also recovered which supports the idea that the prehistoric people spent much time on fishing, and the needle-like bladelets were probably used for fish exploitation (Ossendorf, *Pers. Comm., and May 31, 2021*).

Interestingly, at about the same period when fish was exploited in the Bale Mountains, the Mesolithic societies of Nile valley who settled in quite different environmental region also produced the same type of tools (needle-like bladelets tool) and exploited fish (Phillipson, 2005). The same type of subsistence and technology were practiced by the communities settled in quite different types of environments and altitudes.

On the other hand the tool productions trend in the sites located along a plateau in general and Dimtu in particular dominated by a range of geometric micro-lithic including segments, crescents, also borers and utilized pieces which make it quite different tool production techniques and use from that the northern escarpments (Ossendorf, *Pers. Comm., and May 31, 2021*). Geographical, environmental, technological, and subsistence dissimilar that were recorded between these three sites are ideal evidence that indicates the prehistoric hunter-gatherers used different ecological zones very variably, with different task-specific reasons at different sites.

The early- Holocene layer was represented by charcoal samples obtained only from a single site (Simbero). The result of charcoal analysis from this site shows the domination of both *E. arborea* and *M. africana* with relatively equal proportion again during the early Holocene. The

dominance of these taxa also implies the continuation of the *Ericaceae* and *Myrsinaceae* plant specifying similar vegetation cover during this period. The co-dominance of both taxa may suggest during the early Holocene burring *of E. arborea* and *M. africana* was common due to the sufficient coverage of *Ericaceae* and *Myrsinaceae* vegetation cover. This may hay resulted from the warmer climatic condition that happened at the end of LGM also continued during the early Holocene. The occurrences of rare taxa such as *H. revoltanum, A. afra*, and *S. gigantum* remained constant in the layer of early Holocene indicating the same type of climatic condition between the terminal Pleistocene and early Holocene periods.

Other research such as Kuzmicheva *et al* (2013) indicated that plant families like *Poaceae, Apiaceae, Lactucoideae, Fabaceae,* and *Chenopodiaceae* dominated the BM during the same period that grown in the same ecological region with *Ericaceae* and *Myrsinaceae* that were identified by charcoal analysis.

The Middle Holocene layer (7-5000years ago) was represented by charcoal samples obtained from Simbiro and Fish shelter. From all sites, *M. africana, E. arborea, S. gigantum,* and *H. revoltunum* were identified as dominant taxa. Even though *E. arborea* is still a dominant taxon in this layer, it shows considerable reduction compared to the terminal Pleistocene and early Holocene period. This considerable reduction was not only observed on *E. arborea* tree but also common in all other taxa which specify the vegetation shift from evergreen forest to woodland savanna zone. However, other taxa such as *S. gigantum* and *H. revoltunum* which were recorded as rare taxa in the bottom layers began to appear and dominant equally with Erica indicating the environmental change that happed during this period.

Among all as summarized in chapter 4, the Mid-Holocene occupation layer yielded the smallest amount of charcoal samples compare to terminal-Pleistocene and early Holocene layers indicating a dramatic decline of charcoal concentration during this period. This dramatic decline of charcoal probably associates with the decline of Ericaceae vegetation cover on one hand and evergreen forest on the other hand in the BM in response to climatic change.

As indicated by Sellmer and Bates, (2013), factors such as drought, temperatures fluctuation, and increase in temperatures create a difficult situation for Ericaceae plants whereas adequate humidity and moisture are essential for the continued existence of these plant families. Based on this, the decline of charcoal assemblages on one hand, and the change in the relative abundance of identified taxa types recorded on the Mid-Holocene layer on the other hand, possibly caused by the reduction of Ericaceae plants family surrounding the settlement area. This can be associated with the change of adequate humid and moisture period of terminal Pleistocene and early Holocene to much drier phase during Mid-Holocene.

Pollen and spore analysis obtained from Fincha Habera site also support the result of the charcoal analysis. As indicated by Kuzmicheva *et al.*, 2013, the pollen record obtained from Fincha Habera dated to be 8200–5000 years ago characterized a decline in *Podocarpus*, *Apiaceae*, and *Poaceae* while *Juniperus* and *Caryophyllaceae* increased indicating typical characteristics of dry climate. Other research by Tsige, 2015, also indicates the dramatic decline of charcoal fragments from the sediment core of Lake Chamo during the same period as a result of regional caused aridity.

Unlike previous occupation phases, the late Holocene occupation phase was represented by the largest charcoal samples obtained from all 10 sites. The late Holocene samples have been

divided into two phases: from 5-2ka and 2-0ka. This is for the fact that the material archives of the last LSA (hunting-gathering) occupation in the BM has shown a dramatic decline since 2ka and in the same way, during this period there were ephemeral occupations of pastoralists/herders/ in various rock shelters. This is also demonstrated by the anthacological analysis in which these two phases have very different charcoal spectrums.

The first occupation phase is corresponds to the last LSA occupation in the BM. The result of anthracological investigation has also exhibited some differences from the earlier period where the charcoal assemblages from each site display relatively different results unlike the previous layers. The Taxa found in all of these sites include *E. arborea, M. Africana, S. gigantum A. afra, H. revolutum,* and *J. procera*.

The identified taxa displayed different characteristics in terms of their occurrences along the plateau and northern escarpments demonstrating re-occurrences of dry and humid periods respectively. In all plateau sites, *Erica* is still the dominant taxon whereas in the northern escarpment other taxa such as *M. Africana, A. afra, J. procera, H. abyssinica,* and *H. revolutum* co-occurred with *E. arborea* relatively in equal proportion. For this occupation phase, two different environmental proxies have been reconstructed for both sites located in plateau and northern escarpment.

Consequently, the decline of the *Ericaceae* plant family that was recorded in the northern escarpment is one of the very important indications for the continuous decline of the *Ericaceae* plant family in the region. As indicated above the decline of the *Ericaceae* tree is caused either by increasing temperature or drought. Accordingly, the decline of the *Ericaceae* tree recorded in

the charcoal assemblages of the late Holocene layer indicates the northern escarpment experienced much drier climatic conditions during this period.

Other palaeoenvironmental studies by (Umer *et al* 2007), also agreed with the result of this study. As stated by this study, during the late Holocene BMs were characterized by a decrease in *Ericaceae* and *Poaceae* and an increase in *Podocarpus*, *Juniperus*, *Olea*, and *H. abyssinica* that specify a drier climatic condition.

On the other hand, sites located along the plateaus characterized by the dominance of *Erica trees* indicating *Erica* was still dominantly found near the plateau areas during the late-Holocene period. This implies the presence of adequate conditions such as humidity and moisture that are necessary for the survival and success of the Ericaceae plant family. Accordingly, unlike northern escarpment, the sites located along the plateau were characterized by humid and moist climatic conditions. This is also indicated by Mohammed and Bonnefille's (1996) palaeoenvironmental study. Based on pollen analysis obtained from the Tamsaa swamp, Mohammed and Bonnefille reconstructed the late-Holocene climate of BMs as a humid climatic condition.

The second phase of the late-Holocene occupation period in the BM corresponds to the "early" appearance of pastoralist settlements in the study area. There are no archaeological researches so far done to answer questions of early arrival of pastorals in the BM. However, based on some materials (such as undiagnostic lithics, few potteries, and ash layers) from the rock shelters, the first arrival of pastorals in the BM was supposed to be after 2 ka cal BP. Based on evidence inferred from material archives and chronostratigraphy information some sites such as Fincha

Habera even specify much younger arrival of pastoralists in the BM sometime around 800-600 years ago (Ossendorf, *Pers. Comm., and May 31, 2021*).

The result of this study also suggests the early arrival of pastorals in the BM not to be older than 2ka. This is inferred from antrhracological remains of this period characterized by increases selection of specific taxa toward suitable tinder woods which is unique characteristics of this period. In this occupation phase, woods potential firewood like *Erica arborea, Myrsine africana, Hagenia abyssinica,* and *Hypericum revolutum* co-occurred relatively in equal proportion dominating 90% of identified taxa. Unlike the earlier occupation phases, this phase also showed relatively the same taxa composition between sites located in the plateau and northern escarpments signifying the increased awareness of the wood-burning property.

In addition to signifying the increased trend toward specific taxa, all identified taxa from the pastorals phase of occupation are also an ideal indication for the beginning of present-day vegetation formation in the BM as supposed by Mohammed and Bonnefille (1996). The charcoal assemblages of this period indicate an increased number of *arboreal* taxa including *Hagenia abyssinica, and Juniperus procera, and Ericaceae* as well, but with gradual decreases of *Ericaceae* vegetation compared to the terminal and early Holocene occupation phase.

Based on the anthracological remains corresponding to this occupation phase, it is challenging to understand the vegetation cover and environmental proxy of the BM for the past two thousand years. This is for the fact that the wood collection trend of this period was characterized by increased selection of specific taxa. Regardless of this limitation, the identified taxa make available significant information to reconstruct the vegetation history and environmental proxies of the study area for the past two millenniums.

The co-dominance of *arboreal* trees with a high amount of *Ericaceae* vegetation is one of the indications for the occurrences of the dry and humid period. Scholars such as Jolly *et al,* 1994, Mohammed and Bonnefille 1996, and Umer *et al* 2007, used similar interpretations in which increases in *arboreal* trees such as *Podocarpus*, *Juniperus*, and *Hagenia* inferred as indicative for the dry climatic session. Additionally, the gradual decline of *Ericaceae v*egetation covers recorded after 2ka from its maximum during terminal Pleistocene and early Holocene is also the other significant suggestion for the increased drier climatic condition.

Generally, based on the information retrieved from analysis of anthracological data from the BM, the following conclusions were drawn regarding prehistoric human settlement and adaptation of both northern escarpment and afro-alpine environments throughout the late Pleistocene and Holocene epochs. All sites selected for this study located and displayed a different type of environment. Some sites such as Fincha Habera, Fish shelter, Simbiro, Mararo, Gata I and I, and Wala were located in the northern escarpment in the Web Valley whereas some sites such as Garba Guracha, Dimtu, and Umburi located on the high plateau at the foot of Mt. Tullu Dimtu. The charcoal samples obtained from both geographical locations were analyzed to understand the nature of prehistoric settlement human in the BMs since the MSA period.

Archeological evidence from Fincha Habera sites indicates during MSA sometime between 46.5 to 31.4 ka. Cal. BP Bale Mountains was repeatedly occupied by hunter- gatherers (Ossendorf *et al*., 2019). This occupational phase also yielded a large number of identifiable pieces of anthracological data. However, the attempt to understand the ecological adaptation of hunter-gather during this period was not successful for the reasons discussed in chapter four.

As discussed earlier, re-settlement at Fincha Habera was recorded after long hiatus of 30,000 years at the end of MSA sometimes between the 12th and 13th centuries AD. The recorded long hiatus possibly associates with environmental/ecological/ factors that happened during LGM. In addition to examining those unidentified charcoal samples from the MSA layer, answering the possible factor that is responsible for the recorded hiatus would equally be significant to draw our understanding toward the environmental condition of the study area during MSA.

Interestingly, as discussed above the result of charcoal identification indicates all sites were not only very different in terms of location but also displayed quite a different environment through terminal Pleistocene to late Holocene. Apart from their geographical and environmental difference, they also show technological and substance differences during the same period. This very important dissimilarity between sites located in the plateau and northern escarpment has the potential to validate those prehistoric hunter-gatherers adapted the varied ecological zones very variably, with different activities at different sites during the same period (terminal Pleistocene).

Concerning early Holocene ecological adaptation, we have no sites from the plateau that correspond to this occupation phase. The sites in northern escarpments were also represented by charcoal samples obtained from only a single site. Another material culture that belongs to this occupation phase is also very limited with few dates. These all factors make little obscure our understandings towards ecological adaptations of hunter-gatherers during the early- Holocene. However, the charcoal identification result from the northern escarpment shows the same type of taxa representing similar environments that have been recorded during both terminal Pleistocene and early Holocene periods. This is also true for ecological responses of settlers in which they were adapted to different ecological zones very variably with different subsistence and

technology at different sites during early Holocene as they were doing during terminal Pleistocene.

In terms of ecological adaptation, the mid-late Holocene period was characterized by setting up of relatively planned settlements in the northern escarpment. Starting from 5 ka cal. BP, or maybe even earlier, the number of sites with microlithic of LSA assemblages increased dramatically in the northern escarpments with relatively longer period occupations. This is a very important indicator for establishments of strategic settlement which were more confined to lower areas. The sites on the Plateau remained constant indicating these sites were still visited by prehistoric groups to a much lesser degree for shorter periods or by smaller groups or for certain task-specific reasons.

5.3. Conclusions and Recommendations

5.3.1. Conclusions

This study presents the results of the analysis of the anthracological remains retrieved from ten archaeological sites located in the Bale Mountains from the time span of (15ka) terminal Pleistocene to recent (late-Holocene periods). The results have shed new light on the poorly understood environmental conditions during human occupation phases in the Bale Mountains. By documenting and identifying the anatomical features of several hundreds of charcoals macro-remains from various excavated sites, the study also played a significant role to understand interactions between past humans and their environment in African high-altitude ecozones. In the findings of this study, various important issues such as firewood collection, vegetation cover, palaeoenvironment, prehistoric human settlement., ecological preferences, and adaptation strategies in the afro-alpine region of BM were also well-addressed.

Based on results obtained from anthracological analysis the characteristics of firewood collection in the BM during terminal Pleistocene to mid-Holocene concluded to be either "*naturalistic"* or "*embedded procurement*". Vegetation covers of the study area (characterized by low-density of vegetation cover) and the nature of occupiers (characterized by a group of mobile hunter-gatherers) are the two basic reasons that provided solid evidence to drawn the nature of firewood collection in the region to be "*naturalistic*" from terminal Pleistocene to early Holocene. It is also concluded that the nature of firewood collection in the region at the same time tends to be *embedded procurement*, perhaps, they collect fire wood during hunting expeditions, or when returning. The finding of this study also indicates the change in firewood collection afterward mid-Holocene either caused by increases awareness toward burning properties of specific taxa, environmental change, or change in the dietary system. This change was inferred from the co-occurrences of wood with poor burning properties (*A.afra and S. gigantum*) with wood good burning properties (*H. abyssinica, J. procera,* and *H. revoltanuem*).

Based on the results of antrhacological analysis it is also concluded that the presence of varied vegetation cover and environmental conditions in the sites located along the plateau and northern escarpments in the BM during terminal Pleistocene. Accordingly, the plateau areas were dominantly covered by *Ericaceae* vegetation indicating warmer and moisture climates, whereas in the northern escarpment *Myrsinaceae* and *Ericaceae* vegetation co-dominated together indicating increased drier climatic conditions. The early Holocene period was also characterized by the dominance of *Myrsinaceae* and *Ericaceae* families indicating the continued warmer climatic condition of the terminal Pleistocene. The Mid-Holocene occupation phase yielded the smallest number of charcoal samples indicating a dramatic decline of charcoal concentration caused by the shift of evergreen vegetation of terminal Pleistocene and early-Holocene to

grassland during this period. The late Holocene anthracological analysis results were classified into the last LSA and pastoral occupation phases due to their difference in taxa compositions. The last LSA occupation phases of the late-Holocene period were characterized by the decline of the *Ericaceae* plant in the northern escarpment indicating the drier climatic conditions during this period. Sites located along the plateaus are characterized by the dominance of *Ericaceae* vegetation cover indicating humid and moist climatic conditions. Based on the characteristics of antrhracological remains after 2ka (which was characterized by increases selection toward specific taxa) the early arrival of pastorals in the BM suggested being not earlier than 2ka. This period was characterized by co-dominance of arboreal trees with *Ericaceae* vegetation signifying the occurrences of the dry and humid period.

Regarding ecological adaptation and preferences, the anthracology study results demonstrate that prehistoric hunter-gatherers were used different ecological zones very variably, with different tasks at different sites. This was also proven by geographical, environmental, subsistence, and technological difference that were recorded between sites located in the northern escarpment and high-plateau settlement sites.

5.1.2. Recommendations

Based on the findings of this study, the following recommendations are forwarded:

- The Bale Mountains is known by its plant diversities in Africa. Form these plant diversities, only 7 species of plants were identified by this study. To understand more about the Bale Mountains palaeoenvironments and palaeovegetation, further research is recommended on the remaining charcoal samples.

- This study attempted to reconstruct Paleaoenvironments and human adaptations of afro-alpine environment of Bale Mountains by using archaeological charcoal. Further extensive research using multiple proxies also recommended to understand the vegetation, climate and human history of the study area.
- For the reasons mentioned in chapter three, this study focused only on charcoal samples dated to the LSA occupation period. In order to create a complete picture of human and environmental archive for MIS 2, approximately between 29-12 ka cal. BP of the study area, the unidentified charcoals of the MSA period from Fincha Habra must be tested in light of further investigations.

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APPENDIXES

Appendixes 1 sample size, occupational phase, levels & dating results information of all sites selected for this study.

Sample size, occupational phase, stratigraphic levels & dating results of Mararo sites

	A	B	C	D	E	F	G	H
1	**CAMPAIGN**	**SITE**	**SQUARE**	**LAYER**	**PROVENANCE LEVEL** (Labeling)	**NUMBER OF IDENTIFIABLE PIECES** (my estimation)	**Cal. years BP** (1 SIGMA, CALIB VER. 8.1.0, INTCAL 20)	**Lab. No.**
2	Bale 18/1	A05 Mararo	G8	CWD	L3 NE	1		
3	Bale 18/1	A05 Mararo	G8	CWD	L3 NW	1		
4	Bale 18/1	A05 Mararo	G8	CWD	L3 SE	3		
5	Bale 18/1	A05 Mararo	G8	FDD	*L5 NE*	*no samples*	1.218 – 1.092	COL5192.1.1
6	Bale 18/1	A05 Mararo	G8	LB	L5 SW	1		
7	Bale 18/1	A05 Mararo	G8	BO	*L6 SE*	*no samples*	2.670 – 2.447	COL5193.1.1
8	Bale 18/1	A05 Mararo	G8	BOG	L8 SE	1		
9	Bale 18/1	A05 Mararo	G8	BOG	L8 SW	1		
10	Bale 18/1	A05 Mararo	P2 trench	BOG	*L7*	*no samples*	4.779 – 4.572	Beta-503930
11	Bale 17/1	A05 Mararo	S8	FDD	NW /-115	5		
12	Bale 17/1	A05 Mararo	S8	FDD	SE /-115	3		
13	Bale 17/1	A05 Mararo	S8	FDD	SW /-115	4		
14	Bale 17/1	A05 Mararo	S8	LB	SW /-120	3		
15	Bale 17/1	A05 Mararo	S8	LB	SE /-120	4		
16	Bale 17/1	A05 Mararo	S8	LB	*NE /-125*	*no samples*	*modern*	Beta-461997
17	Bale 17/1	A05 Mararo	S8	BO	NW /-125	1		
18	Bale 17/1	A05 Mararo	S8	BO	NE /-130	10		
19	Bale 17/1	A05 Mararo	S8	BO	SW /-130	6		
20	Bale 17/1	A05 Mararo	S8	BO	NW /-135	3	*modern*	COL5189.1.1
21	Bale 17/1	A05 Mararo	S8	BO	NE /-135	3		
22	Bale 17/1	A05 Mararo	S8	BOG	NW /-140	10		
23	Bale 17/1	A05 Mararo	S8	BOG	SW /-145	3		
24	Bale 17/1	A05 Mararo	S8	BOG	NE /-145	3		
25	Bale 17/1	A05 Mararo	S8	BOG	NW /-145	2		
26	Bale 17/1	A05 Mararo	S8	BOG	NW /-150	2	4.420 – 4.315	COL5190.1.1
27	Bale 17/1	A05 Mararo	S8	BOG	SW /-150	4	4.389 – 4.251	Beta-461998
28						**74**		

CWD	Potential pastoralist occupations
FDD	
LB	
BO & BOG	LSA occupation

Sample size, occupational phase, stratigraphic levels & dating results of Fincha Habera

CAMPAIGN	**SITE**	**SQUARE**	**LAYER**	**PROVENANCE LEVEL / PIECEPLOT** (Labeling)	**NUMBER OF IDENTIFIABLE PIECES** (my estimation)	**Cal. years BP** (1 SIGMA, CALIB VER. 8.1.0, INTCAL 20)	**Lab. No.**
Bale 17/2	*A45 Fincha Habera*	*E8*	*FHL-02*	*L2 SE*	*7*		
Bale 17/2	A45 Fincha Habera	E8	FHL-03/04	L2 NW	5		
Bale 17/2	A45 Fincha Habera	E8	FHL-03/04	L3 SE	7		
Bale 17/2	A45 Fincha Habera	E8	FHL-03/04/05/06	L3 SW	7		
Bale 17/2	A45 Fincha Habera	E8	FHL-05/06	L3 NW	5		
Bale 17/2	A45 Fincha Habera	E8	FHL-05/06	L4 NW	6		
Bale 17/2	A45 Fincha Habera	E8	FHL-05/06	L4 SE	6		
Bale 17/2	A45 Fincha Habera	E8	FHL-07	L5 NW	6		
Bale 17/2	A45 Fincha Habera	E8	FHL-07	L5 SW	3		
Bale 17/2	A45 Fincha Habera	E8	FHL-07	L6 NW	3		
Bale 17/2	A45 Fincha Habera	E8	FHL-07	L6 SE	2		
Bale 17/2	A45 Fincha Habera	E8	FHL-07	L6 SW	4		

Bale 17/2	A45 Fincha Habera	E8	FHL-07	L7 NW	4
Bale 17/2	A45 Fincha Habera	E8	FHL-07	L7 SE	2
Bale 17/2	A45 Fincha Habera	E8	FHL-07	L7 SW	2
Bale 17/2	A45 Fincha Habera	E8	FHL-07	L8 NE	2
Bale 17/2	A45 Fincha Habera	E8	FHL-07	L8 NW	3
Bale 17/2	A45 Fincha Habera	E8	FHL-07	L8 SE	2
Bale 17/2	A45 Fincha Habera	E8	FHL-07	L9 NW	3
Bale 17/2	A45 Fincha Habera	E8	FHL-07		3
Bale 17/2	A45 Fincha Habera	E8	FHL-08 upper	L9 SW	2
Bale 17/2	A45 Fincha Habera	E8	FHL-08 upper	L10 SW	?
Bale 17/2	A45 Fincha Habera	E8	FHL-08 lower	L11 SW	1
Bale 17/2	A45 Fincha Habera	E8	FHL-08 lower	L12 NW	1
Bale 17/2	A45 Fincha Habera	H11	FHL-06	L4 SW	2
Bale 17/2	A45 Fincha Habera	H11	FHL-07	L6 SW	2
Bale 17/2	A45 Fincha Habera	H11	FHL-07	L7 SW	2
Bale 17/2	A45 Fincha Habera	H11	FHL-08 upper	L8 SE	1

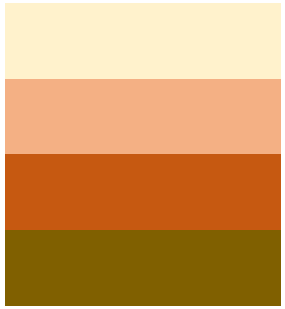
Bale 17/2	A45 Fincha Habera	H11	FHL-08 upper	L9 SW	1
Bale 17/2	A45 Fincha Habera	H11	FHL-08 lower	L10 SW	2
Bale 17/2	A45 Fincha Habera	H11	FHL-09	L12 NE	1
Bale 17/2	A45 Fincha Habera	H11	FHL-09	L13 NE	1
Bale 20/1	A45 Fincha Habera	F13	FHL-02	F12 L2 SE	1
Bale 20/1	A45 Fincha Habera	F13	FHL-05/06	F12 L4 SE	1
Bale 20/1	A45 Fincha Habera	F13	FHL-02/03/04/05/06	#338	1
Bale 20/1	A45 Fincha Habera	F13	FHL-02/03/04/05/06	#339	1
Bale 20/1	A45 Fincha Habera	F13	FHL-02/03/04/05/06	#278	1
Bale 20/1	A45 Fincha Habera	F13	FHL-09	#726	1
Bale 20/1	A45 Fincha Habera	F15	FHL-06	#468	2
Bale 20/1	A45 Fincha Habera	F15	FHL-07	#852	1
Bale 20/1	A45 Fincha Habera	F15	FHL-07	#856	2
Bale 20/1	A45 Fincha Habera	F15	FHL-07	53	2
Bale 20/1	A45 Fincha Habera	F15	FHL-07	#988	2
Bale 20/1	A45 Fincha Habera	F15	FHL-8 upper	#1181	1

Bale 20/1	A45 Fincha Habera	F15	FHL-8 upper	#1186	2
Bale 20/1	A45 Fincha Habera	F15	FHL-8 lower	#1253	1
Bale 20/1	A45 Fincha Habera	F15	FHL-8 lower	#1265	1
Bale 20/1	A45 Fincha Habera	F15	FHL-09	#1300	1
Bale 20/1	A45 Fincha Habera	F15	FHL-09	#1301	1
Bale 20/1	A45 Fincha Habera	F16	PIT1	A45 F15 PIT1	1
Bale 20/1	A45 Fincha Habera	F16	FHL-06	#28	4
Bale 20/1	A45 Fincha Habera	F16	FHL-06	#45	1
Bale 20/1	A45 Fincha Habera	F16	FHL-06	#141	2
Bale 20/1	A45 Fincha Habera	F16	FHL-07	#183	1
Bale 20/1	A45 Fincha Habera	F16	FHL-07	#191	1
Bale 20/1	A45 Fincha Habera	F16	FHL-07	#211	1
Bale 20/1	A45 Fincha Habera	F16	FHL-07	#212	1
Bale 20/1	A45 Fincha Habera	F16	FHL-06	#320	3
Bale 20/1	A45 Fincha Habera	F16	FHL-06	#328	1
Bale 20/1	A45 Fincha Habera	F16	FHL-06	#346	3

Bale 20/1	A45 Fincha Habera	F16	FHL-07	#430	2
Bale 20/1	A45 Fincha Habera	F16	FHL-07	#453	2
Bale 20/1	A45 Fincha Habera	F16	FHL-07	#454	1
Bale 20/1	A45 Fincha Habera	F16	FHL-07	E	2
Bale 20/1	A45 Fincha Habera	F16	FHL-07	#492	1
Bale 20/1	A45 Fincha Habera	F16	FHL-08 lower	#567	1
Bale 20/1	A45 Fincha Habera	F16	FHL-08 lower	#587	1
Bale 20/1	A45 Fincha Habera	F16	FHL-08 lower	#617	1
Bale 20/1	A45 Fincha Habera	F16	FHL-08 lower	#637	1
Bale 20/1	A45 Fincha Habera	F16	FHL-08 lower	#640	1
Bale 20/1	A45 Fincha Habera	F16	FHL-08 lower	#658	1
Bale 20/1	A45 Fincha Habera	F16	FHL-08 lower	#738	2
Bale 20/1	A45 Fincha Habera	F16	FHL-08 lower	#763	2
Bale 20/1	A45 Fincha Habera	F16	FHL-08 lower	#764	1

FHL-02/-03/-04/-05/-06/PIT1

predominantly **0.6 to 0.8 ka** calBP, so 1200-1400 AD

FHL-07		(?) no secure dates, contains very few MSA artifacts. A lot of younger charcoal must have been trickled down from layer
FHL-08 upper		predominantly **31 to 32 ka** calBP
FHL-08 lower		predominantly **34 to 39 ka** calBP
FHL-09		predominantly **42 to 46** ka calBP

Sample size, occupational phase, stratigraphic levels & dating results of Simbero

CAMPAIGN	**SITE**	**SQUARE**	**LAYER**	**PROVENANCE LEVEL** (Labeling)	**NUMBER OF IDENTIFIABLE PIECES** (my estimation)	**Cal. years BP** (1 SIGMA, CALIB VER. 8.1.0, INTCAL 20)	**Lab. No.**
Bale 18/1	A58 Simbero	K4	Unit A	L2 NE	4		
Bale 18/1	A58 Simbero	K4	Unit A	L2 SW	2		
Bale 18/1	A58 Simbero	K4	Unit B (?)	L3 NE	3		
Bale 18/1	A58 Simbero	K4	Unit B (?)	L3 NW	1		
Bale 18/1	A58 Simbero	K4	Unit B	L3 SE	10		
Bale 18/1	A58 Simbero	K4	Unit B	L4 NW	2		
Bale 18/1	A58 Simbero	K4	Unit B	L4 SE	4	2.846 – 2.751	Beta-552721
Bale 18/1	A58 Simbero	K4	Unit B/C	L5 SE	2		
Bale 18/1	A58 Simbero	K4	Unit C	L6 NE	1		
Bale 18/1	A58 Simbero	K4	Unit C	L6 NW	1	3.083 – 2.953	Beta-552722

Bale 18/1	A58 Simbero	K4	Unit C	L6 SE	2		
Bale 18/1	A58 Simbero	K4	Unit C	L6 SW	2		
Bale 18/1	A58 Simbero	K4	Unit D	L7 NE	3		
Bale 18/1	A58 Simbero	K4	Unit D	L7 NW	5		
Bale 18/1	A58 Simbero	K4	Unit D	L7 SW	1		
Bale 18/1	A58 Simbero	K4	Unit D	L8 NE	2	5.327 – 5.272	Beta-552723
Bale 18/1	A58 Simbero	K4	Unit D	L8 SE	1		
Bale 18/1	A58 Simbero	K4	Unit D	L8 SW	2		
Bale 18/1	A58 Simbero	K4	Unit E	L9 NE	4		
Bale 18/1	A58 Simbero	K4	Unit E	L9 NW	3		
Bale 18/1	A58 Simbero	K4	Unit E	L9 SE	3		
Bale 18/1	A58 Simbero	K4	Unit E	L9 SW	2		
Bale 18/1	A58 Simbero	K4	Unit E	L10 NW	1	14.960 – 14.265	Beta-552724
Bale 18/1	A58 Simbero	O6	Unit A	L2 NE	3	*1.975 – 1.976 [cal AD]*	Beta-552719
Bale 18/1	A58 Simbero	O6	Unit A	L2 SE	3		
Bale 18/1	A58 Simbero	O6	Unit B	L4 SE	6	2.277 – 2.153	Beta-552720
Bale 18/1	A58 Simbero	O6	Unit B	L5 N			
Bale 18/1	A58 Simbero	O6	Unit B	L5 N			
Bale 18/1	A58 Simbero	O6	Unit B	L5 SE	4		
Bale 18/1	A58 Simbero	O6	Unit B	L5 SW	2		
Bale 18/1	A58 Simbero	O6	Unit B	L6 NE	6		
Bale 18/1	A58 Simbero	O6	Unit B	L6 NW	2	3.630 – 3.509	COL5452.1.1
Bale 18/1	A58 Simbero	O6	Unit B	L6 SE	4		
Bale 18/1	A58 Simbero	O6	Unit B	L6 SW	5		
Bale 18/1	A58 Simbero	O6	Unit D	L7 NE	1		

Bale 18/1	A58 Simbero	O6	Unit D	L7 NW	2		
Bale 18/1	A58 Simbero	O6	Unit D	L7 SW	2		
Bale 18/1	A58 Simbero	O6	Unit D	L8 NW	1	8.151 – 8.056	Beta-490939
					106		

	recent		
	LSA III	2.2 - 3.6 ka calBP	"Late Holocene"
	LSA II	5.2 - 8.2 ka calBP	"Middle Holocene"
	LSA I	14.3 - 15.0 ka calBP	"Terminal Pleistocene"

Sample size, occupational phase, stratigraphic levels & dating results Fish Shelter

CAMPAIGN	**SITE**	**SQUARE**	**LAYER**	**PROVENANCE LEVEL** (Labeling)	**NUMBER OF IDENTIFIABLE PIECES** (my estimation)	**Cal. years BP** (1 SIGMA, CALIB VER. 8.1.0, INTCAL 20)	**Lab. No.**
Bale 17/1	A61 Fishshelter	F3	?	Test 1 / 5-10cm	4		
Bale 17/1	A61 Fishshelter	F3	B/C	Test 1 / 20cm	3		
Bale 17/1	A61 Fishshelter	F3	B/C	Test 1 / 25cm	5		
Bale 17/1	A61 Fishshelter	F3	D/E	Test 1 / 35cm	3		
Bale 17/1	A61 Fishshelter	F3	D/E	Tes	3	**14.901 – 14.244**	Beta-490940

Bale 20/1	A88 Fishshelter	I4	B upper	B20-A88 NE L2	3	**1.963 – 1.971 [cal AD]**	COL6832.1.1
Bale 20/1	A88 Fishshelter	I4	B lower	B20-A88 NE L3	8		
Bale 20/1	A88 Fishshelter	I4	B lower	B20-A88 NE L4	10	**6.541 – 6.439**	COL6833.1.1
Bale 20/1	A88 Fishshelter	I4	C	B20-A88 NE L5	15		
Bale 20/1	A88 Fishshelter	I4	C	B20-A88 NE L6	10	**6.449 – 6.319**	COL6834.1.1
Bale 20/1	A88 Fishshelter	I4	C/D ?	B20-A88 NE L7	8		
Bale 20/1	A88 Fishshelter	I4	D	B20-A88 NE L8 fireplace	10		
Bale 20/1	A88 Fishshelter	I4	D	B20-A88 NE L8 red loam	8	**14.191 – 14.049**	COL6835.1.1
Bale 20/1	A88 Fishshelter	I4	D	B20-A88 NE L9	10		
Bale 20/1	A88 Fishshelter	I4	D	B20-A88 NE L10	12		
Bale 20/1	A88 Fishshelter	I4	D	B20-A88 NE L11	10		
Bale 20/1	A88 Fishshelter	I4	D/E	B20-A88 NE L12	8	**14.799 – 14.182**	COL6836.1.1
Bale 20/1	A88 Fishshelter	I4	E	B20-A88 NE L13	6		
Bale 20/1	A88 Fishshelter	I4	E	B20-A88 NE L14	6		
Bale 20/1	A88 Fishshelter	I4	E	B20-A88 NE L15	4	**14.275 – 14.076**	COL6837.1.1

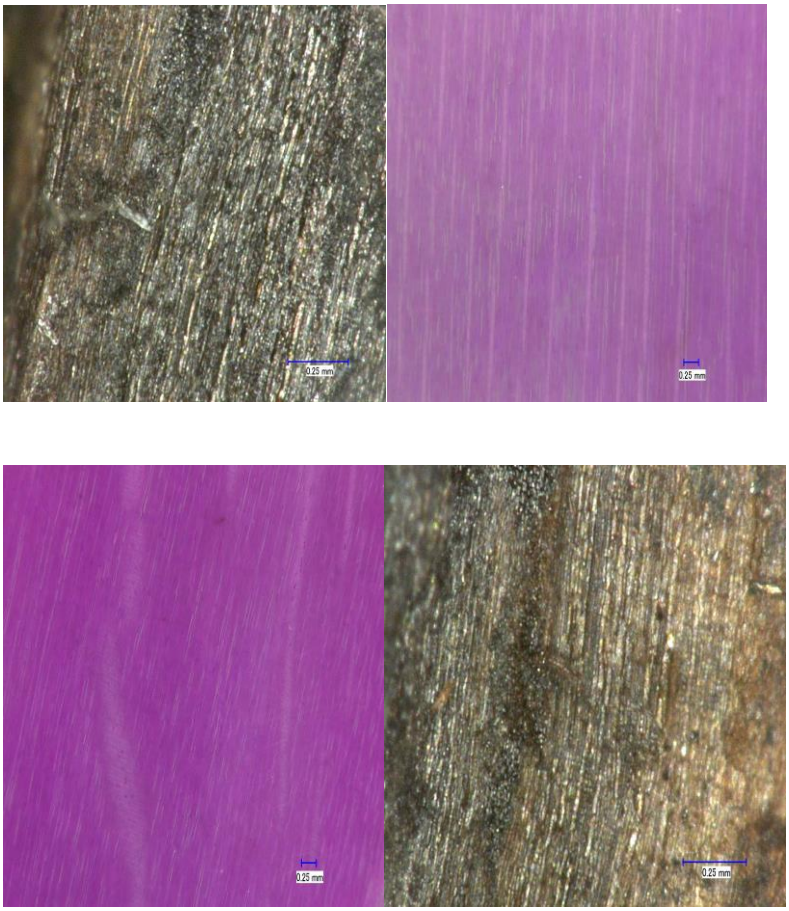
occupation phase I	occupation phase II

Sample size, occupational phase, stratigraphic lev : Diverse Site

CAMPAIGN	SITE	SQUARE	LAYER	PROVENANCE LEVEL (Labeling)	NUMBER OF IDENTIFIABLE PIECES (my estimation)	Cal. years BP (1 SIGMA, CALIB VER. 8.1.0, INTCAL 20)	Lab. No.	
Bale 17/1	A27 Gata II			TB -25	1	2.097 – 2.005	Beta-461995	
Bale 17/1	A27 Gata II			TB -40	1	2.741 – 2.585	Beta-461996	
Bale 17/1	A27 Gata II			TB -72	1			*(?) possibly older than 2.7 ka (assemblage too small)*
Bale 17/1	A27 Gata II			TB -8	1	457 – 338	COL5191.1.1	
Bale 17/1	A27 Gata II			TB -92	1			*(?) possibly older than 2.7 ka (assemblage too small)*
Bale 17/1	A27 Gata II			TB -99	1			*(?) possibly older than 2.7 ka (assemblage too small)*

Bale 17/1	A39 Wela	C/D2 2	5			*No radiocarbon dates from this site, but based on the lithics, all samples belong to the late Holocene LSA period, so roughly **5-2 ka calBP***
Bale 17/1	A39 Wela	C/D2 3	3			
Bale 17/1	A39 Wela	C/D2 4	3			
Bale 17/1	A39 Wela	E2W -5	8			
Bale 17/1	A43 Gata I	B2 C	2			*Totally mixed and disturbed deposits; no reliable statement of the age of the charcoals is possible*
Bale 17/1	A43 Gata I	TB -30 SE	1			
Bale 17/1	A43 Gata I	Y27 D	4			
Bale 17/1	A43 Gata I	Z17 C	1			
Bale 18/1	A49 Umburi	Test 1	1	8.992 – 8.813	Beta-490937	
Bale 18/1	A51 Umburi	Test 1	15	*small and undiagnostic assemblage; age of the charcoal is difficult to assess*		
Bale 18/1	A55 Garba Guracha	Test 2 (base of dark soil)	7	966 – 933	Beta-490938	*This (young) radiocarbon date does not fit to the lithics, which point again to the late Holocene lithics (**5-2 ka calBP**)*
Bale 20/1	A75 Dimtu	C2 L2 NW	2	1.691 – 1.547	COL6828.1.1	*Two different and separate*

						horizons:
Bale 20/1	A75 Dimtu	C2 L3 NW	3	1.714 – 1.616	COL6829.1. 1	
Bale 20/1	A75 Dimtu	C2 L3 SE	3			
Bale 20/1	A75 Dimtu	C2 L6 NW	6			
Bale 20/1	A75 Dimtu	C2 L6 SW	2	14.163 – 14.032	COL6830.1. 1	
Bale 20/1	A75 Dimtu	C2 L7 NE	3	14.822 – 14.296	COL6831.1. 1	



Myesine Africana cross section, radial, and tangential