A Landscape Perspective on the Oldowan

from Olduvai Gorge, Tanzania

# ABSTRACT OF THE DISSERTATION

# A Landscape Perspective on the Oldowan from Olduvai Gorge, Tanzania

by JOANNE CHRISTINE TACTIKOS

Dissertation co-Directors

Dr. J.W.K. Harris

Dr. R.J. Blumenschine

The Oldowan Industrial Complex is the oldest known stone tool technology dating from around 2.6 -1.6 Mya. The lithic artifacts recovered by Mary and Louis Leakey during their 1960-1963 excavations at Olduvai Gorge, Tanzania define the technology, which is typically thought of as simplistic. The first new sample of lithic artifacts to be recovered from Olduvai Gorge in over three decades is described. A systematic technological analysis of the artifacts grouped by spatially discrete landscape groupings revealed variation in assemblage characteristics between spatial groupings. Different production modes and production techniques are identified in synchronous lithic assemblages in the Olduvai Sub-basin, suggesting that variable production modes and production techniques are part of what defines behavioral or regional variants within an Industrial Complex.

The landscape scale of the sample lends itself to behavioral interpretations concerning issues of land use and technological organization that are not achievable with a more spatially restricted sample. Examining the possible impact that varying scales of investigation may have upon a study, two different scales of investigation were applied. Different types of behaviors are visible on different spatial scales. Raw material diversity is more apparent on a broader spatial scale, technological diversity is more apparent on a narrower scale. This may be an indication of the relationship of technological strategies to resource distribution and that technological selection occurs on a scale commensurate with plant and animal resource and risk distribution.

In an attempt to explain the variability evidenced by the spatial distribution of Oldowan artifacts on a landscape scale, models are formulated to explain the spatial distribution of artifact assemblages and are tested against the archaeological record for goodness of fit. The results and implications suggest that the Oldowan is not solely the simplistic technology it has been perceived as, but rather a mosaic of technological strategies, and that simple behavioral models cannot accurately account for the complexity of the Oldowan, which lies in its integration with landscape ecology.

# ACKNOWLEDGMENTS

I would like to thank the members of my thesis committee, Jack Harris, Rob Blumenschine, Craig Feibel, and John Shea for their encouragement and assistance in the completion of this dissertation. Drs. Gail Ashley, Richard Hay, and James Ebert provided invaluable guidance, by way of personal communications, to the completion of this thesis. All of the errors, omissions, and/or opinions stated in this thesis are mine alone.

Without the seminal works of the late Mary Leakey and Glynn Isaac, my work would not have been possible. It was their undaunted quest for knowledge of early human behavior and the meticulous recording of their original data that served as an inspiration for my continued research in understanding stone tools as early human behavioral markers.

I would also like to thank Dr. Fidelis Masao for his insights into Oldowan stone tool technology and his personal guidance in the field in Tanzania. In that respect I would like to thank my gifted field foremen, Augustino Venus and Good Luck Peter, without whose help the excavations of the early human material culture would have been a much more difficult task.

This research was supported by grants from the National Science Foundation, the L.S.B. Leakey Foundation, the Center for Human Evolutionary Studies, and the Graduate School, New Brunswick. The Tanzanian Commission of Science and Technology made that research possible. Many days of research at the Arusha Human Origins Laboratory at Arusha were made easier by the assistance of the Director of the National Museums Tanzania, Arusha, by Ms. Felista Mangalu, and her staff.

I am especially grateful to Janet Bascom and Vicki Rhimes who helped me in all administrative aspects of the pursuit of my degree at Rutgers, the State University of New Jersey.

I would like to thank the graduate students who came before me, Sandi Copeland and Amy Cushing, my family, who supported me throughout my graduate studies, and Sarah W. Timberlake, without whose support I would not have been able to complete this work.

# TABLE OF CONTENTS

## LIST OF TABLES

# LIST OF FIGURES

# CHAPTER ONE

## PART I: INTRODUCTION

Understanding early human behavior and subsistence strategies are cornerstones of paleoanthropological studies. Stone tool manufacture and use is particularly important to paleoanthropological studies, as it is perhaps the earliest recognizably human behavior. Human behavioral ecological studies have become vital to the comprehension of human material cultural evolution and the adaptive significance of stone tools. A key issue in paleoanthropological studies is whether the behavioral ecology of extinct hominids can be ascertained using lithic artifactual traces. And if so, what can they tell us about specific hominid land-use and subsistence strategies.

The following chapters present a description, analysis, and behavioral interpretation of stone tool assemblages recovered from Olduvai Gorge. The research design of this project incorporates innovative methods of lithic analysis and experimental archaeology in elaborating interpretations of early human behavior. In particular, it will address technological organization and behavioral ecology of the early humans at Olduvai Gorge, Tanzania.

This thesis is based on a comprehensive examination of the lithic assemblages recovered by the Olduvai Landscape Paleoanthropology Project (OLAPP) between 1989-2000, from a complex of early Pleistocene archaeological loci within the Olduvai paleo-basin, located in the present day Olduvai Gorge in Tanzania. OLAPP's multi-disciplinary approach has generated a database containing a wide range of paleoenvironmental information specific to the Olduvai Basin during temporally discrete stratigraphic intervals. The results of an exhaustive technological analysis and systematic description of a landscape-scale archaeological sample of about 5000 Oldowan stone artifacts from Middle-Upper Bed I and Lowermost Bed II are presented. These data are also compared to the stone artifact component of the Blumenschine and Peters (1998) predictive model for hominid land use in the Lowermost Bed II paleo-Olduvai Basin, Tanzania, as well as a refined predictive model based upon experimental archaeological data.

The significance of these lithic assemblages lies not only in the fact that the recovered cultural remains constitute the only artifacts excavated from Olduvai Gorge in over three decades, but that it is the first landscape-scale archaeological sample of the Olduvai Basin. An archaeological sample of this nature provides the opportunity to identify ecologically sensitive and behaviorally diagnostic artifact assemblage characteristics and apply them to interpretations of early human behavioral ecology and land-use. This thesis incorporates traditional artifact attribute analysis of the first new lithic data to be recovered since the 1970s with experimental archaeological techniques used in landscape archaeological perspectives and applied to behavioral ecological interpretations of that data. It is the landscape nature of this project's archaeological sample and the questions that can be asked of it which lead to an improved understanding of early Oldowan hominid-landscape interactions.

### *Organizational Overview*

Chapter One introduces the subject and focus of the thesis. Part I states the research problem and briefly discusses the topic and goals of the thesis, providing an outline of related research questions including a conceptual framework and chapter-by-chapter synopsis. Part II discusses pertinent theoretical perspectives, justifying the arguments advanced in the thesis. Part III introduces the landscape perspective in greater detail, including an epistemological review of the landscape perspective. It portrays the role of landscape archaeology in Paleolithic studies, discussing theoretical perspectives of behavioral model building and hypothesis testing in paleoanthropology, from its recent development to its application to behavioral ecological studies. It offers a critical review of literature pertaining to land-use modeling, model building and hypothesis testing in Paleoanthropology, It advocates the significance of landscape and behavioral ecological perspectives on paleoanthropological studies, in particular as they pertain to early hominid behavior and technological organization at Olduvai Gorge. Part IV discusses the shift in focus in lithic analysis from typological descriptions to technological and behavioral interpretations. It includes brief discussion of experimental archaeology and its implications.

Chapter Two describes the study area in Olduvai Gorge, Tanzania, which is pertinent to this thesis. Part I presents the geography and geology of Olduvai, recapitulating previous geologic work carried out there, focusing on the target intervals dealt with in this thesis, Middle-Upper Bed I and Lowermost Bed II. This section characterizes the archaeological context from which the artifacts discussed in this thesis were recovered. Part II presents a review of the history of research in Olduvai Gorge, Tanzania, specifically the work carried out by Mary Leakey between the 1930s and 1970s. Part III focuses on recent work carried out in Olduvai Gorge by the Olduvai Landscape Paleoanthropology Project (OLAPP) between 1989-2000.

Chapter Three focuses on the archaeology, giving a detailed account of the archaeological data used in this thesis. Part I describes the sampling procedures and analytical protocol used. Part II presents a general description of the lithic artifacts excavated by OLAPP between 1989-2000. This section describes the archaeological sample used as a database for this study. It documents the characteristics of the lithic assemblages by paleogeographic groupings and presents a comprehensive and detailed description of lithic assemblages.

Chapter Four compares the typological characteristics and distribution of the OLAPP sample with contemporaneous portions of the Leakey (1971) sample. The OLAPP sample is described using the Leakey typological classification system. The objective of this chapter is to assess the homogeneity of Oldowan lithic assemblage characteristics on a broader landscape scale.

Chapter Five discusses experimental methodology and pertinent perspectives, objectives, and implications of experimental archaeological research both as an analytical tool for the study of archaeological assemblages distributed on a broad, landscape scale and as it is applied to interpretations of behavioral ecology of the early Oldowan hominids. It reveals the specific methods used in the experimental procurement, shaping, use, re-use, and discard of stone from the various raw material sources available in the Early Pleistocene Olduvai Basin that were carried out in order to empirically determine the relative utility of Oldowan tool forms and raw materials. This section will also present the resulting experimental database.

Chapter Six presents a three-step predictive model of artifact distribution across a paleolandscape based upon Isaac's (1981) methodology for explaining assemblage spatial variability. Part I describes the first step of the model, a least-effort technological strategy based on opportunism. Part II describes the second step, an expedient technological strategy, whose operating mechanism is transport. Part II describes the third step, an optimization strategy, whose operating mechanism is optimization of resource processing.

Chapter Seven tests the models presented in the previous chapter. It presents the predicted critical variables for each step of the model and compares them with the actual observed archaeological data for goodness of fit.

Chapter Eight summarizes all that has been introduced in the thesis. It presents a discussion of the results of the technological analysis, typological comparisons, experimental trials, and predictive model implications and offers interpretations of the resulting data. Future research directions are also proposed.

# PART II: THEORETICAL PERSPECTIVES

In order to use material traces of human activity to address questions of early human behavior, the basic unit of investigation must be applicable to the behavior being investigated. Conducting research on a broad spatial scale, one at which, for instance, Oldowan hominids interacted with other vertebrates and resources in their habitats, is a significant step toward a more ecologically oriented archaeology (Behrensmeyer 1983; Blumenschine 1988; Butzer 1982; Clark 1960). Morphological and typological artifact descriptions alone do not provide behavioral ecological interpretations, nor have they been adequately linked in past studies to an ecological context. In this study, early hominid tool-using strategies across a paleolandscape are explored; thus landscape patterns of artifact discard are examined.

The primary goal of this thesis is to report on the first new archaeological data to be recovered from Olduvai in over three decades, and the first landscape-scale archaeological sample from this region and of this magnitude. The archaeological sample is presented in a traditional descriptive manner and also in a manner utilizing its potential for addressing questions of human behavioral ecology.

The secondary goal is to demonstrate the fundamental premise of this thesis, that behaviorally meaningful variation in stone artifact distribution over a landscape exists, and that it is not only discernible, but also predictable and testable. Attempting to do this according to traditional methods whereby lithic analysis begins with the identification and morphological classification of stone artifacts may be problematic. Stone tool classification has generally been used for two basic purposes: to identify diagnostic markers of prehistoric cultures, and to identify functional or behavioral indicators of those cultures. When used as cultural markers, stone artifacts are identified as cultural traits of specific prehistoric peoples. They are often assigned a chronological as well as a geographical connotation. When used in identifying behavioral technology or function (techno-function), classification usually describes types of activities, attempting to identify prehistoric behavior. Whether they are describing culture or techno-function, lithic classificatory systems are generally based upon morphological characteristics. When stone artifacts are placed into morphological typologies, or groups of formal similarity, they become static and unchanging entities. This can be problematic when considering that the fundamental characteristic of stone tools is that they are morphologically and functionally dynamic articles of human material culture.

There is a dynamism involved in the "life" of a tool. It begins with the procurement of raw material (Fig.1.1). This involves quarrying and/or transport. Then there is production or manufacture. A systematic reduction of some sort is carried out to achieve a desired form. This is followed at some point by tool use and discard or loss (or re-use, re-shaping, transport, and then discard). At this point the tool may enter the lithosphere where post-depositional processes may also be involved up to and including the excavation or recovery of a tool. All of these processes affect the tool's morphology and/or context, the two most basic variables in an archaeological assemblage and its subsequent analysis and interpretation.

Oldowan technology is generally considered to be an expedient technology, not bound by design constraints. This factor introduces inherent morphological variation into an Oldowan assemblage. Using morphological criteria alone may not be sufficient in understanding the behavioral ecological context of a stone artifact. Other criteria such as artifact assemblage attributes or discard patterns can be examined in a landscape context. Understanding the correlation of morphology and context examined together may be a stronger interpretive tool for understanding the behavioral processes responsible for the assemblage discard patterns.

**A Tool's Life:**
**The analysis of an artifact**

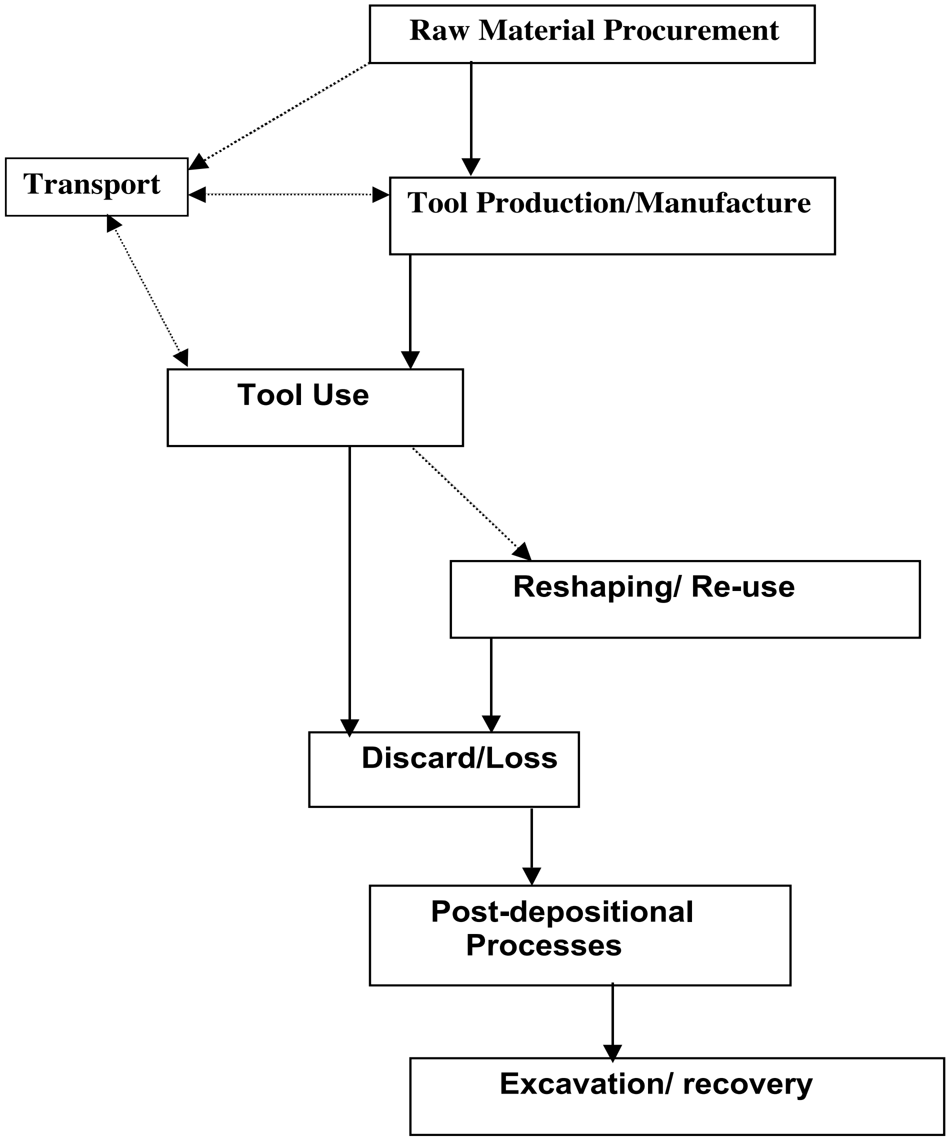


**Fig.1.1. Flow chart showing the lifetime morphological and contextual metamorphosis of a stone tool.**

Lithic artifact and assemblage characteristics are more behaviorally diagnostic if they can be understood in a techno-functional context. This is facilitated by experimental archaeology designed to determine relative tool utility indices. Ranking utility is useful in predicting artifact distribution on a landscape. Once placed in a landscape context, the techno-functional character of tools may be better understood.

Archaeological approaches have undergone profound changes in the last three decades. Among these changes, those that have impacted this research are the scale and resolution of data, which, in many ways, is the novel contribution of this analytical methodology. The scale is a ‘non-site’ or broad landscape scale archaeological sample. The resolution is spatially discrete lithological units of investigation by which the data is grouped and contextual associations and comparisons are made.

While the ultimate issue addressed here is the adaptive significance of tool-use by the Oldowan hominids, a more proximate goal is the understanding of the technological organization. The systemic approach to understanding the technological organization of the Oldowan hominids in Olduvai Gorge entails examining patterns of behavior as they might relate to their ecological context and be visible in various spatial-eco-temporal scales of investigation. The scales of investigation should match the particular question or issue being addressed (see Table 3.1). The broadest scale of investigation dealt with in this thesis is the sub-basin to geographic sub-region scale. It is at this scale that land-use patterns are most completely visible. Determining the behavioral basis for these patterns will permit an understanding of the adaptive significance of tool-use by Oldowan hominids by defining their tool-using strategies, or technological organization. This involves understanding the interaction between hominids and their environment, or their behavioral ecology. Determining the ecological context on a broad scale can elucidate patterns of hominid activity on a landscape when specific areas describe different resource distribution, necessitating different activities. Recognizing the nature of archaeological traces of such activities is facilitated through experimental determination of tool function and utility. Identifying these traces is done on the scale of resource extraction or activity areas. Examining similarities within traces and variation between them will help identify specific activity traces and the context that influenced such behavior.

In recent years, distributional or non-site sampling approaches have expanded the unit of investigation to define the regional archaeological structure (Stafford and Hajic 1992). However, the unit of investigation should not merely be expanded, but should match the scale and scope of that which is being investigated. According to Winterhalder (Winterhalder 1980), there are three spatial scales that are relevant for humans, (1) foraging range, (2) migratory range, (3) extended interaction through trade. If hunter-gatherer behavior is being investigated, the scale of investigation should be set by spatially definitive aspects of foraging ecology (Stafford and Hajic 1992; Stephens and Krebs 1986), where resources and affordances are distributed in discrete spatial units across a landscape, or patches. A broader epistemological view of landscape archaeology is presented in the following chapter, but it is the ‘foraging range’ scale of investigation that will be focused upon in this thesis.

# PART III. LANDSCAPE ARCHAEOLOGICAL PERSPECTIVES AND LAND-USE MODELING: A REVIEW OF THE FIELD

## Introduction

In a predominantly paleontological approach to documenting the narrative of human evolution, paleoanthropological researchers focused on identifying hominid and faunal remains to specific time periods. From the 1930s, the seminal research that was undertaken in Olduvai Gorge, Tanzania, tracked the very early evolution of tool-using hominids and impacted the very paradigms of archaeological investigation (Leakey 1954, 1961, 1963, 1967; Napier *et al*. 1962). These events lead up to and include several prominent archaeological discoveries and describe a methodology of paleoanthropological investigations. The methodology applied by the Leakey team to data recovery at Olduvai Gorge has set standards in documentation, classification, interpretation, and multidisciplinary research that are still applicable today.

In the 1960s through 1980s, middle range research (*cf.* (Binford 1981, Binford 1967, 1983) guided by ethnographic studies informed researchers of the particulars of human land-use and subsistence strategies. Observing living hunter-gatherer populations afforded researchers with an understanding of human interactions with their environment and the factors influencing subsistence behavior. This allowed for various models of land-use and subsistence patterns to be formulated (Binford 1980, 1985; Bunn 1982; Isaac 1968, 1978a, 1978b, 1980; Isaac 1989; Jochim 1976; Lee 1965; Lee and DeVore 1968; Torrence 1983; Winterhalder 1977). Landscape archaeological approaches were developed to accommodate the theoretical advances in paleoanthropology (Binford 1992;

Blumenschine 1991; Camilli and Ebert. 1992; Parkington 1972; Peters and Blumenschine 1996; Potts 1989; Rogers, et al. 1994; Rogers 1996; Thomas 1975; Wandsnider 1992). The methodology of middle range research included model building and hypothesis testing, major components in the interpretation of early hominid behavioral ecology. Predictive modeling and hypothesis testing based on experimentation have influenced the transition from the culture-historical narrative approach to that of a processual interpretation of material traces (Blumenschine 1991; Isaac 1989). Aspects of middle range research have helped to identify site formation processes (Schiffer, 1983), and have allowed for behavioral inferences to be made with greater confidence. One aspect of middle range research was the identification of formation processes as localized occurrences that can be distinguished from ecological causal agents of behavior. When these causal agents are identified and tool-using behavior is modeled, lithic distributional data can be predicted across the paleolandscape. This type of conceptual framework employs predictive modeling informed by experimental archaeological observations to make behavioral inferences, and to refine existing model test implications.

The following section will discuss the recent advances in the landscape archaeological perspectives and land-use modeling.

## Land-Use Modeling and Hypothesis Testing in Paleoanthropology

### *Theoretical Background*

Models are ways of representing a particular reality. Behavioral models are often predictive in nature and their cogency can be tested. In archaeology, closeness of fit of these hypothetical models is tested using the scientific method. Scientific method is defined by Ashmore & Sharer (2000) as an approach to acquiring knowledge that is continuously self-correcting so that the conclusions reached in earlier research are subject to repeated testing and refinement. Conclusions are drawn from direct observation with more confidence if they endure under different yet comparable circumstances. Comparisons can be made by either of two ways: starting from the particular observations and proceeding to the generalizations (i.e. inductive); or starting from accepted generalizations or premises and proceeding to the particulars (i.e. deductive). Conclusions and their implications, however derived, may then be examined in contrast with the archaeological record of evidence to assess their strength. This procedure allows models to be tested and conclusions or test implications to be falsified or accepted.

Based upon his observations of extant Shoshone people in the Great Basin, Julian Steward (1955) developed a generalized system, or summary description of activities and settlements, relating localities to seasonal food procurement cycles. Steward's (1955:37) seminal work introduced the concept of cultural ecology as the "utilization of the environment in culturally prescribed ways". His approach relied upon uniformitarianist principles, applying them to human behavior rather than to geologic processes alone. This is supported by the logic that geological processes are an underlying factor of ecologically determined behavior such as settlement patterns (hydrologic patterns and cycles will determine floral and faunal density and distribution, and related human behavior). Steward (1955) used these generalized data to model behavioral patterns. He employed this behavioral model to describe the prehistoric Shoshonean peoples' distribution of settlements and activities, invoking seasonal cycles as a determinant of prehistoric behavior patterns as well.

Building upon Steward's model of prehistoric people's seasonal settlement patterning, David Hurst Thomas (1973) created a set of relationships based upon Steward's assumptions. Thomas' propositions or hypotheses are derived from and advance Stewards' generalizations, but are applied to particular situations. For example, he extrapolated locational data about stone tool discard based on hypotheses of prehistoric settlement behavior. His methodology employed a generalized subsistence-settlement system and artifact frequencies were examined within three different environmental zones. Thomas (1973) made predictions about specific types of tools associated with specific hunting behaviors that were, in turn, associated with specific localities. He was able to test his hypotheses against the existing ethnoarchaeological record. Such research has spearheaded significant transformations in the application of model building and hypothesis testing to various archaeological paradigms. The following section explores these transformations in greater detail.

## Epistemology: Variations on a Theme

### *Locational Theory and Site Catchment Analysis*

A fundamental premise in human behavioral ecology is that human behavior is governed by certain principles, hence it can be generalized and predicted. Identifying such principles has led to the formulation of a number of human behavioral theories. Theoretical implications can be used to construct specific behavioral models. For example, borrowed from psychology, the "principle of least effort" (Zipf 1965) states that humans will minimize their rate of energy expenditure among a range of alternative strategies. Subsequently, the intensity or magnitude of human resource exploitation will occur in inverse proportion to the time and effort and distance involved in procuring the resource (Jarman 1972:706; Vita-Finzi and Higgs 1970:7). A product of economy, ecology, systems theory, and regional analysis known as locational analysis, or locational theory (Bernick 1983), was used by geographers in Europe during the 1960s. It was introduced to archaeology by Vita-Finzi and Higgs (1970:5) in the form of “site catchment analysis” to explain site location and land-use patterns. They examined the relationships between technology and those natural resources lying within economic range of individual sites. Site catchment analysis examines the distribution of resources in order to predict the distribution of archaeological sites (Jochim 1976, 1983).

A simplified approach to spatial-temporal analysis of artifact assemblage composition assumes that the core area of occupation will be located centrally to resources and travel time to each resource will be a linear measure. However, behavioral ecological determinants are extremely variable and the complexity of human behavioral ecology precludes linear assumptions of cause and effect. Resources may be differentially prioritized and their distribution may be intermittent in time and space. In order to comprehensively examine prehistoric human behavioral ecology, first the intricate undertaking of reconstructing paleoenvironments must be done to better assess their impact on human behavior. Second, the archaeological unit of investigation must match the spatial as well as the temporal scale of the behavior or process being investigated.

How a resource is distributed may vary according to scale and may be episodic, which involves a temporal as well as a spatial domain. Providing a higher resolution to human behavioral ecological studies, a temporal dimension is introduced as a measure of energy expenditure. For example, a time interval on the order of 10 Ka may reflect the response of organisms within a localized area such as a paleo-lake basin to a climatic fluctuation. This interval may be suited for physiognomic vegetation studies and their impact on human behavioral ecology. It does not lend itself to hominid evolutionary studies that are associated with a time frame several orders of magnitude larger and occurring within larger regional scales. Several variations on the temporal-spatial approach to paleoanthropological analysis have been developed in the attempt to interpret human behavioral ecology. A review of some of the sub-disciplines that have emerged relating to paleoanthropological studies is presented below.

### *Contextual Archaeology*

The distribution of resources is of great interest to paleoanthropologists. Gross features such as climate, biological communities, human group distribution, and behavioral patterns all exhibit areal patterning which lend themselves to spatial analyses. Butzer (1971) provided an environmental context to archaeology in a seminal work on the multidisciplinary approach to archaeology, integrating environment, geography, and ecology. He employed stratigraphy and geomorphology, using sedimentology and vegetation studies to reconstruct paleoenvironments, providing an ecological perspective to anthropological prehistory. Subsequently, researchers have included the spatial context to archaeology by examining the relationship of artifact and paleoenvironment (Isaac 1980, 1981), making behavioral inferences based upon interpretations of artifact and bone character and distribution.

One approach, advanced by Butzer in *Environment & Archaeology* (1971), and further articulated in *Archaeology as Human Ecology* (1982), describes the interdependence of cultural and environmental variables and provides a framework within which the various scientific approaches used to interpret such interactions may be discussed. This framework evokes five concepts, which were borrowed from geography and biology but have direct anthropological and archaeological application while incorporating spatial and temporal variation, promoting a multidimensional systemic analyses. The five central themes are; (1) space, (2) scale, (3) complexity, (4) interaction, and (5) equilibrium state.

The goal of environmental archaeology, the study of the environments of prehistoric humans, is to define the characteristics and processes of the biophysical environment that provide a matrix for and interact with the human socioeconomic systems. Evans (1978) examined the environment as it relates to humans, separating the elements of the paleoenvironment into the human environment, plant and animal remains, soils and sediments, and natural and archaeological situations. He listed six factors of interest to the environmental archaeologist with what he called a well-defined set of parameters into which the environment can be broken down and for which paleoanthropological evidence can be found: (1) climate, (2) geology, (3) soil, (4) vegetation, (5) fauna and, (6) diseases (1978:2). Given the interaction of these factors within the two less obvious but equally important factors of space and time, he examined what impact this may have had on human behavior, particularly the impact of man on the environment and vice versa. This was done with an organization or grouping of parts of the environment as those exploited by humans for food, those exploited by humans for reasons other than food, those not directly exploited by humans but affecting them, and those not directly exploited or affecting humans but useful in reconstructing the paleoenvironment. Environmental archaeology thus understood is a highly descriptive approach to archaeological analyses that examines environmental factors that may have been behavioral determinants.

Schiffer (1976) presented four organizational strategies towards a behavioral archaeology, with the specific goal of providing scientific explanations for variability and change in human behavior. The first strategy uses past material culture to address descriptive and explanatory issues of the behavior and organizational properties of past cultural systems. The second strategy employs the study of material culture in order to describe and characterize the nature of past behavior. The third strategy looks at present human behavior in order to understand past material cultures. The fourth strategy looks at present material culture and its relationship to present human behavior. One of the strongest contributions of behavioral archaeology to the concept of paleoenvironmental reconstruction is distinguishing the site formation processes that occur after deposition of artifact and bone from the behavioral processes that were responsible for their primary deposition. Schiffer (1983) examined artifact deposit properties as indicators of site formation processes (SFP) and how SFP can affect them by considering simple traits such as size and their effects. For example, reducing size of individual specimens or winnowing the assemblage by size affects archaeological visibility and sampling. Flowing water, wind, and trampling all have size effects as does bone modification by carnivores. He argued that material traces of organizational patterns might be disturbed or adulterated by diverse processes, human or natural in origin, creating new patterns. This leads to the concept that explicative or diagnostic behavior, activities or organizational characteristics are reflected in artifacts and faunal remains (Blumenschine and Marean 1993; Shipman and Harris 1988; Yellen 1977) and that remains recovered archaeologically have been deposited by way of adaptive systems and subsequently subjected to other cultural and natural processes. In order to identify the primary systemic properties, the latter processes must be identified and so must their influence on the original deposition of the artifact (Gifford-Gonzalez, 1991). This 'transformational' concept of formation processes stresses the fact that when artifacts have been modified after deposition, behavior and organizational properties cannot be discerned directly from patterns emerging from those archaeological assemblages. Formation processes themselves exhibit a discernible patterning which, using knowledge of certain laws governing such processes, can be identified (Schiffer, 1976). Schiffer (1983) proposed using (1) simple artifact properties like size, shape, density (specific gravity) and orientation and dip, which can be affected by aeolian and fluvial processes (as well as other natural and man-made processes), (2) complex artifact properties like artifact quality, vertical and horizontal distribution, artifact density and diversity, and (3) deposit properties such as sediments, ecofacts, geochemistry, deposit structure and context, and site morphology, as ways to trace formation processes.

### *Spatial Analysis*

Glynn Isaac proposed a division of archaeological site types based on differential occurrence of artifacts and bones (Isaac, 1981; Isaac and Harris; 1980). He identified four basic types of artifact concentrations:

Type A- artifacts only

Type B-artifacts and a large animal’s bones

Type C- artifacts and many animal remains

Type D- bones only

Artifact concentrations may constitute different activity areas in which one site type may exist by itself or as a component of the next type. These “stone age visiting cards” (Isaac, 1981) designate arrays of points in space which, linked and compounded, formed patterned sets whose locations are determined by other environmental and economic factors (i.e. resource distribution or settlement patterns). Although this approach may have been borrowed from ecology, it is nonetheless archaeologically anchored and focuses mainly on the nature and characteristics of artifacts and/or faunal assemblages and the resultant human behavioral implications.

In a similar approach, Kuhn (1993) utilized stone artifacts as markers of human behavior by examining the variation in patterns of stone tool manufacture, use and discard, as they might portray changes in hominid foraging behavior, land use and mobility. Kuhn (1993) considered artifact variability as well as density, assuming tool morphology to vary as a function of how and what a tool was used for, and that tactics of manufacture are contingent on timing and spatial distribution of use events.

In a monumental work on the application of middle range research to zooarchaeology, Gifford-Gonzalez (1991) examined the transition from agent identification studies and analogical inferences drawn from them to stronger inferences made about hominid behavior. She used experimental and naturalistic observations to more accurately define the morphologically distinctive traces of human actions and carnivores on bone (e.g., bone gnawing; trampling). The effects of flowing water in modifying bone surfaces and structuring element frequencies and orientations were detailed as well as other attritional processes affecting bones. Her research used contemporary observations to specify causal linkages between the actions of various agents on bone and the physical results of those actions. Gifford-Gonzalez described modern analogue studies as a way to advance to more complex analyses and more quantitative inferences about the life relations of prehistoric hominids (Gifford 1981, 1991). She cautioned that our understanding of the role of faunal remains in human systems and ecosystems is still rudimentary. A problem she saw with modern analogue studies involved the likely misapplication of assumptions, such as 'transferred ecology' or attributing a modern ecosystem's features to an ancient one's based on a few points of similarity. Another problem was assessing the validity or strength of a proposed analogical relationship. Gifford-Gonzalez outlined two sources of inferential uncertainty (1991):

1. The relationship of patterning in faunal assemblages to ancient behaviors of hominids or other agents and their ecological contexts, a) unclear analytic concepts b) equifinality of causes in patterning c) lack of information on faunal relationships in behavioral and ecological contexts.
2. The nature of causation in biological systems and its impact of expectable levels of inferential confidence.

She described a nested hierarchy wherein trace refers to the remains (1991), causal agent to the physical cause that is actor and then effector, which exists in first a behavioral and then an ecological context. It is evident that making behavioral inferences is a complex process with inherent uncertainties resulting from the multivariate nature of the systems that researchers wish to indirectly infer. Deterministic relationships are not denied but multiple lines of evidence supporting general uniformitarian principles are stronger bridging arguments for implying causal agency or ecological context.

### ***Site Models***

Socio-economic functions of specific loci were modeled by Isaac in his home-base model (1978; 1981), and later revised as the central-place model (1983), in which he proposed discrete points on a landscape as being safe areas where activities such as the deferred consumption of transported food for the sake of provisioning a mate, offspring, or other group members would be carried out.

Focusing on energy cost as well as risk reduction, Potts' stone cache model (1984; 1988; 1991) suggested a delayed exploitation of resources through early hominid's efficient transport and use of stone minimizing expenditure and risk. This refers back to Binford's (1984) routed foraging model as the scavenger's risk avoidance strategy.

Keeping in mind the sources of inferential uncertainty outlined above (Gifford-Gonzalez, 1991), an anticipated problem with using site models is that they may operate under the assumption that a site distribution is the result only of the type of activity to the exclusion of the numerous other formational processes attributable to the site. Traditionally excavated point-specific aggregations of behavioral traces are commonly relied upon to support the interpretations made by locational models. Besides overlooking taphonomic issues, this approach may have inherent problems related to, among other things, scale, and resolution.

Expanding the traditional point-specific archaeological focus to include a landscape style archaeological sample, Rogers *et al.* (1994) examined changing land-use patterns in the Lake Turkana Basin, Kenya, over three different time intervals. They compared artifact types and densities, correlating the geological, paleontological, and archaeological records of the three different archaeological loci, providing strong paleoenvironmental contexts for their behavior interpretations.

A caveat to be noted is that several natural and human behavioral factors contributing to the formation and character of an archaeological aggregation other than its geographic location may obscure its interpretation. In addition to formational processes acting upon artifact distributions, sediment accumulation rates for an assemblage matrix which do not match the time it takes for a fossil or artifact assemblage to be created may produce a 'time averaged' aggregation (Stern 1994). Focusing on problems of geologic context and time resolution, Stern (1994) argued that there is an inverse relationship between the ancient landscape area, the artifactual density, and the time represented by the aggregation and its matrix. She stated that sedimentation and fossil accumulation vary in magnitude and frequency, and artifact aggregations are the result of the actions of many different individuals. Compounding this problem, depositional and post-depositional processes may be localized and occurring on a small scale (Ebert 1992), whereas human behavioral ecological factors affecting land-use patterns are not necessarily occurring on the same scale.

### *Off-Site Archaeology*

In what began as a descriptive framework for the location of archaeological occurrences, the concept of a 'site' became an archaeological concept all its own. Dunnell (1992) referred to this notion as defective and detrimental to archaeological interpretation. He argued that regardless of whether they exist arbitrarily, tangibly, or ideologically, they need not be an elemental archaeological unit. Dunnel (1992:35) suggested a ‘siteless’ approach and that the formation of the archaeological record should be seen as a sedimentary process (Dunnell and Dancey 1983).

Searching for a more suitable framework to human behavioral ecological studies, Foley (1981) took the site formation process idea beyond the arbitrary realm of the ‘site’ to a spatially continuous ‘off-site’ concept. He brought the fundamental unit of archaeology from a site to an artifact and its context, focusing on the spatially continuous distribution of artifacts. Isaac and Harris’ (1975)‘scatter between the patches’ differentiated 'scatters' from 'patches' or 'sites' by density of distribution across the landscape as follows:

- Low-density groupings of artifacts (scatters) found with a minimum density of 1 piece per 10,000 square meters.
- Higher density groupings (patches) containing 1-100 per square meter.

The integrity and resolution of a distribution are crucial to its interpretation. Whether a site is the result of a single activity or process, making it very high resolution, or of many activities and processes, making it low resolution, will affect the strength of the interpretation. In “Small is Informative”, Isaac *et al.* (1981) addressed this issue in an effort to quantify as well as characterize archaeological data.

### *Distributional and Non-Site Archaeology*

The distribution of archaeological traces, or distributional archaeology, can be used to characterize the spatial clustering of archaeological traces across broad spatial areas. This can be behaviorally diagnostic, especially in terms of land-use pattern studies. Ebert (1992:43) stated that “the material record will almost certainly be acted upon by a series of partially overlapping depositional and post-depositional processes of widely varying scales, combining the products of behavioral episodes, blurring or sharpening (and in fact often creating) their apparent boundaries, and differentially affecting the placement of artifacts depending on their sizes and shapes." However, these spatial clusters or distributional patterns are dependent upon the applied observational scale or resolution. For instance, if the distribution of hominid stone tool-using traces is to be examined, then the scale of observed distribution should match that of the ecological context influencing, impacting, or determining the behavior resulting in those traces. This brings us back to the problematic notion of "site". Defined as both the loci for a past activity and the unit of archaeological discovery, the site notion involves sampling methods, which can provide inconsistencies in archaeology. The search for solutions leads to non-site approaches to archaeology. The distributional approach focuses on the trace cluster patterns, rather than the arbitrary site boundaries. In order to interpret behavioral variation across a continuous space, certain landscape parameters should be set that help to identify the ecological context for the behavior. A conceptual framework that includes predictive modeling should be effective in behavioral ecological interpretation providing that knowledge of the systemic driving mechanisms of the activities across a landscape under investigation are understood (Ebert 1992:46). Landscape archaeology implements this conceptual framework by archaeologically sampling on a landscape scale and grouping the analytical units into discrete paleogeographic units or landscape associations (Blumenschine and Peters 1998; Peters & Blumenschine 1995, 1996). Behavioral generalizations that are environmentally linked can thus be modeled, and distributional data can be predicted across the paleolandscape.

### ***Landscape Archaeology and Land-Use Modeling***

Departing from traditional site-based archaeology, landscape archaeology draws on sub-regional scale sampling and paleogeographic reconstruction to evaluate early hominid behavior and land-use patterns. Observable variability in the distribution and character of archaeological traces can be used to identify early hominid behavior on a scale comparable to daily, seasonal, or longer-term hominid ranges. Examining variability in land use patterns of early *Homo* in the Lake Turkana basin over several different time intervals, Rogers *et al*. (1994) consider the distribution of resources such as stone, water, shade, shelter and food as determinants of where lithic remains would be discarded. In their study, they discussed the distribution of artifacts in relation to paleoenvironments at three different time intervals (*see also* Feibel 1988; Feibel et al. 1991). At 2.3 Ma, artifacts were found in small densities in close proximity to water, shade, raw material, and food resources. At 1.8 Ma, non-local raw materials are introduced into the equation and evidence of hominid activity occurs at the lake margin. Hominid movement appears to be expanding into new regions, and by 1.6 Ma they no longer appear tethered to resources.

Potts applied a landscape archaeological approach to studies of Early and Middle Pleistocene contexts at Olorgesailie in Kenya (1989). He examined models employing socio-economic variables to explicate hominid land use patterns, arguing that environment-behavior covariation is not represented by a single best explanation (1994). In his work on lithic assemblage collections from Olduvai Gorge, Tanzania, he demonstrated the interplay of variables in comparison with other Plio-Pleistocene contexts. He found that resource tethering was important for some raw materials and possibly handaxes, but not for other components of the artifact assemblage. He also argued that stone transport distances varied greatly among different basin contexts. He stated that predation risk to hominids was not as big a factor at Olorgesailie as it was at Olduvai. He concluded that models may define one or more important variables linking behavior and environmental conditions, but they are not singularly explanatory for human behavior. Models are also not mutually exclusive explanations of human behavior: different models explain different aspects and contexts of human behavior, with all variables at certain times being critical and potentially simultaneous in their effect on human behavior. The concerns articulated by Potts are not necessarily shortfalls of predictive modeling, but suggest that that temporal and spatial scales used in general models must be specified.

Another concern of landscape archaeology is time averaging (Stern 1994, 1995). Time averaging implies that archaeological assemblages may be palimpsests of behavioral traces, evidencing several events or occupations thus, the broader the area of a paleolandscape the greater the probability that archaeological traces are being sampled from more than one occupational horizon. This phenomenon does not hinder the investigation of variability of artifact distribution on a landscape in this case, as a broad landscape scale of investigation permits artifacts to be derived from environmentally diverse settings, thereby allowing strong patterns of association between material traces of hominid land use and the environmental setting of these activities to emerge. This is tantamount to identifying basic paleoecological factors that may have driven environmentally specific technological and subsistence strategies evidenced by the Oldowan archaeological record (see Chapter 3, Part I).

Potts (1994) argued that models are useful when applied to particular situations. In keeping with this argument, the landscape approach taken by OLAPP focuses on a geographically restricted area and a specific temporal period: the paleo-Olduvai Basin during Middle-Upper Bed I and Lowermost Bed II times. The landscape sample of synchronous time intervals and the experimental archaeology are implemented in this study to develop a model for a particular situation: the tool-using strategies of the Oldowan hominids during Middle-Upper Bed I and Lowermost Bed II times. The experimental data are applied to; a) the development of a methodology with which early hominid subsistence-related land use can be interpreted utilizing lithic remains as behavioral traces, b) the identification of specific artifact and artifact assemblage attributes which can be diagnostic of habitat-specific early hominid behavior, c) the development of ecologically sensitive stone tool using behavioral models for the Oldowan hominids, and for future research, d) the comparison of the model for stone-tool-using behavior in the paleo-Olduvai region with other regions and other time periods.

It is evident that land-use modeling and hypothesis testing play an important role in the ever-widening body of research associated with human behavioral ecology studies in paleoanthropology and, coupled with experimental archaeology, will allow for broader goals in lithic technological studies to be addressed. The following section discusses experimental archaeology as a tool in constructing behavioral models and in understanding the technological function and ultimately the adaptive significance of stone tools.

# PART IV. THE APPLICATION OF EXPERIMENTAL ARCHAEOLOGY AND PREDICTIVE MODELING TO BEHAVIORAL AND TECHNO-FUNCTIONAL STUDIES

## Introduction

Experimental archaeology can provide an interpretive bridge between prehistoric activity traces such as stone tool discard and loss patterns and the paleoecological contexts that influenced the tool-using behavior that created them (e.g., Binford 1977, 1981, 1983). By replicating and using stone artifacts, experimentation has been applied to specific technological and behavioral issues concerning lithic reduction sequences (Bradbury 1999; Shott 1994,1996). It has been implemented in studies of the variation in manufacturing techniques (Ohnuma 1995; Speth 1979), as well as in typological assessments (Bradbury & Carr 1995; Jones 1994), technological evaluations (Crabtree 1975; Dibble 1985), tool function, utility and efficiency studies (Hardy & Garufi 1998; Hurtado & Hill 1989; Keeley 1980; Sahnouni, Schick & Toth 1997; Speth 1979), and the interpretation of lithic artifact assemblages (Mauldin & Amick 1989; Newcomer 1980; Ohel 1977; Rogers 1996; Shott 1989). Behavioral implications have been made based on the experimentally informed analyses of lithic artifact morphology and distribution (Bradbury & Carr 1995, 1999; Collins 1975; Flenniken & Raymond 1986; Jones 1981; Lieberman and Shea 1994; Shea 1991,1998; Shott, 1994,1996; Toth, 1982,1987). The importance of experimental archaeology to interpreting Early Stone Age assemblages (Toth, 1991) and its broad application to prehistoric behavioral studies has been well demonstrated.

The focus of paleoanthropology has appreciably shifted from describing cultures based on artifact morphology and distribution, or modeling prehistoric behavior based on ethnographic observation and analogy, to interpreting early hominid behavior through multi-faceted studies integrating experimental archaeology, actualistic studies, taphonomic studies, geological and archaeological excavations, predictive modeling and hypothesis testing which, among other things, provides an ecological context for archaeological occurrences. The following section discusses hypotheses formulation, predictive modeling, and various approaches to interpreting archaeological evidence.

### ***Behavioral Studies: Linking Tool Form, Function, and Context***

Clark (1982:236) hypothesized the nature of stone artifact assemblage variability, linking tool form and function, assemblage characteristics, and activity. He based his hypothesis on the assumption that tool form is related to function and therefore wider ranges of tool forms would be expected where several sets of activities were undertaken. Interpretations of the palimpsestic formation of archaeological ‘sites’ were made by Glynn Isaac at Olorgesailie, leading to his construction of early hominid behavioral models such as food sharing (Isaac, 1971) and the home base (Isaac, 1976). These models were subsequently tested by examining surface artifact distributions along the Karari Escarpment (Harris & Isaac 1976; Isaac & Harris 1980). Other artifact characteristics such as size, assemblage density, and presence of primary flakes, placed into a behavioral context, have been correlated with distance from raw material source (Harris, 1978; Isaac, 1984; Schick, 1987). Artifact form and flake type have been used as proxy measures to determine the potential range of subsistence activities necessitating stone tool use (Jones, 1979,1981; Toth, 1982,1987). Incorporating an ecological perspective into archaeological interpretations, Peters & Blumenschine (1995: *see also* Blumenschine & Peters 1998) predicted that degree of predation would affect artifact density and diversity.

Ecological perspectives on Pleistocene faunal assemblages have already been shown to be beneficial in understanding past environments and hominid subsistence practices (Binford, 1978; Blumenschine 1986, 1988; Blumenschine & Selvaggio 1988; Blumenschine & Madrigal 1993; Blumenschine & Marean 1993; Blumenschine *et al.* 1994; Grayson 1989; Jones 1988; Kappelman *et al.* 1997; Lyman 1984; Marean *et al.* 1992). Lithic artifact assemblages seen in an ecological context can be useful in understanding early hominid behavioral ecology as well.

Through the analysis of lithic archaeological traces, researchers have attempted to identify how ecological mechanisms may have affected hominid behavior. Isaac (1983:42-43) provided the beginnings for such an undertaking using lithic assemblages when, regarding Oldowan stone artifacts, he presented alternative models of artifact assemblage formation and hypothesized some basic functions for tools and forms that made them possible.

Building on Isaac's (1983) work, Blumenschine and Peters (1998) hypothesized that particular landscape facets (*re* Gerresheim, 1974) offer different risks and affordances to hominids requiring differential tool use. They made predictions of expected archaeological traces of this differential tool use. For instance, in an area of high predation risk, a low diversity and density of artifact types is expected if one considers that reduction of risk through minimal time expenditure will be reflected in a smaller range of activities. In most of these high-risk areas, they predict low-density artifact assemblages dominated by flaking debris (core shatter) and discarded cutting tools (e.g., whole flakes). Higher density and more functionally diverse artifact assemblages were predicted for landscape facets affording relatively low predation risk (see Table 3, Blumenschine & Peters, 1998). Predictions of the stone tool component of the Blumenschine and Peters model are based in part upon a basic understanding of the range of Oldowan technology from the available raw material clast sizes and forms (Hay, 1976), to the tool type (Leakey 1971, 1975), to the possible tool function (Isaac, 1983; Schick and Toth, 1993). Their model also draws from existing ecological, geological, actualistic, and paleoanthropological data, which facilitated the construction of a hypothetical paleolandscape, to predict the landscape distribution of Oldowan artifact assemblages for the Early Pleistocene Olduvai Basin.

Functional tool utility rankings based upon typological criteria have been identified (Schick & Toth 1993), but systematically quantified indices based on technological criteria determined through experimentation and linked to specific eco-functions have not. As Isaac (1983:12) pointed out, “It is necessary for archaeologists to go out into savanna environments and look for opportunities (and problems) in which use of simple equipment should make a significant difference.”

## Experimental Archaeology

### *Previous Research*

Understanding prehistoric human behavior without the benefit of such direct observational data as that which can be gathered through actualistic studies, is difficult at best. However, the experimental manufacture and use of lithic material has been implemented (Collins 1975; Jones 1981; Toth 1987; Schick & Toth 1993) in order to provide the missing behavioral link between archaeological trace and process, and has helped develop theoretical models of human technological organization (Bleed 1995; Nelson 1988; Torrence 1989a, 1989b).

Focusing on the Early Stone Age of East Africa, Toth (1987) performed experiments in Koobi Fora, Kenya, in an effort to understand the tool manufacturing processes. Holding raw material and original form constant (basalt river cobbles), he examined proportions of flake types in both experimental and prehistoric assemblages. By replicating the tool forms found in the archaeological record (47 specimens from FxJj50, in the Okote Tuff, 1.56 Ma) he was able to make comparisons regarding manufacturing sequences. He developed 'Toth flake types' (Bunn 1980; Toth 1982), which described the sequence of flake removal from the original river cobble. These six categories of flake types (Types I-III unifacial; IV-VI bifacial flaking) allowed for a classification of the dynamic manufacturing process, or a specific stage within that process, to be identified. This enabled him to recognize the stage at which a given artifact could be placed on the continuum or "stone flow" of a reduction and transport sequence.

Peter Jones also attempted to go beyond the traditional descriptive lithic analysis by asking what artifacts or assemblages "actually mean in a given situation" (1994:254). He used an experimental archaeological approach to examine the variability in biface manufacture classified as the Developed Oldowan and Acheulean Industries that were evident in Middle and Upper Bed II, Bed III and Bed IV, from Olduvai Gorge. He questioned the interstratified occurrences of refined and not-so-refined handaxes, and determined that differences in biface morphology were attributable to raw material quality (*see also* Jones 1979), and not cultural development. In his “given situation,” he found that raw material variability accounted for variation in hand axe morphology.

### ***Identifying the Problem; Interpreting the Archaeological Evidence***

Torrence (1989) suggested that we conceive of technology as one way in which people solve problems posed by both external, environmental factors and by internal, social needs. Following this suggestion, a logical progression of thoughts and assumptions are proposed in order to understand the tool-using strategy of the early Oldowan hominids: (1) tools are created and employed to satisfy a perceived need, (2) tool-using was carried out in such a way as to optimize the expenditure of time and energy (more specifically, a particular adaptation created by the operation of general principles of optimizing which were working within specific local conditions), (3) in order to understand the tool-using strategy one must first isolate the problems for which tools can be the solution, predict the optimal technology, then test the predictions against the archaeological evidence.

Variation in lithic artifact distribution on the Olduvai paleolandscape has been theoretically correlated by Peters and Blumenschine (1995; 1996) to specific activities, which were necessitated by different ecological contexts, based on the following assumptions: (1) the abundance and variety of resources and hazards requiring stone tool use affect the frequency and clustering of artifacts, (2) the raw material transport cost increases with distance to use location, (3) the degree of predation will influence patterns of stone tool use, discard, and loss.

One goal of this research is to expand Blumenschine & Peters' (1998) hypotheses by incorporating empirical tool utility data and hypothesized optimization into the equation. Experiments carried out in Olduvai Gorge, Tanzania, were designed to directly determine the relative utility of the various Oldowan tool forms. The resulting tool rankings were used to formulate predictions of tool distribution on a landscape, based on assumptions of optimal selection, and to identify patterns in lithic assemblages that can be linked experimentally to context-specific activities (Tactikos 2001). For example, high utility or optimal tool forms (of a relatively large size) will be more abundant closer to a raw material source, while low utility, sub-optimal forms (of a relatively diminutive size) may be expected further away from the source[1]. The high utility forms have been identified through the experimental determination and ranking of relative tool utility (this will be discussed in more detail in Chapter 5). The amount of time taken to perform a task was used as a measure of utility based on the premise that reducing time spent on an activity reduces the costs/risks involved, hence a more efficient tool. Utility rank has also already been demonstrably useful in the application of faunal analysis to human behavioral studies (Binford 1978; Blumenschine & Madrigal 1993; Grayson 1989; Jones 1988; Lyman 1984).

In order to better understand the behavioral patterns represented by stone tools, the following section presents a brief discussion of optimization theory as a behavioral model and underlying assumption in this thesis.

---

[1] These hypotheses were developed under the assumptions that hominids did not possess utilitarian transport items such as carrying-bags, and that ≤ 4 cobbles per individual were transportable.

### *Optimization and Predictive Models*

Optimization of technology is a revisited theme but does not always address a theoretical basis capable of accounting for a wide range of tool use. The sources of variability in prehistoric tools will be better understood when tool function is better defined and tool-use is seen in the broader context of subsistence.

Human subsistence-related studies have generally focused on questions that isolated biological stresses on a population and examined the efficacy of various responses to these stresses. Placing stress response into a cost-benefit framework facilitates the creation of simple predictive behavioral models for different environments. These models often referred to foraging. Three primary areas of focus in optimal foraging models are:

1. Food choice and dietary composition (optimum diet)
2. Group organization (optimal group size)
3. Site location and patch use (optimal foraging space)

Optimization models are generally based upon the (Neo-Darwinian) assumptions that a) natural selection and competition are the inevitable outcome of reproduction in a finite environment and, b) adaptive processes select for behaviors that allow an organism to efficiently and effectively achieve life goals. According to these assumptions greater efficiency confers greater fitness. Within the confines of these assumptions, optimal foraging models examine the costs and benefits associated with different activities and predict an optimal strategy. Assessing behavior thus requires a currency, or significant cost-benefit measure. The currency employed is almost exclusively energy (or energy-capturing behavior and/or devices). Maximizing the efficiency of energy capture confers a selective advantage. Many studies recognize energy as the currency to be optimized.

Others include time as a currency. Tools are among the primary means for humans to reduce the potential effects of risk. Tool using is most efficient at reducing risk that occurs because resources are only available for a short time. Time thus becomes *not* a currency to be optimized for its own sake, but the most relevant attribute of the type of risk to which technology provides an optimal response. It may also be considered as an energy capture or conservation, when minimizing the amount of time spent on a task reduces the expenditure of energy.

The body of research already undertaken in experimental archaeology supports its utility in interpreting archaeological evidence. Carrying out research that documents differential efficacy of form, raw material, and size of stone tools during the experimental performance of various tasks in particular situations, interpretive tools such as utility rankings can be determined and may help characterize and predict task and habitat-specific archaeological traces. This utility of experimental archaeology goes a long way toward understanding early hominid technological organization and the overall adaptive significance of stone tools.

# CHAPTER TWO

# OLDUVAI GORGE

## Introduction

This chapter presents a brief geological and paleogeographic description of the study area, Olduvai Gorge, Tanzania. As a prologue to the following sections, Part I characterizes the geological context from which the artifacts discussed later in this thesis were recovered. It portrays pertinent aspects of the geologic and paleoenvironmental reconstructive work carried out in Olduvai by Richard Hay as an overview, focusing on the temporal target intervals dealt with in this thesis, namely Middle-Upper Bed I and Lowermost Bed II. Part II discusses the history of past research undertaken at Olduvai, focusing on the work carried out by the Leakeys on Lowermost Bed II. Part III discusses more recent research undertaken at Olduvai. It discusses multiple areas of research including paleoenvironmental reconstructions based upon the multidisciplinary approach of the Olduvai Landscape paleoanthropology Project (OLAPP).

## PART I. THE STUDY AREA

### *Modern Geography*

Olduvai Gorge is a valley in the Serengeti Plain at the western margin of the Eastern Rift Valley, in Northern Tanzania. It is bordered by volcanic highlands to the south and east and the Serengeti Plain to the north and west, which in the area surrounding the Gorge, slopes gently east to west in a series of steps (Figure 2.1). Metamorphic rock inselbergs and hills interrupt the plain and metamorphic rock highlands border the gorge 20 km to the north. The principal branch of Olduvai Gorge, the Main Gorge, originates from Lakes Masek and Ndutu and extends 46 kilometers eastward to Olbalbal. The rivers forming the Main and Side Gorges meet before emptying in to the Olbalbal Depression. The Side Gorge stems from the volcanic uplands of Lemagrut (one of the volcanoes in what is collectively known as the volcanic highlands) to the south and joins the Main Gorge about 9 km west of the Olbalbal depression. The western margin of the Olduvai Basin is described by a succession of rapids and falls known as Granite Falls. The western head of the gorge is broad and shallow while the eastern half is relatively narrow and deep. The steep-sided eastern part of the Main Gorge can be up to 90 m deep and between .5 and 1.5 km wide. The modern Olduvai Basin is a remnant of the paleo-Olduvai Basin, which was formed by the growth of the volcanic highlands on the metamorphic basement rock, and has been filled in by Pleistocene sedimentary deposits known as the Olduvai Beds (Hay 1976).

The present day Olduvai Basin has undergone considerable geomorphologic change from the paleo-Olduvai Basin, largely due to geologic faulting. The drainage sump, the lowest part of the basin, for instance, lies much further east today than in the Pleistocene. Faulting occurred during the deposition of the Olduvai Beds and continued through to the Holocene. The majority of the main faulting episodes were downward displacements on the eastern side of the faults, creating a west-to-east step-like topography in the basin. Displacements range from a few centimeters up to 40 m in the west, and further east, at the western margin of the Olbalbal Depression, the displacement may be up to 100 m (*see* Hay 1976; Fig.4).

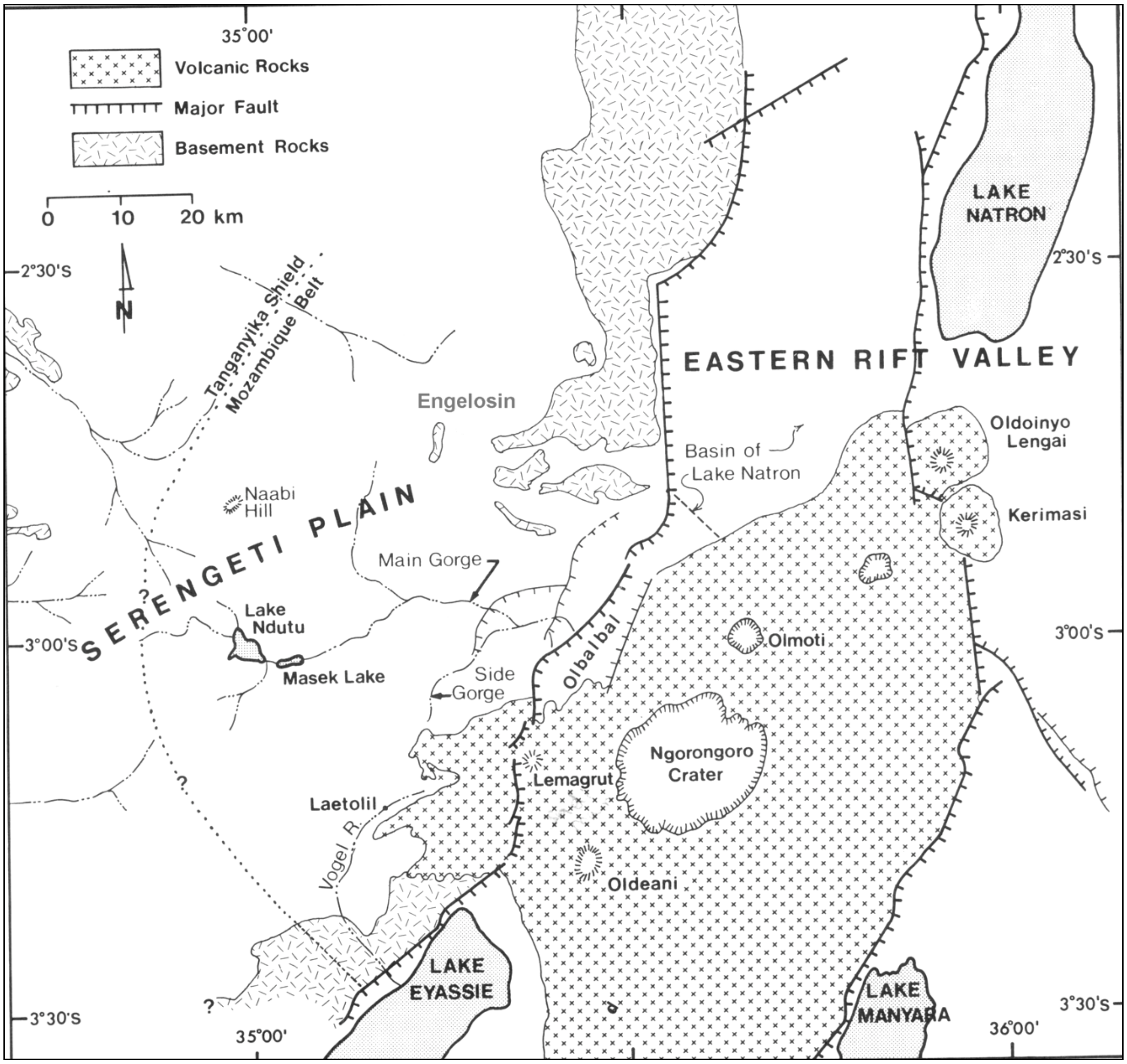


**Figure 2.1. Location of Olduvai Gorge within the Eastern Rift System on the Serengeti Plain (*from* Hay, 1976).**

### *Geology of Olduvai Gorge*

The geological narrative that is the history of tectonic and volcanic activity in Olduvai Gorge since the Pliocene has shaped not only its physical structure, but its ecological structure as well. Hans Reck first recognized the basic distinguishable rock units when he began his research at Olduvai Gorge in 1913. Reck subdivided the Olduvai Beds into five mappable units, Beds I-V, and identified four of the major faults. Reck focused on the lower eastern 9-10 km of the gorge. In subsequent research, as a member of L.S.B. Leakey's archaeological expedition in 1931, he identified one more fault. Although the simplicity of the stratigraphic subdivisions was thought of as problematic in describing more complex stratigraphic units, they remained as Beds I-V. Consequent research by Reck (1951), Hay (1967; 1971), and L.S.B. Leakey (1951; 1965), culminated in the modification of Beds IV and V to include the Masek, Ndutu, and Naisiusiu Beds (*see* Hay, 1971; Fig. 5).

In his seminal work, "Geology of Olduvai Gorge; a study of sedimentation in a semiarid basin" (1976), Hay has recorded the geologic history of Olduvai Gorge in great detail. In his monograph, from which this section draws heavily upon, Hay not only describes the geology, but the paleoenvironmental reconstruction and the patterns of hominid activity as evidenced by archaeological remains. One of many of Hay's major advances in the geological studies of Olduvai Gorge is the correlation of volcanic marker tuffs within Beds I and II, whereby he sorted out the lateral variation in the Bed I and Lowermost Bed II stratigraphy across the Olduvai Basin. Hay’s work is of great consequence to subsequent research carried out in the gorge, and those portions of his work pertinent to this thesis will be briefly summarized in this section.

### *Paleogeographic and geologic summary of Plio-Pleistocene Olduvai*

The deposits of basal Bed I are 2.0 to 2.1 million year old volcanic tuffs erupted from Ngorongoro, part of the volcanic highlands southeast of the gorge (Fig. 2.1), which overlie the Naabi Ignimbrite lava flow on a northeasterly sloping land surface of basement metamorphic rock in the western gorge. The basement metamorphic rock of the Olduvai area is part of the Mozambique belt, made up primarily of granitic gneiss exposed in the western part of the gorge forming the Kelogi inselbergs, and a coarse-grained and commonly micaceous quartzite forming the inselbergs and hills at Naisiusiu and to the east (*see* Chapter 3, Part II). At about 1.85 Ma lavas, mostly from the volcano Olmoti (east of the gorge), flooded the eastern part of the paleo-basin, a closed lake basin containing a fluctuating shallow saline-alkaline lake. These eruptions caused a westward displacement of the lake to the position it held throughout the remainder of Bed I time (*see* Hay 1976; Fig.18). Lacustrine clays accumulated up to 26 m thick in the center of the basin and deposited widely over lavas to the east. Subsequent volcanic eruptions at around 1.79 Ma were deposited subaerially, reworked to form an alluvial fan that displaced the lake further westward. The upper Bed I western basin was incised by at least one freshwater perennial stream feeding the saline lake (Hay 1976).

The Lower Bed II paleogeography is similar to that of Bed I. During lowermost Bed II times the eastern lake margin supported a freshwater wetland fully exposed during times of low lake levels fed by streams from the volcanic highlands. During times of higher lake levels the lacustrine plain migrated further eastward, and the alluvial plains dominated by volcanic sediments extended further to the east. There were lacustrine plains also to the northeast and the southwest. The western lake margin may also have been stream-fed (Hay 1976).

### *Paleoenvironmental reconstruction*

Prior to Hay's work in the 1960s, paleoenvironmental reconstruction generally described an oversimplified dichotomy of either lacustrine or subaerial depositional environments. In a 1963 *Science* paper, Hay concluded that Bed I and Bed II environments were predominantly non-lacustrine. He interpreted Bed I as being an alluvial fan of tephra deposits interfingering westward with tuffs and claystones, suggesting both subaerial and lacustrine deposits (1963). Bed II deposits were interpreted as a more diverse sequence of fluvial, aeolian, pyroclastic, and lacustrine sediments. The saline and alkaline lake deposits were mainly a Bed I phenomenon, the lake fluctuating as much as 3 m in depth and 7-15 Km in diameter. At times of low lake levels, broad lake-margin areas were exposed. Bed II deposits, while similar in paleogeographic character and nature to Bed I, were affected by tectonic activity, i.e., faulting and folding, during the time of their deposition, causing a progressive reduction in the lake size. The lake margin areas were increasingly dominated by fluvial and grassland environments. This was also reflected in the decrease in water-loving animal populations, and increase in grazing cursorial animals (Hay 1990).

Sedimentary deposits of the Olduvai lake basin of Bed I and lower Bed II are divided into three lithofacies from which are inferred the Central Basin, Lake margin zone, and the Alluvial Fan. They are demarcated on the basis of lithology, biogenic and archaeological evidence, and mineral composition (Hay *pers. comm.*).

Paleoenvironmental reconstructions based on lithofacies characterization classify the Pleistocene deposits in the westernmost area of the modern day Main Gorge (Fig.2.1), referred to in this study as the western sub-basin, as lake margin and fluvial lacustrine deposits within a lake margin zone (Table 2.1; *see* Hay 1976). Lake margin deposits consist primarily of clays and claystones, whereas fluvial lacustrine deposits include sandstones (Hay *pers comm.*). Landscape associations previously assigned by Peters and

| Sub-basin | Landscape Association | Hay (1976) Paleogeographic zone (lithofacies) | OLAPP Paleogeographic Locale | No. of trenches in target interval | Geologic Bed/ Approx. thickness | Hay (1976) Lithology |
|---|---|---|---|---|---|---|
| Western Sub-basin | Western Lacustrine Plain | Western Lake Margin | Loc 64 | 2 | M-UB I/ 11m | Sandy claystone (w/ tuff and limestone) |
| | | Western Lake Margin | Naisiusiu | 8 | M-UB I/ 8m | Mafic tephra/ Tuffaceous limestone and Claystone |
| | | Western Lake Margin/ Intermittent dry Saline Lake | West-Lake | 2 | LMB II 10-13m | Sandstone and tuff |
| | South-western Lacustrine Plain | South-western Lake Margin | Kelogi | 4 | LMB II 6m | Siliceous earthy claystone/re-worked tuff |
| Eastern Sub-basin | Lake | Central Basin | Lake | 1 | LMB II | Claystone |
| | Eastern Lacustrine Plain | Eastern Lake Margin/ Intermittent dry Saline Lake | MNK | 3 | LMB II 4-18m | Claystone w/chert nodules<br>Tuffaceous zeolitite |
| | | Eastern Lake Margin/ | FLK | 8 | LMB II 9-10m | Claystone<br>Siliceous earthy claystone w/ rootmarkings |
| | | Eastern Lake Margin | VEK | 4 | LMB II 11m | Alternating Claystone/ Tuffaceous siliceous earthy claystone |
| | | Eastern Lake Margin | HWKW | 5 | LMB II 11m | Claystone<br>Siliceous earthy claystone w/ rootmarkings |

**Table 2.1. Table showing relationship of geographic zones, locales, and scales with geologic beds and lithology (Middle-Upper Bed I = M-UB I; lowermost Bed II = LMB II).**

| **Sub-basin** | **Landscape Association** | **Hay (1976) Paleogeographic zone (lithofacies)** | **OLAPP Paleogeographic Locale** | **No. of trenches** | **Geologic Bed/ Approx. thickness** | **Hay (1976) Lithology** |
|---|---|---|---|---|---|---|
| Eastern Sub-basin (cont'd) | Eastern Lacustrine Plain (cont'd) | Eastern Lake Margin | HWKE | 7 | LMB II<br>11m | Claystone<br>Siliceous earthy claystone w/ rootmarkings |
| | | Eastern Fluvial-Lacustrine | HWKEE-KK | 10 | LMB II<br>9-10m | Claystone/ Tuffaceous siliceous earthy claystone |
| | | Eastern Lake Margin | MCK | 5 | LMB II<br>12m | Claystone/ Tuffaceous siliceous earthy claystone |
| | | Eastern Lake Margin | TK-Loc 20 | 2 | LMB II<br>8-18m | Claystone<br>Rootmarked tuff |
| | | Eastern Lake Margin | LongK | 4 | LMB II<br>10-11m | Tuffaceous siliceous earthy claystone w/ rootmarkings |
| | Eastern Lacustrine Plain/ Eastern Alluvial Plain | Eastern Fluvial-Lacustrine/ Eastern Lake Margin | JK-WK | 7 | LMB II<br>13m | Claystone |
| | | | DK-Complex | 4 | LMB II<br>12-13m | Claystone w/tuffaceous conglomerate |
| | Eastern Alluvial Plain | Alluvial Fan | THC-Complex | 6 | LMB II<br>10-18m | Claystone w/ interbedded Tuffs, tephra, and tuffaceous conglomerate |
| | North-eastern Lacustrine Plain | Eastern Lake Margin | Fifth-Fault | 4 | LMB II<br>3m | Claystone w/ Interbedded mafic tuff |

**Table 2.1(cont'd). Table showing relationship of geographic zones, locales, and scales with geologic beds (Middle-Upper Bed I = M-UB I; Lowermost Bed II = LMB II) and lithology.**

Blumenschine *et al* (1995, 1996) classify the western sub-basin as the Western Lacustrine Plain. The current landscape classification system implemented by OLAPP (Fig. 2.2) refers to Paleogeographic Locales (a geomorphologic grouping identified by modern geological outcrops) in the western sub-basin, which include Loc.64, Naisiusiu, the West-Lake, and Kelogi.

Sixteen trenches that fell within the temporal target intervals for this study were placed by OLAPP within the western sub-basin, and sampled deposits in Middle-Upper Bed I and lowermost Bed II. Middle-Upper Bed I is the target interval in the extreme western sub-basin, and is underlain by volcanic Tuff IB, dated to 1.84 Ma. (Blumenschine *et al.* 2003). Normal geomagnetic polarity of the entire sequence of deposits exposed in these excavations is equated to the Olduvai Geomagnetic Polarity Subchron, dated from 1.95 to 1.78 Ma, giving the western sub-basin sequence a minimum age of 1.78 Ma (Blumenschine *et al.* 2003). The western transition between lake and lake margin deposits occurs within the Paleogeographic Locale Naisiusiu. This locale also separates the synchronic target intervals addressed in this study. The West-Lake and Kelogi are the only Paleogeographic Locales in the western sub-basin that sample lowermost Bed II, a second temporal target interval, which is bracketed above by volcanic Tuff IIA (1.7Ma), and below by volcanic Tuff IF (1.75Ma) (Walter 1991). In the western sub-basin, lowermost Bed II is about 10-13 meters thick and consists predominantly of lake deposits.

Paleoenvironmental reconstructions based on lithofacies characterization classify the southwestern area of the modern day Side Gorge (Fig.2.1) as the Southwestern Lacustrine Plain and include the Paleogeographic Locale Kelogi. The areas east of the paleo-lake referred to in this study as the eastern sub-basin, are classified as eastern lake margin, eastern fluvial lacustrine, and alluvial fan deposits within the lake margin zone and alluvial fan (*see* Table 3.2 *and* Hay 1976). Landscape associations previously implemented by Peters and Blumenschine (1995, 1996) classify the eastern sub-basin as follows (from west to east): Lake, Eastern Lacustrine Plain, Eastern Lacustrine Plain/Eastern Alluvial Plain (transitional), Northeastern Lacustrine Plain, and the Eastern Alluvial Plain. The current landscape classification system implemented by OLAPP (Fig. 2.2) refers to Paleogeographic Locales in the eastern sub-basin: Kelogi, Lake, MNK, FLK, VEK, HWK W, HWK E, HWK EE-KK, MCK, TK-Loc.20, LongK, JK-WK, DK-Complex, THC-Complex, and Fifth-Fault (Fig. 2.2).

The relevance of the different scales of investigation, both spatially and temporally, is discussed in the following chapters (*see* Chapter 3).

Seventy trenches were placed by OLAPP within the temporal target interval for this study in the eastern sub-basin defined as Lowermost Bed II, which is bound above by volcanic Tuff IIA (1.7Ma.) and below by volcanic Tuff IF (1.75Ma) (Walter 1991).

The target interval is exposed in the western, southern, central, and eastern parts of the modern day gorge. In the eastern sub-basin, Lowermost Bed II varies in thickness from west to east. From the Southwestern Lacustrine Plain, to the west of the Main/Side Gorge junction at Paleogeographic Locale MNK, Lowermost Bed II is roughly 6 meters thick. At TK-Loc.20, Lowermost Bed II is dominated by lake deposits up to 8-18 meters thick in the Side Gorge and possibly 10-12 meters thick in the main gorge.

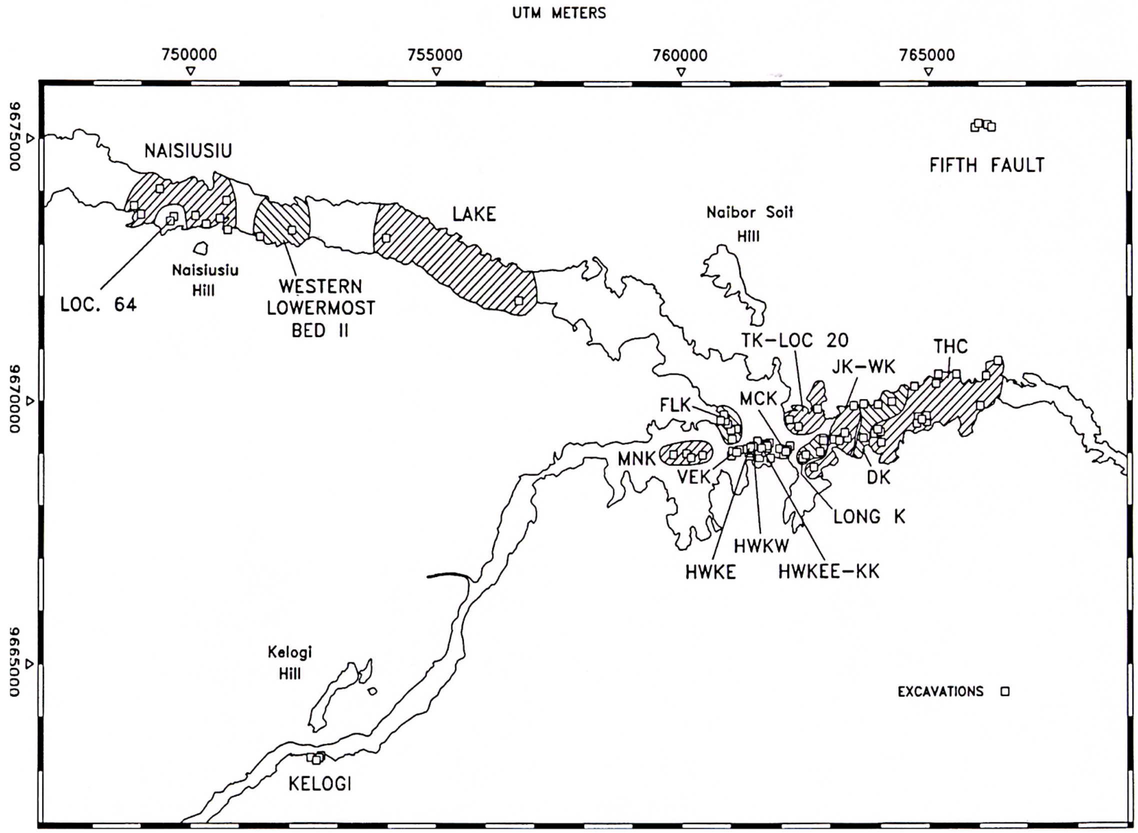


**Fig. 2.2. Map of gorge showing Paleogeographic Locales and trench locations. (from Blumenschine et al. *in press*).**

Further east at the Paleogeographic Locale DK-Complex (on the North Side of the Main Gorge), and at the Paleogeographic Locale JK-WK (on the South Side of the Main Gorge), Lowermost Bed II is roughly 15 meters thick and the depositional environment transitions between an alluvial plain and an eastern fluvial lacustrine, the alluvial fan deposits interfingering with lake margin deposits. In closer proximity to the volcanic sources, sediments in the easternmost landscape association in Lowermost Bed II are primarily volcanic tuff and alluvial fan deposits and can be as thick as 30 meters. Lowermost Bed II comprises four facies: lake, lake-margin, eolian, and alluvial fan. They represent a lake basin bordered on the east by an alluvial fan of pyroclastic materials discharged from Olmoti. (Hay 1976:97).

It should be noted that lithofacies variation is identified here as a classificatory basis for lateral artifact distributional differentiation. The fact that two discrete temporal intervals are sampled in the western sub-basin does not obscure the issue of landscape variability examined here in light of the fact that the paleogeography in Lowermost Bed II was essentially the same as in Bed I (Hay 1976:66). Those trenches not within the temporal target interval, without artifacts or without stratigraphic provenience were omitted.

### *Paleogeographic patterning of hominid behavior*

Hay's (1976) contribution to the interpretation of the Olduvai archaeological record went beyond simple stratigraphic or geologic interpretations. He posited that the patterns and paleogeography of hominid activity can be determined through the distribution of artifacts, occupation sites, and hominid remains in different lithofacies (i.e., the rock record of any sedimentary environment, including physical and organic characters), that hominid dietary and hunting practices can be inferred somewhat from the butchery sites and faunal remains, hominid group size can be estimated by occupation site size, and that a knowledge of raw material sources used for tool making can show ranging patterns (1976:180).

The majority of archaeological deposits in Bed I occur in lacustrine lithofacies. Amongst these are the oldest hominid occupation sites (Hay 1976:53-54). Both *Australopithecus boisei* and *Homo habilis* fossils were recovered from Bed I. Most sites are on the eastern lake margin, and only a few are on the western lake margin. In Lowermost Bed II, below the Disconformity, there is an increase in range of the geographic distribution of archaeological loci, but still nearly all are lake margin deposits. Most common are loci along the southeastern margin of the lake (Hay 1976:112; Table 18).

The basic trend in archaeological occurrences regarding lithic industries and their paleogeographic context is that the Oldowan, Developed Oldowan A, and Developed Oldowan B occur mostly within Lake margin deposits, while Acheulean sites occurring mostly within alluvial or fluvial deposits (Hay 1976:113; Table19).

According to Hay, of the16 hominids found in Bed II, *Homo habilis* remains were recovered below Tuff IIB, in the Lowermost and Lower Middle Bed II, *Australopithecus boisei* in Upper and Lower Bed II, and *Homo erectus*, in the Upper Bed II (Table 2.2).

| **Stratigraphic Position** | **Locality** | **Specimens** | **Taxonomic Status** | **Associated Lithic Industry** |
|---|---|---|---|---|
| Lower Bed I | MK, DK East | H4, H24 | *H. habilis* | Oldowan *inferred* |
| Middle Bed I | FLK,<br>FLK NN | H5, H7, H8 | *A. boisei,*<br>*H. habilis* | Oldowan *inferred* |
| Upper Bed I | FLK N, West HWK, East, Loc 64 | H10,<br>OH65 | *A. boisei,*<br>*H. habilis* | Oldowan |
| Lowermost Bed II | FLK | H16 | Australopithecus | Oldowan *inferred* |
| Lower Middle Bed II | MNK | H13, H15, | *H. habilis, H. sp.* | Oldowan |
| Middle Bed II | FC West, | H19 | Unknown | Dev. Oldowan B |
| Upper Bed II | BK | H3 | *H. erectus* | Dev. Oldowan B |

**Table 2.2. Stratigraphic position of *in situ* Oldowan hominids from Beds I and II and their associated lithic industries (*after* Hay, 1976; Leakey, 1971; Blumenschine *et al*, 2003).**

The hominid remains have been associated with three major lithic Industries characterized by Leakey as the Oldowan, the Developed Oldowan (A & B), and the

Acheulean. From the base of the Upper Member of Bed I to the lowest part of Bed II only the Oldowan Industry is represented, as Leakey does not identify discernible differences in the technology, and states that the cultural material "…remains virtually unchanged…" (see Chapter 4). Leakey characterizes the Oldowan in the following manner:

> It [the Oldowan] is characterized by choppers of various forms, polyhedrons, discoids, scrapers, occasional subspheroids and burins, together with hammerstones, utilized cobbles, and light-duty utilized flakes (Leakey 1971:1).

This characterization will be addressed further in Chapter 4, where the homogeneity of the described Oldowan Industry will be examined on the basin-wide landscape scale.

### *Stratigraphy*

In the *Geology of Olduvai Gorge,* Hay (1976) describes the sequence of geologic deposits known as the Olduvai Beds in immaculate detail. This thesis focuses upon discrete horizons within two of the major subdivisions, Beds I and II. The Beds vary in thickness and composition from east to west across the gorge. The following summaries are taken directly from Hay's monograph:

> Bed I
>
> As much as 60 m thick in the eastern part of the main gorge becoming thinner in a westward direction to 43 m in the western basin. Bed I is further subdivided into five lithofacies. It consists mainly of lava flows overlain by sedimentary deposits of lake, lake margin, alluvial fan, and alluvial plain.
>
> Bed II
>
> With a slightly wider distribution, Bed II lies conformably over Bed I. A regional disconformity subdivides Bed II into a Lowermost and an Upper Bed II. It is the lowermost portion of Bed II that displays commonalities

> with features in Bed I, which is of interest to this study. These lithofacies consist of lake, lake-margin, alluvial fan, and aeolian deposits. The paleo-lake, which fluctuated in level and extent, occupied the central part of the basin. Lake deposits are made up mainly of claystones that are bordered by lake-margin deposits of claystone and tuff. The lake-margin deposits interfinger with alluvial fan and aeolian deposits toward the east. The alluvial fan deposits are comprised mainly of stream-worked tuff overlain by wind-worked deposits of aeolian tuff.

It was previously noted by Hay (*in* Leakey 1971:16) that occupation sites and stone artifacts in Bed I are only known to occur in the tuffs and claystone sequence of the Upper Member, deposited near the southeastern margin of the lake, most within or upon paleosols. Hay reports that, while Bed II contains numerous sites containing Oldowan, Developed Oldowan, and Acheulean sites, Oldowan sites and remains from *Homo habilis* and *Australopithecus boisei* are known from the base of Bed II to the top of the Lemuta Member. Most of these sites are in the eastern fluvial-lacustrine deposits with the remainder either in lake-margin or in the western fluvial-lacustrine deposits (1976:112).

It has been the general consensus among researchers that the Oldowan is a homogenous Industry, represented by type-sites in the Olduvai Basin. The characteristics espoused in defining this Industry have been used to determine Oldowan Industrial Complex. It is this point that will be addressed in the following chapters, when a landscape sample of artifacts will be examined to determine the degree of assemblage homogeneity that exists on a broad, sub-basin scale. The following section (Chapter 2, Part II) will address the history of research in Olduvai Gorge, focusing primarily on the work carried out there by the Leakeys in the 1950s and 1960s.

# PART II. A HISTORY OF RESEARCH AT OLDUVAI GORGE, TANZANIA

## Introduction

Olduvai Gorge, Tanzania has been the focus of archaeological and paleoanthropological investigations since the 1930s. Its rich history tracks not only the seminal research that was undertaken in Olduvai Gorge, but the very paradigms of archaeological investigation. These events lead up to and include some monumental archaeological discoveries describing a developmental narrative of paleoanthropological investigations. The methodology applied to data recovery at Olduvai Gorge has set standards in documentation, classification, interpretation, and multidisciplinary research that are still applicable today. The following section will give a brief account of the research undertaken at Olduvai Gorge since the early 1900s, with a focus on the more recent work done by L.S.B. and Mary Leakey.

### *Previous Research at Olduvai Gorge*

From the early 1900's researchers realized the paleontological importance of Olduvai Gorge. Their discoveries brought the Leakeys to Olduvai Gorge, over half a century ago. The Leakey's work is scrupulously documented in five volumes spanning over four decades of research. Olduvai Gorge has since then been crucial to paleoanthropological studies, which have been in many ways defined by the research carried out by Louis and Mary Leakey.

The discovery of *Zinjanthropus* in 1959 (Leakey 1959a, 1959b, 1959c; Leakey & Oakley 1959) and *Homo habilis* in 1960 sparked an intense interest in paleoanthropological research in the area. The Olduvai Gorge deposits have provided a long chronological sequence of artifacts and fossils. Mary Leakey's meticulous documentation of the artifacts and their distribution (Leakey 1967; Leakey 1971) provided many insights into early hominid cultural behavior. Analysis of the "living floors" and other archaeological occurrences at Olduvai enabled her to construct an early hominid cultural narrative, measuring cultural change through time (Leakey 1975) through lithic technology.

Analyzing and interpreting lithic artifacts has been a mainstay of paleoanthropologists in their efforts to better understand of human behavior over a wide temporal and geographical range from Plio-Pleistocene Africa (Harris & Capaldo 1993; Isaac 1983; 1986; Leakey 1975; Potts 1991; Rogers 1996) to the European Paleolithic (Barton 1988; Binford 1973; Bordes 1961; Bordes & de Sonneville-Bordes 1970; Henry 1989; Kuhn 1993; Mellars & Stringer 1989).

Despite various dating studies at Olduvai over three decades (1960-1990), chronology for Bed I and Lower Bed II was largely unknown due to the anomalous dates caused by contaminated tephras. Using a single-crystal laser-fusion technique to avoid contamination, Bed I was dated by Walter *et al* (1991). Paleomagnetic studies show a period of normal polarity for the Bed I and Lower Bed II lavas and tuffs. This Subchron of normal polarity falls within the Chron known as the Matuyama Epoch of reversed polarity, which has been dated to between 1.87 and 1.67 Ma. Tuff IF, at the base of Lower Bed II, is dated to about 1.75 Ma.

Olduvai Gorge provided a unique opportunity for multidisciplinary studies to converge upon the major issues associated with the early human occupation there. Lithic analysis was one of the many sub-disciplines wherein scientific contributions were made by research carried out at Olduvai Gorge. Early studies by the Leakeys and colleagues included dating methods such as fission track (Fleischer et al. 1965), and later studies included laser fusion (Walter et al. 1991), geological studies provided temporal frames and environmental reconstructions (Hay 1971, 1976a, 1976b; Leakey 1967; Leakey, et al. 1968) cultural material provided relative dates (Leakey 1957; Leakey 1976; Leakey 1971) faunal analysis provided environmental and behavioral data (Kappelman 1984; Kappelman, et al. 1997)

### *Lithic Technology: The Oldowan Industrial Complex*

Employing a site-based archaeological method, Mary Leakey established a diachronous "culture-stratigraphic yardstick" for the Early to Middle Pleistocene through her lithic artifact analysis. In effect, Mary Leakey documented cultural change through time by the typological classification of Oldowan style tools.

The earliest phase of intentional human-made stone tool manufacture known to date is the Oldowan, named after the place where these tools were first recognized and described, Olduvai Gorge, Tanzania (Leakey 1971). During the course of her work at Olduvai Gorge, Mary Leakey created a system of classification for the Oldowan Industry (1971), which has been adopted and applied to most typological assessments of lithic industries in some form or another. These typological categories may have arisen from the Oldowan Industry, but the tool types exist throughout the Lower Paleolithic in Europe, Southwest Asia, North Africa, and the archaeological record as a whole in what is known as the Oldowan Industrial Complex. The Oldowan Industrial Complex occurs as early as 2.6 million years ago in the Gona River, the Hadar region of Ethiopia (Semaw, et al. 1997;  2003). Previously known as a ‘pebble’ tool culture, the Oldowan Industrial Complex is made up predominantly of choppers, but polyhedrons, discoids, spheroids, scrapers and pounded pieces are also present in varying frequencies.

The heuristic importance of the Olduvai Gorge study area to paleoanthropological research is still not completely appreciated. Given the abundance of information provided by decades of research, and opportunities provided by the resolution of paleoenvironmental studies available, it is surprising that relatively little has been done in the way of human behavioral ecological studies at Olduvai.

# PART III. RECENT RESEARCH AT OLDUVAI GORGE

## Introduction

The history of research at Olduvai is indeed a rich one, and the more recent research carried out there continues in the same strain, with numerous paleoanthropological studies undertaken in various subfields, such as physical anthropology and comparative anatomy (Aiello and Wheeler 1995; Grine, et al. 1996; Groves 1975; Holloway 1980; Johanson, et al. 1987; Lemonick and Dorfman 2002), experimental archaeology, actualistic studies, and landscape archaeology. This thesis is most impacted by the latter subfields of investigation, namely landscape and experimental archaeology. It is within this scope that this section discusses recent research carried out in Olduvai, as it is the most logical progression to the presentation and justification of this thesis.

The epistemological narrative to the landscape archaeological approach (*see* Chapter 1, Part III) set the stage for the following section. It deals with a specific case study of landscape archaeology in Olduvai Gorge.

The Olduvai Landscape Paleoanthropology Project (OLAPP) has carried out a landscape scale paleoanthropological study of the Olduvai Basin (Blumenschine & Masao 1991) since 1989. They adopted a synchronic approach to paleoanthropological research, in an effort to reconstruct the paleoecology of a particular place at a specific time. Among other methods, they incorporated archaeology, geology, paleoanthropology, and modern analog studies as a basis for the predictive modeling of prehistoric hominid land use in Olduvai Gorge. Focusing on a synchronous interval, Lowermost Bed II, was possible due to the stratigraphic distinction created by the basal Marker Tuff IF and the disconformity separating Lowermost Bed II from the overlying Bed II sediments in most of the gorge. Incorporating a landscape sampling strategy, OLAPP has recovered cultural remains from over 300 km$^3$ in the Olduvai basin. These remains constitute the only artifacts excavated from Olduvai Gorge in over three decades, the first to be excavated by discrete synchronic target intervals on a broad scale, and the very first landscape-scale archaeological sample of the Olduvai Basin.

OLAPP's multi-disciplinary approach has generated a database including a wide range of paleoenvironmental information specific to the Olduvai Basin during Middle and Upper Bed I and Lowermost Bed II times. OLAPP's research focuses on the particular relationship between hominids and their environment, the paleo-Olduvai Basin (Blumenschine 1989; Blumenschine & Masao 1991, 1997) during specific time intervals. An archaeological sample of this nature provided the opportunity to identify various ecologically sensitive artifact and bone distributions and behaviorally diagnostic assemblage characteristics.

Peters & Blumenschine predicted the composition and landscape distribution of stone artifact assemblages in the paleo-Olduvai Basin based upon geomorphic and ecological principles (Peters & Blumenschine 1995; 1996; Blumenschine and Peters 1998). They incorporated aspects of geologic data from Lowermost Bed II (Hay 1971, 1976a, 1976b) and modern landscape (Prins & Loth 1988; Prins & van der Jeugd 1993) and biotic analogues (e.g., Behrensmeyer 1983) into a landscape classification system. In this system, the smallest working unit is the *landscape facet* (Gerresheim 1974), which corresponds to a local habitat type, with varying hypothesized degrees of predation risk to hominids like high-risk water holes and low-risk woodlands. These facets may be grouped into larger landscape associations. For each facet, they hypothesized costs and benefits, or “affordances”, encountered by fruit/root eating and carnivorous scavenging hominids and corresponding hominid activities requiring stone tool use (Peters and Blumenschine 1995, 1996). Two alternative landscapes are modeled for lowermost Bed II Olduvai Basin: a) a lakeshore river mouth, riparian corridor and upland co-dominated land system based on Hay’s (1976) paleogeographic reconstructions and, b) a lakeshore spring and restricted upland co-dominated land system under the influence of mock aridity due to volcanism. The latter landscape model is supported by reconstructions of depositional environments based on OLAPP’s geological observations (e.g. Ashley and Feibel, 1995). Peters and Blumenschine (1995,1996) hypothesized land use patterns for fruit/root eating hominids as well as carnivorous scavenging hominids for both landscape models during wet and dry seasons and climate extremes.

Building on Peters and Blumenschine’s preliminary model (1995, 1996), and following Gifford-Gonzalez (1991), Blumenschine and Peters (1998; 571) incorporated hierarchical inferences of stone tool use into their model linking behavioral traces to paleoecological ‘driving forces’. They predicted archaeological traces of Oldowan hominid land use, focusing on stone artifact and butchered animal bone remains. For the stone artifact assemblages of each landscape facet, they hypothesize artifact density, artifact dispersion, and the relative abundance of artifact functional types and raw material types. Their predictions are based upon three ecological mechanisms that link hypothesized facet-specific activities to recoverable stone traces: a) the abundance, distribution and variety of resources and hazards requiring stone tool use in a facet affect the frequency and clustering of stone artifacts, b) that raw material transport cost increases with distance to use location, and c) that the degree of predator encounter risk in a facet will influence patterns of stone tool use, discard, and loss (1998:587).

Through detailed geological work, OLAPP researchers, in consultation with Richard Hay, have attempted to correlate the archaeological sample to specific landscape facets hypothesized by Peters and Blumenschine (1995, 1996). Each landscape facet has been characterized by fundamental ecostructural characteristics including the degree of tree and shrub cover abundance and the correlated degrees of competition among larger carnivores for carcasses and the predation risk encountered by hominids (Blumenschine and Peters 1998). This landscape ecostructural model then serves as the basis for predicting the manner in which the artifact assemblages from each paleolandscape facet should reflect that facet's ecostructure.

According to the deductive approach taken by Blumenschine and Peters (1998; Peters & Blumenschine 1995, 1996), observed ecological analogs were used to construct a model of hazards and affordances determining behavioral solutions and creating behavioral traces. Two classes of hypotheses have been advanced to explain areally broad-scale stone artifact distributions. One class of hypotheses concerns simple linear functions involving distance of artifact discard to lithic material sources and the effects of associated time and energy expenditure during material transport on artifact size and shape (*cf.* the "Frison effect"; Frison 1968; Jelinek 1976) and on artifact diversity (*cf.* the "Clark effect"; Schiffer 1975). Using lithic remains as markers of hominid behavior on a paleolandscape, Isaac's stone flow model (1984) used the raw material 'proximity effect' as an explanation of apparent artifact distributions along outcrops of the Koobi Fora and

Okote Members at East Lake Turkana. The spatial scales over which these linear functions can be expected to occur are poorly known for Oldowan times. OLAPP's landscape samples for two stratigraphic intervals permits testing of the operation of these linear functions on the organization of hominid technology over distances of up to seven kilometers. A limited inter-facet comparison of percentage of quartzite and distance from raw material source showed that as distance increases, percentage of quartzite artifacts decreases for all facets save the Lower Lacustrine Plain (Blumenschine and Masao 1991).

A second class of hypotheses concerns more complex ecological relationships such as those hypothesized in Blumenschine and Peters' (1998) predictive model of hominid tool use in the Lowermost Bed II Olduvai Basin. The model predicts the density and composition of stone artifact assemblages between hypothesized and geologically evidenced landscape facets. It hypothesizes that landscape facet-specific stone artifact traces correspond to the landscape facet-specific predation risk and the diversity and abundance of food sources and arboreal refuge sites. Note that while Blumenschine and Peters' (1998) predictions of the landscape artifact assemblages are also based in part on a general understanding of Oldowan artifact form and technology, the predictions they make concern an independent class of information, namely, the density and composition of facet assemblages in eco-structurally distinct portions of the Lowermost Bed II landscapes. Together, tests of these two classes of hypotheses are relevant to major issues in Oldowan hominid behavioral ecology and of stone tool technology and its associated organizational strategies. For the purposes of this thesis, technological organization (Nelson 1988; Torrence 1989) is defined as lithic technology, conditioned by ecological factors such as distance from source of material, raw material quality, risk of predation, and degree of food competition (Blumenschine and Peters 1998) and their effect on the procuring, shaping, using, re-using, and discarding/losing of stone by hominids on a paleolandscape.

Testing a predictive model involves comparing the expected or predicted traces with the actual or observed traces. This comparison will result in either a good fit, and the acceptance of the model's hypotheses pertaining to human behavioral ecology, or a bad fit and the falsification of the model's hypotheses (or aspects thereof). Falsification of the model or aspects of it should inspire a reiteration of the modeling process and its subsequent refinement.

In order to understand the ecological mechanisms that may have collectively affected hominid activity, they must be identified through the archaeological traces left behind. Before lithic archaeological traces can be linked back to the land use and other process that created them, the technological and functional character of the archaeological traces must be identified.

As a member of OLAPP, I carried out experimental archaeological research designed to quantify Oldowan tool utility and better understand its function. This involved a process that represents a full cycle of middle range research (*cf.* Binford, 1981, 1983):

i. The systematic quantitative laboratory analysis of the stone artifact collection according to basic technological criteria was carried out in order to gain a detailed understanding of technological variability in the landscape archaeological assemblages, thus identifying the technological character of the lithic behavioral traces.

ii. The experimental manufacture and use of stone tools was implemented in order to determine the relative utility of various tool forms and raw materials so as to identify the functional character of the prehistoric lithic behavioral traces.

The results of this experimental research will be discussed at length in Chapter 5.

Behaviors that may have brought about the formation of archaeological assemblages are inferred by linking archaeological traces, by way of proxy diagnostic variables, to the behavioral and ecological context (Fig.2.3). Behavioral inferences are made by modeling the simple linear and the more complex ecological relationships of lithic artifacts and their contexts, and testing how well they match the observed or actual archaeological traces.

**Type of Predicted Trace**

- artifact morphology and size
- artifact density
- artifact variety
- % cortical flakes
- cutting edge angle
- presence of unmodified cobbles

**Proxy Measure**

- relative tool utility
- amount of material used
- tool type
- amount of time spent on task
- range of activities

**Ecological Variable**

- raw material quality and distance from source
- predation risk
- competition for carcasses
- resource distribution and availability

**Fig. 2.3. Archaeological traces, diagnostic behavioral variables and associated ecological variables.**

Experimental archaeology (discussed in more depth in Chapter Five) helps identify the effects of such ecological factors as of the degree of competition for carcasses and the distribution of resources on lithic artifact assemblage composition by demonstrating their practical impact on the assemblage in a quantifiable way. Isaac (1983:42-43) provided the beginnings for such experimental archaeological theory and method when he hypothesized some basic tool functions and the forms that made them possible. He also presented alternative models of artifact assemblage formation (Isaac 1983).

It should be noted that the landscape classification of the paleo-Olduvai Basin at Olduvai Gorge has undergone several incarnations. At present the landscape groupings have evolved from landscape facet designations to modern outcrop groupings, or Paleogeographic Locales (e.g. Blumenschine et al. in press).

### *Continued Research at Olduvai*

Since completion of the laboratory stage of this study in 2001, OLAPP has continued developing models of Oldowan hominid land use at Olduvai Gorge. They have done this through the integration of the first-generation models of both the paleolandscape ecology of the Plio-Pleistocene Olduvai Basin and the corresponding patterns of Oldowan hominid land use (Peters & Blumenschine 1995, 1996), revealed by Hay's (1976, 1996) paleogeographic reconstruction and their ongoing actualistic studies in modern landscapes.

Currently, OLAPP is developing paleolandscape reconstructions for the whole of the exposed Lowermost Bed II basin based on survey and excavation data pertaining to depositional environments, terrain, hydrology, tephrochronology, vegetation, and fauna. This will allow for the comparison of excavated material with the predicted distribution of resources and behavioral traces.

# CHAPTER THREE

# METHODS

## Introduction

This chapter presents an account of the sampling and analytical procedures used to gather the data and descriptive characteristics derived from the extensive typological and technological analysis of the OLAPP lithic assemblage. Part I discusses the conceptual framework underlying the methodology and Part II describes the archaeological sample that supports this thesis. As this is the first large sample of *in situ* lithic artifacts systematically excavated from Early Pleistocene deposits in Middle-Upper Bed I and Lowermost Bed II from Olduvai Gorge in over three decades, it is important to describe the analytical methods and the assemblage in their entirety.

## Part I. Conceptual framework

As the focus of paleoanthropology shifts from site-based culture-historical and time-transgressive descriptions of the prehistoric record to interpretations of early hominid behavior and interaction with their environment, so too, does the applied research methods and theories. In order to address early hominid behavior, paleoanthropological research borrows principles and models derived from studies of the behavior and ecology of modern and ancient organisms, or neo- and paleoecology. These principles and practices have become known as hominid behavioral ecology (Oliver, et al. 1994). Since the factors determining the features of a local community of organisms (evolutionary stage, regional geographic distribution, and local environment) apply to both living communities and fossil assemblages (LaPorte 1968), neoecological and paleoecological methods seem well-suited to early hominid behavior-ecological studies. Integrating archaeological data with paleoecological interpretation, this thesis examines the landscape distribution and composition of stone artifact assemblages from the paleo-Olduvai Basin, addressing the question of why the Oldowan hominids produced the various stone forms they did in particular environments.

Focusing on the ‘why’ of early hominid behavior as well as the ‘who, what, when, where, and how’ supplements the interpretive aspect of behavioral ecology. Borrowing from biological theory, there are different ways of answering the question ‘why’ (Tinbergen 1963):

1. In terms of survival value or function (ULTIMATE)

   What was the adaptive significance of behavior, which maximizes reproductive fitness and enhances reproductive success?

2. In terms of causation (PROXIMATE)

   What were the internal and external factors or the environment and ecology of the animal that dictates which strategy is the best for a particular time and place?

3. In terms of evolutionary history (ULTIMATE)

   What are the physiological factors that are determined by phylogeny and ecology, or the pre-adaptations existing in the primate behavioral repertoire?

4. In terms of development (PROXIMATE)

   Who were those most successful at their particular strategies and why will they outcompete others? Most successful is determined by a combination of ecological, and physiological factors, or learned patterned behavior.

Focusing on a specific tool technology in a particular region at established times, this thesis will address the proximate causational factors affecting tool making decisions by early hominids in the paleo-Olduvai Basin during Middle-Upper Bed I and Lowermost Bed II times. The results of this investigation can be put toward a better understanding of the ultimate causal factors mentioned above, namely the adaptive significance of the Oldowan hominid tool-using behavior. In order to accomplish this research goal, a number of spatial and eco-temporal scales will be utilized. Peters & Blumenschine (1995) constructed a nested hierarchy of space-time analytical scales for land use by mobile early hominids. Table 3.1 shows that hierarchy, modified for application to this thesis.

| **Spatial Scale** | **Eco-temporal Scale** | **Archaeological Investigative Scale** | **Behavioral Trace; Related Concepts** |
|---|---|---|---|
| Land Element | Event point.<br>Instantaneous to occasional | Excavated unit (trench) | Artifact occurrence;<br>Point of manufacture, use, etc. |
| Landscape Facet | Activity or resource extraction area.<br>Occasional to recurrent | Paleogeographic Locale | Artifact assemblage; tool function;<br>Raw material source; biotic community; habitat; niche |
| Landscape Association | Local resource distribution; aggregation and dispersal.<br>Seasonal to annual circuit: | Landscape Association | Archaeological assemblages;<br>Technological organization;<br>resource transport; land-use patterns |
| Sub-basin to Geographic Sub-region to Region | Evolutionary stage; regional distribution.<br>Lifetime individual to intergenerational range | Sub-basin | Archaeological sample;<br>Tool-using behavior, subsistence and adaptive strategy; home range |

**Table 3.1. Hierarchical scales of investigation.**
**Based in part on Peters & Blumenschine 1995 (*after* Gamble, 1986).**

This nested landscape classification system is based upon geomorphic and ecological principles, whereby the smallest analytical unit is the *land element*. That corresponds to the smallest archaeological unit of investigation, the trench. The next working unit is the *landscape facet* (Gerresheim 1974). The landscape facet is equivalent to a local habitat type, with ecological determinants having varying impact upon hominid behavioral ecology. It also corresponds to the paleogeographic locale, a geomorphologic grouping identified by modern geological outcrops, and the major analytical unit within which archaeological data will be grouped for this study. The next larger class is the *landscape association*, which contains one or several paleogeographic locales, displaying similar lithological facies. It is at this level where behavior evidenced by distributional patterns may emerge from archaeological sample analysis and interpretation. The Sub-basin scale is the largest unit pertinent to this study. It groups several paleogeographic locales together for the sake of comparison with other broad landscape classifications.

A basic premise, upon which this thesis is built, is that the scale of archaeological investigation should match the scale of the behavior being investigated. The range of units of investigation should be comparable to the range of time and space within which specific events or activities took place. The behavior being investigated is the tool-using strategy of the Oldowan hominids, or their technological organization. The Paleogeographic Locale is the scale of investigation proposed to be the best suited to infer that behavior.

This thesis advances the hypothesis that specific Paleogeographic Locales, with their particular resources and hazards, compel specific activities, which leave distinct archaeological traces. If local habitat-specific lithic assemblage attributes can be identified from an existing archaeological sample, they can be used to test predictions of early hominid land-use and behavior patterns. Ecological mechanisms such as quality and distribution of resources, hominid technological capabilities, degree of predation risk to hominids, (e.g. high risk water holes and low risk woodlands) are hypothesized to influence hominid behavior and the ensuing behavioral traces. Variables like risk of predation to hominids may have been a factor in their technological organization, or the decisions made concerning tool making and tool using. For the purposes of this thesis, relative tool utility, amount of material used, type of tool used, amount of time spent on task, and range of activity in a given area are considered bridging factors affected by ecological mechanisms (also referred to as eco-variables), and will be used to experimentally link eco-variables with lithic behavioral traces (see Chapter 5).

### The Raw Material Component:

Artifact raw material distribution on a landscape is considered in this thesis as one of the primary indicators of land and tool using strategies. It will be included in a more comprehensive discussion of the distribution of raw material types as artifacts is in Chapters 6 & 7, and in the interpretive section (Chapter 8). However, the names, lithologic descriptions, and source locations of the raw material component are described (*summarized from* Hay 1976) below.

The quartzites, which make up majority of the total assemblage include:

**Naibor Soit**- a very coarse-grained milky to clear tabular micaceous quartzite, from an inselberg north of the main gorge.

**Naisiusiu**- a medium grained milky to lavender tabular quartzite from Naisiusiu Hill, south of the main gorge in the Western Lacustrine Plain, also occurs as cobbles in the upper Olduvai river channel above Granite Falls.

The lavas, which make up 12.1% of the total assemblage include:

**Lemagrut**- a fine-to-coarse grained grayish blue trachyandesite and gray olivine basalt from stream channels to the southeast that feed the main and side gorge.

**Sadiman**- a dark greenish gray nepheline phonolite and porphyritic nephelinite, often with white phenocrysts, from stream channels in the main gorge and junction area.

The remaining raw materials, which make up 3.8% of the total assemblage and are grouped into the ‘Other’ category, include:

**Kelog**i- a friable yellow to reddish brown coarse-grained granite gneiss from inselbergs to the southwest at the western edge of the side gorge.

**Engelosin**- a greenish-gray flow-banded nepheline phonolite (slightly porphyritic) lava from an extinct Pliocene (or older) volcanic chimney covered by calcrete cemented talus breccia to the northeast of the gorge.

**Naabi**- a bluish-green welded tuff erupted from Ngorongoro, found in flows in the western part of the main gorge.

**Cher**t occurs as a white to beige nodules formed in lake deposits.

**Obsidian** is a rare black volcanic glass whose origin is unknown.

The location of the raw material sources in relation to the paleolandscape is shown below (Fig. 3.1). Note that at the highest lake stands, access to some of the raw material sources may have been hindered or obstructed by water.

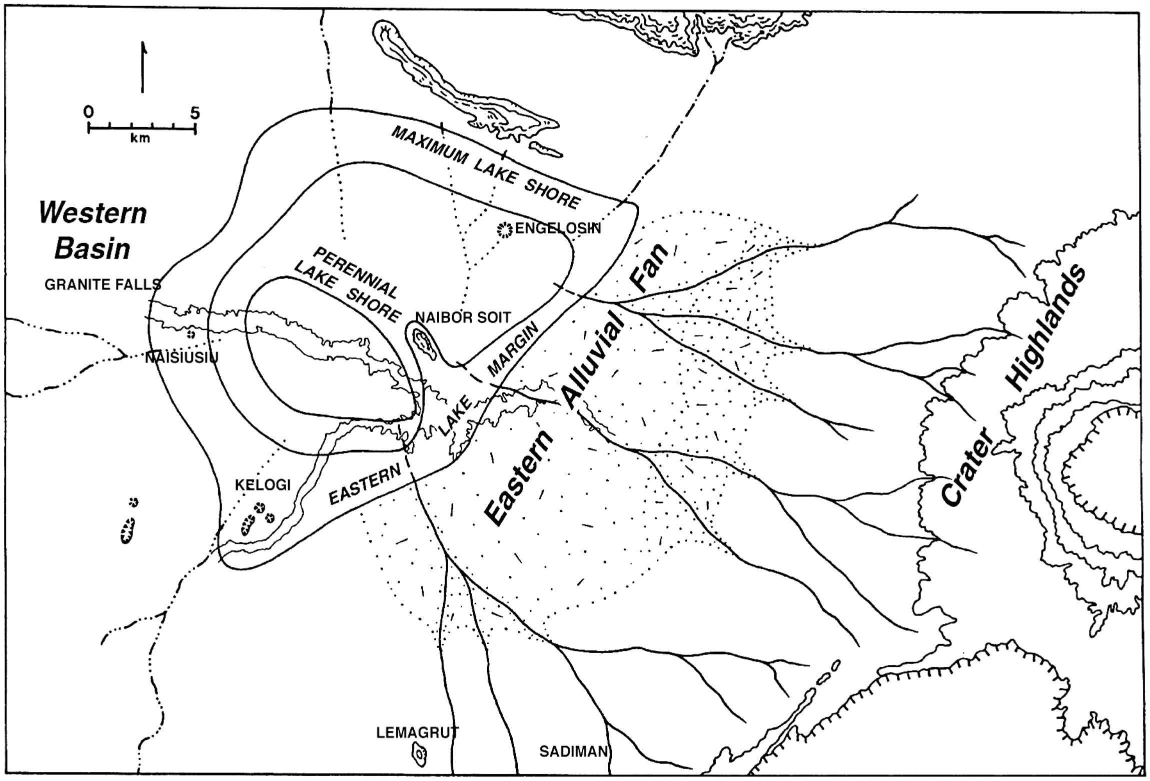


**FIG. 3.1. Olduvai Gorge with paleolake superimposed over modern-day gorge and raw material sources (*after* Blumenschine *et al.* n.d.). Map data compiled by J. I. Ebert.**

*Sampling procedure and analytical protocol*

This study bases its arguments on an archaeological sample recovered from *in situ* Plio-Pleistocene deposits in Middle-Upper Bed I and lowermost Bed II at Olduvai Gorge, Tanzania, between 1989-2000 by the Olduvai Landscape Paleoanthropology Project (OLAPP). The synchronic approach taken by OLAPP focused archaeological excavations in discrete stratigraphic horizons known as temporal target intervals. Excavations were placed where marker volcanic tuffs exposed the target intervals. During the 1989-2000 field seasons, 106 trenches encompassing eighteen Paleogeographic Locales were excavated from the target intervals of Middle-Upper Bed I and lowermost Bed II within two sub-basin units of investigation, the western, and the eastern sub-basins.

The westernmost deposits in the western sub-basin and comprise four Paleogeographic Locales containing sixteen excavated trenches (Table 2.1). The western sub-basin sample, including the western portion of the paleo-lake and deposits to the southwest, is made up of artifacts recovered from those sixteen excavated trenches from deposits in Middle-Upper Bed I and lowermost Bed II.

The eastern sub-basin sample comprises fourteen Paleogeographic Locales containing seventy excavated trenches (Table 2.1) from paleo-lake and other deposits to the northeast of the paleo-lake as well as lacustrine and alluvial fan deposits further to the east. The eastern sub-basin sample includes artifacts recovered from seventy of the excavated trenches from deposits in Lowermost Bed II.

Excavating units on slopes of up to $40^0$ required that trenches were dug in a step-wise manner. Trench width was often determined by terrain constraints but was generally two meters wide. Trench surface length and depth of steps varies according to the angle of the slope and thickness of the target interval deposits (as discussed above).

Surface characteristic observations such as vegetation type and distribution, slope angle, and artifact occurrence were recorded on field data forms. The collection of surface artifacts was carried out in the designated excavation areas. Surface artifacts were bagged and transported to the field lab where counts and weights were recorded.

All of the data presented in this thesis were derived from artifacts recovered from *in situ* deposits. Each trench was excavated by hand using pick axes, hand picks, shovels, trowels, dental picks, and other custom-fashioned wooden digging implements. The recovered sediments were dry-screened through a 3mm mesh. Artifacts were bagged and labeled in the field and transported to the field lab for preliminary washing. The artifacts were subsequently transported to the Human Origins Laboratory in Arusha (HOLA), Tanzania for preliminary analysis. The preliminary analysis was comprised of a basic inventory including sorting, counting and weighing of artifacts by general artifact type according to OLAPP's analytical protocol. Raw material was determined by visual evaluation and based upon comparative geological collections.

A second and more comprehensive analysis was carried out in HOLA. This entailed the curation (labeling) and systematic documentation of specific variables (see below). It involved the documentation of the pertinent locational (context) and morphological (content) variables.

### *Analytical protocol*

The following section describes the analytical protocol used in the comprehensive analysis. These protocols were used to classify and categorize the stone artifacts and their raw material sources, gross morphological characteristics, technological characteristics, landscape distribution and contextual integrity. The archaeological sample characteristics were identified and entered into an Excel spreadsheet. More than thirty possible variables and numerous variable states were recorded.

These are the basic variable categories:

1. Cataloging and locational data
2. Qualitative raw material data
3. Quantitative gross morphology
4. Quantitative specific morphology
5. Technological attributes
6. Behavioral and taphonomic indicators
7. Typological classification

The basic categories are more specifically defined by the following criteria:

1. <u>Cataloging and locational data</u>
    a) Specimen number. The artifacts in this assemblage are housed in the National Museums of Tanzania in Arusha. For cataloging and curation purposes each specimen has been given an accession number (e.g. 57:23 refers to the twenty-third specimen catalogued from Trench 57).
    b) Trench number. Trench designation locates the archaeological unit of investigation in an arbitrary numerical order of excavation. Lateral extensions of trenches have been grouped into a general trench number.
    c) Landscape association. Categorical landscape associations implemented by Peters and Blumenschine (1995; 1996).
    d) Unit. Each trench has been designated to a Paleogeographic Locale according to unit groupings.

e) Grid. Horizontal square meter provenience is recorded within certain individual archaeological units of investigation.

f) Level. Numerical stratigraphic excavation designations assigned by excavator.

g) Lithology. Lithological designations assigned by geologists in the field.

2. Qualitative raw material data

a) Raw Material. Describes basic raw material types. Raw material is defined as any unmodified piece of lithic material that is structurally and morphologically suitable for modification into implements (Bradley, 1975). The raw material identifications in this study were based on careful visual examination of the color, the groundmass or matrix, and the presence/absence of conspicuous crystals or phenocrysts). They were guided by a comparative geological collection of known rock types from the Olduvai Basin. Variable states include (see Chapter 3, Part II):

1) Quartzite
2) Lava
3) Granitic quartzite
4) Trachyandesite
5) Porphyritic phonolite (with phenocrysts)
6) Phonolite (w/out phenocrysts)
7) Chert
8) Gneiss
9) Obsidian
10) Ignimbrite
11) Other

b) Point Source. Describes origin of raw material (Table 3.2). Point source was identified by evaluating the macroscopically observable rock characteristics against a reliable comparative collection of known geologic sources in the Olduvai Basin (see Fig. 3.4). Variable states include:

1. Naibor Soit
2. Naisiusiu
3. Olduvai River (above Granite Falls)
4. Sadiman
5. Lemagrut
6. Engelosin
7. Kelogi Naabi
8. Other
9. Indeterminate

| Raw Material | Quartzite | Lava | Chert | Obsidian | Other |
|---|---|---|---|---|---|
| Point Source | | | | | |
| Naibor Soit | + | | | | |
| Naisiusiu | + | | | | |
| Olduvai River | + | | | | |
| Sadiman | | + | | | |
| Lemagrut | | + | | | |
| Engelosin | | + | | | |
| Kelogi | + | | | | + |
| Naabi | | | | | + |
| Other/Indet | | | + | + | + |

**Table 3.2. Determination of OLAPP data set raw material sources**

3. Quantitative gross morphology
    a) Maximum dimension. Describes in millimeters the maximum observable dimension and was measured using standard metric calipers.
    b) Technological length. Describes in millimeters the length of a specimen measured from the center of an observable point of percussion to an observable termination (Dibble 1997). Technological length applies only to those specimens displaying characteristics diagnostic of tool orientation. When such characteristics were not present, technological length was equal to maximum dimension.
    c) Breadth. Describes in millimeters the measure taken perpendicular to the midpoint of technological length.
    d) Width. Describes in millimeters the thickness of specimen taken at midpoint of technological length.
4. Quantitative specific morphology
    a) Platform breadth. Describes in millimeters the lateral measure of a striking platform taken between intersecting dorsal and ventral surface points.
    b) Platform width. Describes in millimeters the maximum thickness of the striking platform between dorsal and ventral surfaces.
5. Technological attributes
    a) Toth types. Describes the flake type variations of a reduction sequence in a ranked order (Toth 1982), by classifying the type of platform preparation and the cortical percentage of a specimen. Variable states include:
        1. plain with cortex/cortical dorsal
        2. double faceted with cortex/ <50% dorsal cortex

3. multi-faceted with cortex/non-cortical dorsal
4. plain without cortex/ cortical dorsal
5. double-faceted without cortex/<50% dorsal cortex
6. multi-faceted without cortex/non-cortical dorsal

b) Terminal release. Describes the type of flake termination in a nominal order. Variable states include:

1. normal (feather)
2. hinge
3. step (concave)
4. step (vertical)
5. plunging

c) Edge angle. Describes in degrees the angle of dorsal and ventral surface intersection on the working edge of a tool.

c) Exterior platform angle. Describes in degrees the angle of intersection of the striking platform and the dorsal surface.

6. <u>Behavioral and taphonomic indicators</u>

a) Retouch. Describes in a ranked nominal order the amount of modification on an artifact. Variable states:

0. none
1. modified/utilized
2. unifacial (normal)
3. unifacial (inverse)
4. bifacial (alternate)

        5. bifacial (alternating)
        8. not applicable
    b) Weathering. Describes in a ranked nominal order the amount of surface modification on an artifact due to natural processes. Variable states include:
        1. no patination / no rounding (no weathering)
        2. slight patination / rounding (slightly weathered)
        3. patination extreme / rounding (extremely weathered)

7. <u>Typological classifications</u>
    a) Artifact type general. Describes a general technological artifact type classification (Isaac 1977, 1983) (this classificatory system has been modified by OLAPP).
    b) Artifact type specific. Describes a specific technological artifact type (OLAPP)
    c) M.D. Leakey type. Describes artifacts according to the Leakey classification system (Leakey 1971)

Notes on typological classifications:

<u>The general artifact type</u> is based upon Isaac's (1983) classifications. These are the general technological categories:

1) Flaked piece: lithic core material (cobble, nodule, or tabular block) displaying the intentional modification to its surface i.e. the removal of one or more flakes.
2) Detached piece: lithic material that has been removed from a core piece by percussion, i.e. a flake, flake fragment, flaking debris, or core shatter.
3) Manuport (unmodified cobble): lithic material that has not been intentionally modified. Lithic material that is distinguished from its lithological matrix by size

or character and does not display morphological commonalities with the surrounding matrix

4) Split cobble (including cobble fragments), and pounded pieces: lithic material displaying the same characteristics of manuports and are not whole pieces, and/or display pitted or bruised surfaces.

The specific artifact type is based upon OLAPP's classifications, used first by Blumenschine & Ebert for digital surface survey and analysis in 1989. They have since been modified by Blumenschine & Tactikos and are more explicit technological categories that discriminate finer degrees of technological manipulation.

These are the specific technological categories:

1) Unifacially flaked on less than 50% of the circumference of the core: lithic core material displaying the intentional removal of flakes from a striking platform on one side only, the extent of flake removal does not exceed 50% of the core.
2) Unifacially flaked on more than 50% of the circumference of the core: lithic core material displaying the intentional removal of flakes from a striking platform on one side only, the extent of flake removal exceeds 50% of the core.
3) Bifacially flaked on less than 50% of the circumference of the core: lithic core material displaying the intentional removal of flakes from alternate striking platforms, the extent of flake removal does not exceed 50% of the core.
4) Bifacially flaked on more than 50% of the circumference of the core: lithic core material displaying the intentional removal of flakes from alternate striking platforms, the extent of flake removal exceeds 50% of the core.

5) Multidirectionally flaked: lithic core material displaying the intentional removal of flakes from more than two striking platforms and directions.
6) Whole flake, non-cortical dorsal: lithic material that has been detached from a core piece and displays the diagnostic characteristics of a flake, i.e. striking platform (the point of applied force to the core), both lateral margins on either side of the longitudinal axis, a distal end or termination, a ventral surface (smoothed surface containing no previous flake removal scars, except for the bulb of percussion), and a dorsal surface (containing no cortical or weathered surface).
7) Whole flake, less than 50% cortical dorsal: same as above except that the dorsal surface displays a weathered cortex not exceeding 50%.
8) Whole flake, less than 50% cortical dorsal: same as above except that the dorsal surface displays a weathered cortex that exceeds 50%.
9) Flake fragment, non-cortical: lithic material that has been detached from a core piece and displays partial diagnostic characteristics of a flake (see above), without a weathered cortical surface.
10) Flake fragment, less than 50% cortical dorsal: same as above except that the dorsal surface displays a weathered cortex not exceeding 50%.
11) Flake fragment, more than 50% cortical dorsal: same as above except that the dorsal surface displays a weathered cortex exceeds 50%.
12) Whole flake, cortex indeterminate: same as above except that the cortical surface is indeterminate due to weathering.
13) Flake fragment, cortex indeterminate: same as above except that the cortical surface is indeterminate due to weathering.

14) Indeterminate fragment: flake fragment whose characteristics are indeterminate due to weathering.
15) Manuport: same as above
16) Split cobble, block: same as above
17) Core Fragment: same as cobble fragments
18) Pounded pieces, hammerstones, manuports, displaying pitting, or bruising.

The M.D. Leakey typology is based on the Leakey classification system (1971). It has been modified for comparative purposes as follows:

1) Choppers – trimmed and blunted along upper and lower edges, majority are bifacial but lack secondary trimming.
2) Proto-bifaces and bifaces – Bifacially flaked along both lateral edges and tip.
3) Polyhedrons (and discoids) – three or more working edges (Bifacially flaked along the whole or most of its circumference.
4) Spheroids (and sub-spheroids) – projecting ridges smoothed from extensive multidirectional flaking (more angular, less flaking than spheroids).
5) Modified, battered nodules and blocks – no particular form, angular, with a minimum of flaking and/or utilization.
6) Scrapers – steeply trimmed on one or more sides.
7) Burins (and awls) – transverse broken or trimmed edges (pointed projections).
8) Sundry tools (and laterally trimmed flakes) – minimum flaking and/or modification in no particular form (both lateral edges trimmed)

9) Anvils (hammerstones, cobblestones, nodules) and manuports – blocks with battered utilization (cobbles with pitting, bruising or battering), no modification, but not naturally occurring or transported.
10) Debitage, broken flakes (angular waste) – unmodified flakes and fragments, 'waste' (core shatter).
11) Light-duty flakes – flakes and fragments with chipping and blunting.
12) Heavy-duty flakes – large flakes with some chipping >50 mm in maximum dimension.

### *Interpretive Justification of Attributes Examined*

The following section discusses the implications of the examined attributes for understanding the behavioral significance of the stone tool assemblages. While many of the attributes examined are purely descriptive, some have specific technological and behavioral implications.

#### Qualitative raw material data implications:

The characteristics or qualities found in lithic artifacts will primarily be determined by the kinds of raw material available, and how they were acquired. Acquiring raw material is the first step in the organization of technology as defined by Nelson (1988) who argued that technological strategies, which are influenced by environmental conditions and socio-economic strategies, are implemented through the distribution of design and activity, which will ultimately be reflected in raw material type, artifact form and artifact distribution.

Tools are created and employed to satisfy a perceived need. Identifying raw material types can be indicative of a particular adaptation created by the operation of general optimization principles that work within specific local conditions. Essentially, acquisition of raw material calls for direct or indirect contact with the physical environment, and cannot exceed the limits imposed by that environment (Collins 1975). Hence raw material identification is the gateway to understanding early hominid technological organization, resource exploitation, and land-use behavior.

### Quantitative gross morphological data implications:

Examining artifact size (i.e., maximum dimension, technological length, breadth, and width) is especially useful when formulating archaeological correlates for the relationship between technology and land-use patterns. The basic ‘decay model’, or linear function that artifact size diminishes as distance to raw material source increases, is a standard assessment of transport behavior. Transport behavior may be much more complex, however. The decay model has been contrasted by a behavioral ecological model (Henry 1989) that links optimization of reduction sequences to distance of raw material source as well as mobility patterns.

Home range areas of Paleolithic hominids have been estimated using lithic transport data (Gamble and Steele 1999). Building on Isaac’s ‘stone flow’ model (Isaac 1984) raw material transport was examined as a means of determining a transport range.

### Quantitative specific morphology data implications:

Specific morphology describes those characteristics of flaked pieces that have been argued to lie at the heart of two fundamental research questions on prehistoric lithic assemblages (Dibble 1997). First, what were the processes by which prehistoric flintknappers produced their implements? And second, why did they produce the forms they did?

This thesis addresses lithic technological variability in terms of its adaptive significance by focusing on the relationship between certain morphological variables, raw material differences, and their landscape distribution. Quantifying specific attributes not only provides a higher resolution to morphological distinction, but also can be used to construct predictive models. For example, in controlled laboratory experiments that examined Cotterell & Kamminga's (1986) model of flake initiations and terminations in relation to platform thickness and exterior platform angle, Pelcin (Pelcin 1997) demonstrated that for a given exterior platform angle, as platform thickness was increased, predictable changes occurred in the type of initiations and terminations produced. In addition, low exterior platform angles were found to produce changes similar to those usually attributed to indentor types. Such predictors are useful in the reconstruction of manufacturing processes.

Toth examined the type of platform preparation relative to the percentage of cortical surface to establish ‘Toth types’ (Toth 1982), an indicator of reduction sequence on Oldowan style tools. He and others (Kibunjia 2000; Ludwig 1998; Whittaker 1994) have also used flake termination states as an indication of skill level. Examining the exterior platform angle of a flake can indicate the knapper’s choice of platform angle during reduction, hence level of skill.

### *Behavioral and taphonomic implications*

Behavioral indicators such as retouch are important for inferring transport decisions, the extent of raw material exploitation, the degree of manufacturing investment, etc. Surface modification due to weathering can be informative as to the archaeological integrity of an assemblage. Artifacts not in primary context are not as useful behavioral ecological indicators as those in primary context.

Classifying artifacts technologically and typologically allows for broader assemblage comparisons to be made. It also provides a basic morphological characterization of assemblages. This can be useful in determining the nature of landscape distributional variability. The typological classifications will allow for comparisons to be made between typological and technological methodological approaches and their implications. A more comprehensive presentation and discussion of this issue follow in Chapter 4.

# PART II. THE ARCHAEOLOGICAL SAMPLE: CHARACTERISTICS OF THE OLDOWAN LITHIC ASSEMBLAGES

## Introduction

This chapter describes the archaeological sample characteristics. Post excavation examination of stratigraphic proveniences revealed that some of the trenches and/or levels comprising the original archaeological sample did not fall within the target intervals for this study. Artifacts recovered from trenches not within the stated target intervals are not presented here. Consequently, only those data that do fall within the target intervals are presented as the archaeological sample from which all the subsequent tables, figures, and interpretations, will be derived.

One objective of this study is to ascertain whether different patterned archaeological traces can be determined at different scales of investigation. Examining artifact distribution on different spatial scales may provide the flexibility of focus necessary to demonstrate geographic variability in artifact distribution that has not yet been adequately described for the Oldowan Industry, and may establish which kinds of behavioral patterns may be seen at which scales of investigation.

### The archaeological sample:

Of the initial 106 OLAPP archaeological units (trenches), 86 were artifact-bearing trenches within the target temporal horizon. They contained 4334 *in situ* lithic specimens. The artifact counts from each trench and specific excavation level are presented as a whole in the Appendix (Appendix 1). The Landscape Association distribution is summarized in tabular form below (Table 3.3).

| **Landscape Association** | **Geologic Bed** | **No. of Trenches** | **Artifact Count** | **Artifact per Trench (Mean)** | **Artifacts per Trench (SD)** |
|---|---|---|---|---|---|
| Western Lacustrine Plain | M-UB I/ LMB II | 12 | 1619 | 134.92 | 238.77 |
| Southwestern Lacustrine Plain | LMB II | 4 | 212 | 53.00 | 65.86 |
| Lake | LMB II | 1 | 1 | | |
| Eastern Lacustrine Plain | LMB II | 48 | 2320 | 48.33 | 76.12 |
| Eastern Lacustrine Plain/<br>Eastern Alluvial Plain (transitional) | LMB II | 11 | 82 | 7.45 | 4.08 |
| Eastern Alluvial Plain | LMB II | 6 | 35 | 5.83 | 3.37 |
| Northeastern Lacustrine Plain | LMB II | 4 | 65 | 16.25 | 6.50 |
| **Totals** | | **86** | **4334** | | |

**Table 3.3. Summary of archaeological sample in a Landscape Association scale of resolution. M-UB I = Middle-Upper Bed I; LMB II = lowermost Bed II.**

Table 3.3 demonstrates a disproportionate distribution of artifact counts across the landscape when grouped by Landscape Associations. The mean artifact count in each Landscape Association varies independent of the trench count. The standard deviations from the mean suggest that greater variation in artifact counts per trench exists in the Western, Southwestern, and Eastern Lacustrine Plains.

The artifact count distribution is summarized next in the Paleogeographic Locale scale. Table 3.4 demonstrates that a more narrow range of variation in the number of trenches portrays a more homogenous distribution of artifact counts by Paleogeographic Locales. The standard deviation from the mean suggests less variation in artifact counts per trench as well.

| Landscape Association | Paleo-geographic Locale | Geologic Bed | No. of Trenches | Artifact Count | Artifacts per Trench (Mean) | Artifacts per Trench (SD) |
|---|---|---|---:|---:|---:|---:|
| Western Lacustrine Plain | Loc 64 | M-UB I | 3 | 1178 | 392.67 | 397.65 |
| | Naisiusiu | M-UB I | 7 | 118 | 16.86 | 15.79 |
| | West-Lake | LMB II | 2 | 323 | 161.50 | 105.36 |
| Southwestern Lacustrine Plain | Kelogi | LMB II | 4 | 212 | 53.00 | 65.86 |
| Lake | Lake | LMB II | 1 | 1 | | |
| Eastern Lacustrine Plain | MNK | LMB II | 3 | 23 | 7.67 | 6.03 |
| | FLK | LMB II | 8 | 137 | 17.13 | 21.95 |
| | VEK | LMB II | 4 | 287 | 71.75 | 38.53 |
| | HWKW | LMB II | 5 | 355 | 87.50 | 137.42 |
| | HWKE | LMB II | 7 | 649 | 92.71 | 100.56 |
| | HWKEE-KK | LMB II | 10 | 243 | 24.30 | 21.25 |
| | MCK | LMB II | 5 | 510 | 102.00 | 141.56 |
| | TK-Loc 20 | LMB II | 2 | 39 | 19.50 | 19.09 |
| | LongK | LMB II | 4 | 77 | 19.25 | 13.74 |
| Eastern Lacustrine Plain/ Eastern Alluvial Plain | JK-WK | LMB II | 7 | 58 | 8.29 | 2.56 |
| | DK-Complex | LMB II | 4 | 24 | 6.00 | 6.16 |
| Eastern Alluvial Plain | THC-Complex | LMB II | 6 | 35 | 5.83 | 3.37 |
| Northeastern Lacustrine Plain | Fifth-Fault | LMB II | 4 | 65 | 16.25 | 6.50 |
| **Totals** | | | **86** | **4334** | | |

**Table 3.4. Summary of archaeological sample by Landscape Association and Paleogeographic Locale. M-UB I = Middle-Upper Bed I; LMB II = lowermost Bed II.**

Comparing artifact count distribution on both scales of investigation it is evident that the broader scale Landscape Association grouping shows more variation in artifact count between Landscape units. The deviation from the mean, range of artifact count values and variance are greater in the Landscape Association scale than shown in the Paleogeographic Locale scale (Table 3.4A). This suggests a more even distribution of artifacts when they are grouped by

| | Mean | Std. Dev. | Std. Error | Count | Variance | Range |
|---|---:|---:|---:|---:|---:|---:|
| Landscape Association | 725.33 | 998.52 | 407.64 | 6 | 997033.87 | 2301.00 |
| Paleogeographic Locale | 254.88 | 299.10 | 72.54 | 17 | 89459.86 | 1155.00 |

**Table 3.4A. Comparison of artifact count descriptive statistics for Landscape Association and Paleogeographic Locale scales.**

Paleogeographic Locales.

A graphic comparison of the Landscape Association and Paleogeographic Locale scale artifact count distribution is shown in the histograms below (Fig. 3.2).

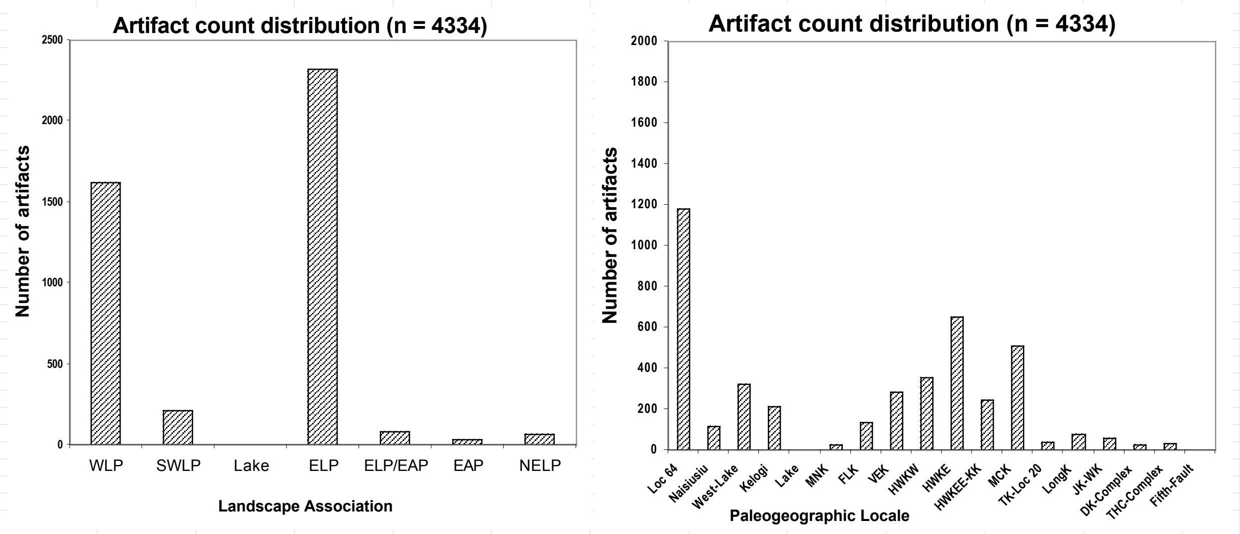


**Figure 3.2. Comparison of artifact count distribution by Landscape Association and Paleogeographic Locale scales.**

Aside from artifact counts, the raw material composition is presented as a basic sample characteristic. The total assemblage distribution of raw material across the paleolandscape is broken down into the three major raw material groups of quartzite, lava, and other. Quartzite is the dominant material, comprising 84.08% of the total artifact assemblage, lava comprises 12.18% of the total assemblage, and ‘other’ raw material makes up for the remaining 3. 74% (Table 3.5).

| | | **Raw Material** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Landscape** | **Paleogeographic** | **quartzite** | | **lava** | | **other** | | **unit totals** | |
| **Association** | **Locale** | **count** | **%** | **count** | **%** | **count** | **%** | **count** | **%** |
| WLP | Loc 64 | 1161 | 26.79 | 3 | 0.07 | 14 | 0.32 | 1178 | 27.18 |
| | Naisiusiu | 116 | 2.68 | 1 | 0.02 | 1 | 0.02 | 118 | 2.72 |
| | West-Lake | 319 | 7.36 | | | 4 | 0.09 | 323 | 7.45 |
| SWLP | Kelogi | 148 | 3.41 | 31 | 0.72 | 33 | 0.76 | 212 | 4.89 |
| Lake | Lake | 1 | 0.02 | | | | | 1 | 0.02 |
| ELP | MNK | 13 | 0.30 | 1 | 0.02 | 9 | 0.21 | 23 | 0.53 |
| | FLK | 114 | 2.63 | 15 | 0.35 | 8 | 0.18 | 137 | 3.16 |
| | VEK | 242 | 5.58 | 39 | 0.90 | 6 | 0.14 | 287 | 6.62 |
| | HWKW | 317 | 7.31 | 23 | 0.53 | 15 | 0.35 | 355 | 8.19 |
| | HWKE | 556 | 12.83 | 72 | 1.66 | 21 | 0.48 | 649 | 14.97 |
| | HWKEE-KK | 221 | 5.10 | 18 | 0.42 | 4 | 0.09 | 243 | 5.61 |
| | MCK | 254 | 5.86 | 247 | 5.70 | 9 | 0.21 | 510 | 11.77 |
| | TK-Loc 20 | 35 | 0.81 | 1 | 0.02 | 3 | 0.07 | 39 | 0.90 |
| | LongK | 41 | 0.95 | 36 | 0.83 | | | 77 | 1.78 |
| ELP/EAP | JK-WK | 40 | 0.92 | 17 | 0.39 | 1 | 0.02 | 58 | 1.34 |
| | DK-Complex | 19 | 0.44 | 5 | 0.12 | | | 24 | 0.55 |
| EAP | THC-Complex | 17 | 0.39 | 15 | 0.35 | 3 | 0.07 | 35 | 0.81 |
| NELP | Fifth-Fault | 30 | 0.69 | 4 | 0.09 | 31 | 0.72 | 65 | 1.50 |
| Raw Material Totals | | 3644 | 84.08 | 528 | 12.18 | 162 | 3.74 | **4334** | **100** |

**Table 3.5. Distribution of general raw material types by Landscape Association and Paleogeographic Locale scales.**

Quartzite artifacts are unevenly distributed across the landscape with the majority occurring nearer to their respective quartzite inselberg sources. Lava artifacts are unevenly distributed over the landscape in relatively small proportions with the exception of the Paleogeographic Locale MCK, where the highest occurrence of lava is found, and where lava and quartzite are found to be in similar proportions (Fig. 3.3).

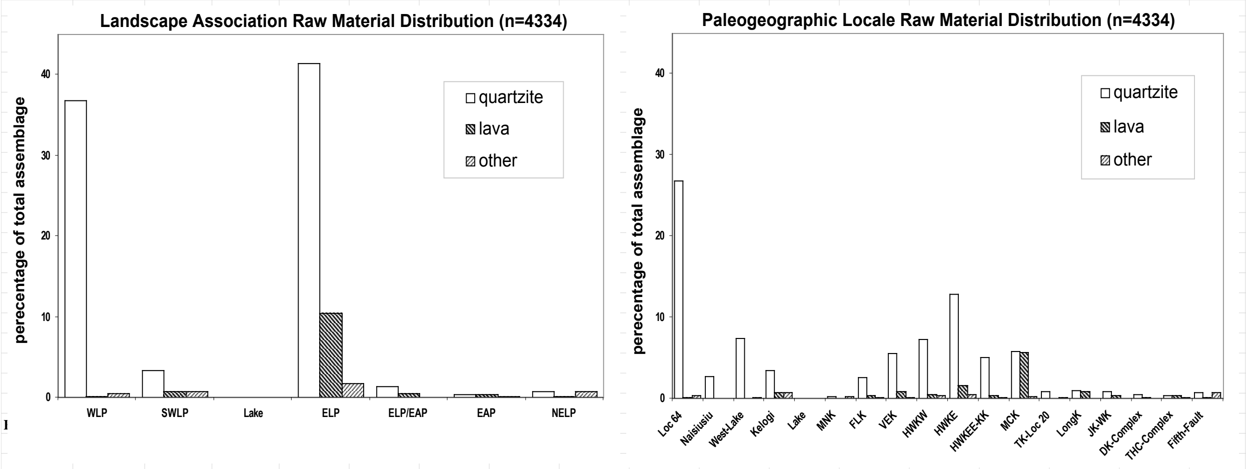


**Fig. 3.3. Side-by-side comparison of Landscape Association and Paleogeographic Locale scale raw material distribution.**

The tables and histograms illustrate the spatial variation in artifact assemblage sizes and raw material composition in both scales of resolution. The following chapters will explore that spatial variation as it is evidenced by several other lithic artifact assemblage characteristics and discuss the implications of that variation.

# CHAPTER FOUR

# A MORPHOLOGICAL TYPOLOGICAL DESCRIPTION OF ARTIFACT DISTRIBUTION ON A LANDSCAPE SCALE

## Introduction

Based upon the recommendations of the 29th Wenner Gren Symposium in 1965, "*Systematic Investigation of the African Later Tertiary and Quaternary*", an Industrial Complex refers to a grouping of Industries considered to represent part of the same whole (this term is to be coupled with a name based on an acceptable type site) while an Industry is represented by *all* the known objects that a group of prehistoric people manufactured *in one area* over some span of time (*italics added*, Clark et al, 1966). The Oldowan Industrial Complex has been used as a cultural and technological marker for several geographic regions. The Oldowan Industry is characterized by type assemblages such as those recovered from the archaeological loci DK, FLK, and HWK at Olduvai Gorge, Tanzania (Leakey, 1971). These type assemblages define not only the Oldowan Industry in Bed I and Lowermost Bed II at Olduvai Gorge, but also the Oldowan Industrial Complex in general.

Although the type assemblages from Olduvai Gorge define the Oldowan Industrial Complex, they have never been empirically demonstrated to represent a homogenous or common tool-using tradition over a broad landscape such as the paleo-Olduvai Basin itself.

The basic question addressed in this chapter is, do the geographically restricted Oldowan type-site assemblages represent a homogenous Industrial Complex that occurs over a broad landscape? This section examines the morphological typological variability distribution of the Oldowan type assemblages from the MNK, FLK, HWK, and DK sites at Olduvai (excavated by the Leakeys between 1960-1963), representing the Oldowan Industrial Complex in a limited area within the Olduvai Basin. It compares that with the morphological typological variability distribution of the lithic artifact assemblage recovered at Olduvai Gorge by the Olduvai Landscape Paleoanthropology Project (OLAPP) between 1989-2000, representing a comparable temporal horizon but sampling a broader, landscape-scale. The OLAPP archaeological specimens were recovered from two synchronous sub-basin regions in Middle Bed I and Lowermost Bed II. The OLAPP assemblages fall within the culture-chronological range of the Oldowan Industry as, according to Leakey, "the cultural material from Bed I and the base of Bed II can be referred to as the Oldowan, and remains virtually unchanged from the Base of Upper Bed I to the lowest part of Bed II (1971:1)".

This examination is done in order to determine whether typological classifications are sensitive to spatial variability in Oldowan lithic assemblages and if so, whether that variability, which may not have been evident in a geographically limited scale, becomes evident at broader geographic (spatial) scales.

The Oldowan Industry is described by M.D. Leakey in the following manner:

> “It [the Oldowan] is characterized by choppers of various forms, polyhedrons, discoids, scrapers, occasional subspheroids and burins, together with hammerstones, utilized cobbles, and light-duty utilized flakes” (Leakey 1971:1).

The Oldowan type-sites discussed here are those sites that represent the Oldowan by their ”…proportionate occurrences of the various tool types…” (Leakey 1971:264) with those proportions being only relative to the Developed Oldowan and Acheulean in Beds I and II. Due to possible incongruities in the representation of tool type categories within the Leakey monograph, the lithic data used here to describe the Oldowan type-site assemblages has been derived directly from within the text and tables of the Leakey (1971) monograph and converted to a format uniform to this thesis. This allows for comparisons to be made between Leakey's original data and my own data. The tool categories[2] represented here are, 1) choppers, 2) proto-bifaces, 3) polyhedrons/discoids, 4) spheroids/subspheroids, 5) anvils, hammerstones, modified, battered nodules and blocks, 6) cobblestones, manuports, 7) scrapers 8) burins, awls, 9) sundry tools, laterally trimmed flakes, and 10) debitage.

## The Oldowan Type-Site Assemblages:

The total distribution of artifact types from all the Oldowan type-sites combined shows a predominance of debitage (81.52%), followed by anvils, hammerstones and modified blocks (7.31%), choppers (4.49%), cobblestones, manuports (2.38%), polyhedrons and discoids (1.69%), scrapers (1.65%), spheroid/subspheroids (0.52%), sundry tools and burins/awls (0.18% and 0.15%), respectively (Fig 4.1).

---

[2] For the sake of comparison, the distribution of tool types is displayed with polyhedrons and discoids, and spheroids and subspheroids combined into single categories. Light and heavy-duty flake s have also been combined into the debitage category.

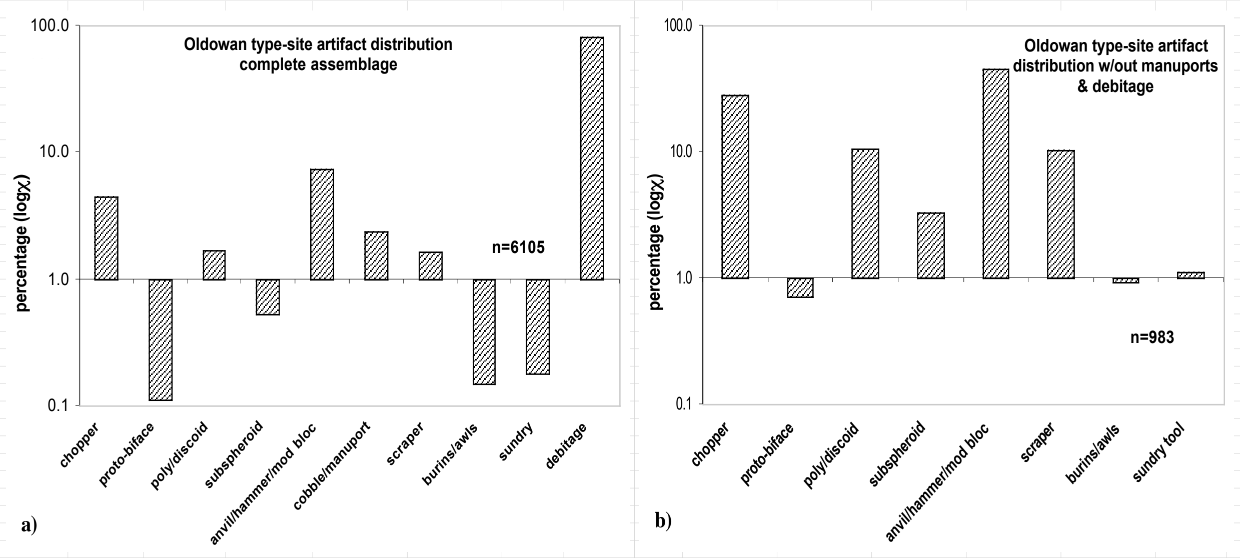


**Fig. 4.1. Comparison of combined Oldowan type-site tool frequency distribution a) with debitage and manuports and, b) w/out manuports and debitage (after Leakey, 1971).**

In Leakey's type-site histograms (1971:265) only those forms considered as tools and utilized materials were included in the distribution. Manuports (considered to lack evidence of modification) and debitage (not considered tools) were both omitted. When the manuports and debitage are removed from the total assemblage (Fig.4.1b), the proportions of the remaining tool categories appear more evenly distributed (with the exception of proto-bifaces, a rare occurrence in the Oldowan). This distribution, comprised of a high frequency of anvils, hammerstones, modified nodules and blocks3 (45.37%), followed by choppers (27.87%), polyhedrons/ discoids (10.48%), and scrapers (10.27%), and the low frequency of sundry tools (1.12%), burins/awls (0.92%), and proto-bifaces (0.71%), is what is more commonly identified as a typical Oldowan assemblage.

---

[3] The combination of anvils, hammerstones and modified nodules and blocks results in inflated numbers in this category compared to the Leakey (1971) distributions.

The OLAPP Archaeological Assemblages:

The Leakey (1971) typological classification system is applied to the description of the Oldowan artifact types from the geographically broader OLAPP landscape-based sample. In the OLAPP archaeological assemblage the total distribution of artifact types (Fig. 4.2A) also shows a predominance of debitage (86.23%), followed by cobbles, manuports (3.71%), sundry tools (2.70%), polyhedrons and discoids (2.47%), choppers (2.24%), anvils, hammerstones, modified nodules and blocks (0.90%), scrapers (0.78%), proto-bifaces (0.60%), burins (0.23%), and spheroid/subspheroids (0.14%).

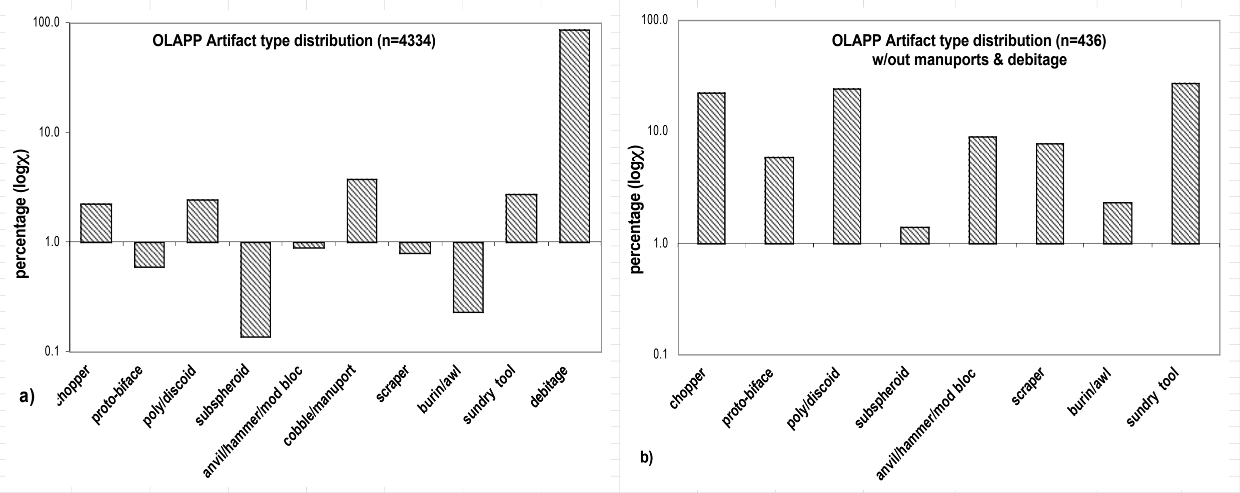


**Fig. 4.2. Comparison of a) complete OLAPP assemblage and, b) type-selective OLAPP assemblage typological distribution.**

When the manuports and debitage are removed from the assemblage distributions (Fig. 4.2B), the remaining tool types display high artifact richness (i.e. number of different artifact types present) but low evenness (i.e. relative proportion of each artifact type). This distribution of surprisingly high frequencies of sundry tools (26.83%), followed by polyhedrons/discoids (24.54%), choppers (22.25%), anvils/hammerstones, modified nodules/blocks (8.94%), scrapers (7.80%), proto-bifaces (5.96%), burins/awls (2.29%), and subspheroids (1.38%) is a departure from the classic Oldowan profile that typically describes a higher percentage of choppers and a low percentage of polyhedrons and sundry tools (Fig.4.3).

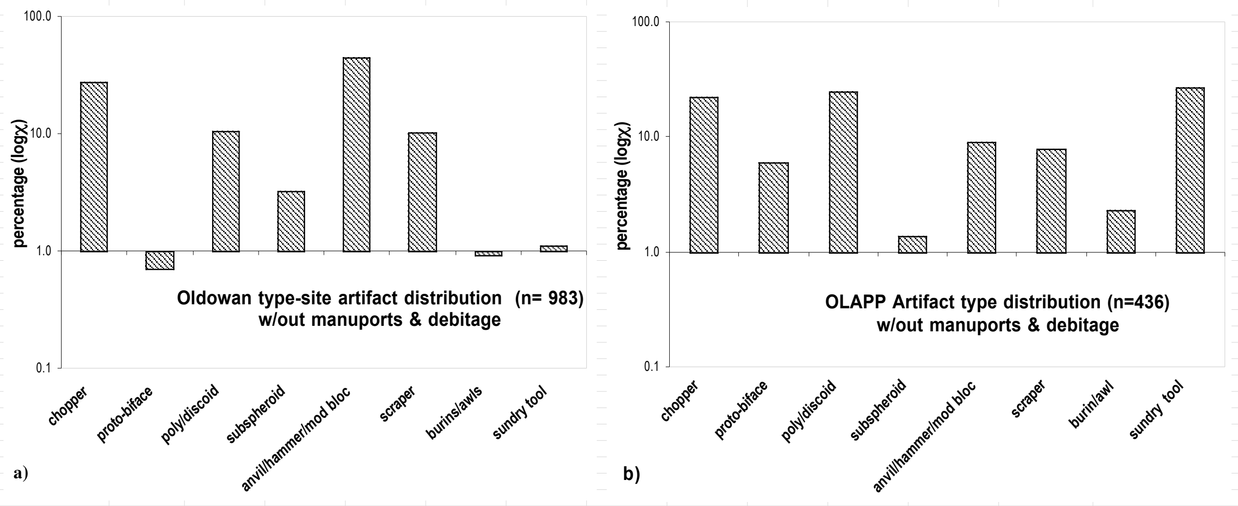


**Fig. 4.3. Side-by-side comparison of MDL type-site and OLAPP assemblages.**

This proportional difference may be due to the fact that categories such as 'sundry tool' and 'modified nodule or block' are somewhat ambiguous or subject to researcher bias. Thus what I deemed to be one type may have been determined as the other by M.D. Leakey. This would result in inflated proportions of one or the other category. The difference in tool proportions may also be due to the fact that the Oldowan type-sites are derived from a geographically restricted area (~20 km2), and the OLAPP landscape scale assemblage samples an area that is roughly an order of magnitude greater (~300 km2). To try and determine whether spatial scale is affecting the typological composition, the OLAPP archaeological assemblage typological distribution will be examined in two different spatial scales.

<u>Landscape Association scale of variability</u>:

The first spatial scale of investigation is referred to in this study as the Landscape Association (*see* Table 3.1). This is one of the hierarchical landscape scales used in Peters and Blumenschine's (1995; 1996) landscape model of the paleo-Olduvai Basin. The Landscape

Associations include (from west to east); the Western Lacustrine Plain (WLP), the Southwestern Lacustrine Plain (SWLP), the Lake, the Eastern Lacustrine Plain (ELP), the transitional zone between the Eastern Lacustrine Plain/Eastern Alluvial Plain (ELP/EAP), the Eastern Alluvial Plain (EAP), and the Northeastern Lacustrine Plain (NELP). To put the typological composition of these assemblages into perspective, the Oldowan type-site assemblages are shown below compared to the OLAPP assemblage artifact type counts and percentages (Table 4.1) grouped in a tripartite typology also used by Leakey (1971). The tripartition is a simplified grouping of three basic artifact types: tools, utilized materials, and debitage.

| **Oldowan** | **Tools** | | **Utilized Material** | | **Debitage** | | **Site Total** |
|---|---|---|---|---|---|---|---|
| **Type-site** | **count** | **%** | **count** | **%** | **count** | **%** | |
| DK | 154 | 12.80 | 187 | 15.60 | 857 | 71.50 | 1198 |
| FLKN 'Zinj' | 60 | 2.40 | 135 | 5.40 | 2275 | 92.10 | 2470 |
| FLKN 5 | 30 | 19.90 | 29 | 19.20 | 92 | 60.90 | 151 |
| FLKN 4 | 19 | 28.30 | 28 | 41.80 | 20 | 29.80 | 67 |
| FLKN 3 | 28 | 16.40 | 49 | 28.60 | 94 | 55.00 | 171 |
| FLKN 1 & 2 | 149 | 12.40 | 214 | 17.70 | 842 | 69.90 | 1205 |
| HWKE 1 | 52 | 33.80 | 69 | 44.80 | 33 | 21.40 | 154 |
| MNK 'skull site' | 45 | 6.50 | 76 | 11.00 | 568 | 82.40 | 689 |
| **Totals** | **537** | **8.80** | **787** | **12.89** | **4781** | **78.31** | **6105** |
| **OLAPP Landscape Assoc.** | | | | | | | |
| WLP | 62 | 3.83 | 281 | 17.36 | 1276 | 78.81 | 1629 |
| SWLP | 26 | 12.26 | 47 | 22.17 | 139 | 65.57 | 212 |
| LAKE | 0 | 0.00 | 0 | 0.00 | 1 | 100.00 | 1 |
| ELP | 199 | 8.58 | 482 | 20.78 | 1639 | 70.65 | 2320 |
| ELP/EAP | 8 | 9.76 | 18 | 21.95 | 56 | 68.29 | 82 |
| EAP | 1 | 2.86 | 13 | 37.14 | 21 | 60.00 | 35 |
| NELP | 5 | 7.69 | 14 | 21.54 | 46 | 70.77 | 65 |
| **Totals** | **301** | **6.95** | **855** | **19.73** | **3178** | **73.33** | **4334** |

**Table 4.1. Oldowan type-site and OLAPP Landscape Association assemblage distribution by a tripartition of tools, utilized materials, and debitage**

The Oldowan type-sites show more variation in the tripartition than the OLAPP assemblages. All of the Oldowan type-sites except FLK 4 and HWKE 1 are dominated by debitage. This is perhaps due to the fact that the type-site distribution is in a higher spatial resolution. Among

Landscape Association units, the artifact counts show a range of variation but in terms of percentages, the OLAPP typological distribution shows very little spatial variability. With the exception of the Lake, whose sample size is but a single specimen, the Landscape Association units are similar to each other in artifact type proportions (Fig.4.4). The OLAPP artifact type proportions are quite similar in that debitage dominates the typological composition of every Landscape Association, followed by utilized material and then tools.

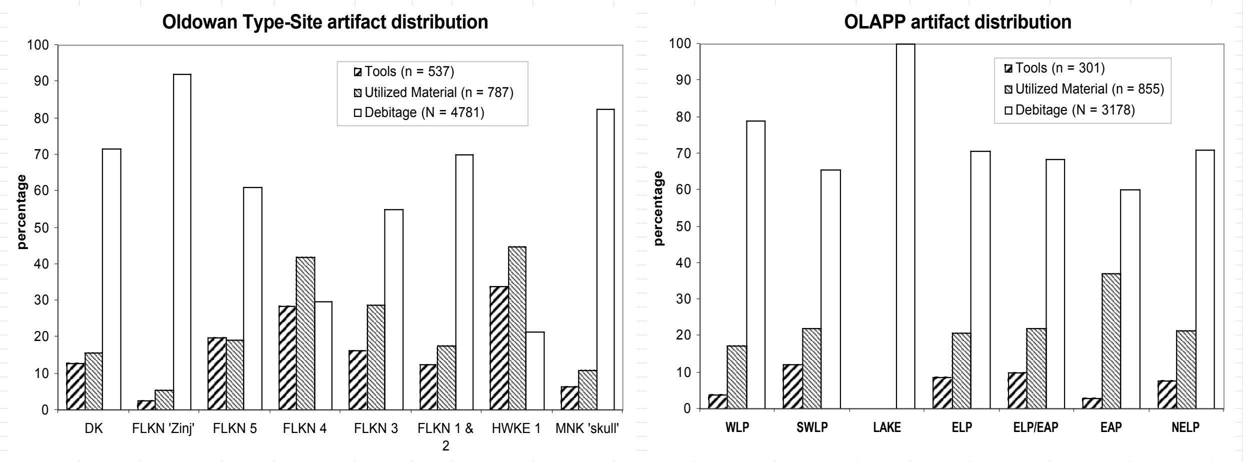


**Fig. 4.4. Comparison of the morphological typological composition of Oldowan type-sites and OLAPP assemblages on a Landscape Association scale.**

<u>Paleogeographic Locale scale of variability</u>:

The second spatial scale of investigation referred to in this study is the Paleogeographic Locale (Table 3.1). This landscape classification system is a geomorphologic grouping identified by modern geological outcrops and is currently employed by OLAPP in their work at Olduvai Gorge (Table 4.2).

| Paleogeographic locale | Tools no. | % | Utilized Material no. | % | Debitage no. | % | Total no. |
|---|---|---|---|---|---|---|---|
| LOC.64 | 36 | 3.11 | 211 | 18.24 | 910 | 78.65 | 1157 |
| NAISIUSIU | 9 | 6.47 | 20 | 14.39 | 110 | 79.14 | 139 |
| WEST-LAKE | 17 | 5.26 | 50 | 15.48 | 256 | 79.26 | 323 |
| KELOGI | 26 | 12.26 | 47 | 22.17 | 139 | 65.57 | 212 |
| LAKE | 0 | 0 | 0 | 0 | 1 | 100 | 1 |
| MNK | 8 | 34.78 | 6 | 26.09 | 9 | 39.13 | 23 |
| FLK | 9 | 6.57 | 20 | 14.60 | 108 | 78.83 | 137 |
| VEK | 13 | 4.53 | 40 | 13.94 | 234 | 81.53 | 287 |
| HWKW | 16 | 4.51 | 52 | 14.65 | 287 | 80.85 | 355 |
| HWKE | 45 | 6.93 | 81 | 12.48 | 523 | 80.59 | 649 |
| HWKEE-KK | 7 | 2.88 | 37 | 15.23 | 199 | 81.89 | 243 |
| MCK | 87 | 17.06 | 218 | 42.75 | 205 | 40.20 | 510 |
| TK-LOC.20 | 2 | 5.13 | 9 | 23.08 | 28 | 71.79 | 39 |
| LONGK | 12 | 15.58 | 19 | 24.68 | 46 | 59.74 | 77 |
| JK-WK | 3 | 5.17 | 17 | 29.31 | 38 | 65.52 | 58 |
| DK-COMPLEX | 5 | 20.83 | 1 | 4.17 | 18 | 75.00 | 24 |
| THC-COMPLEX | 1 | 2.86 | 13 | 37.14 | 21 | 60.00 | 35 |
| FIFTH-FAULT | 5 | 7.69 | 14 | 21.54 | 46 | 70.77 | 65 |
| TOTALS | 301 | 6.95 | 855 | 19.73 | 3178 | 73.33 | 4334 |

**Table 4.2. OLAPP assemblage tool tripartition grouped by Paleogeographic Locales listed from west to east.**

The OLAPP artifact assemblages grouped according to Paleogeographic Locales display more morphological typological variability than was apparent in the Landscape Association grouping. In the higher resolution Paleogeographic Locale scale debitage also dominates utilized materials and tools. However, the Paleogeographic scale distribution shows the relationship of debitage to utilized material to tools to vary from the Landscape Association scale (Fig. 4.5). In the Landscape Association scale the relationship of debitage to utilized materials to tools is consistent, as in each Landscape Association debitage dominates, utilized materials occur in the middle range values, and tools in the lowest percentages. In the Paleogeographic Locale scale that relationship varies. In MNK the percentage of debitage is slightly higher than that of tools, higher than utilized material. In DK-Complex tools also appear in a higher percentage than utilized material and in MCK utilized material dominates the assemblage. Perhaps the higher resolution of the Paleogeographic Locale units helps this different pattern to emerge. It appears that the different scales of investigation may impact the perceived degree of variability in tool proportions.

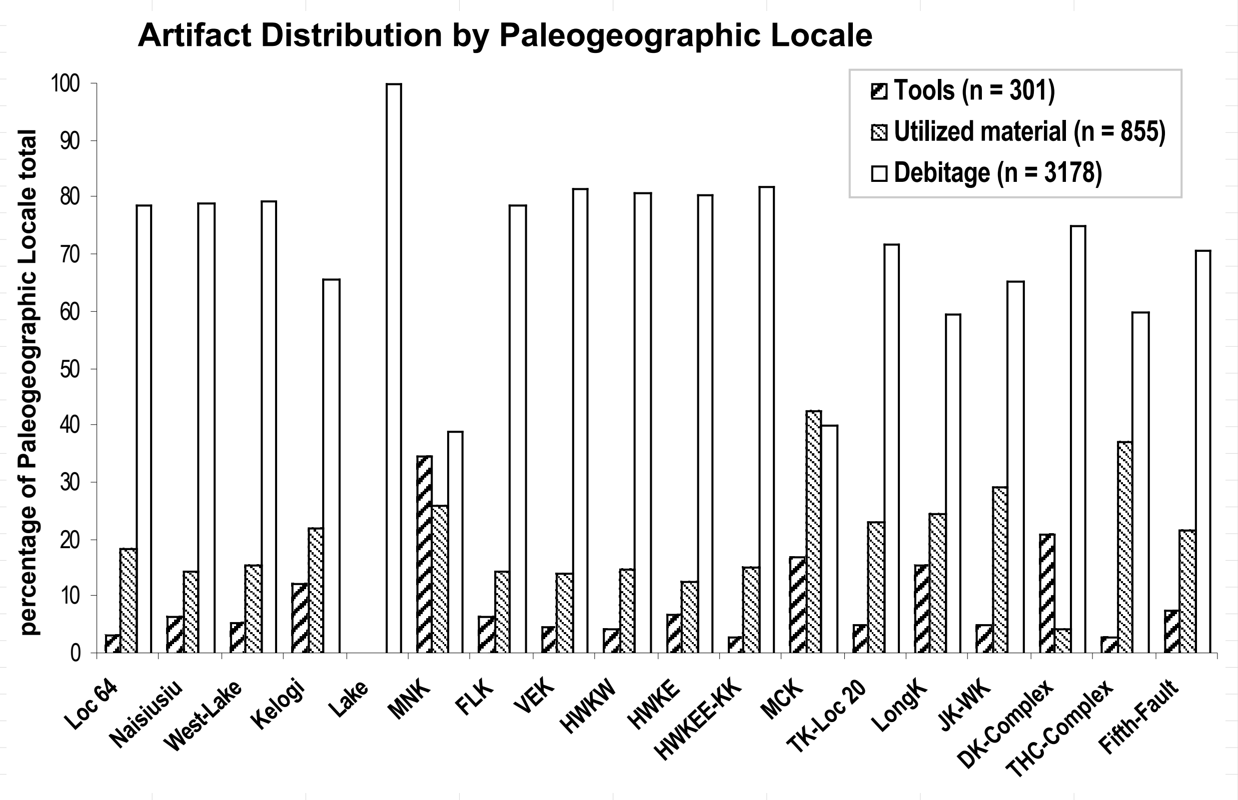


**Fig. 4.5. Morphological typological Paleogeographic Locale scale distribution of artifact tripartition of tools, utilized materials, and debitage.**

Assemblage Diversity:

Another way to use typological classifications to explore variability in an artifact distribution is to examine the diversity of an assemblage. In her 1971 monograph, Leakey noted that in Bed I and Lowermost Bed II the average number of tool types is six, but this number rises in the Developed Oldowan, suggesting a temporal trend in tool diversity. In that usage, diversity may be understood as the different number of artifact types, also referred to as artifact richness (*re* Grayson, 1998). A different way to look at artifact typological diversity is to measure the ratio of the number of artifact types, and frequency of occurrence of artifact types. The diversity values shown here are calculated using a formula derived from an equation introduced by Shannon and Weaver in 1949 for use in quantitative biology (*after* Hutchinson 1957):

$$\text{Diversity} = ( -\Sigma p_i \log_{10} p_i )$$

If the Oldowan type-sites represent components of a homogenous culture and the artifact assemblage features are culturally and not ecologically driven, then the lithic artifact assemblage features found in one type-site should be similar to those found in another. The typological diversity of each site should not vary significantly across the landscape, even if the scale of resolution is increased. When the diversity indices of all artifact types from the type-site assemblages is compared to that which excludes manuports and debitage a dissimilar diversity distribution is evidenced among type-sites (Fig. 4.6). Removing the manuports and debitage raises some of the diversity indices but diminishes the standard deviation from the mean, the variance, and range of diversity values (Table 4.3).

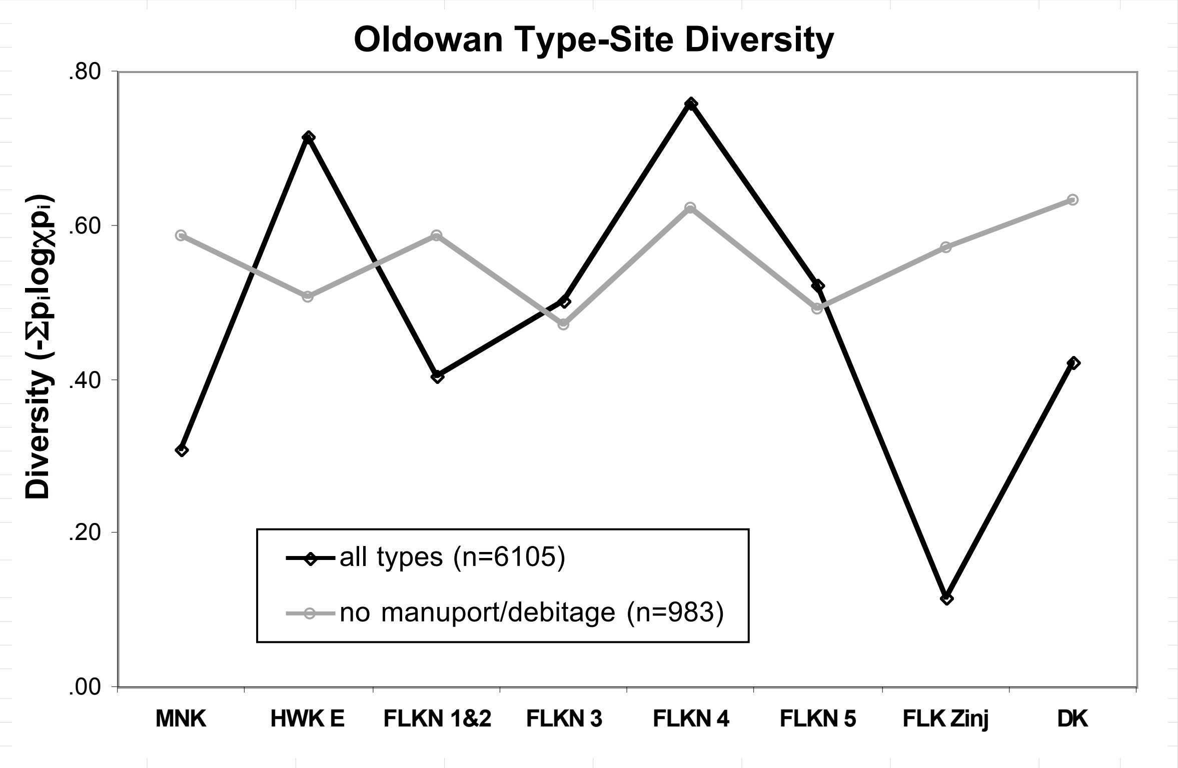


**Fig. 4.6. Comparison of complete assemblage (including all types) and type-selective assemblage (with manuports and debitage removed) Oldowan type-site assemblage diversity.**

| | Mean | Std. Dev. | Variance | Range |
|---|---|---|---|---|
| Complete (all types) | .467 | .207 | .043 | .640 |
| W/out manuports and debitage | .559 | .061 | .004 | .160 |

**Table 4.3. Oldowan type-site diversity descriptive statistics**

This obvious disparity in diversity values between the complete and incomplete assemblages may suggest that the typological homogeneity assumed for the Oldowan type-site assemblages could be the result of examining the composition of assemblage features from a typologically biased sample.

The typological diversity of OLAPP's assemblage from each Landscape Association unit is shown in Fig.4.7a. Typological diversity is highest in the Southwestern Lacustrine Plain, nonexistent in the Lake, and fairly moderate in the remaining eastern sub-basin units.

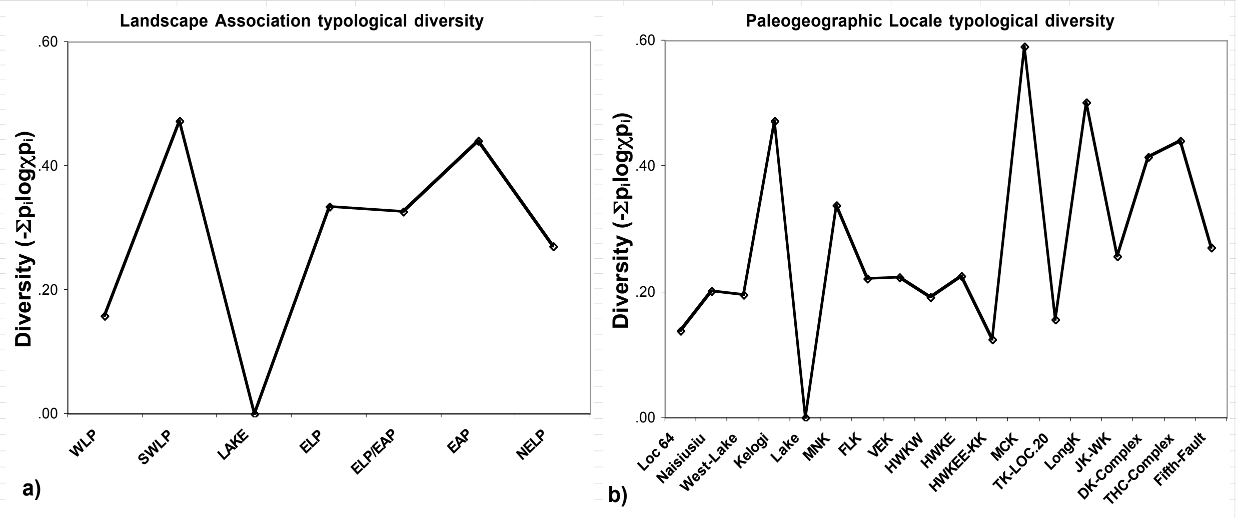


**Fig. 4.7. Comparison of typological diversity as seen in a) Landscape Association and, b) Paleogeographic Locale scales. Associations and Locales are listed from west to east.**

When the artifacts are grouped according to Paleogeographic Locales (Fig.4.7b), the level of assemblage diversity varies considerably in both the western and eastern sub-basin units. The very high diversity values of MCK and LongK as well as the low values of HWKEE-KK and TK-Loc. 20 are not evident in the Landscape Association scale grouping.

Debitage dominates most often in the assemblages discussed so far, and as seen with the Oldowan type-site assemblages, it might be expected that when the manuports and debitage are removed diversity values may increase in some cases, but the range of variation will decrease across both the Landscape Associations and Paleogeographic Locales. Figure 4.8 compares Landscape Association assemblages that are complete (including all types of artifacts) with those that are incomplete (manuports and debitage have been selectively removed). Surprisingly, removing the manuports and debitage from the OLAPP Landscape Association assemblages increases the variance and range of diversity values (Table 4.4). It also has a considerable impact on variability in the eastern sub-basin (except for the EAP).

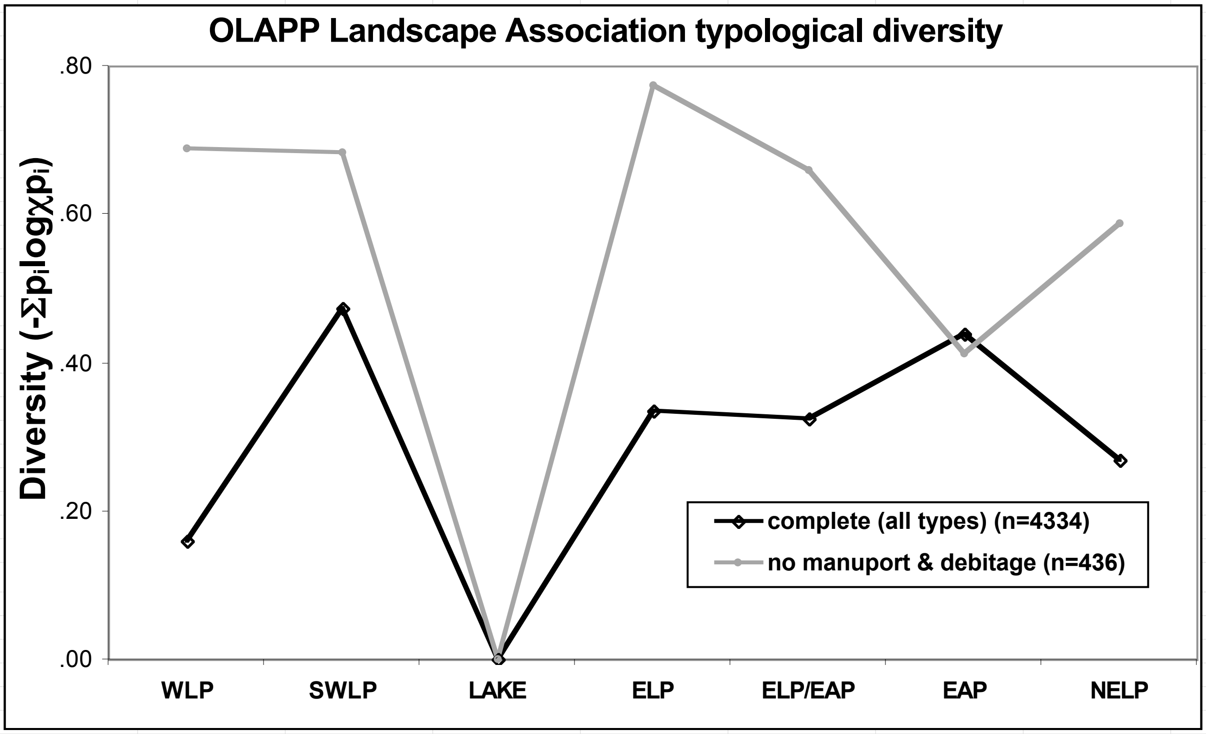


**Fig. 4.8. Comparison of complete (including all types) and incomplete (w/out manuports and debitage) OLAPP assemblage diversity.**

| | Mean | Std. Dev. | Variance | Range |
|---|---|---|---|---|
| OLAPP complete (all types) | .286 | .163 | .027 | .470 |
| OLAPP w/out manuports and debitage | .543 | .265 | .070 | .770 |

**Table 4.4. Landscape Association scale diversity descriptive statitics**

Figure 4.9 compares Paleogeographic Locale assemblages that are complete (including all types of artifacts) with those that are incomplete (manuports and debitage have been selectively removed).

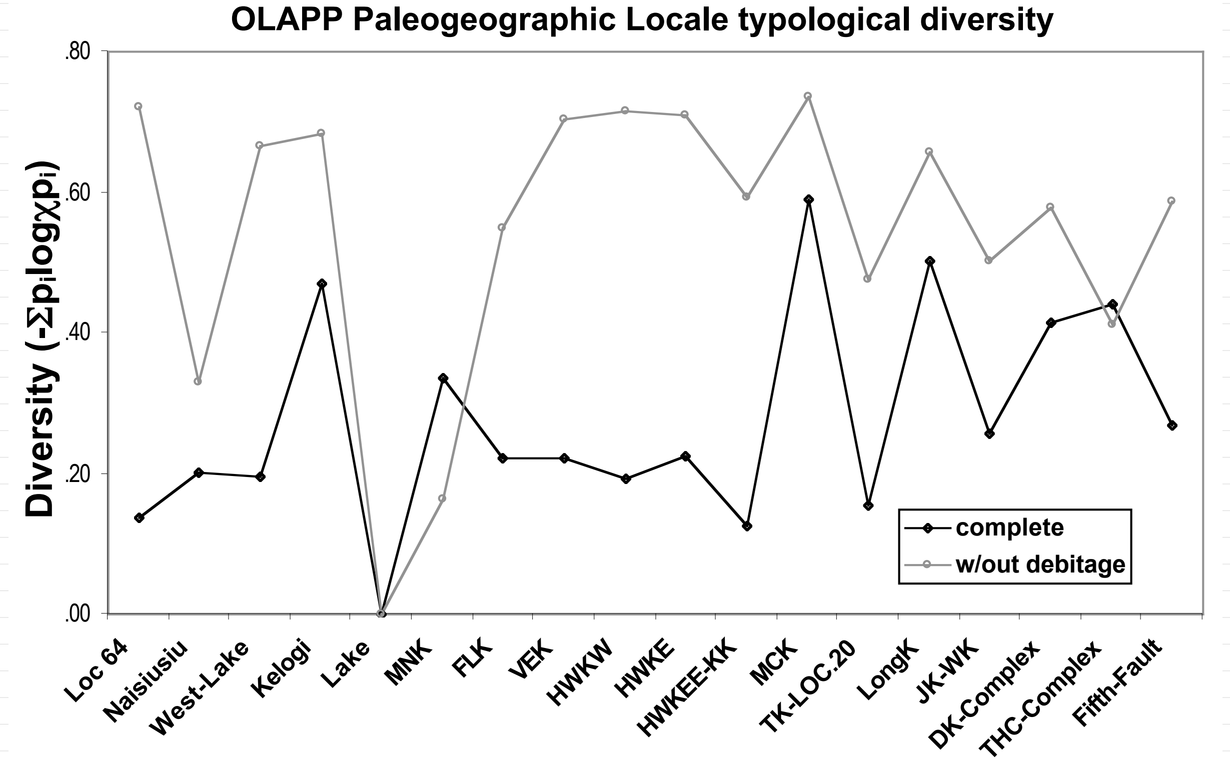


**Fig. 4.9. Comparison of complete (including all types) and incomplete (w/out manuports and debitage) OLAPP assemblage typological diversity.**

Removing the debitage from the OLAPP assemblage Paleogeographic Locale grouping has a similar effect of increasing the variance and range of diversity values, but to a lesser degree (Table 4.5). The exceptions are Loc. 64, whose assemblage is almost entirely debitage, and the eastern sub-basin Locales of FLK, VEK, HWKW, HWKE, and HWKE-KK.

| | Mean | Std. Dev. | Variance | Range |
|---|---|---|---|---|
| OLAPP complete (all types) | .276 | .152 | .023 | .590 |
| OLAPP w/out manuports and debitage | .543 | .205 | .042 | .740 |

**Table 4.5. Paleogeographic Locale scale diversity descriptive statistics**

### *Summary of Observations*

This chapter examined the morphological typological variability of artifact assemblages from both the Oldowan type-sites excavated by Leakey from Bed I and lowermost Bed II, and the OLAPP assemblages recovered from a comparable stratigraphic horizon. The Oldowan type-sites are a fairly high-resolution sample (individual trenches), but are geographically restricted. The OLAPP assemblages are geographically broadly distributed, and can be broken down into two spatial scales of resolution. The OLAPP assemblages were compared and contrasted at both scales of spatial resolution.

I examined two different assemblage characteristics. First I looked at the typological frequency distribution of both samples, noting the effect that removing the manuports and debitage (type-selection) had on distributional patterns. The incomplete Oldowan type-site assemblages (with manuports and debitage removed) adhered more closely to the generally accepted Oldowan typological profile than the complete assemblages did. When the manuports and debitage were removed from the OLAPP assemblage, it did not adhere to the typical Oldowan typological profile. Perhaps it is the broader spatial scale of the OLAPP assemblages that produces greater assemblage variation whether the sample is complete or incomplete. In order to examine the impact of spatial scale on assemblage variability, I then examined the same OLAPP sample in two different spatial scales of resolution.

The Landscape Association scale of analysis showed a more uniform distribution in terms of artifact type proportions, similar to the Oldowan type-site assemblages. This suggests that even on a very broadly distributed spatial scale, the Oldowan is a homogenous Industry. However, at the finer Paleogeographic Locale scale of analysis, variation in tool proportions was more evident, suggesting that a higher resolution reveals more variation in the assemblages.

When typological diversity was examined in the Oldowan type-site sample, the exclusion of manuports and debitage increased the mean diversity value, but drastically decreased the range and variance. In the OLAPP sample on a Landscape Association scale, exclusion of manuports and debitage increased the mean considerably, as well as the range, and variance. On the finer Paleogeographic Locale scale, exclusion of manuports and debitage nearly doubled the mean diversity value, but only moderately increased the range and variance.

The exclusion of manuports and debitage had a similar impact of increasing the mean diversity value as well as the range and variance on both scales of resolution in the OLAPP sample. However, the exclusion of manuports and debitage had a different effect on the Oldowan type-site assemblages, i.e. increasing the mean diversity value while decreasing the range and variance. This difference is perhaps related to the geographical limitation of that sample.

## Discussion

The typological classifications used to describe the Oldowan accommodate the more broadly distributed OLAPP sample. That is to say that the OLAPP sample can be characterized by its proportion of choppers, polyhedrons, discoids, scrapers, occasional subspheroids and burins, together with hammerstones, utilized cobbles, and debitage as part of the Oldowan Industrial Complex. However, the proportionate occurrence of the different tool types has been shown to vary depending upon the spatial scale or resolution of the assemblage examined.

Spatial or geographic variation in lithic assemblage characteristics of the Oldowan Industry has not been well documented and even less well understood or explained. Typological variability expressed as frequency distributions does not necessarily illustrate the compositional variability of lithic artifact assemblages when they are represented in a low-resolution grouping as well as typological diversity indices do. This could be a shortcoming when typological frequency distributions are applied to questions of early hominid behavioral strategies that deal with the spatial variability of Oldowan assemblages in a low resolution.

Traditional studies of Oldowan assemblages deal with identifying the toolmaker, their level of skill and cognition, and a particular lithic assemblage's place in the evolution of stone tool industries. Morphological studies of the Oldowan have focused upon the manufacturing process and the reduction sequence. This may be problematic due to the inherent variation that exists in an unstandardized technology that is not bound by design constraints. Functional studies of the Oldowan have, for the most part, been limited to feasibility of some of the tool forms and functions, and to raw material determination. However, a correlation between typology and specific function has never been empirically proven and the ecological-functional relevance of typological categories is uncertain. It is also not clear whether typological distributions will correlate with tool using behavior or geographical variation in any predictable manner.

Determining the function of an Oldowan tool *is* problematic, but it is the next step in understanding the adaptive significance of stone tools. Even more problematic is determining technological organization, which incorporates the technological system of reduction and tool production with land-use strategies. While attempts to identify functions of early stone artifacts have included several approaches, few have integrated technological systems with feasibility experiments and contextual associations of artifacts and other ecological features.

More recent archaeological investigations have focused on hominin behavior using lithic artifact distributions to address questions of early hominin behavior and land use emphasizing the role of lithic technology as a subsistence strategy associated with different costs and benefits that vary across a landscape (i.e. Nelson 1988; Torrence 1989). Discerning behavior as implied by the characteristics of a lithic Industry (which encompasses raw material selection, tool production techniques, tool form, tool and land use, and tool maintenance and discard), without using what may well be arbitrary or researcher-subjective typological criteria necessitates the identification of a suite of characteristics that describe the technological organization or tool-using behavior. This behavior may also occur on a broader scale than can be described through limited geographic samples, illustrating the problem of using typological classifications to address behavioral issues. Typological classifications do not describe technological processes involved in the formation of a lithic artifact assemblage and are not suited for interpreting behavioral traces of tool use that exist as stone tool discard and loss patterns on a landscape. This must be done by first identifying what the behaviorally diagnostic variables are.

The following chapter presents the role of experimental archaeology in the interpretation of artifact discard patterns on a landscape and a series of experiments designed to address the question of tool function.

# CHAPTER FIVE

# THE ROLE OF EXPERIMENTAL ARCHAEOLOGY IN PREDICTING EARLY HOMINID BEHAVIORAL TRACES AT OLDUVAI GORGE

## Introduction

In the introductory chapter, I discussed the application of experimental archaeology to the predictive modeling of early hominid technological organization and to the behavioral and techno-functional studies of the adaptive significance of stone tools in general. This chapter examines the role of experimental archaeology specifically as it applies to the predictive modeling of stone tool discard and loss patterns by Oldowan hominids in Olduvai Gorge. I present a methodology and the resulting data generated by experimental trials that were designed to provide empirical data for modeling stone tool use in the Olduvai paleobasin during Middle-Upper Bed I and lowermost Bed II times.

### *Experimental Methodology And The Experimental Data*

Steward (1938:2) stated that the analysis of human ecology

> "…requires consideration first of certain features of the natural landscape or environment; second, of cultural devices by which the environment was exploited; and third, of resulting adaptations of human behavior."

He posited that physical factors such as rainfall, soils, topography, and climate determined the nature, distribution, and abundance of subsistence resources (Steward 1938). Extrapolating from Steward's principals to the early tool-using hominid behavior at Olduvai Gorge, I include the notion that available technology limited the quantity of those resources that could be procured by tool-using hominids. Identifying the feasible range of tool utility would help ascertain the scope of hominid resource exploitation. If investment in stone tool technology is considered a decision variable, the costs of that technology are as important as the benefits. Ugan *et al* (2003) propose that,

> "…even if we are unlikely to know the exact amount of time invested in a particular artifact or assemblage, knowing more about these functions will improve predictions about categorical variation in design and morphology."

In this section I present an experimental methodology used to determine the limiting factors, or costs, and the relative functional utility of Oldowan tool forms. The results of these experiments are presented in a relative utility ranking of artifact technological types and are incorporated in the following chapter into a predictive model of landscape stone tool distribution during Middle-Upper Bed I and lowermost Bed II times at Olduvai Gorge, Tanzania.

### *Experimental Methodology*

Building on an approach first developed by Glynn Isaac *et al* (1981), I assessed stone tool utility through the experimental manufacture and use of replicated Oldowan tools. Utilizing the available raw material at Olduvai Gorge, Tanzania, I carried out a series of experimental trials that were designed to empirically determine the relative utility of the entire range of observed Oldowan tool forms. My replication of the experimental lithic assemblages was guided by the observed morphological characteristics of size, shape, and raw material types exhibited among the 6,000 plus specimens excavated from Olduvai Gorge (see Chapter 3).

The experimental tool forms included:

1. Unmodified cobble
2. Detached piece (i.e., flake)
3. Flaked piece flaked around <50% of core circumference (i.e., chopper)

4. Flaked piece flaked around >50% of core circumference (i.e., proto-bifacial, discoidal and polyhedral forms)
5. Sharpened stick.

Simulating the raw material component of an Oldowan assemblage, raw materials used in the experiments were sampled from various sources (Ch.3, Part 1) that were all represented in the Oldowan archaeological assemblages. These sources included:

1. Mts. Lemagrut and Sadiman – lava cobbles from various drainages off the Southeastern and Southern Volcanic Highlands.
2. Naibor Soit - a quartzite inselberg to the immediate north of the junction area of Olduvai Gorge.
3. Naisiusiu - a quartzite inselberg in the western region of Olduvai.
4. Junction Channel – Olduvai River channel bed, a secondary source of quartzite and lava.
5. Olduvai River - In the Western gorge, above Granite Falls, a secondary source of various types of raw materials, predominantly Naisiusiu quartzite cobbles.

The raw material types were categorized as follows:

1. Lava (Lemagrut)
2. Lava (Sadiman)
3. Quartzite (Naibor Soit)
4. Quartzite (Naisiusiu)
5. Other

The observed size range of artifacts in the archaeological record for Middle-Upper Bed I and lowermost Bed II at Olduvai Gorge determined the sizes of artifacts produced in replicated assemblage. The maximum dimension of each replicated tool was measured in millimeters (to the nearest .10 mm). Weight was measured in grams (to the nearest .10 g). The mass of each specimen was calculated as a ratio between its weight and maximum dimension. The mass ratio numbers ranged from 0.02-15.89. The size class category was formulated by converting the mass ratio into intervals as follows:

(1) small: 0.01-5.3 g/mm.

(2) medium: 5.31-10.6 g/mm.

(3) large: 10.61-15.9 g/mm.

The experimental trials were performed in order to determine the feasibility of employing a variety of tool forms in different subsistence-related tasks, and to assess the advantages and limitations of those forms in performing specific activities or tasks. I considered specific activities to be ecological proxies, or behaviors that reflect a specific habitat or resource availability based on Blumenschine and Peters' (1998, Table 1) hypothetical landscape facet vegetation cover of woody plants, predator variables, and opportunities for hominid scavengers. This is supported by the assumption that different habitats necessitate and provide opportunity for different activities. The activities included the general subsistence-related tasks of woodworking, butchery, pounding, and digging. I based my selection of simulated subsistence activities on hypotheses that have been advanced regarding the specifics of early hominid subsistence strategies. The hypotheses and activity selections are discussed briefly below.

### *Simulated Subsistence Activities*

Studies of non-human primates and the similarity in dental and mandibular morphology between early hominid fossils and middle Miocene apes (Andrews and Martin 1991) implied a dietary similarity and suggested little change in the foraging strategies of the early hominids compared with their ape ancestors. Andrews and Martin (1991) maintained that the similarity might even have extended to other aspects of behavior, such as patterns of tool manufacture and use.

The adaptive utility of stone tool use may be factored into hypothesized early hominid subsistence behaviors. For instance, while baboons may have harvested underground storage organs (USOs) in the dry season without the benefit of technology (DeVore 1963), early hominids may have advantageously used technology in a similar dry season subsistence strategy. In order to address the feasibility of the early hominid use of technology to exploit USOs (see (DeVore 1963), as well as the early hominid use of fire (Barbetti 1986; Bellomo 1994; Clark 1985; Gowlett 1981,1982; Isaac 1982), I included woodworking into the suite of tasks performed.

Woodworking tasks included:

1. Chopping the hard woods (tool-assisted harvesting) available in the Olduvai area - *Balanites aegyptica, Acacia mellifera, Acacia tortilis, Cordia monoica, Grewia bicolor*, and *Salvadora persica.*

2. Procuring (tool-assisted harvesting and sharpening) smaller softer wood branches in order to manufacture digging tools- The *Isteti (Grewia sp.)* tree was used.

3. Digging for underground storage units (i.e. roots or tubers) using sharpened sticks and stone tools.

Diagnostic bone modification strongly suggests that hominids exploited meat and bone marrow (Blumenschine 1988). Whether hominids systematically or occasionally scavenged (Bartholomew 1953; Binford 1985) or hunted (Bunn 1981), meat and bone marrow would have been important early hominid energy sources (Blumenschine 1991,1995; Madrigal 2000; Speth 1989). In order to address the feasibility of the early hominid stone-tool-assisted meat and bone marrow consumption as well as fruit and nut exploitation (Andrews and Martin 1991), I carried out a series of butchery and pounding tasks.

Butchery tasks included:

1. Disarticulation of goat (and deer) fore and hind limbs, and rib cages. This was done prior to skinning.
2. Skinning. Limbs, torso, and head were skinned separately.
3. Bulk defleshing. The bulk meat was removed from limbs and torso.
4. Scrap Defleshing. The remaining flesh was removed from limbs, torso, and head separately.

Pounding tasks included:

1. Removal of bone marrow and brain (from deer and goat limb and goat skull bones).
2. Pounding nuts (nuts from *Ximenia* and *Balanites*).

It is important to discuss the possible limiting factors related to my being a relatively small modern human whose subsistence does not depend on the successful employment of Oldowan stone tool technology. While I undoubtedly am less proficient in stone-tool- aided subsistence practices, less tied to the landscape ecology, and possess less strength and stamina than an early hominid, I am attempting to establish a relative tool utility ranking, i.e., to determine the utility of each tool relative to each other tool, within the range of variation of the Oldowan tool types size, shape, and raw material. As the sole manufacturer of the tools, my skill, strength, and cognitive abilities remained consistent throughout the experiments, so my assessment of relative utility is reasonable. While my selection of activities may not reflect the full range of subsistence activities carried out by an early hominid, they do address general tasks or activities commonly thought of as being important in early hominid subsistence. Other factors (socio-economic and otherwise) affecting early hominid subsistence decisions are not touched upon here. Another limiting factor in my experimental work had to do with time and financial constraints. The paucity of both of these currencies led to a less than desirable sample size. It would have been more advantageous if I had been able to perform several trials of each task using every size range, tool form, and raw material discussed above. This was unfortunately not possible and, while still being enormously informative, the non-parametric sample may possibly result in biases.

### *Data Collection*

The independent variables that were recorded during each trial are: type of task, form of tool used, raw materials used, and size of tool. The dependent variable, the amount of time needed to successfully complete the task, was considered to be the currency to measure stone tool utility. A task was terminated if the tool could not perform, or if it failed (e.g., broke, split, etc.) and the specific tool was considered ineffective. In both cases, the relative inefficiency of a particular tool for a particular a task was recorded. Time taken to perform a task was recorded in minutes and seconds using a digital stopwatch, later converted to fractions of a minute (to the nearest 0.1 of a minute). For example, 1 minute and 30 seconds was converted to 1.50. In pounding experiments (accessing bone marrow and nut flesh), the number of strikes or blows was also recorded.

### *Experimental trials*

A total of 168 experimental trials were completed in 1999-2000. The majority of the experiments were carried out at Olduvai Gorge, Tanzania, using locally available resources. A small number of experiments were undertaken at the Rutgers University Graduate Research Laboratory, using raw materials transported from Olduvai Gorge, and local faunal resources. I performed most of the experiments alone but at times with a young Maasai assistant named Lerau, who carried out whichever task I requested to the best of his ability with the tool given to him, or assisted me while I performed the task. Although Lerau used tools replicated by me, his butchering experience may have been more extensive than my own. On the other hand, my experience butchering using stone tools was greater than his, so during the months that we carried out the experiments both of us experienced a learning curve as far as time needed to perform a task. Augustino Venus (a member of the Olduvai Landscape Paleoanthropology Project) also helped me by timing and photographically documenting some of the experiments.

| Task | Number of trials |
|---|---:|
| Procuring Stick | 13 |
| Sharpening Stick | 15 |
| Chopping Wood | 5 |
| Skinning | 21 |
| Disarticulation | 17 |
| Digging | 4 |
| Defleshing | 29 |
| Pounding (nut/bone) | 64 |
| Total | 168 |

**Table 5.1. Summary table of experimental trials by task category.**

Table 5.1 summarizes the number and different type of experimental trial. Digging experiments were designed to access underground storage organs. Twenty-four of the 64 pounding episodes were performed to access bone marrow (12 from humeri and femurs, and 12 from radio-ulnae and metapodials). The remaining 40 pounding episodes were performed to access nut flesh.

The results of the experimental trials and their associated measures of efficiency (time and number of strikes) are presented in their entirety in Appendix 2. They are summarized in Table 5.2 by the average time taken to perform a task and grouped by tool form, raw material type, and size range.

The digging experiments were omitted from the analysis which follows because they were carried out primarily with sharpened sticks and cannot be compared to stone tools in the diagnostic categories of size, shape, and raw material type. The nut pounding experiments were also excluded, because the currency used to measure their efficiency (number of strikes/blows) is not directly comparable with time as a measure of efficiency.

| Tool form | Raw material^ | Size range* | procuring stick | sharpening stick | skinning | disarticulation | chopping wood | digging | defleshing | pounding |
|---|---|---|---|---|---|---|---|---|---|---|
| **Unmodified cobble** | Lava (Lem) | 5 | | | | | 60.00 | | | |
| | Quartzite (Nais) | 4 | | | | | | | | 0.15 |
| | Other | 4 | | | | | | | | 0.12 |
| | | 5 | | | | | | | | 0.05 |
| **Detached piece** | Lava (Lemagrut) | 1 | | | 7.00 | 18.00 | | | 8.72 | |
| | | 2 | 60.00 | 8.20 | 5.00 | 10.00 | | | 28.00 | |
| | | 5 | 2.40 | | | | | | | |
| | Lava (Sadiman) | 1 | | | 7.28 | | | | 19.10 | |
| | | 2 | 3.50 | | | 10.00 | | | 4.00 | 60.00 |
| | | 3 | | | 5.00 | | | | | |
| | Quartzite (Naibor Soit) | 1 | | 15.00 | 4.83 | | | | 11.86 | 60.00 |
| | | 2 | | | 2.47 | 2.40 | | | | 60.00 |
| | Quartzite (Naisiuiu) | 1 | 60.00 | | | 2.10 | | | | |
| | | 2 | | | | 1.36 | | 0.20 | 3.05 | |
| | Other | 1 | | | | 2.10 | | | 24.53 | |
| | | 2 | | | 3.05 | 3.05 | | | 7.55 | |
| **Flaked piece on <50% of its surface** | Lava (Lemagrut) | 2 | | | 34.50 | | | | | |
| | | 3 | | 2.47 | 11.00 | | | | | |
| | | 4 | 0.30 | 5.10 | | 3.73 | | | | |
| | | 5 | 4.10 | | | | 23.58 | | | |
| | Lava (Sadiman) | 3 | | | | | | | 8.53 | |
| | | 4 | | 5.00 | | | | | 38.00 | |
| | | 5 | 3.44 | 4.45 | | | | | | |
| | Quartzite (Naibor Soit) | 3 | | 4.45 | | 2.37 | | | | |
| | | 4 | | | | | | | 5.25 | |
| | | 5 | 2.59 | | | | | | | |
| | Quartzite (Naisiuiu) | 3 | | 3.00 | 6.50 | 5.01 | | | 8.69 | |
| | | 4 | | | | 0.13 | | | | |
| | | 5 | 2.58 | | | 6.27 | 60.00 | | | |
| | Other | 2 | | | | | | | 6.42 | |
| | | 3 | | 6.15 | | | | | | 2.00 |
| | | 4 | | | 7.56 | | | | 9.00 | |
| **Flaked piece on >50% of its surface** | Lava (Lemagrut) | 3 | | 4.30 | | 2.47 | | | 24.45 | |
| | | 4 | | 4.40 | | | | | | |
| | | 5 | | | | 11.00 | | | | |
| | Lava (Sadiman) | 3 | 2.45 | 5.35 | 11.54 | 60.00 | | | | |
| | | 4 | | | | | | | | 0.20 |
| | | 5 | | | | | | | | |
| | Quartzite (Naibor Soit) | 1 | | | | | | | 5.07 | |
| | | 4 | | | | 0.21 | | | | |
| | Quartzite (Nais) | 4 | | | 60.00 | | | | | |
| | Other | 2 | 2.58 | | 10.30 | | | | | |
| | | 3 | | | 33.63 | | | | | |
| | | 4 | | 5.08 | 6.05 | | | | | |
| **Stick (sharpened)** | Other (wood) | 5 | | | | | | 0.24 | | |
| **Total Experiments in Each Task Category** | | | 13 | 15 | 21 | 19 | 5 | 4 | 26 | 11 |

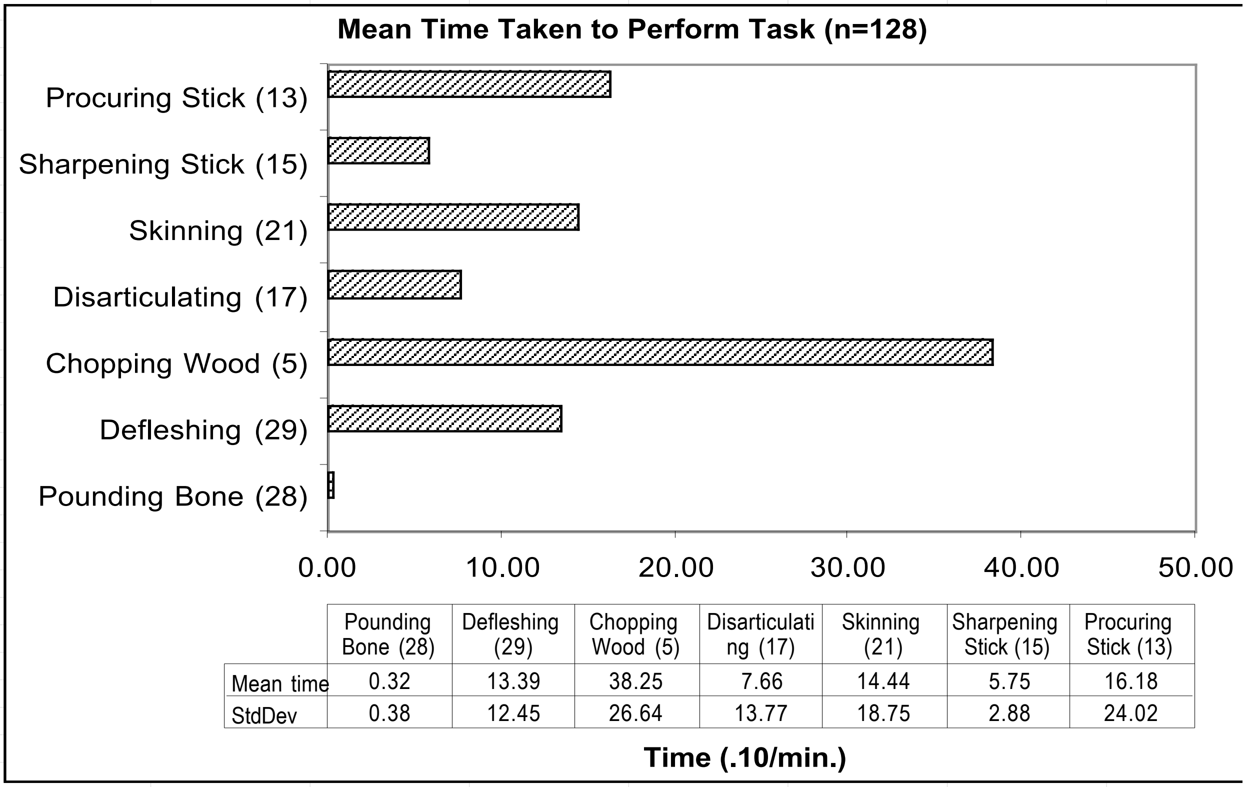
^Raw material types consist of Naibor Soit and Naisiusiu Quartzites, Lemagrut and Sadiman Lavas, and 'other'.

*Size range is a ranked order of mass (weight (g)/maximum dimension (mm)) from smallest (1) to largest (5).

**Table 5.2. Average time taken to complete each task ( to the nearest .10 of a minute)**

*Results: Interpreting the data*

The experimental trials demonstrated variation in the average time taken to perform different tasks (Fig.5.1). On average, pounding of bones (for marrow removal) took the least amount of time (0.32 min.), followed at a substantial increase in time cost by sharpening a stick (5.75 min.), disarticulation (7.66 min.), defleshing (13.39 min.), skinning (14.44 min.), and procuring a stick (16.18 min.). The most time consuming task was chopping wood (38.25 min.).



| | Pounding Bone (28) | Defleshing (29) | Chopping Wood (5) | Disarticulating (17) | Skinning (21) | Sharpening Stick (15) | Procuring Stick (13) |
|---|---|---|---|---|---|---|---|
| Mean time | 0.32 | 13.39 | 38.25 | 7.66 | 14.44 | 5.75 | 16.18 |
| StdDev | 0.38 | 12.45 | 26.64 | 13.77 | 18.75 | 2.88 | 24.02 |

**Fig. 5.1. The average time taken to perform each task.**

Variability in time taken to perform a task is evident *within* each task category, as demonstrated by the standard deviation from the mean, which is, is most cases, close to or greater than the mean. This may be attributed to the fact that within each raw material category, the physical characteristics that determine 'knappability' vary by individual specimen and affect performance. Those physical characteristics include brittleness, homogeneity, and isotropy

(Cotterell & Kamminga 1990), as well as the general condition of the specimen related to weathering. In the chopping wood category, variance may also be attributed to the thickness and hardness of the wood as well as the sharpness (working edge angle) of the tool. I recorded these factors while performing my experiments, but they are not quantified here. However, such information is important when considering the degree of risk presented by a specific landscape locale and will be taken into account when discussing the optimization model in Part II.

| Task | Form | Raw Material | Size Class | Time taken | Rank |
|---|---|---|---|---|---|
| Procuring Stick (13) | FP<50 | Lava (Lem) | small | 0.50 | 1 |
| | DP | Lava (Lem) | medium | 2.67 | 2 |
| | FP >50 | Lava (Sad) | small | 2.75 | 3 |
| | FP<50 | Lava (Sad) | large | 2.97 | 4 |
| | FP<50 | Quartz (Nais) | medium | 2.97 | 4 |
| | FP >50 | Other | smallest | 2.97 | 4 |
| | FP<50 | Quartz (NS) | large | 2.98 | 7 |
| | DP | Lava (Sad) | smallest | 3.83 | 8 |
| | FP<50 | Lava (Lem) | medium | 4.17 | 9 |
| | FP<50 | Lava (Sad) | medium | 4.50 | 10 |
| | DP | Lava (Lem) | smallest | 60.00 | 11 |
| | DP | Quartz (Nais) | smallest | 60.00 | 11 |
| | DP | Quartz (Nais) | smallest | 60.00 | 11 |
| Sharpening Stick (15) | FP<50 | Lava (Lem) | small | 2.78 | 1 |
| | FP<50 | Quartz (Nais) | small | 3.00 | 2 |
| | FP >50 | Other | medium | 4.00 | 3 |
| | FP<50 | Other | small | 4.50 | 4 |
| | FP >50 | Lava (Lem) | small | 4.50 | 4 |
| | FP >50 | Lava (Lem) | small | 4.67 | 6 |
| | FP<50 | Lava (Sad) | medium | 4.75 | 7 |
| | FP<50 | Quartz (NS) | small | 4.75 | 7 |
| | FP<50 | Lava (Sad) | small | 5.00 | 9 |
| | FP<50 | Lava (Lem) | small | 5.17 | 10 |
| | FP >50 | Lava (Sad) | small | 5.58 | 11 |
| | FP >50 | Other | small | 6.25 | 12 |
| | FP<50 | Other | small | 8.00 | 13 |
| | DP | Lava (Lem) | smallest | 8.33 | 14 |
| | DP | Quartz (NS) | smallest | 15.00 | 15 |

**Table 5.3. Time taken to complete task grouped by task; ranked in ascending order from most effective to least or ineffective. The replicated Oldowan tool forms are: UC = Unmodified cobble; DP = Detached piece; FP <50 = Flaked piece (on less than 50% of its surface); FP >50 = Flaked piece (on more than 50% of its surface).**

| Task | Form | Raw Material | Size Class | Time taken | Rank |
|---|---|---|---|---|---|
| Skinning<br>(21) | DP | Quartz (NS) | smallest | 2.78 | 1 |
| | DP | Other | smallest | 3.08 | 2 |
| | DP | Quartz (NS) | smallest | 4.67 | 3 |
| | DP | Lava (Lem) | smallest | 5.00 | 4 |
| | DP | Lava (Sad) | smallest | 5.00 | 4 |
| | DP | Quartz (NS) | smallest | 5.00 | 4 |
| | DP | Quartz (NS) | smallest | 5.17 | 7 |
| | DP | Lava (Sad) | smallest | 6.00 | 8 |
| | FP >50 | Other | small | 6.08 | 9 |
| | FP<50 | Quartz (Nais) | small | 6.83 | 10 |
| | DP | Lava (Lem) | smallest | 7.00 | 11 |
| | FP >50 | Other | small | 7.42 | 12 |
| | FP<50 | Other | small | 7.93 | 13 |
| | DP | Lava (Sad) | smallest | 8.92 | 14 |
| | FP<50 | Lava (Lem) | smallest | 9.00 | 15 |
| | FP >50 | Other | smallest | 10.50 | 16 |
| | FP<50 | Lava (Lem) | small | 11.00 | 17 |
| | FP >50 | Lava (Sad) | small | 11.90 | 18 |
| | FP<50 | Lava (Lem) | smallest | 60.00 | 19 |
| | FP >50 | Quartz (Nais) | small | 60.00 | 19 |
| | FP >50 | Other | small | 60.00 | 19 |
| Pounding<br>Bone<br>(24) | FP<50 | Lava (Sad) | small | 0.05 | 1 |
| | UC | Other | largest | 0.07 | 2 |
| | UC | Other | small | 0.08 | 3 |
| | UC | Other | medium | 0.08 | 3 |
| | FP >50 | Lava (Sad) | medium | 0.08 | 3 |
| | UC | Other | medium | 0.09 | 6 |
| | UC | Other | small | 0.10 | 7 |
| | FP<50 | Lava (Sad) | small | 0.13 | 8 |
| | UC | Quartz (Nais) | smallest | 0.20 | 9 |
| | UC | Quartz (Nais) | small | 0.20 | 9 |
| | FP<50 | Lava (Sad) | small | 0.20 | 9 |
| | UC | Other | largest | 0.23 | 12 |
| | UC | Quartz (Nais) | smallest | 0.25 | 13 |
| | UC | Other | small | 0.27 | 14 |
| | UC | Other | small | 0.28 | 15 |
| | UC | Quartz (Nais) | small | 0.30 | 16 |
| | UC | Other | small | 0.32 | 17 |
| | UC | Quartz (Nais) | smallest | 0.33 | 18 |
| | UC | Other | largest | 0.33 | 18 |
| | FP >50 | Lava (Sad) | medium | 0.33 | 18 |
| | UC | Other | small | 0.37 | 21 |
| | FP<50 | Lava (Sad) | small | 0.48 | 22 |
| | UC | Other | medium | 1.16 | 23 |
| | FP<50 | Other | small | 2.00 | 24 |
| Chopping<br>wood<br>(5) | FP<50 | Lava (Lem) | largest | 5.50 | 1 |
| | FP<50 | Lava (Lem) | largest | 5.75 | 2 |
| | UC | Lava (Lem) | large | 60.00 | 3 |
| | FP<50 | Lava (Lem) | medium | 60.00 | 3 |
| | FP<50 | Quartz (Nais) | largest | 60.00 | 3 |

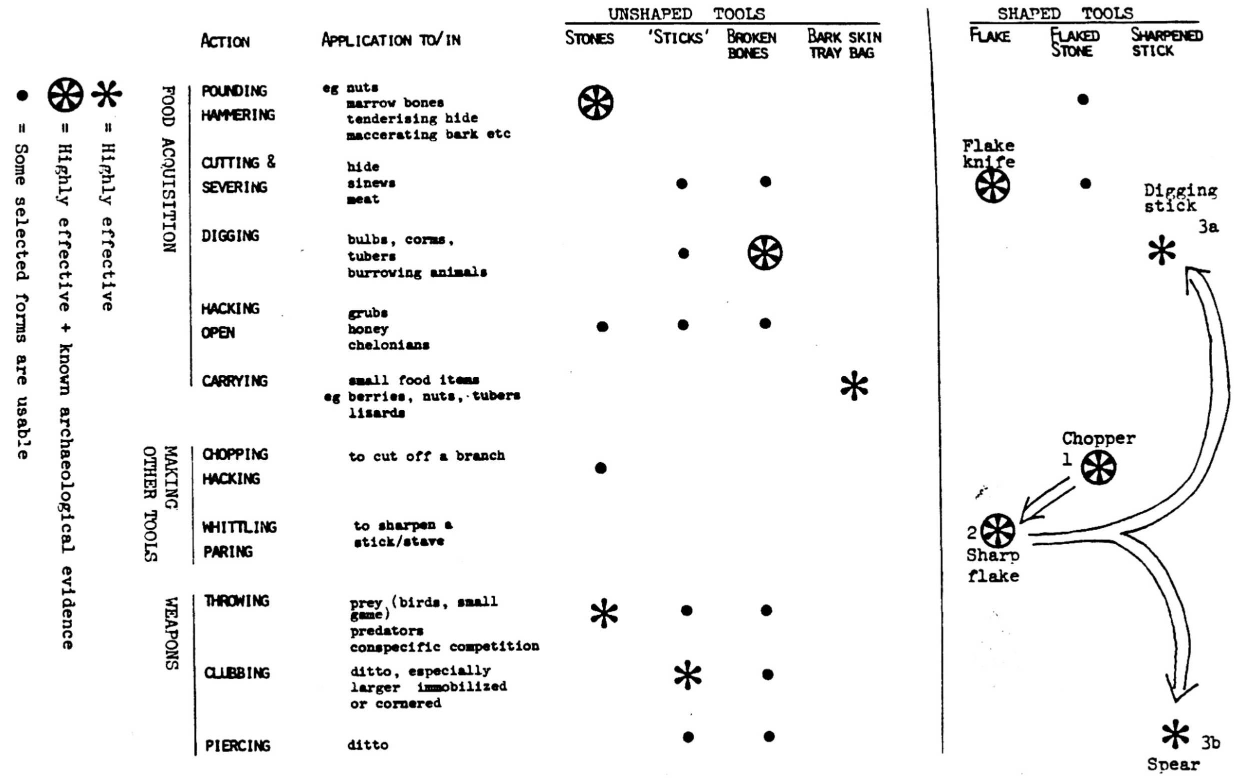
**Table 5.3. (cont'd)**

| Task | Form | Raw Material | Size Class | Time taken | Rank |
|---|---|---|---|---|---|
| Defleshing (29) | DP | Quartz (NS) | smallest | 2.67 | 1 |
|  | DP | Quartz (Nais) | smallest | 3.08 | 2 |
|  | DP | Other | smallest | 3.08 | 2 |
|  | DP | Lava (Sad) | smallest | 3.50 | 4 |
|  | DP | Quartz (NS) | smallest | 3.70 | 5 |
|  | DP | Lava (Sad) | smallest | 4.00 | 6 |
|  | FP >50 | Quartz (NS) | smallest | 5.12 | 7 |
|  | FP<50 | Quartz (NS) | medium | 5.42 | 8 |
|  | DP | Lava (Lem) | smallest | 6.00 | 9 |
|  | FP<50 | Other | smallest | 6.70 | 10 |
|  | DP | Lava (Lem) | smallest | 7.00 | 11 |
|  | DP | Lava (Lem) | smallest | 7.50 | 12 |
|  | DP | Other | smallest | 7.92 | 13 |
|  | FP<50 | Quartz (Nais) | small | 8.58 | 14 |
|  | FP<50 | Lava (Sad) | small | 8.88 | 15 |
|  | FP<50 | Other | small | 9.00 | 16 |
|  | FP<50 | Quartz (Nais) | small | 9.05 | 17 |
|  | DP | Other | smallest | 11.25 | 18 |
|  | DP | Lava (Lem) | smallest | 11.50 | 19 |
|  | DP | Lava (Lem) | smallest | 12.00 | 20 |
|  | DP | Other | smallest | 13.08 | 21 |
|  | FP<50 | Lava (Sad) | small | 16.00 | 22 |
|  | DP | Quartz (NS) | smallest | 20.50 | 23 |
|  | FP >50 | Lava (Lem) | small | 24.75 | 24 |
|  | DP | Lava (Sad) | smallest | 25.00 | 25 |
|  | DP | Lava (Lem) | smallest | 28.00 | 26 |
|  | DP | Lava (Sad) | smallest | 29.00 | 27 |
|  | DP | Other | smallest | 36.00 | 28 |
|  | FP<50 | Lava (Sad) | small | 60.00 | 29 |
| Dis-articulation (17) | FP<50 | Quartz (Nais) | small | 0.22 | 1 |
|  | FP >50 | Quartz (NS) | small | 0.35 | 2 |
|  | FP<50 | Lava (Lem) | small | 0.77 | 3 |
|  | DP | Quartz (Nais) | smallest | 1.60 | 4 |
|  | DP | Quartz (Nais) | smallest | 2.17 | 5 |
|  | DP | Other | smallest | 2.17 | 5 |
|  | FP<50 | Quartz (NS) | small | 2.62 | 7 |
|  | FP >50 | Lava (Lem) | small | 2.78 | 8 |
|  | DP | Lava (Lem) | smallest | 3.20 | 9 |
|  | DP | Lava (Sad) | smallest | 3.37 | 10 |
|  | DP | Lava (Sad) | smallest | 3.42 | 11 |
|  | FP<50 | Quartz (Nais) | small | 5.02 | 12 |
|  | FP<50 | Quartz (Nais) | large | 6.45 | 13 |
|  | FP<50 | Lava (Lem) | small | 7.00 | 14 |
|  | FP >50 | Lava (Lem) | largest | 11.00 | 15 |
|  | DP | Lava (Lem) | smallest | 18.00 | 16 |
|  | FP >50 | Lava (Sad) | small | 60.00 | 17 |

**Table 5.3. (cont'd)**

Isaac's (1983) discussion of lifeways of the earliest toolmakers characterizes optimal tool forms for specific tasks, hypothesizing the relative utility of Oldowan tool forms based upon the results of feasibility experiments carried out by Peter Jones (1979,1980,1981) at Olduvai Gorge, and by Nick Toth (1982), at Koobi Fora. However, Isaac's hypothesized rankings do not reflect the full range of Oldowan tool types observed in the archaeological record (*see* Chapter 3).

Isaac separated tool use for food acquisition from tool use in making other tools or as weapons (Figure 5.2). In an attempt to refine Isaac's hypothesized utility ranking, I used my experimental data to formulate another relative utility index.



| | Action | Application to/in | Unshaped tools: Stones | 'Sticks' | Broken bones | Bark skin tray bag | Shaped tools: Flake | Flaked stone | Sharpened stick |
|---|---|---|---|---|---|---|---|---|---|
| FOOD ACQUISITION | POUNDING<br>HAMMERING | eg nuts<br>marrow bones<br>tenderising hide<br>maccerating bark etc | ⊛ | | | | | ● | |
| | CUTTING &<br>SEVERING | hide<br>sinews<br>meat | | ● | ● | | Flake knife ⊛ | ● | |
| | DIGGING | bulbs, corms,<br>tubers<br>burrowing animals | | ● | ⊛ | | | | Digging stick 3a * |
| | HACKING<br>OPEN | grubs<br>honey<br>chelonians | ● | ● | ● | | | | |
| | CARRYING | small food items<br>eg berries, nuts, tubers<br>lizards | | | | * | | | |
| MAKING OTHER TOOLS | CHOPPING<br>HACKING | to cut off a branch | ● | | | | | Chopper 1 ⊛ | |
| | WHITTLING<br>PARING | to sharpen a stick/stave | | | | | 2 ⊛ Sharp flake | | |
| WEAPONS | THROWING | prey (birds, small game)<br>predators<br>conspecific competition | * | ● | ● | | | | |
| | CLUBBING | ditto, especially larger immobilized or cornered | | * | ● | | | | |
| | PIERCING | ditto | | ● | ● | | | | * 3b Spear |

* = Highly effective

⊛ = Highly effective + known archaeological evidence

● = Some selected forms are usable

Fig. 5.2. Hypothesized utility rankings for Oldowan tools (*after* Isaac, 1983).

In my newly hypothesized relative utility index, tasks are separated into woodworking and butchery (Fig. 5.3). The utility index is presented in a matrix of task (action) and tool, but uses only stone tool type categories that are also used in the technological description of known Oldowan archaeological material. Within each tool group, the utility of that type is presented by the ranked categories of highly effective, adequate, and poor to ineffective. The last category (poor to ineffective) includes both tools that performed poorly, but could still do the job, and those that on occasion failed or were deemed ineffective thus the task was abandoned.

| | **Action** | **Tool** | | | |
|---|---|---|---|---|---|
| | | Unmodified Cobble | Detached Piece | Flaked Piece < 50% | Flaked Piece > 50% |
| Woodworking | Procuring Stick | ⊖ | ⊖ | ✪ | ☆ |
| | Chopping Wood | ⊖ | ⊖ | ✪ | ⊖ |
| | Sharpening Stick | ⊖ | ⊖ | ✪ | ☆ |
| Butchery | Defleshing | ⊖ | ✪ | ⊖ | ☆ |
| | Pounding (Bone) | ✪ | ⊖ | ✪ | ☆ |
| | Skinning | ⊖ | ✪ | ☆ | ⊖ |
| | Disarticulating | ⊖ | ☆ | ✪ | ⊖ |

✪ = highly effective ☆ = adequate ⊖ = poor to ineffective

**Fig. 5.3. Modified from Isaac's (1983) hypothesized tool utility rankings, the utility is defined here in terms of tool form only. Utility rankings shown here represent new experimental data using replicated Oldowan tool forms.**

Instead of separating tool-assisted tasks according to food acquisition or tool making, tool-assisted tasks might also be grouped as those which are extractive, whereby the yield of a resource is immediate (such as chopping wood, defleshing, pounding bone, and carcass disarticulation), and those which are investitive, whereby the yield of a resource may be a delayed (such as procuring and sharpening a stick, and skinning). For instance, sharpening a stick does not produce an immediate yield, but the sharpened stick may be used to access USOs. Skinning is classified as an investitive task; a means of gaining access to flesh.

Artifacts can be described by different morphological variables. In the experimental methodology presented in this thesis, the variables include, but are not limited to, tool form. They also incorporate tool size and raw material type. In order for the new relative utility ranking to truly be refined and reflect a fuller range of Oldowan tool forms, it should consist of all three of the diagnostic variables which I have previously discussed. The incorporation of the full suite of variables into a relative utility ranking is shown below (Table 5.4).

**Relative Tool Utility Ranking**
according to tool form, raw material type, and size range

| Ranking / Task | Highest (4) | High (3) | Medium (2) | Low (1) | Lowest-None (0) |
|---|---|---|---|---|---|
| **Procuring stick** | FP>50<br>Naibor Soit<br>large | FP<50<br>Sadiman<br>medium | DP<br>Lemagrut<br>largest | other<br>Naisiusiu<br>small | UC<br>other<br>smallest |
| **Sharpening stick** | FP<50<br>Naisiusiu<br>largest | FP<50<br>Lemagrut<br>medium | DP<br>Sadiman<br>large | other<br>Naibor Soit<br>small | UC<br>Other<br>smallest |
| **Skinning** | DP<br>Naibor Soit<br>smallest | FP<50<br>Sadiman | FP>50<br>other | other<br>Lemagrut | UC<br>Naisiusiu |
| **Disarticulation** | FP<50<br>Naibor Soit<br>large | DP<br>Other<br>small | FP>50<br>Naisiusiu<br>smallest | Other<br>Lemagrut<br>largest | UC<br>Sadiman<br>medium |
| Chopping Wood | FP<50<br>Lemagrut<br>largest | FP>50<br>Naisiusiu<br>large | NA<br>NA<br>medium | NA<br>NA<br>NA | UC, DP<br>other<br>small, smallest |
| Digging (USO's) | other(stick)<br>other(stick)<br>NA | DP<br>Naisiusiu<br>largest | NA | NA | FP<,FP>50<br>NA<br>NA |
| Defleshing | DP<br>Naisiusiu<br>small | FP>50<br>Naibor Soit | FP<50<br>Lemagrut | Other<br>Sadiman | UC<br>other |
| Pounding (nut/bone) | UC<br>Naisiusiu<br>largest | FP>50<br>Other<br>large | FP<50<br>Sadiman<br>medium | other<br>Lemagrut<br>small,<br>smaller | DP<br>NA<br>NA |

Table 5.4. Relative utility index. Tool forms based on Isaac, 1983. Size range based on index of weight(gms)/maximum dimension (mm) from smallest-largest. Shaded cells are investitive procedures, unshaded are extractive procedures.

The inherent complexity of representing three different variables with several variable states is dealt with next by grouping the utility ranking by tool form. Variation in tool size is described by their mass ratio. The raw material component has been collapsed into three materials classes; Lava, Quartzite, and Other. The difference between Lemagrut and Sadiman lava, or Naibor Soit and Naisiusiu quartzite is of interest, especially in matters of transport cost, and will be considered later on in the modeling process. It is not directly relevant to function and is not considered at present. While the representation of raw material types is inequable in the experimental trials, the raw material type proportions that are represented may actually reflect the raw material composition in the archaeological record more accurately.

**Experimentally derived utility rankings**

| | | Lava | Quartzite | Other |
|---|---|---|---|---|
| Unmodified Cobble | Small | | pounding ○ | pounding ○ |
| | Medium | | pounding ○ | pounding ✻ |
| | Large | chopping wood ● | | pounding ✻ |

| | | Lava | Quartzite | Other |
|---|---|---|---|---|
| Detached Piece | Small | procure stick ●<br>sharpen stick ●<br>skinning ○<br>deflesh ✻<br>disarticulate ○ | procure stick ●<br>sharpen stick ●<br>skinning ✻<br>deflesh ✻<br>disarticulate ○<br>pounding ● | deflesh ● |
| | Medium | procure stick ○ | | |
| | Large | | | |

| | | Lava | Quartzite | Other |
|---|---|---|---|---|
| Flaked Piece <50% | Small | procure stick ✻<br>sharpen stick ✻<br>skinning ○<br>deflesh ○<br>pounding ● | sharpen stick ✻<br>skinning ○<br>deflesh ○<br>disarticulate ○ | |
| | Medium | procure stick ○<br>sharpen stick ○<br>deflesh ○<br>chopping wood ●<br>disarticulate ✻<br>pounding ✻ | procure stick ○<br>skinning ○<br>deflesh ○<br>disarticulate ✻ | |
| | Large | chopping wood ✻ | chopping wood ● | |

| | | Lava | Quartzite | Other |
|---|---|---|---|---|
| Flaked Piece >50% | Small | procure stick ○<br>sharpen stick ○<br>skinning ●<br>deflesh ●<br>disarticulate ○ | sharpen stick ○<br>skinning ○<br>deflesh ○<br>disarticulate ✻ | procure stick ○ |
| | Medium | sharpen stick ○<br>pounding ○ | sharpen stick ○<br>skinning ○ | pounding ✻ |
| | Large | disarticulate ● | | |

✻ = **highly effective** ○ = **adequate** ● = **poor to ineffective**

**Table 5.5. The hypothesized advanced relative utility of Oldowan tool forms by the ranked categories: highly effective, adequate, and poor to ineffective.**

The utility of the tool type is presented in Table 5.5. Here the tool effectiveness is ranked relative to a specific task, grouped by size and raw material type. It is important to note that these experiments were carried out with the intention of assessing tool utility alone. They did not account for ecological context (i.e., resource availability). These results do not differentiate which of the gross variables of size, shape, and raw material has the most impact upon the tool's efficiency.

In order to model the ideal tool form for a particular task, I identify the individual best time for each variable (Table 5.6) and use only the hypothetical optimal tool forms for each task to model the expected tool forms discussed in the following chapter (Part III).

**Best mean time for each gross variable category**

| TASK | Form | Raw Material | Mass |
|---|---:|---:|---:|
| **Procuring stick** | Flaked Piece >50% | Quartzite (Naibor Soit) /Other | small |
| **Sharpening stick** | Flaked Piece <50% | Quartzite (Naisiusiu) | medium |
| **Chopping wood** | Flaked Piece <50% | Lava (Lemagrut) | largest |
| **Skinning** | Detached Piece | Quartzite (Naibor Soit) | smallest |
| **Disarticulation** | Flaked Piece <50% | Quartzite (Naibor Soit) | smallest |
| **Defleshing** | Detached Piece | Quartzite (Naisiusiu) | medium |
| **Pounding (bone)** | Unmodified Cobble | Lava (Sadiman) | medium |

**Table 5.6. The minimum amount of time taken to perform each task is represented for individual categories of tool form, raw material type, and tool mass.**

### *Summary of Observations*

The experimental manufacture and use of the various Oldowan tool forms provided empirical data concerning their relative utility. Considering all of the tool form gross variables, (i.e., raw material, and size), the resulting data demonstrates a distinct optimal tool for each task.

The relative utility of tool forms presented here is based solely upon the amount of time taken to complete a task. The amount of energy expenditure involved in completing a task was not factored into the utility assessment. For instance, only those Flaked pieces >1 kg were useful in chopping wood, but large pieces are generally tiresome to wield (in general, after 20 minutes, a task becomes increasingly exhaustive). Flaked Pieces <50% are, on average, most efficient at sharpening sticks, chopping wood, and limb disarticulation. These tasks all call for considerable applied force. The unmodified edge, present in a Flaked Piece <50%, is easier to grip, allowing for a more efficient application of force.

Some observations made while performing the experiments were noted and may prove useful in future research. For instance, while it is not surprising that unmodified cobbles are on average most efficient at pounding bone for marrow extraction, it is surprising that small detached pieces are on average most efficient at skinning and defleshing considering the following:

- Skinning was the most labor intensive butchery task
- Scrap defleshing is extremely time consuming and the smallest detached pieces were most efficient.
- Prior to skinning, only large tools are useful for disarticulation.
- After skinning, disarticulation is possible with just about any tool form.

In the methodology I employed, the modeling process that begins with proposing an explicit set of tasks, currencies, and constraints is followed by experimentally establishing how variation in the material record should respond. The experimental data and the qualitative observations presented and discussed in this section will be used to generate some of the test implications that model the nature and distribution of lithic assemblages in the paleo-Olduvai Basin in the following chapter.

# CHAPTER SIX

# MODELING EARLY HOMINID STONE TOOL DISCARD PATTERNS AT OLDUVAI GORGE

## Introduction

Variability in the composition of Oldowan lithic artifact on the assemblage level across landscapes has not been well described and is even less well understood. In an attempt to identify and better understand the character of distributional patterns seen in the Oldowan artifacts during Middle-Upper Bed I and lowermost Bed II times in Olduvai Gorge, the main question put forward in this thesis is whether simple behavioral models can be used to explain the variability in artifact discard and loss patterns across the Olduvai paleolandscapes. In order to address this question, this chapter presents an approach derived from a method first hypothesized by Isaac *et al.* (1981) to explain inter and intra-site artifact assemblage variability. Regarding simple stone tools as the material traces of early hominid behavior, Isaac *et al.* (1981) constructed a step-wise mechanism in reference to a series of factors ranked by their complexity. This step-wise mechanism is the foundation for the ensuing discussion and development of my predictive model.

Using Isaac's (1981) hypothetical technological strategies as heuristics in a hierarchical three-step predictive model for lithic artifact distribution across the Olduvai paleolandscape, I explore how simple or complex a model can or need be to address questions of early human stone tool-using behavior.

Isaac's hypothesized first step, the simplest explanation to account for the range of forms within a lithic artifact assemblage, is the application of flaking procedures to the most readily available material. That is referred to herein as the opportunistic strategy. Any tool form not accounted for in step one might be accounted for in his hypothesized second step, if distance to source and the economization of resources (i.e., raw material and energy as transport cost) were a factor. This is referred to herein as the expedient strategy. Tool forms not accounted for in the preceding two steps might be accounted for in the hypothesized third step, whereby energy invested in technology is a decision that factors in tool function and the cost and benefits associated with tool use and ecological factors relative to a specific task. That is referred to herein as the optimization strategy. The remaining forms unaccounted for by steps 1-3 may be attributed to cultural or stylistic preferences, which are not considered in this thesis.

The three-step model describes an increasing complexity in the interpretation of stone tool use across the paleolandscape, beginning with the tool manufacture and use as it relates to available raw material, then as it applies to transport and re-use of materials, then as it pertains to availability of resources and their associated exploitation risks, and the anticipated task. Table 6.1A illustrates the behavioral models' increasing complexity of determinants that influence the behavior and the underlying principle of each behavioral strategy.

Along with the increasing contextual complexity discussed above, an increase in the number of diagnostic lithic assemblage variables is assumed. These variables are identified in Table 6.1B.

| **Behavioral Model** | **Determinants** | **Underlying Principle** |
|---|---|---|
| **1. Opportunistic Strategy** | Raw material availability | Least effort |
| **2. Expedient Strategy** | Raw material availability anticipated tasks | Raw material conservation<br>Economization |
| **3. Optimization Strategy** | Resource availability and distribution, anticipated tasks predator encounter risk | Maximization of resource exploitation<br>Minimization of risk |

Table 6.1A. Hierarchy of theoretical model variables.

| Lithic Morphological Variables | Step 1 Opportunistic Strategy | Step 2 Expedient Strategy | Step 3 Optimization Strategy |
|---|---|---|---|
| Raw Material Type | X | X | X |
| Raw Material Quality | | | X |
| Flaked Piece Size | X | X | X |
| Detached Piece Size | | X | X |
| Flaked Piece Type (form) | | X | X |
| Detached Piece Type (form) | | X | X |
| Artifact Density | X | X | X |
| Artifact Diversity | | | X |

**Table 6.1B. Lithic assemblage variables used for predictions of different technological strategies.**

In the first step of the model, the opportunistic technological strategy, "*strictly* situational tool manufacture and use" (*italics added,* Nelson 1988) is theorized, whereby the unplanned rather than the anticipated manufacture and use of tools is indicated. The first step utilizes locational data based on the distance of raw material sources to specific Landscape Associations to predict a least-effort opportunistic stone tool discard and loss pattern on a landscape.

In the second step, the expedient strategy, economization of raw material is assumed and the extent of manufacture is subject to the proximity of raw materials and transport in anticipation of future need of tools (*see* Binford 1979). In the expedient technological strategy, the reuse of resources is indicated, most notably in a simple linear transport “stone flow” (*re:* Isaac 1984) whereby raw material is transported in a unidirectional manner away from its source. The second step incorporates morphological data (assumed to be diagnostic of transport behavior) with source distance data, and is used to predict economizing stone tool discard and loss patterns on a landscape.

In the third step, the optimization strategy, a behavioral ecological approach considering cost and benefit is assumed in the exploitation of available resources and the minimization of predator encounter risk. The third step combines hypothesized relative tool utility data resulting from the replicative experiments presented in the previous chapter with ecological variables to predict optimizing stone tool discard and loss patterns on a landscape.

### *Linking Behavioral Traces to Behavioral Strategies: Theory*

Behavioral traces such as lithic artifact assemblages are influenced by to the context in which they were deposited. If opportunistic tools are likely to be manufactured and used impromptu and discarded or lost in the context of their use (Jones *et al* 1989), then their distribution on a landscape should reflect the available clast size and raw material density indicative of proximity to a particular source. The nature of expedient technology also supports arguments that spatial distributional patterns (e.g., scatters and patches) more likely result from behavioral processes rather than random ones (Binford, 1980,1983; Foley 1981; Isaac 1981). If expedient tools are manufactured and used and subsequently transported in anticipation of future need, re-use, and material conservation, then their distribution on a landscape should reflect the extent of manufacture, or reduction stage, indicative of the distance from their source. If optimization involves using the most efficient tool form for a specific task, then the distribution of lithic artifacts on a landscape should reflect the distribution of resources, the associated risks to exploiting those resources, and the optimal tool forms for accomplishing those tasks. By integrating empirical tool function data with hypothesized risk and resource availability, the optimization model presented here refines the stone tool component of the Blumenschine and Peters (1998) predictive model of Oldowan artifact discard and loss patterns across landscapes in the paleo-Olduvai Basin during LMB II times.

Since variation in lithic artifact density and diversity has already been demonstrated for Middle and Upper Bed I and lowermost Bed II times at Olduvai (Tactikos 2002), perceiving how this is related to ecological context is the logical next step in furthering the understanding of lithic artifact distributional variability, and ultimately, of the tool-using strategy of the early Oldowan hominids.

### *Methodological and Analytical Tools*

An underlying premise of lithic artifact analysis is that production of different kinds of stone tools can produce distinctive types of debitage, and detached pieces have morphological characteristics that provide clues to how and from what kind of core they were derived (Andrefsky 2001). Lithic tool production is a subtractive process, through which the systematic reduction of a stone core is carried out to achieve a desired product. This concept is recognized as the reduction sequence in North America (Bradley 1975; Frison 1968; Shott 2003; Villa 1978) and *chaine operatoire* in Europe (Leroi-Gourhan 1964), and is meant to incorporate the processes of lithic production and use into the classification and technological interpretation of stone tools. Isaac and Harris (1980) formulated the classificatory system of “Flaked Piece, Detached Piece, and Pounded Piece” (*see also* Isaac *et al*. 1981) with the intention of describing lithic artifacts and illustrating a range of potentially useful forms, but not presupposing purpose or function. A Flaked Piece type conveys the morphology of a specimen, the degree of core reduction done on a specimen, and its place in a reduction and transport sequence (Isaac 1984). It is likely that as the tool-using behavior is conducted further from the source of stone, the degree of core reduction will be higher, and the Flaked Piece size will diminish, resulting in more extensively flaked pieces of a smaller size. A Detached Piece type can also indicate by the percentage of cortex on the striking platform and cortical surface, its relative place in the core reduction sequence (Toth 1982, Villa 1978). A Pounded piece, when distinct in its size and character from the matrix it was recovered in, can convey human transport, and pitting and/or bruising on its surface can indicate its utility as a percussor tool and/or a hammer for fashioning another tool.

Since both the opportunistic and expedient strategies are linked to raw material availability, it should be noted that there are many unknowns concerning raw material provenience. First of all, it is assumed that the raw material available today in the Olduvai area was also available 1.7-1.8 Ma. Raw material from currently available inselbergs like Naibor Soit is known to have been available prehistorically (Hay 1976) but may have been inaccessible during intermittent high lake stands. Other inselbergs that are buried today may also have been available earlier. Tabular nodules of Naibor Soit in the archaeological record suggest they were harvested close to their source, as the shape is consistent with mass wasting, rather than long distance stream transport and fluvial rounding (*see* Pearce 1971). The provenance data for quartzite and gneiss used in this study were calculated using the primary source areas’ UTM (Universal Transverse Mercator) coordinates for Naibor Soit, Naisiusiu, and Kelogi, documented by OLAPP, and for lava using the UTM coordinates recorded by myself during the sampling of raw materials from modern drainages of Sadiman and Lemagrut. Those sample points were taken from drainages where no other tributaries were present. This criterion was probably irrelevant to the early hominid raw material selection process, but it is assumed for the purposes of this thesis. Sampling of clasts from Sadiman and Lemagrut drainages revealed several varieties of these two lavas, many of which are not seen in the archaeological record. From this fact one could surmise that either these varieties were not available to hominids 1.7-1.8 Ma, or that the hominids did not transport such raw material into the central basin. Modern channels draining the volcanic highlands of Lemagrut and Sadiman were used as secondary source points for the lavas, whose primary sources are at considerable distances from the Gorge. Exactly where the secondary source drainages were in the paleo-Olduvai Basin is not known, but secondary source locations were extrapolated using estimates of where the extreme southwestern lake margin might have been during lowermost Bed II times (Hay, *pers comm*.). The existence of fresh water stream inlets along the eastern margin of the paleo-lake is supported by evidence for fluvial transport of lavas into the paleobasin during the deposition of Bed I at loc. 37, above the basal basalt but below Tuff IB. In this locality, basalt pebbles between 2-6 inches in diameter were observed in coarse channel deposits (Hay, *pers comm.)*. The highest lake level known at the time of the deposition of Tuff IF, the base of lowermost Bed II, is considered as the maximum distance that drainages might have carried volcanic clasts from Lemagrut and Sadiman, and is speculated as a minimum distance that hominids might have had to transport a lava clast to the point of discard, barring extremes of climate resulting in heavy flooding episodes that could have otherwise carried clasts of these sizes.

Besides the main thesis question of whether hypothetical strategies can be used to explain spatial distributional patterns of stone artifacts, another concern is the effect of the spatial scale of investigation upon the perceived patterns of lithic discard. It is not known at what scale distance functions involving transport of stone by hominids were operable, or archaeologically visible. Another related concern is that the effect distance has on the threshold between different size clasts, raw material densities, and core reduction stages are unknown (Shott 1996, 2003). These variables are dependent upon a range of factors including specific raw material type, topography, and hominid physical capability and behavioral preference. The relationship of distance to any of these variables may exist in any number of regression scenarios described by various slope and Y-intercept values.

Addressing these considerations, I model and test the hypothetical strategies of land use against the observed archaeological occurrences. I employ two different spatial scales of analysis in testing the proposed models: the scale of Landscape Association, and the scale of Paleogeographic Locale (see Table 3.1). For the purpose of this thesis, I will assume a linear relationship between transport distance and clast size, raw material, artifact densities, and reduction stages, and use relative interval values to describe the variable states.

### ***Step 1: The opportunistic strategy***

In the most rudimentary of the behavioral models, the opportunistic strategy, lithic artifact discard and loss pattern differentiation would be attributable to raw material availability in a given area. Both the size and abundance of available raw material are assumed to diminish as the distance from their source increases. Following this logic, the major factor affecting the type, size, and density of available raw material and the associated lithic behavioral traces at a particular locus is considered to be source provenience.

I begin by modeling lithic behavioral traces of the opportunistic strategy in the Landscape Association scale. Given the extremely small sample size of the Lake Landscape Association (n = 1), it has been omitted from further comparisons. The expected occurrences of raw material types in each Landscape Association unit are based upon the distance from each raw material source (Table 6.2A). Distances from each Landscape Association to each raw material source were derived from the mean northing and easting coordinates of each Landscape Association and applying the following formula:

SQRT((northing 1-northing 2)^2 + (easting 1-easting 2)^2)

| **Landscape Association** | **Raw Material Source** | | | | |
|---|---|---|---|---|---|
| | Lemagrut | Sadiman | Naibor Soit | Naisiusiu | Kelogi |
| **WLP** | 11.42 | 12.91 | 10.99 | 0.58 | 9.30 |
| **SWLP** | 5.50 | 10.09 | 12.66 | 9.92 | 1.25 |
| **ELP** | 5.62 | 1.65 | 3.38 | 11.92 | 9.95 |
| **ELP/EAP** | 7.39 | 2.77 | 3.70 | 13.72 | 11.94 |
| **EAP** | 8.40 | 3.72 | 4.36 | 14.77 | 13.05 |
| **NELP** | 13.24 | 8.89 | 5.58 | 16.04 | 17.15 |

**Table 6.2A. Distance (in km) from Landscape Associations to raw material sources**

The expected artifact size and abundance values are ranked within each Landscape Association, according to the relative distance of each Landscape Association from every raw material source. For example, the source of Sadiman lava is 12.91 km from the WLP. It is the most distant raw material source from the WLP and is ranked lowest, meaning that it is expected to occur in the lowest frequency, and to represent the smallest-sized artifacts in the WLP. Lemagrut (11.42 km), Naibor Soit (10.99 km), Kelogi (9.30 km) and Naisiusiu (0.58 km) are closer to the WLP and are ranked accordingly (Fig. 6.1).

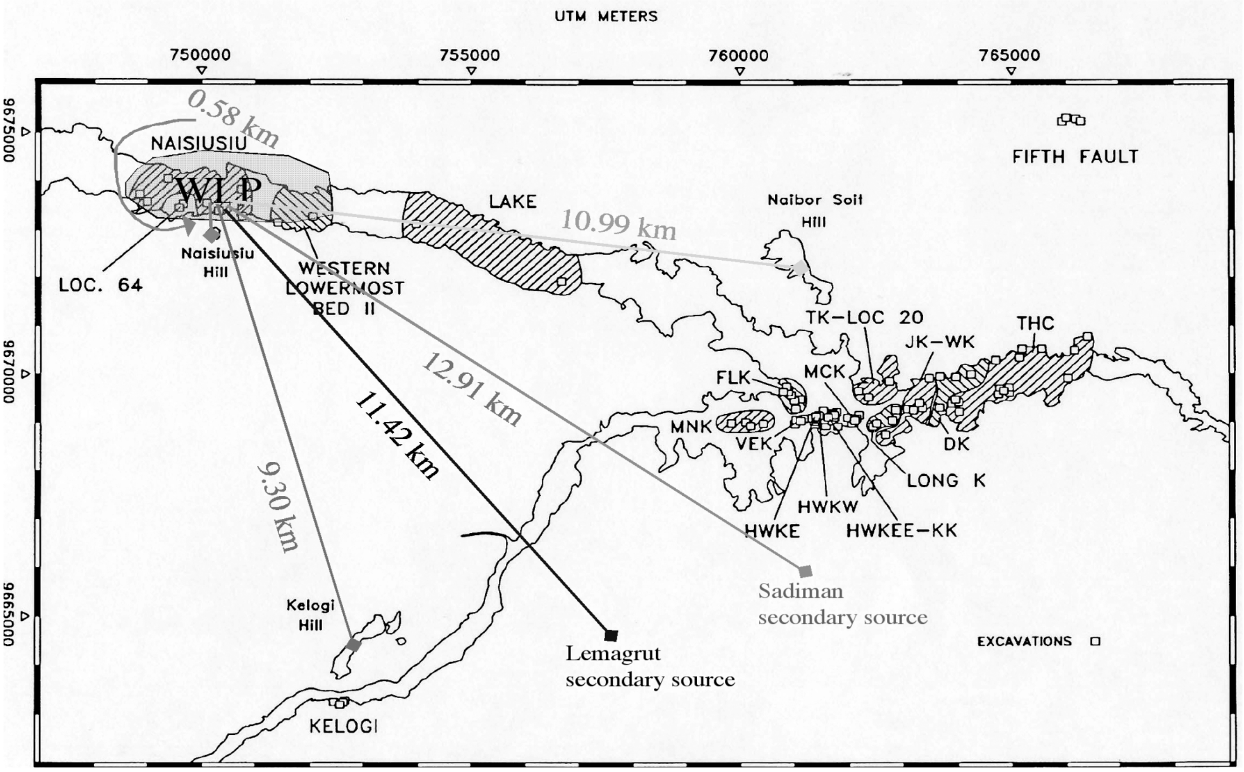


**Fig. 6.1. Map of gorge showing UTM coordinates and distances from raw material sources to the WLP (*from* Blumenschine et al. *in press*.).**

The values are represented ordinally as highest, or the nearest to the source (therefore the greatest expected density and largest size) to lowest, or the furthest from the source (therefore the least expected density and smallest size) in a specific Landscape Association (Table 6.2B).

| Expected frequency of artifact size and density | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Landscape Association | Lemagrut | | Sadiman | | Naibor Soit | | Naisiusiu | | Kelogi | |
| | size | density | size | density | size | density | size | density | size | density |
| WLP | small | low | smallest | lowest | medium | medium | largest | highest | large | high |
| SWLP | large | high | small | low | smallest | lowest | medium | medium | largest | highest |
| ELP | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| ELP/EAP | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| EAP | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| NELP | medium | medium | large | high | largest | highest | small | low | smallest | lowest |

**Table. 6.2B. Hypothesized relative occurrences of raw material type, artifact size and density for the opportunistic strategy. Relative size classes are smallest, small, medium, large, largest. Relative density states are lowest, low, medium, high, highest.**

Of the six Landscape Association units, the model predicts 67% of the loci will display distinctive or variable raw material compositional characteristics. The Eastern Lacustrine Plain, the transitional Eastern Lacustrine, Eastern Alluvial Plains, and Eastern Alluvial Plain are expected to show similar patterns of stone tool discard and loss in that artifacts made on Sadiman lava will display the highest density and largest size, followed by artifacts made on Naibor Soit quartzite, Lemagrut lava, Kelogi gneiss, and Naisiusiu quartzite. That will differ from the Western Lacustrine Plain, with artifacts made on Naisiusiu quartzite displaying the highest density and largest size, followed by artifacts made on Kelogi gneiss, Naibor Soit quartzite, Lemagrut lava, and Sadiman lava. In the Southwestern Lacustrine Plain artifacts made on Kelogi gneiss should display the highest density and largest size followed by artifacts made on Lemagrut lava, Naisiusiu quartzite, Sadiman lava, and Naibor Soit quartzite. In the Northeastern Lacustrine Plain artifacts made on Naibor Soit quartzite should display the highest density and largest size followed by artifacts made on Sadiman lava, Lemagrut lava, Naisiusiu quartzite, and Kelogi gneiss.

The model also predicts that in the Western Lacustrine Plain, the highest artifact density and largest Flaked and Detached Pieces will be comprised of Naisiusiu quartzite. In the Southwestern Lacustrine Plain these values will be highest for Kelogi gneiss/quartzite. In the Northeastern Lacustrine Plain these values will be highest for Naibor Soit quartzite, and in the Eastern Lacustrine Plain, the transitional area (ELP/EAP), and the Eastern Alluvial Plain the highest values will be seen for Sadiman lava.

Examining the relationship of raw material availability to artifact size and density in a higher resolution spatial scale, the distance from each Paleogeographic Locale to each raw material source is shown in Table 6.3A. Distances from each Paleogeographic Locale to each raw material source were derived by applying the same formula as discussed above (page 141) to the mean northing and easting coordinates of each Paleogeographic Locale. The predicted relative artifact size and abundance values within each Paleogeographic Locale is shown in Table 6.3B.

| **Paleogeographic Locales** | **Distance (km) from raw material sources to locales** | | | | |
|---|---|---|---|---|---|
| | Lemagrut | Sadiman | Naibor Soit | Naisiusiu | Kelogi |
| Loc. 64 | 11.88 | 13.52 | 11.67 | 0.84 | 9.50 |
| Naisiusiu | 12.12 | 13.70 | 11.77 | 1.08 | 9.76 |
| West-Lake | 10.32 | 11.53 | 9.54 | 1.54 | 8.78 |
| Kelogi | 5.50 | 10.09 | 12.66 | 9.92 | 1.25 |
| MNK | 4.45 | 2.17 | 3.91 | 10.60 | 8.43 |
| FLK | 5.57 | 2.16 | 3.00 | 11.25 | 9.63 |
| VEK | 5.25 | 1.66 | 3.48 | 11.53 | 9.49 |
| HWKW | 5.45 | 1.64 | 3.42 | 11.74 | 9.74 |
| HWKE | 5.48 | 1.46 | 3.56 | 11.97 | 9.85 |
| HWKEE-KK | 5.66 | 1.59 | 3.44 | 12.05 | 10.03 |
| MCK | 5.92 | 1.58 | 3.55 | 12.45 | 10.37 |
| TK-Loc. 20 | 6.75 | 2.35 | 3.13 | 12.79 | 11.14 |
| LongK | 6.33 | 1.78 | 3.73 | 12.98 | 10.88 |
| JK-WK | 6.99 | 2.39 | 3.66 | 13.43 | 11.54 |
| DK-Complex | 7.78 | 3.15 | 3.79 | 14.01 | 12.35 |
| THC-Complex | 8.40 | 3.72 | 4.36 | 14.77 | 13.05 |
| Fifth-Fault | 13.24 | 8.89 | 5.58 | 16.04 | 17.15 |

**Table. 6.3A. Mean distance (km) from raw material source to Paleogeographic Locale.**

These values are represented using the same ranking as was implemented in the Landscape Association scale.

**Expected occurrence of artifact size and density**

| **Paleogeographic Locales** | Lemagrut | | Sadiman | | Naibor Soit | | Naisiusiu | | Kelogi | |
|---|---|---|---|---|---|---|---|---|---|---|
| | size | density | size | density | size | density | size | density | size | density |
| Loc. 64 | small | low | smallest | lowest | medium | medium | largest | highest | large | high |
| Naisiusiu | small | low | smallest | lowest | medium | medium | largest | highest | large | high |
| West-Lake | small | low | smallest | lowest | medium | medium | largest | highest | large | high |
| Kelogi | large | high | small | low | smallest | lowest | medium | medium | largest | highest |
| MNK | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| FLK | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| VEK | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| HWKW | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| HWKE | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| HWKEE-KK | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| MCK | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| TK-Loc. 20 | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| LongK | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| JK-WK | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| DK-Complex | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| THC-Complex | medium | medium | largest | highest | large | high | smallest | lowest | small | low |
| Fifth-Fault | medium | medium | large | high | largest | highest | small | low | smallest | lowest |

**Table. 6.3B. Hypothesized relative occurrences of artifact size and density for the opportunistic strategy. Relative size classes are smallest, small, medium, large, largest. Relative density states are lowest, low, medium, high, highest.**

At the Paleogeographic Locale scale, the model predicts that in Loc. 64, Naisiusiu, and the West-Lake, the highest artifact density and largest Manuports and Flaked Pieces will be comprised of Naisiusiu quartzite; in Kelogi it will be Kelogi gneiss/quartzite; in MNK, FLK, VEK, HWKW, HWKE, HWKEE-KK, MCK, TK-Loc. 20, LongK, JK-WK, the DK-Complex, and the THC-Complex it will be Sadiman lava; and in the Fifth-Fault it will be Naibor Soit quartzite.

At this spatial scale, even less variation is expected between landscape units in relative artifact size and density. Of the seventeen Paleogeographic Locales, only four (24%) provide data that predict distinctive artifact discard and loss patterns for each raw material type. In fact, in this higher-resolution grouping, I am unable to predict differences in the raw material composition among the three locales in the western landscape or among most of the locales in the eastern landscape (MNK, FLK, VEK, HWKW, HWKE, HWKEE-KK, MCK, TK-Loc. 20, JK-WK, DK and THC Complexes).

Given the higher number of sampling points and greater variation in distances from Paleogeographic Locale to raw material sources, this highly uniform prediction may reflect the incapacity of Paleogeographic Locale scale to demonstrate the opportunistic strategy's patterned variation.

The opportunistic model is an essentialized one that assumes only raw material availability as a factor in stone tool use, discard, and loss patterns. If a behavioral model such as the opportunistic strategy is adequate in explaining the distributional patterns of stone artifacts on a landscape, the observed discard and loss patterns should occur in the archaeological record in similar proportions to that predicted by the model. Any observed assemblage characteristics not accounted for in the opportunistic strategy model might be explained by the expedient strategy, which is discussed in the following section.

### ***Step 2: The expedient strategy***

In the expedient strategy, economization of raw material is a factor and transport and re-use of tools is assumed as a cost-reduction measure. This economizing 'stone flow' tactic (Fig. 6.2; Isaac 1984) incorporates the concept of curation, "the practice of maximizing the utility of tools by carrying them between successive [activity areas] (*re:* Binford 1979:263)," with Bamforth's (1986) argument that tool maintenance and re-use was often a response to raw material shortage rather than curation. Raw material provenience and availability at a particular location are still considered to be factors affecting the expedient nature of lithic discard and loss patterns, but with one other major consideration. The expedient strategy model assumes transport and re-use of material to be indicated by the extent of flaking on a Flaked Piece and the associated proportion of Detached Piece types relative to their raw material source.

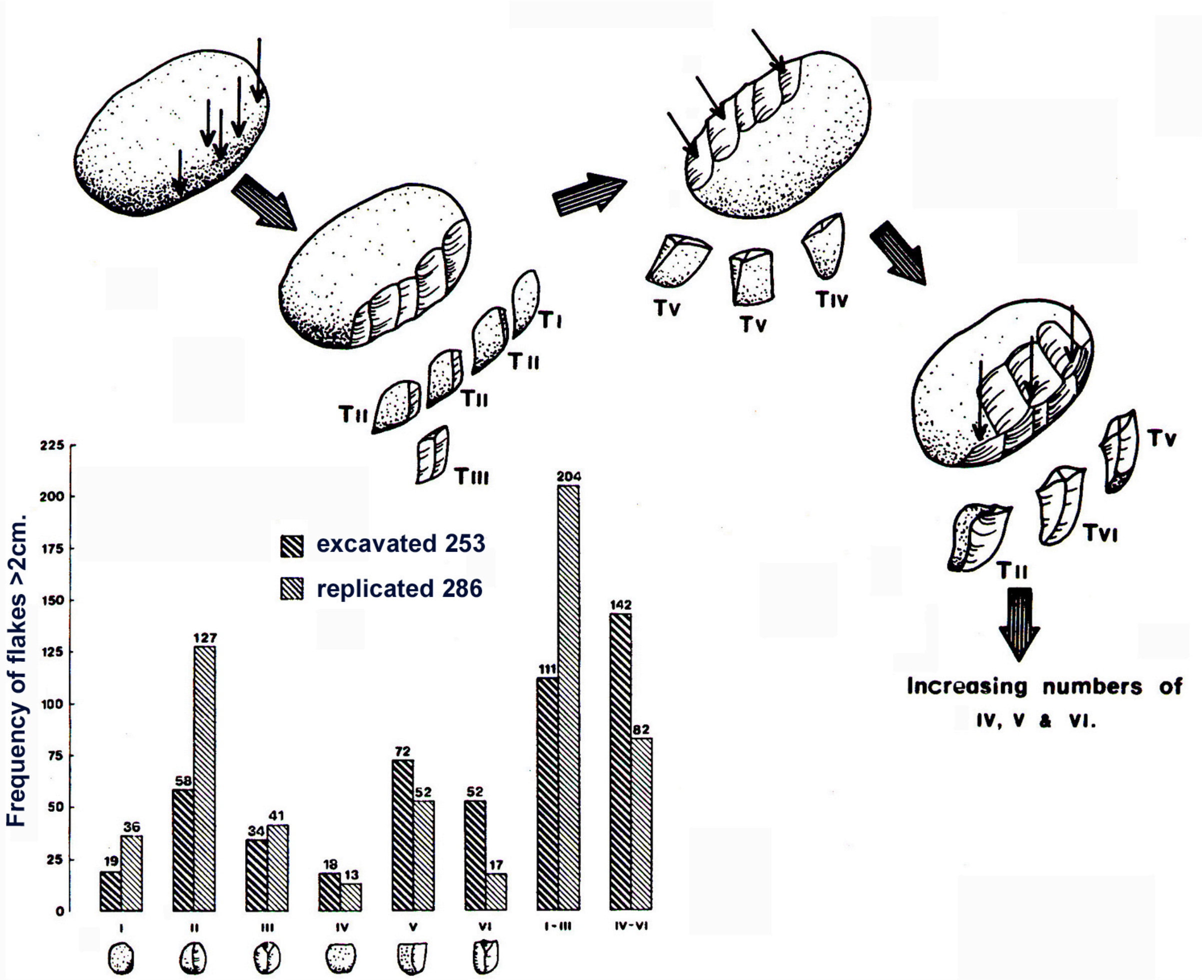


**Fig. 6.2. Stone flow and flake type models (*after* Isaac, 1984).**

Thus, the artifact discard and loss pattern should vary spatially in Flaked and Detached Piece composition by raw material type, Flaked and Detached Piece type, size, and abundance (*see* Table 6.1).

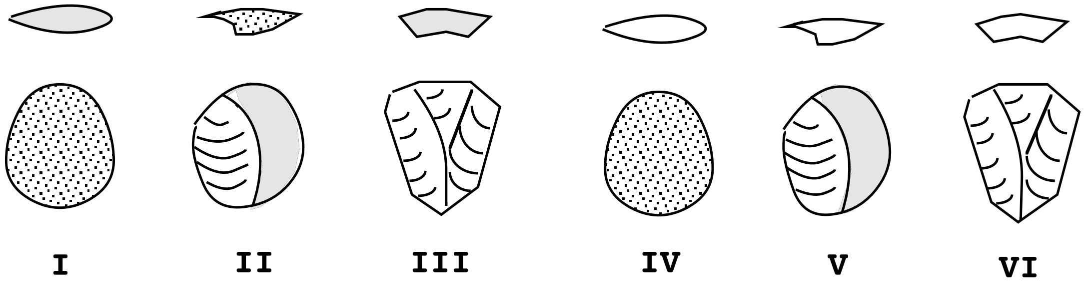
The variable states for Flaked Piece types are broken down as follows:

1) uni <50% = unifacially flaked piece on less than 50% of its surface.
2) bi <50% = bifacially flaked piece on less than 50% of its surface

3) uni >50% = unifacially flaked piece on more than 50% of its surface

4) bi >50% = bifacially flaked piece on more than 50% of its surface

For the associated Detached Piece type classification, I borrow a scheme that describes the extent of flaking in a sequence as indicated by the detached piece morphology (Toth 1985, Isaac, 1984). The Detached Piece type is represented by six variable states (Fig. 6.2). They describe the amount of cortex and the condition of the striking platform of whole flakes representing various stages of core reduction or flake removal.



**I=** plain with cortex/cortical dorsal; II= double faceted/<50% dorsal cortex
III= multi-faceted/non-cortical dorsal; IV= plain,without cortex/cortical dorsal
V= double faceted, without cortex/<50% dorsal cortex; VI= multi-faceted (three or more) /non-cortical dorsal

**Fig. 6.3. Detached Piece classification, reflecting sequence of removal (*after* Toth, 1985).**

Many of the reduction stages described in this Detached Piece classification assume an initially rounded core and a radial flaking technique (re: Schick & Toth, 1993). Much of the quartzite identified in the Oldowan artifact assemblages from Olduvai Gorge is from the Naibor Soit inselberg and typically occurs in tabular nodules. As the tabular nodules move or are eroded from their parent material, they also sustain sufficient weathering to exhibit an effected cortical surface, but do not necessarily provide the same striking platform opportunities for flaking as rounded cores (pers. observation). It has been argued (Braun *et al.*, 2005), that Toth's (1985) classification may only be useful in portraying a relative flaking sequence, but it nonetheless serves the modeling purpose here and is used as a generalized description of the relative flaking sequence in predictions of the Detached Piece composition.

Detached Piece types can be associated with specific Flaked Piece types (Table 6.4). For example, a Type I Detached Piece is a whole flake with a cortical dorsal surface and cortical plain (non-faceted) striking platform. This type of Detached Piece is associated with the initial flaking stage and a unifacially Flaked Piece on <50% of its surface. A Type II Detached Piece is subsequently removed and is still associated with the initial flaking stage and a unifacially Flaked Piece on <50% of its surface. The greater the extent of flaking on a flaked piece, the greater the likelihood of a Type III Detached Piece is to occur as a result of unifacial flaking on >50% of the surface. A Type IV Detached Piece is a result of utilizing a new platform surface, as with bifacially flaking a piece on <50% of its surface. Continued flaking at this point results in a Type V Detached Piece. The greater the extent of bifacial flaking on a flaked piece (on >50% of its surface), the greater the likelihood of Type V and VI Detached Pieces is to be produced. Regardless of the reduction technique, i.e. unifacial, bifacial, multidirectional, etc., primary flaking (on <50% of the surface) is assumed to occur at an earlier reduction stage than secondary flaking (on >50% of the surface). The most extensive flaking would produce more

| **Associated Technological Types (from early to later stages of reduction)** | |
|---|---|
| **Flaked Piece Type** | **Detached Piece Type (after Toth, 1985)** |
| 1. Unifacially flaked on <50% of its surface | I, II |
| 2. Bifacially flaked on <50% of its surface | IV, V |
| 3. Unifacially flaked on >50% of its surface | 1, II, III |
| 4. Bifacially flaked on >50% of its surface | IV, V, VI |

**Table. 6.4. Relative reduction stages for Flaked Pieces and associated Detached Pieces**

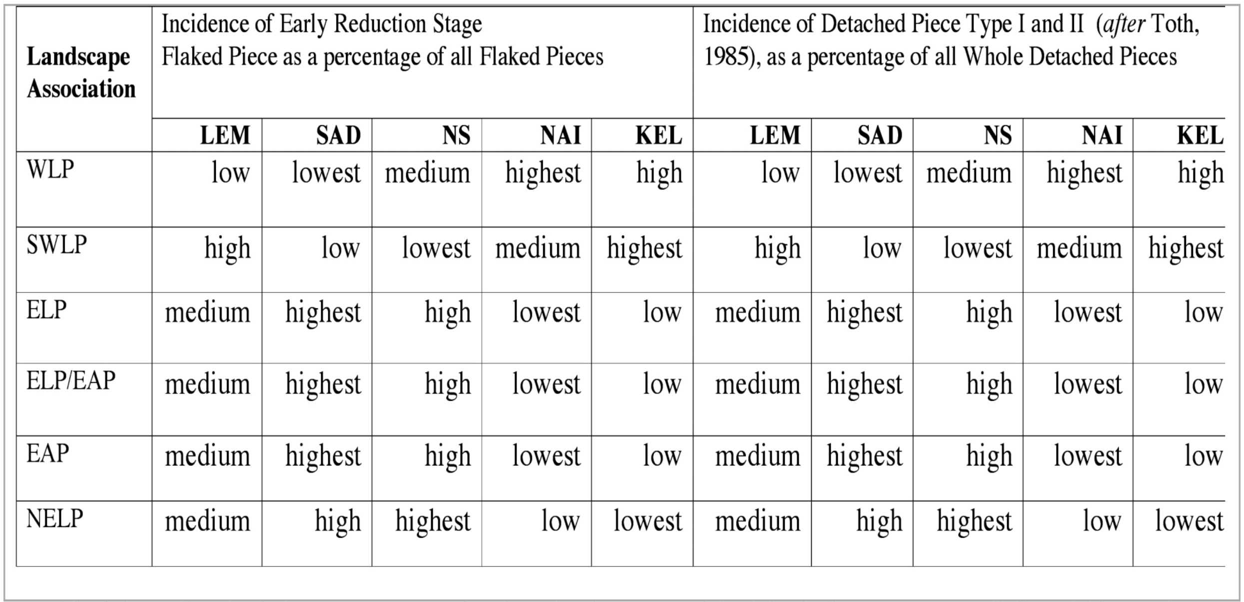
Type III Detached Pieces in the primary stage and more Type VI Detached Pieces in the secondary stage. If transport is assumed, as in the expedient strategy, the Detached Piece types are expected to occur in association with particular Flaked Piece types, ranked from lowest to highest degree of reduction in the order shown in Table 6.4.

Neither the quantitative predictive value of distance upon degree of reduction, nor the spatial scale over which distance dependent reduction occurs is known for Oldowan technology. However, if Isaac's (1984) 'stone flow' model is accurate, one could predict the following relationships between these more generalized phenomena and increasing distance from source:

a) The size of unmodified cobbles should decrease.
b) The size of Flaked Pieces should decrease.
c) The size of Detached Pieces should decrease.
d) The number of Flaked Pieces >50% should increase relative to Flaked Pieces <50%.
e) The percentage of Detached Pieces Types I and II should decrease relative to Detached Pieces Types III to VI.
f) The weight density of artifacts (g/m$^3$ of excavated deposit) should decrease.

The threshold between reduction stages may also vary according to factors other than distance, including raw material quality. However, what can be assumed with greater confidence is that the earliest reduction stage, represented by Manuports and Flaked Pieces flaked on <50% of their circumference, and their associated Detached Pieces (Type I & II) will occur in higher frequencies closer to the source of raw material than the later reduction stages, regardless of the absolute distance threshold to the different stages.

The second step of the model operates under the assumption that the relative stages of core reduction will scale linearly with distance. The early reduction stage will be compared to the later reduction stage. If variation in hominid technological organization is manifested and visible at the Landscape Association scale, then the incidence of early reduction stage Flaked and Detached Pieces is expected as presented below (Table 6.5).



| **Landscape Association** | Incidence of Early Reduction Stage Flaked Piece as a percentage of all Flaked Pieces | | | | | Incidence of Detached Piece Type I and II (*after* Toth, 1985), as a percentage of all Whole Detached Pieces | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **LEM** | **SAD** | **NS** | **NAI** | **KEL** | **LEM** | **SAD** | **NS** | **NAI** | **KEL** |
| WLP | low | lowest | medium | highest | high | low | lowest | medium | highest | high |
| SWLP | high | low | lowest | medium | highest | high | low | lowest | medium | highest |
| ELP | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| ELP/EAP | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| EAP | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| NELP | medium | high | highest | low | lowest | medium | high | highest | low | lowest |

Table 6.5. Predicted relative occurrences of early reduction stage Flaked (including Manuports, Split Cobbles, and Pounded Pieces) and Detached Pieces. Raw material sources are Lemagrut (LEM); Sadiman (SAD); Naibor Soit (NS); Naisiusiu (NAI); Kelogi (KEL).

When all of the diagnostic variables are considered, then raw material type, artifact size, and density, as well as incidence of early reduction relative to later reduction stage Flaked and Detached Piece types would be predicted to occur as presented in Table 6.6. For instance, in the Western Lacustrine Plain, the largest size, highest density, highest percentage of Manuports and Flaked Pieces in the primary or early reduction stages (Flaked Piece <50%), and the associated early reduction stage Detached Pieces Types I and II would be of Naisiusiu quartzite.

In contrast, if variation in hominid technological organization is manifested and detectable at the Paleogeographic Locale scale, then in the expedient strategy the expected lithic artifact discard and loss pattern of the diagnostic variables might appear as shown in Table 6.7.

| **Expected highest incidences of raw material and artifact types** | | |
|---|---|---|
| | Availability | Transport and Curation |
| **Landscape Association** | Largest Size/ Highest Density | Early Reduction Stage Flaked Pieces (as a percentage of all Flaked Pieces)/ Early Reduction Stage Detached Pieces (as a percentage of all Whole Detached Pieces) |
| Western Lacustrine Plain | Naisiusiu quartzite | Naisiusiu quartzite |
| Southwestern Lacustrine Plain | Kelogi Gneiss | Kelogi Gneiss |
| Eastern Lacustrine Plain | Sadiman lava | Sadiman lava |
| Eastern Lacustrine Plain/ Eastern Alluvial Plain (transitional) | Sadiman lava | Sadiman lava |
| Eastern Alluvial Plain | Sadiman lava | Sadiman lava |
| Northeastern Lacustrine Plain | Naibor Soit quartzite | Naibor Soit quartzite |

**Table 6.6. Expedient model predictions of lithic discard and loss patterns in a Landscape Association scale.**

| **Paleogeographic Locale** | **Expected Incidence of Early Reduction Stage Flaked Pieces as a percentage of all Flaked Pieces (including Manuports, Split Cobbles, and Pounded Pieces)** | | | | | **Expected Incidence of Early Reduction Stage Detached Pieces Type I and II (*after* Toth, 1985), as a percentage of all Whole Detached Pieces** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **LEM** | **SAD** | **NS** | **NAI** | **KEL** | **LEM** | **SAD** | **NS** | **NAI** | **KEL** |
| Loc. 64 | low | lowest | medium | highest | high | low | lowest | medium | highest | high |
| Naisiusiu | low | lowest | medium | highest | high | low | lowest | medium | highest | high |
| West-lake | low | lowest | medium | highest | high | low | lowest | medium | highest | high |
| Kelogi | high | low | lowest | medium | highest | high | low | lowest | medium | highest |
| MNK | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| FLK | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| VEK | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| HWKW | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| HWKE | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| HWKEE-KK | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| MCK | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| TK-Loc.20 | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| LongK | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| JK-WK | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| DK-Complex | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| THC-Complex | medium | highest | high | lowest | low | medium | highest | high | lowest | low |
| Fifth-Fault | medium | high | highest | low | lowest | medium | high | highest | low | lowest |

**Table 6.7. Predicted lithic discard and loss patterns of the expedient strategy.**

As seen in the opportunistic model, at the higher resolution Paleogeographic Locale spatial scale even less variation between units is expected than in the Landscape Association scale. Both the opportunistic and the expedient models are based upon raw material availability, but the higher resolution does not predict more variation in artifact size, density, and incidence of early reduction stages among units and does not seem to increase the sensitivity of the model.

When all of the diagnostic variables of the expedient strategy, raw material type, artifact size and density, as well as early reduction stage Flaked and Detached Piece type, would be predicted to occur as shown in Table 6.8 (note that only the highest expected occurrences are presented).

At the Paleogeographic Locale scale, the expedient model predicts that in Loc. 64, Naisiusiu, and the West-Lake, the highest artifact density, the largest Manuports and Flaked Pieces, as well as the highest incidence of Manuports and early reduction stage Flaked Pieces relative to later reduction stages will be comprised of Naisiusiu quartzite. In the Kelogi Paleogeographic Locale it will be Kelogi gneiss. In MNK, FLK, VEK, HWKW, HWKE, HWKEE-KK, MCK, TK-Loc. 20, LongK, JK-WK, the DK-Complex, and the THC-Complex it will be Sadiman lava. In the Fifth-Fault it will be Naibor Soit quartzite.

Any observed assemblage characteristics not accounted for in the expedient strategy model might be explained by the optimization strategy, which is discussed in the following section.

| **Expected highest incidences of raw material and artifact types** | | |
|---|---|---|
| | **Availability** | **Transport and Curation** |
| **Paleogeographic Locale** | Largest Size/ Highest Density | Manuports and Flaked Pieces <50% (as a percentage of all Manuports and Flaked Pieces)/ Whole Detached Pieces Types I & II (as a percentage of all Whole Detached Pieces) |
| Loc. 64 | Naisiusiu quartzite | Naisiusiu quartzite |
| Naisiusiu | Naisiusiu quartzite | Naisiusiu quartzite |
| West-Lake | Naisiusiu quartzite | Naisiusiu quartzite |
| Kelogi | Kelogi gneiss | Kelogi gneiss |
| MNK | Sadiman lava | Sadiman lava |
| FLK | Sadiman lava | Sadiman lava |
| VEK | Sadiman lava | Sadiman lava |
| HWKW | Sadiman lava | Sadiman lava |
| HWKE | Sadiman lava | Sadiman lava |
| HWKEE-KK | Sadiman lava | Sadiman lava |
| MCK | Sadiman lava | Sadiman lava |
| TK-Loc. 20 | Sadiman lava | Sadiman lava |
| LongK | Sadiman lava | Sadiman lava |
| JK-WK | Sadiman lava | Sadiman lava |
| DK-Complex | Sadiman lava | Sadiman lava |
| THC-Complex | Sadiman lava | Sadiman lava |
| Fifth-Fault | Naibor Soit quartzite | Naibor Soit quartzite |

**Table 6.8. Expedient model predictions of lithic discard and loss patterns on a Paleogeographic Locale scale.**

### *Step 3: The optimization strategy*

Isaac (1978) considered the comparative ecology, feeding strategies and behavior of non-human primates and that of other large omnivores and carnivores in formulating various hypotheses regarding early hominid behavior, in order to understand

> "…[in] what aspect of a small-brained, bipedal savanna hominid's life we could envisage simple tools providing evolutionary advantages."

In the optimization strategy, lithic artifact discard patterns on a landscape would reflect raw material availability, the specific activity at a given area being determined by the distribution and availability of resources, the costs and benefits of tool using associated with that activity (including transport), as well as technological factors such as differential tool type efficiency. In this case, stone tool discard and loss patterns should vary in Flaked and Detached Piece composition, density of occurrence, and diversity of raw material type, size, and tool form. Overall, the greatest variation in both density and tool form diversity would be expected from this strategy. Because optimization introduces a behavioral ecological perspective, and is more complex than the previous strategies discussed, some of the formative theories influencing the model are examined prior to presenting the actual model.

As stated earlier (Chapter 1, Part IV), tools are among the primary means for humans to reduce the potential effects of risk, whether that risk is malnutrition or exposure to predation. The risk factor is compounded when resources are difficult to access or available for only a short time. In a more complex ecological perspective, large carnivore predation and feeding risks would also be considered as limiting factors. Available technology would contribute to reducing risks as well. Hominids using tools would seek an optimal response between reducing risk and increasing energy capture, conferring a selective advantage on the tool user. This reflects a driving principle in foraging theory: "the forager who captures the most energy, and does it with the least expenditure of time and effort, has a competitive edge over his less efficient rivals" (Raven and Elston 1989).

The following section incorporates the resource availability and distribution, and the predation risk components of the Blumenschine and Peters (1998) distributional model with the hypothesized relative functional utility of the technology used to exploit those resources, in order to refine the model. Since the Blumenschine and Peters model predictions comprise fundamental elements of the optimization model, I will summarize them briefly below and discuss some of the conditions applied to the refined model.

### *The Blumenschine and Peters Model*

In the spirit of Isaac's more complex explicative mechanism, Blumenschine & Peters (1998) formulated a theory-driven model of Oldowan artifact and scavenged larger mammal bone assemblage composition across the paleo-Oldowan basin during lowermost Bed II times. The authors specified the main parameters and components of their predictive model and generated some preliminary predictions (*see* Chapter 2, Part III *and* Tables 1-3 in Blumenschine & Peters, 1998). Borrowing a concept explicated by Gifford-Gonzalez (1991), they established theoretical immediate causal links between hominid behavior and the traces thereof. Blumenschine & Peters (1998) also modeled stone tool-using trace residues based on hypothesized patterns of stone artifact discard and loss in a series of 'landscape facets', or habitats, incorporating independent ecological variables, such as the abundance and variety of 'affordances' or resources and hazards, and their associated cost/benefits and risks necessitating stone tool use. They generated test implications about the types of tools, density of assemblages, and clustering of artifacts (*see* Table 3, Blumenschine & Peters, 1998). For example, landscape facets with a higher abundance and diversity of positive affordances were predicted to contain higher densities and diversities of discarded and lost artifacts. Localized concentrations of resources would lead to clustering of artifacts. Blumenschine & Peters (1998) predicted that the amount of stone material transported to a landscape facet should decrease with increasing distance from the lithic source, and the size of flaked pieces should decrease as distance from source increases. They hypothesized that predation by large carnivores would also influence discard and loss patterns. In their model, high risk encourages transport of tools and resources out of a higher-risk landscape facet into a lower-risk landscape facet, and artifact size and type will reflect that transport flow. They hypothesized that the overall artifact composition will also be determined by:

1. the relative abundance of raw material type, based on the proximity to source
2. the usefulness of slabs and cobbles
3. the affordance-specific usefulness of different artifact forms
4. the inequities of hard hammer vs. bi-polar technique
5. the extent of transport and re-use

Factors hypothesized by Blumenschine & Peters (1998) as determinants of artifact assemblage composition are discussed below as caveats of the refined model.

1. The proximity to raw material source is only known for primary sources, and is contingent upon on the assumption of primary source procurement and transport from that point for use. Secondary source locations for Sadiman and Lemagrut have only been estimated. As many predictions rely on proximity to source, this may lead to inaccuracies.

2. The uncertainties about the "usefulness of slabs and cobbles" and the "affordance-specific usefulness of different forms" are addressed through feasibility experiments (discussed Chapter 5, Part II) designed to identify the relative utility of Oldowan tool forms.
3. The bi-polar technique is not well documented in the Oldowan Industry from Olduvai Gorge. Because bi-polar reduction is considered more advantageous than hand-held hard hammer techniques in reducing very small cobbles (Odell 1996:70), it may be considered as an extreme reduction stage and an alternate indicator of distance from raw material source. But recognition of bi-polar flaking is difficult, especially on quartzite artifacts. For instance, one indicator of bi-polar reduction is a high degree of shatter. Naibor Soit quartzite tends to be more friable than Naisiusiu quartzite and shatters more frequently. This ambiguity may lead to equifinalities. Thus, the bi-polar technique is not considered in this thesis.
4. Transport out-of-facet (for re-use or defense while transiting relatively dangerous facets) assumes anticipation of future need. It is implicit in the expedient strategy and may be considered as a risk management strategy in the optimization strategy as well.

It should be noted that Blumenschine and Peters' (1998) model incorporates defense as a stone tool utility. While throwing stones may have been an early hominid defensive strategy against predation, the act of throwing stones as a defensive tactic has not been modeled and will not be tested here. This model considers that the optimal tool form for a specific task minimizes the amount of time a hominid would be exposed to predation risk while exploiting a food resource, the tool-using hominid’s defensive strategy against predation is to utilize the most efficient and risk-minimizing tool.

Following the Blumenschine & Peters (1998) model, and the stipulation that ecological variables will affect the stone tool discard and loss patterns based on artifact size, density of occurrence and technological diversity, we might expect that:

- As distance from raw material source increases, artifact size, and density should decrease.
- As the availability and variety of resources (other than stone) increases, the density and technological diversity of artifact assemblages should increase.
- As the degree of competition for carcasses in a particular location increases, the availability of scavengeable resources decreases, as should the density and technological diversity of artifact assemblages.
- As predation risk in a particular location increases, the density and technological diversity of artifact assemblages should decrease (except for the case of the “small spring”).

The optimization model assumes that ecological factors such the cover abundance and distribution of trees and shrubs, competition among carnivores for carcasses, the completeness of available carcasses, and predation risk, all affect artifact density and diversity. The impact of the degree of resource availability and risk on artifact density and diversity is shown in Table 6.9.

| | | **Predation Risk** | |
|---|---|---|---|
| | | **Low** | **High** |
| **Resource Availability** | **High** | High Artifact Density<br>**High Artifact Diversity** | High Artifact Density<br>Low Artifact Diversity |
| | **Low** | Low Artifact Density<br>High Artifact Diversity | Low Artifact Density<br>Low Artifact Diversity |

**Table. 6.9. The effect of resource availability and predation risk on artifact assemblages in terms of artifact density and technological diversity. Density = artifact weight (gm)/ excavated volume (**$m^3$**). Diversity = a ratio of the number of types represented and the relative proportion of each type represented (**$-\Sigma p_i \log_{10} p_i$**).**

In the refined model of Oldowan artifact discard and loss patterns in the paleo-Olduvai Basin during lowermost Bed II times, I predict not only the density distribution and technological diversity of artifact assemblages among landscapes, but also the specific tool types that might be expected to occur most often in various landscape facets across the Olduvai paleolandscape.

### *The Refined Model*

The distributional model formulated here is a compilation of data from several sources. It incorporates raw material provenance data derived from both primary source data (using UTM coordinates) and data resulting from the experimental trials discussed earlier (see Chapter 5), but is based primarily upon a modified version of Blumenschine and Peters' (1998) model. However, only those variables that pertain to the lithic component of the model are presented.

As discussed above, the refined predictive model of stone tool discard and loss patterns is built upon anticipated tasks related to resource exploitation and subsistence. The degree of risk associated with performing each task was established using the relative average time taken to experimentally perform each task (Table 6.10, *see* Fig. 5.1).

| | Duration of exposure to predation risk | | | |
|---|---|---|---|---|
| **Task** | **Lowest** | **Low-moderate** | **Moderate-high** | **Highest** |
| Butchery (Complete Carcass) | Limb disarticulation | Pounding (marrow bone) | Bulk and Scrap defleshing | Skinning |
| Woodworking | | Sharpening stick | Procuring stick | Chopping wood |

**Table 6.10. Degree of exposure to predation risk associated with each task based upon experimental efficiency.**

The activities represented in the model are constrained by particulars of hominid capabilities and resource availability, which necessitate the activities. Hominid morphology and capabilities were stipulated by Blumenschine & Peters (1998) as: small body size (40-50kg for males, smaller for females) with a relatively enlarged cranial capacity, whose dentition was not suitable to piercing even small ungulate skin, fascia, or access brain and marrow cavities. While the upper trunk may have been strong enough to facilitate arboreal refuging, it was not strong enough to dismember or eviscerate a medium or large-sized carcass without technological assistance. Lower trunk was bipedal and capable of substantial distance walking but not built for competitive cursorial locomotion. Their tool kit included Flaked and Detached Piece cutting tools, and pounding tools, and possibly modified wooden branches and sticks for defense and digging. Peters and Blumenschine (1995,1996), and Blumenschine and Peters (1998) also modeled resource availability for the paleo-Oldowan Basin during lowermost bed II times. The resources include scavengeable carcass parts for food, tree cover for refuge (and wood modification), shrub cover for harvesting plant foods, nuts, fruits, berries, etc., and sticks for digging. Copeland (2004) recently refined their model of plant food and refuge availability. Her modifications have been incorporated into the model.

Unlike the opportunistic and expedient models that are based upon raw material distribution, the optimization model is based upon functional tool utility and involves more than locational data. Function is defined here as an action or use for which something is suited or designed. In order for the functional role to be more than arbitrary, the functional utility of stone tools is based upon a set of interrelated independent and dependent variables. The variables are presented in stratified sets, the first being the fundamental environmental variables (Table 6.11A). These independent variables describe the landscape upon which the tool-using behavior in question is taking place. The landscape units (Landscape Association and Paleogeographic Locale) range from local resource distribution areas to specific activity or resource extraction areas and are distinguished by depositional environments and modern outcrop groupings (respectively). The raw material sources that occur within these groups are ranked relative to their proximity to each Paleogeographic Locale. This represents the broadest scale distribution of resources dealt with here.

**Independent environmental variables in the optimization model**

| | | | Relative distance from raw material source | | | | |
|---|---|---|---|---|---|---|---|
| Landscape Association | Paleogeographic Locale | Depositional Environment | Lava | | Quartzite | | Gneiss |
| | | | Lemagrut | Sadiman | Naibor Soit | Naisiusiu | Kelogi |
| Western Lacustrine Plain | Loc 64 | Stream channel/Interfluve.<br>Riparian woodland/grassland | 2 | 1 | 3 | 5 | 4 |
| | Naisiusiu | Interfluve, seasonal | 2 | 1 | 3 | 5 | 4 |
| | West-Lake | Lake-margin-Deltaic | 2 | 1 | 3 | 5 | 4 |
| Southwestern Lacustrine Plain | Kelogi | Serengeti peneplain,<br>Upper lacustrine plain | 4 | 2 | 1 | 3 | 5 |
| Eastern Lacustrine Plain | MNK | Lower lacustrine plain/<br>Grassland or marshland vegetation | 2 | 3 | 5 | 4 | 1 |
| | FLK | Middle lacustrine plain | 3 | 5 | 4 | 1 | 2 |
| | VEK | Middle lacustrine plain | 3 | 5 | 4 | 1 | 2 |
| | HWKW | Middle lacustrine plain | 3 | 5 | 4 | 1 | 2 |
| | HWKE | Middle lacustrine plain | 3 | 5 | 4 | 1 | 2 |
| | HWKEE-KK | Middle lacustrine plain | 3 | 5 | 4 | 1 | 2 |
| | MCK | Middle lacustrine plain | 3 | 5 | 4 | 1 | 2 |
| | TK-Loc.20 | Middle lacustrine plain | 3 | 5 | 4 | 1 | 2 |
| | LongK | Middle lacustrine plain | 3 | 5 | 4 | 1 | 2 |
| Eastern Lacustrine Plain/<br>Eastern Alluvial Plain | JK-WK | Upper lacustrine plain/Distal alluvial fan | 3 | 5 | 4 | 1 | 2 |
| | DK-Complex | Upper lacustrine plain/Distal alluvial fan | 3 | 5 | 4 | 1 | 2 |
| Eastern Alluvial Plain | THC-Complex | Stream channel/Interfluve.<br>Riparian woodland/grassland | 3 | 5 | 4 | 1 | 2 |
| Northeastern Lacustrine Plain | Fifth-Fault | Lower lacustrine plain/<br>Grassland or marshland vegetation | 3 | 4 | 5 | 2 | 1 |

**Table 6.11A. The relationship between the Landscape Association and Paleogeographic Locale scales of investigation is shown here with the associated depositional environments and relative distances from raw material sources. The distances are ranked relative to each Paleogeographic Locale as, (5) =nearest; (1) =closest. Ecological variables are adapted from Blumenschine & Peters, (1998).**

In the western landscape, there is variation among depositional environments but not the relative distance from raw material sources. In the eastern landscape there is little variation in both the depositional environments and distance from raw material sources.

The second stratum is comprised of the ecological variables used in this model, which are dependent upon the environments and classified by the landscape unit. The vegetation cover types and abundances also describe the level of the food resource availability (plant and animal), which influences the carcass part availability and the degree of predator encounter risk (Table 6.11B).

**Dependent ecological variables in the optimization model**

| Paleogeographic Locale | Vegetation cover abundance | | Degree of competition and/or risk | |
|---|---|---|---|---|
| | Trees | Shrubs | Availability of carcass parts | Predator encounter risk |
| Loc.64 | Moderate to high | Moderate | Moderate | High |
| Naisiusiu | Low | Low | Lowest to Low | Very high |
| West-Lake | Lowest | Low | Moderate | Very high |
| Kelogi | High to highest | Moderate to very high | Lowest to Moderate | High |
| MNK | Lowest | Lowest | Lowest | High |
| FLK | Lowest | Low | Low | Very high |
| VEK | Lowest | Low | Low | Very high |
| HWKW | Lowest | Low | High | Highest |
| HWKE | Lowest | Low | High | Highest |
| HWKEE-KK | Lowest | Low | High | Highest |
| MCK | Lowest | Low | High | Highest |
| TK-Loc.20 | Lowest | Low | High | Highest |
| LongK | Lowest | Low | High | Highest |
| JK-WK | Moderate to very high | High | High | High |
| DK-Complex | Moderate to high | High | Moderate to high | Moderate |
| THC-Complex | Moderate to very high | High | Moderate to high | Moderate |
| Fifth-Fault | Low | Lowest | Moderate to high | Very high |

**Table 6.11B. Ecological variables influencing the stone tool discard and loss patterns in an optimization strategy (adapted from Blumenschine & Peters, 1998). Note that the vegetation cover abundance and degree of competition and/or predator risk values were modeled for the broader scale Landscape Facets, not individual Paleogeographic Locales. Vegetation abundance is ranked as follows: Lowest = (0%) no cover; Low = 1-5% cover; Moderate = 5-25% cover; High = 25-50% cover; Very High = 50-75% cover; Highest = >75%cover. The degree of competition is determined by the amount of vegetation cover, which affects availability of carcasses, which in turn affects encounter risk. Availability of carcass parts is inversely related to the degree competition between and among carnivores and are based upon Blumenschine & Peters, 1998.**

In the western landscape (in the Loc. 64, Naisiusiu, and West-Lake Paleogeographic Locales), the vegetation cover abundance and availability of carcass parts ranges from low to moderate, with high to very high predator encounter risk. In the eastern landscape these values are unknown for each Paleogeographic Locale and no distinction is made between the MNK, FLK, VEK, HWKW, HWKE, HWKEE-KK, MCK, TK-Loc. 20, and LongK Paleogeographic Locale values.

The third stratum comprises the behavioral variables examined in the model that are contingent upon the ecological variables (*see* Table 6.9). The behavioral variables are limited to the hypothesized tool-assisted tasks that would produce the behavioral traces ultimately being modeled in the opportunistic strategy. They are determined by the availability of resources and the degree of risk associated with exploiting those resources. (Table 6.11C).

**Dependent behavioral variables in the optimization model**

| Paleogeographic Locale | Predicted tool-assisted tasks | | | | | | |
|---|---|---|---|---|---|---|---|
| | Wood-working | | | Butchery/Marrow Access | | | |
| | Chopping Wood | Procuring Stick | Sharpening Stick | Skinning | Disarticulating Limb | Defleshing | Pounding Bone |
| Loc.64 | 0 | 0 | 0 | Low | Very high | Moderate | Low |
| Naisiusiu | 0 | 0 | 0 | 0 | High | 0 | Moderate |
| West-Lake | 0 | 0 | 0 | 0 | High | 0 | Moderate |
| Kelogi | 0 | High | 0 | Low | Very high | Low | 0 |
| MNK | 0 | 0 | 0 | 0 | Moderate | 0 | Low |
| FLK | 0 | 0 | 0 | 0 | High | 0 | Moderate |
| VEK | 0 | 0 | 0 | 0 | High | 0 | Moderate |
| HWKW | 0 | 0 | 0 | 0 | Very high | 0 | Low |
| HWKE | 0 | 0 | 0 | 0 | Very high | 0 | Low |
| HWKEE-KK | 0 | 0 | 0 | 0 | Very high | 0 | Low |
| MCK | 0 | 0 | 0 | 0 | Very high | 0 | Low |
| TK-Loc.20 | 0 | 0 | 0 | 0 | Very high | 0 | Low |
| LongK | 0 | 0 | 0 | 0 | Very high | 0 | Low |
| JK-WK | 0 | Moderate | 0 | Low | Very high | Low | 0 |
| DK-Complex | Low | High | Low | Moderate | High | Moderate | Moderate |
| THC-Complex | Low | High | Low | Moderate | High | Moderate | Moderate |
| Fifth-Fault | 0 | 0 | 0 | 0 | High | 0 | Moderate |

**Table 6.11C. Tasks are predicted on the basis of the average time needed to perform a task, the degree of available carcass parts, and the degree of predator encounter risk associated with each Paleogeographic Locale. Predicted tasks are ranked according to the degree of tree and shrub cover; abundance of task occurrences are (0) nil; (1) low; (2) moderate; (3) high; (4) very high; (5) highest.**

In both the western and eastern landscapes (with the exception of the Kelogi and JK-WK Paleogeographic Locales), the predicted occurrences of woodworking tasks are nil to low. Predicted butchery tasks show more variation across the paleolandscapes. Skinning, defleshing, and pounding bone are expected to occur less frequently (nil to moderate). Limb disarticulation is expected to occur more frequently (moderate to very high).

The fourth stratum comprises the nature of specific artifact assemblages in terms of density and diversity and the relative frequencies of the specific tool types that are expected to occur in the optimization strategy. They are determined by the ecological variables as well as the relative functional utility of each tool type. Table 6.11D presents the predictions of the optimization model.

**Expected relative frequency of specific tool types**

| Paleogeographic Locale | Assemblage Composition | | Expected Occurrence of tool types | | | |
|---|---|---|---|---|---|---|
| | Density | Diversity | FP <50% | FP >50 % | PP/MP | DP |
| Loc.64 | Very High | Moderate | 4 | 1 | 2 | 3 |
| Naisiusiu | Moderate | Low | 4 | 1 | 3 | 1 |
| West-Lake | Moderate | Low | 4 | 1 | 3 | 1 |
| Kelogi | Highest | Moderate | 4 | 3 | 1 | 2 |
| MNK | Highest | Moderate | 3 | 1 | 4 | 1 |
| FLK | Moderate | Low | 4 | 1 | 3 | 1 |
| VEK | Moderate | Low | 4 | 1 | 3 | 1 |
| HWKW | High | Lowest | 4 | 1 | 3 | 1 |
| HWKE | High | Lowest | 4 | 1 | 3 | 1 |
| HWKEE-KK | High | Lowest | 4 | 1 | 3 | 1 |
| MCK | High | Lowest | 4 | 1 | 3 | 1 |
| TK-Loc.20 | High | Lowest | 4 | 1 | 3 | 1 |
| LongK | High | Lowest | 4 | 1 | 3 | 1 |
| JK-WK | Highest | Moderate | 4 | 2 | 1 | 2 |
| DK-Complex | Highest | High | 4 | 2 | 1 | 3 |
| THC-Complex | Highest | High | 4 | 2 | 1 | 3 |
| Fifth-Fault | Moderate | Low | 4 | 1 | 3 | 1 |

**Table 6.11D. Density and diversity measures are based upon the combined resource availability and the predator encounter risk. Expected occurrence of tool types ranked as (4) high; (3) moderate; (2) Low; (1) lowest-nil**

The optimization model predicts the relative composition of artifact assemblages and the relative occurrence of artifacts. For example, in Loc. 64, given moderate resource availability and high predation risk, the most frequently predicted task is limb disarticulation (for transport to a safer area), followed by defleshing, skinning (for access) and bone pounding (marrow removal). The highest expected incidence of associated archaeological traces of such activities would be Flaked Pieces <50%, followed by a moderate frequency of Detached Pieces, followed by a low incidence of Manuports (Pounded Pieces) and lower-nil incidence of FP>50%.

In both the eastern and western landscape, in all of the Paleogeographic Locales except MNK, Flaked Pieces (flaked on less than 50% of their circumference) are expected to occur in the highest frequencies. The expected occurrence of Flaked Pieces (flaked on more than 50% of their circumference) and Detached Pieces ranges from lowest-nil to moderate. Pounded pieces and Manuports show the full range of expected occurrences.

The opportunistic strategy model is the highest level of complexity supported by the available data presented in this thesis. This predictive model also constitutes the refined lithic component of the Blumenschine and Peters (1998) model, and will be tested against the first landscape sample of artifacts recovered from Middle and Upper Bed I and lowermost Bed II deposits from Olduvai Gorge in the following chapter.

# CHAPTER SEVEN

# TESTING THE MODEL PREDICTIONS

## *Introduction*

Studies that combine experimental replicative studies with theoretical models or with careful analyses of Paleolithic archaeological occurrences have been carried out in previous years (Isaac 1983; Toth 1987). Such studies have led to hypothetical utility rankings for Oldowan tools; a methodological approach for assessing the nature and paleographic distribution of early stone artifact assemblages and the potential possibility to reconstruct entire technological systems, but they have yet to be verified. This chapter tests the predictions made by the step-wise models presented in the previous chapter. The predictions outlined in each of the models' steps will be compared to actual archaeological data from Olduvai Gorge Middle Bed I and lowermost Bed II deposits for accuracy of fit.

This approach will focus on the critical variables outlined in the previous chapter as being diagnostic of certain technological strategies. This development of predictive distributional models and the testing of those model predictions are not rigorous as, in most cases, the variables examined are presented as ordinal attributes, and their ranked occurrences and variation are seldom qualified by a statistical significance. Nonetheless, by actually testing the predictions for behavioral traces on a landscape scale with data that matches that scale, this treatment attempts to qualify spatial variation and approaches the ultimate goal of this thesis: describing and explicating the landscape variability in lithic assemblage composition at Olduvai Gorge during Middle Bed I and lowermost Bed II times. At the very least, the observed data should help in demonstrating the model's possible shortcomings in order to facilitate or improve the model building and hypothesis testing methodology.

## PART I. Testing the opportunistic model (Step 1)

Step 1 models an opportunistic tool using strategy whereby the operating hypothesis is that if tool using activities and their resulting discard and loss patterns were opportunistic in nature, then artifact size and assemblage density would diminish as distance from their raw material source increases. The opportunistic model hypothesizes that spatial variation in lithic artifact assemblage characteristics would be determined by raw material provenience alone. The morphological variables that I consider as diagnostic of provenience are raw material type, artifact size and artifact density (*see* Table 6.1).

The data used in this comparison are presented first in tabular form as Flaked Piece counts and as a percentage of all artifacts (Table 7.1A). It should be noted that the percentage of *all artifacts* (n=3966) in this case refers only to those specimens whose raw material source has been established for the purposes of this study. A total of 368 artifacts fall into the “Other" raw material category and are not included in this comparison.

| **Landscape** | **Lemagrut** | | **Sadiman** | | **Naibor Soit** | | **Naisiusiu** | | **Kelogi** | | **Unit Totals** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Association** | Count | % | Count | % | Count | % | Count | % | Count | % | Count | % |
| WLP | 0 | 0 | 2 | 0 | 0 | | 85 | 5.55 | 1 | 0.07 | 88 | 5.74 |
| SWLP | 24 | 12.24 | 0 | 0 | 0 | | 4 | 2.04 | 26 | 13.27 | 54 | 27.55 |
| ELP | 131 | 6.24 | 57 | 2.71 | 105 | 5.00 | | | | | 293 | 13.95 |
| ELP/EAP | 9 | 11.84 | 2 | 2.63 | 4 | 5.26 | | | | | 15 | 19.74 |
| EAP | 10 | 37.04 | 0 | 0 | 1 | 3.70 | | | | | 11 | 40.74 |
| NELP | 3 | 9.09 | 0 | 0 | 4 | 12.12 | | | | | 7 | 21.21 |
| Raw Material Tota | 177 | | 61 | | 114 | | 89 | | 27 | | 468 | |

**Table 7.1A. Flaked Pieces (including Split Cobbles, Pounded Pieces, and Manuports) are represented by their count and as a percentage of all artifacts of each raw material by Landscape Association.**

The Flaked Piece assemblage from the Eastern Lacustrine Plain (ELP) contains the highest artifact count of all the Landscape Associations, but the 293 Flaked Pieces comprise only 13.95% of the total ELP assemblage. In contrast, the Flaked Piece assemblage from the Southwestern Lacustrine Plain (SWLP), with a moderate artifact count of 54, comprises 27.55% of the total SWLP assemblage. The ratio of Flaked Piece to total artifact counts may be an indicator of either the extent of reduction of each piece or the possible transport of Flaked Pieces in or out of an area. The spatial variation evidenced between Landscape Association counts and percentage of the total assemblages may suggest that determinants other than raw material provenience may be affecting the Flaked Piece discard and loss patterns.

To test the first step of the model on the scale of Landscape Association, I compare the expected occurrences of various raw material types' artifact size (excluding detached pieces and shatter) and assemblage density, with the observed archaeological occurrences relative to the distance from their source. For example, the nearer a Landscape Association is to the Naibor Soit inselberg, the larger and more abundant the available clasts and the larger the ensuing Flaked Pieces of Naibor Soit quartzite are expected to be relative to artifacts of Naisiusiu quartzite, Lemagrut and Sadiman lava, and Kelogi gneiss in that same Landscape Association.

Examining the spatial distribution of artifact raw material type, size, and density, the mean maximum dimensions of 468 artifacts (Flaked and Pounded Pieces, Split Cobbles, and Manuports) are presented along with the mean weight density[4] of artifact assemblages from each Landscape Association grouped by their raw material source (Table 7.1B).

| **Landscape** | **Lemagrut** | | **Sadiman** | | **Naibor Soit** | | **Naisiusiu** | | **Kelogi** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Association** | Mean Mxdm | Density | Mean Mxdm | Density | Mean Mxdm | Density | Mean Mxdm | Density | Mean Mxdm | Density | SD |
| WLP | | | 74.50 | 8.73 | | | 55.68 | 246.69 | 75.50 | 3.87 | 22.64 |
| SWLP | 84.78 | 614.89 | | | | | 52.40 | 51.48 | 104.08 | 1436.38 | 32.80 |
| ELP | 84.59 | 255.82 | 81.45 | 98.71 | 63.52 | 142.05 | | | | 0.04 | 23.64 |
| ELP/EAP | 87.88 | 45.20 | 71.30 | 10.20 | 48.725 | 5.42 | | | | | 25.44 |
| EAP | 51.95 | 18.67 | | | 46.80 | 1.99 | | | | | 16.73 |
| NELP | 77.17 | 42.20 | | | 62.13 | 56.07 | | | | | 12.04 |
| **Raw Material SD** | **SD 17.75** | | **SD 19.74** | | **SD 27.27** | | **SD 22.13** | | **SD 38.97** | | |

**Table 7.1B. Mean Mxdm (= Mean Maximum Dimension (mm)) and Density (weight (gm)/excavated volume (m³)) of all Flaked Pieces (including Split Cobbles, Pounded Pieces and Manuports) in each raw material category by Landscape Association.**

---

[4] Artifact weight density was determined by dividing the total artifact weight (g) for a specific raw material by the total excavated volume (m$^3$) for each unit of investigation.

In general, the mean maximum dimension values within each raw material type fall within a close range. This may be a function of raw material quality or availability that is influencing a technological standardization or size preference. However, standard deviations values for raw material sources and Landscape Association units indicate variation to be high within both groups.

The opportunistic model implicitly predicts that size and density will co-vary according to distance from raw material source. Grouped by raw material types, the predicted relative Flaked Piece size and assemblage density values are compared with the observed relative values (Table 7.2). The data show that in 22 of 30 observations (73%), the maximum dimension values are consistent with the density values in terms of their relative occurrences within each Landscape Association, suggesting some correspondence between these two variables. However, when comparing the expected relative values with the observed maximum dimension and density values, it is evident that the observed values for each of the Landscape Associations do not correspond well with the expected values. The observed values that do correspond with expected values for a specific Landscape Association are presented in **bold face** type below (Table 7.2).

Only 22 of 60 observed occurrences (37%) correspond with the predicted values. The fact that 63% of the observed values do not fit the model suggests that an opportunistic strategy as it is modeled here does not adequately explain the spatial variability in artifact discard and loss patterns across the Olduvai paleolandscape.

| **Expected Relative Occurrences** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lemagrut | | Sadiman | | Naibor Soit | | Naisiusiu | | Kelogi | |
| Landscape Association | Max Dm | Dens | Max Dm | Dens | Max Dm | Dens | Max Dm | Dens | Max Dm | Dens |
| WLP | small | low | smallest | lowest | med | med | largest | **highest** | large | high |
| SWLP | **large** | **high** | small | low | **smallest** | **lowest** | **med** | **med** | **largest** | **highest** |
| ELP | med | med | largest | highest | large | **high** | **smallest** | **lowest** | small | **low** |
| ELP/EAP | med | med | largest | highest | large | high | **smallest** | **lowest** | small | low |
| EAP | med | med | largest | highest | **large** | **high** | **smallest** | **lowest** | small | low |
| NELP | med | med | large | high | largest | **highest** | small | low | **smallest** | **lowest** |

| **Observed Relative Occurrences** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lemagrut | | Sadiman | | Naibor Soit | | Naisiusiu | | Kelogi | |
| Landscape Association | Max Dm | Dens | Max Dm | Dens | Max Dm | Dens | Max Dm | Dens | Max Dm | Dens |
| WLP | 0 | 0 | 74.50 | 8.73 | 0 | 0 | 55.68 | **246.69** | 75.50 | 3.87 |
| SWLP | **84.78** | **614.89** | 0 | 0 | **0** | **0** | **52.40** | **51.48** | **104.08** | **1436.38** |
| ELP | 84.59 | 255.82 | 81.45 | 98.71 | 63.52 | **142.05** | **0** | **0** | 0 | **0.04** |
| ELP/EAP | 87.88 | 42.20 | 71.30 | 10.20 | 48.73 | 5.42 | **0** | **0** | 0 | 0 |
| EAP | 51.95 | 18.67 | 0 | 0 | **46.80** | **1.99** | **0** | **0** | 0 | 0 |
| NELP | 77.17 | 42.20 | 0 | 0 | 62.13 | **56.07** | 0 | 0 | **0** | **0** |

**Table 7.2. Comparison of expected and observed mean maximum dimension (mm) and density (artifact weight (g) /excavated volume ($m^3$)) values by raw material type.**

To further examine the affect of distance from raw material source upon Flaked Piece size and artifact density, the archaeological data from each Landscape Association are plotted against the distance from their raw material sources. The relationships between both variables and distance are hypothesized to be negative ones: as the distance from raw material source increases, maximum dimension and density values are expected to decrease. The first graph shows the mean maximum dimension values of Flaked Pieces (including Pounded Pieces, Split Cobbles, and Manuports) of each Landscape Association unit relative to the distance from the raw material sources (Fig. 7.1A). Each point represents the mean maximum dimension of Flaked Pieces of a specific raw material group in a specific Landscape Association.

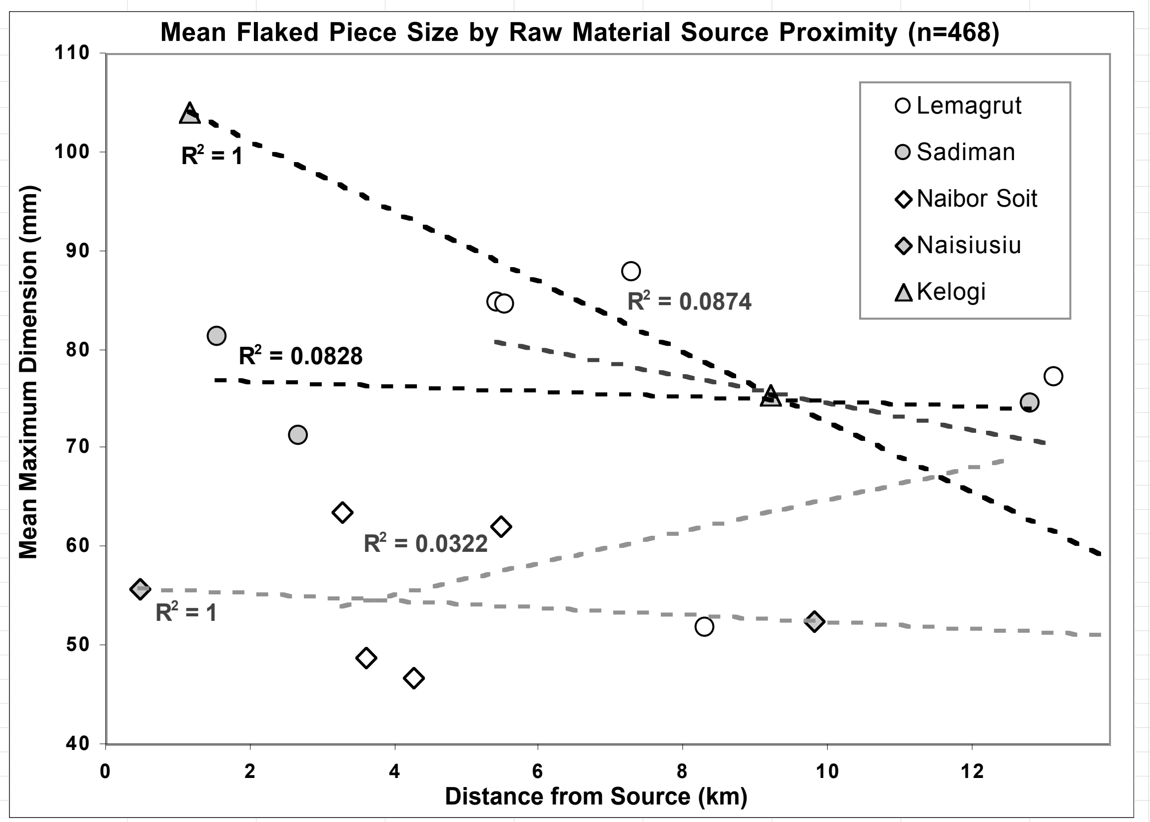


**Fig. 7.1A. Effect of distance from raw material source on mean Flaked Piece size.**

In this graph, Flaked Pieces made of Naisiusiu quartzite and Kelogi gneiss display a perfect negative correlation with distance from raw material source ($R^2$ = 1), but each assemblage samples only two Landscape Associations. Weak negative correlations are observed with artifacts of Lemagrut ($R^2$ = 0.0828) and Sadiman ($R^2$ = 0.0874) lavas, and a very weak positive correlation is seen with artifacts of Naibor Soit quartzite ($R^2$ = 0.0322).

Figure 7.1B shows the effect of distance from raw material source on artifact density. Each point represents the mean artifact density of a specific raw material group in a specific Landscape Association.

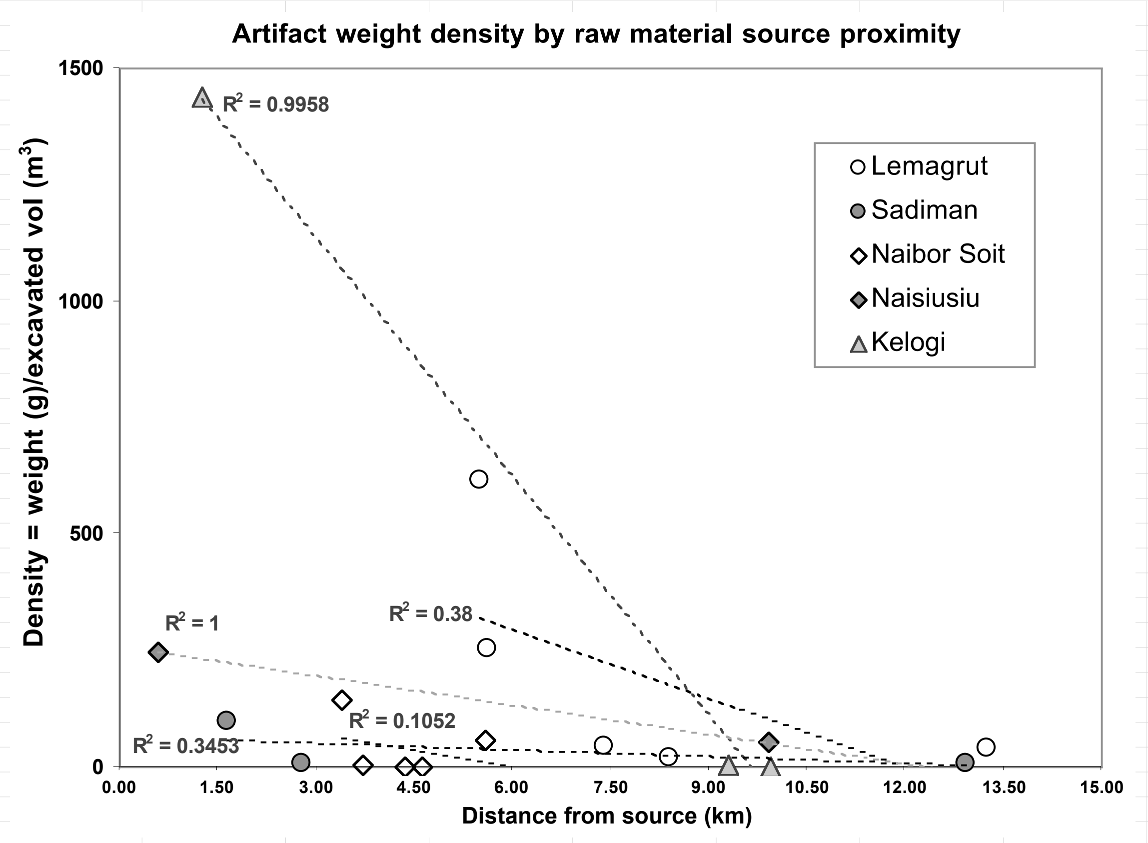


**Fig. 7.1B. Effect of distance from raw material source on artifact weight density.**

In general, as the model predicts, the density values for each raw material group exhibit a negative correlation with distance from their sources. Artifacts made of Naisiusiu quartzite display a perfect negative correlation of density with distance ($R^2 = 1$), but the assemblage samples only two Landscape Associations. The strongest correlation is apparent with artifacts made of Kelogi gneiss ($R^2 = 0.9958$). A moderate correlation is seen with artifacts made of Lemagrut lava ($R^2 = 0.38$) and of Sadiman lava ($R^2 = 0.3453$). The weakest correlation is seen with artifacts made of Naibor Soit quartzite artifacts ($R^2 = 0.1052$).

The correlation coefficients observed in these two figures may be disparate, but the affect of distance on the two variables is similar in regards to raw material types. Both size and density data from artifacts of Naisiusiu quartzite and Kelogi gneiss show the strongest correlation with distance, followed by Lemagrut and Sadiman lavas. Naibor Soit quartzite shows the weakest correlation. This may suggest that raw material type and/or availability is a factor in the technological strategy.

The poor fit of expected and observed maximum dimension and artifact density values and the overall weak correlations between these variables and distance from raw material source are not definitive and do not support the hypothesis that an opportunistic strategy will fully account for the artifact discard and loss patterns observed on the Olduvai paleolandscape. These results may be due in part to a very small sample size. The Landscape Association units total a mere seven sampling points and in most cases, only a few of the Landscape Associations are represented.

As previously discussed, the scale at which technological strategies are sensitive to distance or become archaeologically visible has not been established. In order to explore the possibility that the scale of investigation might have an effect upon the outcome of this comparison, I contrast the comparison of expected relative occurrences of artifact size and assemblage density with the observed archaeological occurrences of various raw material types relative to the distance from their source, using the Paleogeographic Locales as units of investigation, which sample the paleolandscape at a higher spatial resolution than the Landscape Association scale does. The Flaked Piece data used in this comparison are presented in a tabular form as counts and as a percentage of all artifacts (Table 7.3A).

| Paleogeographic | **Lemagrut** | | **Sadiman** | | **Naibor Soit** | | **Naisiusiu** | | **Kelogi (gneiss)** | | **Unit Totals** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Locale** | **Count** | **%** | **Count** | **%** | **Count** | **%** | **Count** | **%** | **Count** | **%** | **Count** | **%** |
| Loc.64 | | | 2 | 0.18 | | | 53 | 4.75 | | | 55 | 4.93 |
| Naisiusiu | | | | | | | 6 | 5.61 | | | 6 | 5.61 |
| West-Lake | | | | | | | 26 | 8.41 | 1 | 0.32 | 27 | 8.74 |
| Kelogi | 24 | 171.43 | | | | | 4 | 2.04 | 26 | 13.27 | 54 | 27.55 |
| MNK | | | | | | | | | | | | |
| FLK | 6 | 4.84 | 2 | 1.61 | 6 | 4.84 | | | | | 14 | 11.29 |
| VEK | 10 | 3.82 | 1 | 0.38 | 8 | 3.05 | | | | | 19 | 7.25 |
| HWKW | 10 | 3.16 | 3 | 0.95 | 9 | 2.85 | | | | | 22 | 6.96 |
| HWKE | 13 | 2.19 | 8 | 1.35 | 28 | 4.71 | | | | | 49 | 8.25 |
| HWKEE-KK | 3 | 1.29 | | | 5 | 2.15 | | | | | 8 | 3.43 |
| MCK | 72 | 15.96 | 43 | 9.53 | 45 | 9.98 | | | | | 160 | 35.48 |
| TK-Loc.20 | | | | | 2 | 5.56 | | | | | 2 | 5.56 |
| LongK | 17 | 23.94 | | | 2 | 2.82 | | | | | 19 | 26.76 |
| JK-WK | 5 | 8.93 | 2 | 3.57 | 2 | 3.57 | | | | | 9 | 16.07 |
| DK-Complex | 4 | 20.00 | | | 2 | 10.00 | | | | | 6 | 30.00 |
| THC-Complex | 10 | 37.04 | | | 1 | 3.70 | | | | | 11 | 40.74 |
| Fifth-Fault | 3 | 9.09 | | | 4 | 12.12 | | | | | 7 | 21.21 |
| Raw Material Totals | 177 | | 61 | | 114 | | 89 | | 27 | | **468** | |

**Table 7.3A. Flaked Pieces (including Manuports, Split Cobbles, and Pounded Pieces) are represented by count and as a percentage of all artifacts of each raw material by Paleogeographic Locale.**

At the scale of the Paleogeographic Locale, there are some interesting distributional observations to be made regarding the relationship between Flaked Piece counts and percentages of the total assemblage. The higher resolution grouping shows variable tendencies regarding Flaked Piece counts and their ratio to Detached Pieces. MCK shows the highest Flaked Piece count (160) making up 35% of the total unit assemblage. On the other hand, the THC-Complex shows a very low Flaked Piece count of 11, comprising 40% of the total unit assemblage.

Continuing with the examination of artifact size and density in the Paleogeographic Locale scale, the mean maximum dimension of 468 Flaked Pieces, (including Manuports, Split Cobbles and Pounded Pieces) is presented together with the mean weight density of artifact assemblages from each unit of investigation grouped by the raw material type (Table 7.3B).

| Paleogeographic | Lemagrut | | Sadiman | | Naibor Soit | | Naisiusiu | | Kelogi (gneiss) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Locale | Mean Mxdm | Density | Mean Mxdm | Density | Mean Mxdm | Density | Mean Mxdm | Density | Mean Mxdm | Density | Unit SD |
| Loc.64 | | | 74.50 | 33.57 | | | 61.98 | 704.23 | | | 23.98 |
| Naisiusiu | | | | | | | 49.98 | 26.78 | | | 25.24 |
| West-Lake | | | | | | | 44.40 | 228.93 | 75.50 | 17.8585 | 13.92 |
| Kelogi | 84.78 | 615.01 | | | | | 52.40 | 51.49 | 104.08 | 1436.67 | 32.80 |
| MNK | | | | 0.13 | | 0.91 | | | | | 0 |
| FLK | 87.55 | 89.20 | 85.95 | 38.18 | 109.88 | 190.40 | | | | | 22.56 |
| VEK | 92.22 | 244.00 | 44.80 | 6.55 | 63.84 | 117.45 | | | | | 32.91 |
| HWKW | 83.10 | 199.15 | 74.13 | 46.36 | 61.73 | 112.99 | | | | 0.39 | 19.67 |
| HWKE | 78.88 | 174.86 | 67.63 | 58.86 | 55.54 | 291.50 | | | | | 22.01 |
| HWKEE-KK | 85.97 | 55.30 | | 1.54 | 72.82 | 113.18 | | | | | 47.44 |
| MCK | 85.68 | 859.28 | 85.17 | 475.59 | 61.98 | 268.96 | | | | | 20.72 |
| TK-Loc.20 | | | | 0.07 | 41.95 | 18.52 | | | | | 21.43 |
| LongK | 79.42 | 243.65 | | 2.62 | 75.85 | 36.78 | | | | | 14.27 |
| JK-WK | 87.48 | 28.90 | 71.30 | 15.74 | 50.25 | 6.09 | | | | | 28.07 |
| DK-Complex | 88.38 | 75.22 | | | 47.20 | 4.18 | | | | | 23.48 |
| THC-Complex | 51.95 | 18.66 | | | 46.80 | 1.99 | | | | | 16.7299 |
| Fifth-Fault | 77.17 | 42.19 | | | 62.13 | 56.06 | | | | | 12.03962 |
| | **SD 17.75** | | **SD 19.74** | | **SD 27.27** | | **SD 22.13** | | **SD 38.97** | | |

**Table 7.3B. Mean Mxdm (= Mean Maximum Dimension (mm)) and Density (weight (g)/ volume ($m^3$)) of all Flaked Pieces (including Split Cobbles, Pounded Pieces,and Manuports) in each raw material category is shown grouped by Paleogeographic Locale.**

The mean maximum dimension values within each Paleogeographic Locale display more variation than was apparent at a lower spatial scale. The actual assemblage mean maximum dimension and weight density values of the various raw material types in each Paleogeographic Locale are compared with the predicted values for goodness of fit in Table 7.4.

On the Paleogeographic Locale scale, the observed data show that in terms of relative size and density, there is a slightly higher percentage (77%) of covariance than was evidenced in the Landscape Association scale. However, when comparing the expected and observed maximum dimension and density values, the overall observed values do not correspond well with the expected values in terms of their relative occurrences. In fact, even fewer (32%) of the observed occurrences actually fit the model than in the Landscape Association scale. Data grouped at a Paleogeographic Locale scale may show the spatial distribution of artifact size and density and their relationship to distance from raw material source at a higher spatial resolution, thereby revealing greater variation, but they still do not support the hypothesis that the opportunistic strategy is solely accountable for the variability in spatial distribution of artifacts across the

Olduvai paleolandscape. Note that the observed values that match the expected values are represented in boldface type.

**Ranked Artifact Size and Density by Paleolandscape Locale and Raw Material Source**

| **Expected** | **Lemagrut** | | **Sadiman** | | **Naibor Soit** | | **Naisiusiu** | | **Kelogi** | |
|---|---|---|---|---|---|---|---|---|---|---|
| Paleogeographic Locale | Max Dm | Dens | Max Dm | Dens | Max Dm | Dens | Max Dm | Dens | Max Dm | Dens |
| Loc.64 | small | low | smallest | lowest | med | med | largest | highest | large | high |
| Naisiusiu | small | low | smallest | lowest | med | med | largest | highest | large | high |
| West-Lake | small | low | smallest | lowest | med | med | largest | highest | large | high |
| Kelogi | large | high | small | low | small | low | med | med | largest | highest |
| MNK | med | med | largest | highest | large | high | smallest | lowest | small | low |
| FLK | med | med | largest | highest | large | high | smallest | lowest | small | low |
| VEK | med | med | largest | highest | large | high | smallest | lowest | small | low |
| HWKW | med | med | largest | highest | large | high | smallest | lowest | small | low |
| HWKE | med | med | largest | highest | large | high | smallest | lowest | small | low |
| HWKEE-KK | med | med | largest | highest | large | high | smallest | lowest | small | low |
| MCK | med | med | largest | highest | large | high | smallest | lowest | small | low |
| TK-Loc. 20 | med | med | largest | highest | large | high | smallest | lowest | small | low |
| LongK | med | med | largest | highest | large | high | smallest | lowest | small | low |
| JK-WK | med | med | largest | highest | large | high | smallest | lowest | small | low |
| DK-Complex | med | med | largest | highest | large | high | smallest | lowest | small | low |
| THC-Complex | med | med | largest | highest | large | high | smallest | lowest | small | low |
| Fifth-Fault | med | med | large | high | largest | highest | small | low | smallest | lowest |

| **Observed** | **Lemagrut** | | **Sadiman** | | **Naibor Soit** | | **Naisiusiu** | | **Kelogi** | |
|---|---|---|---|---|---|---|---|---|---|---|
| Paleogeographic Locale | Max Dm | Dens | Max Dm | Dens | Max Dm | Dens | Max Dm | Dens | Max Dm | Dens |
| Loc.64 | 0 | 0 | 74.50 | 33.57 | 0 | 0 | 61.98 | **704.23** | 0 | 0 |
| Naisiusiu | 0 | 0 | **0** | **0** | 0 | 0 | **49.98** | **26.78** | 0 | 0 |
| West-Lake | 0 | 0 | **0** | **0** | 0 | 0 | 44.40 | **228.93** | 75.50 | **17.86** |
| Kelogi | **84.78** | **615.01** | 0 | 0 | **0** | **0** | **52.40** | **51.49** | **104.08** | **1436.7** |
| MNK | 0 | 0 | 0 | 0.13 | 0 | 0.91 | **0** | **0** | 0 | 0 |
| FLK | 87.55 | 89.20 | 85.95 | 38.18 | 109.88 | 190.40 | **0** | **0** | 0 | 0 |
| VEK | 92.22 | 244.0 | 44.80 | 6.55 | **63.84** | **117.45** | **0** | **0** | 0 | 0 |
| HWKW | 83.10 | 199.15 | 74.13 | 46.36 | 61.73 | **112.99** | **0** | **0** | 0 | **0.39** |
| HWKE | 78.88 | 174.86 | 67.63 | 58.86 | 55.54 | 291.50 | **0** | **0** | 0 | 0 |
| HWKEE-KK | 85.97 | 55.30 | 0 | 1.54 | **72.82** | 113.18 | **0** | **0** | 0 | 0 |
| MCK | 85.68 | 859.28 | 85.17 | 475.59 | 61.98 | 268.96 | **0** | **0** | 0 | 0 |
| TK-Loc. 20 | 0 | 0 | 0 | 0.07 | 41.95 | 18.52 | **0** | **0** | 0 | 0 |
| LongK | 79.42 | 243.65 | 0 | 2.62 | **75.85** | **36.78** | **0** | **0** | 0 | 0 |
| JK-WK | 87.48 | 28.90 | 71.30 | 15.74 | 50.25 | 6.09 | **0** | **0** | 0 | 0 |
| DK-Complex | 88.38 | 75.22 | 0 | 0 | **47.20** | **4.18** | **0** | **0** | 0 | 0 |
| THC-Complex | 51.95 | 18.66 | 0 | 0 | **46.80** | **1.99** | **0** | **0** | 0 | 0 |
| Fifth-Fault | 77.17 | 42.19 | 0 | 0 | 62.13 | **56.06** | 0 | 0 | **0** | **0** |

**Table 7.4. Comparison of expected and observed actual values of mean maximum dimension and density.**

When the size and density values are grouped by raw material, a Spearman's rank correlation shows that there are significant correlations (shown in **boldface** type) between the expected and observed size and density values of specific raw materials in each Paleogeographic Locale (Table 7.4A).

| **Spearman's rank Correlation** | **P-value ($\alpha = .01$)** | |
|---|---|---|
| **Raw Material Type** | **Maximum Dimension** | **Density** |
| Lemagrut lava | **.0045** | **.0062** |
| Sadiman lava | .1110 | .0354 |
| Naibor Soit quartzite | .0196 | **.0009** |
| Naisiusiu quartzite | **.0001** | **.0001** |
| Kelogi gneiss | **.0007** | **.0020** |

**Table 7.4A. Spearman rank correlation of expected and observed maximum dimension and density values.**

To further examine the effect of distance on the two variables (artifact size and density) using the higher resolution sample, the observed mean maximum dimension and mean weight density data for each Paleogeographic Locale are plotted against the distance from raw material source.

Figure 7.2A shows the effect of distance on a Paleogeographic Locale scale distribution of artifact mean maximum Flaked Piece dimensions in a global raw material grouping. The very weak negative correlation seen here ($R^2 = 0.0175$) does not support the least effort opportunistic hypothesis as evidenced by the distribution of Flaked Piece sizes.

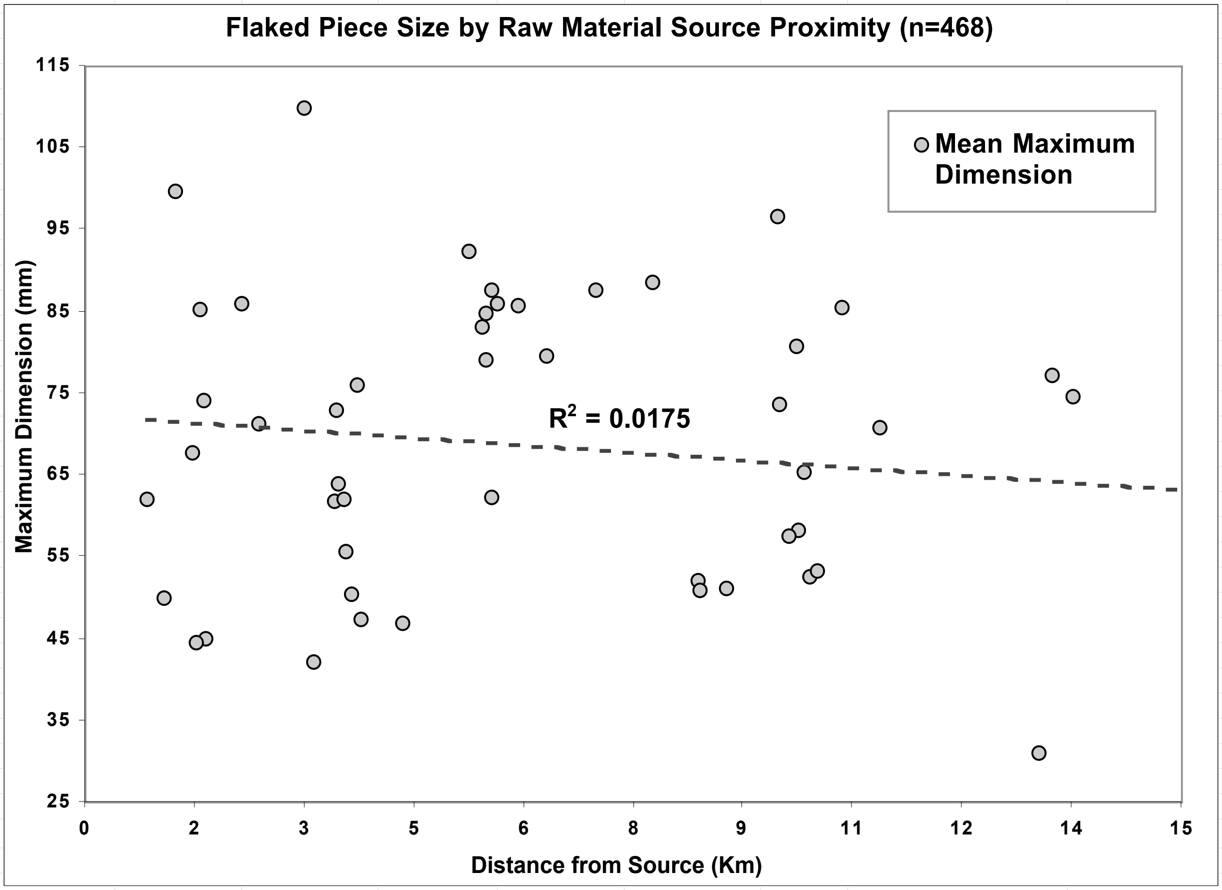


**Fig. 7.2A. Effect of distance from raw material source on Flaked Piece size in Paleogeographic Locale scale.**

Fig. 7.2B illustrates the effect of distance from the raw material sources upon the Flaked Piece size distribution for each raw material type in each Paleogeographic Locale. The addition of more data points changes the R-values from Naisiusiu quartzite and Kelogi gneiss assemblages quite drastically, with Naisiusiu quartzite now showing a virtually non-existent correlation ($R^2$ = 0.0017), and Kelogi gneiss showing a moderate negative one ($R^2$ = 0.4085). Weak negative correlations are seen with artifacts of Naibor Soit quartzite ($R^2$ = 0.0663), Sadiman lava ($R^2$ = 0.1556) and lavas, and a very weak positive correlation with artifacts of Lemagrut lava ($R^2$ = 0.0101).

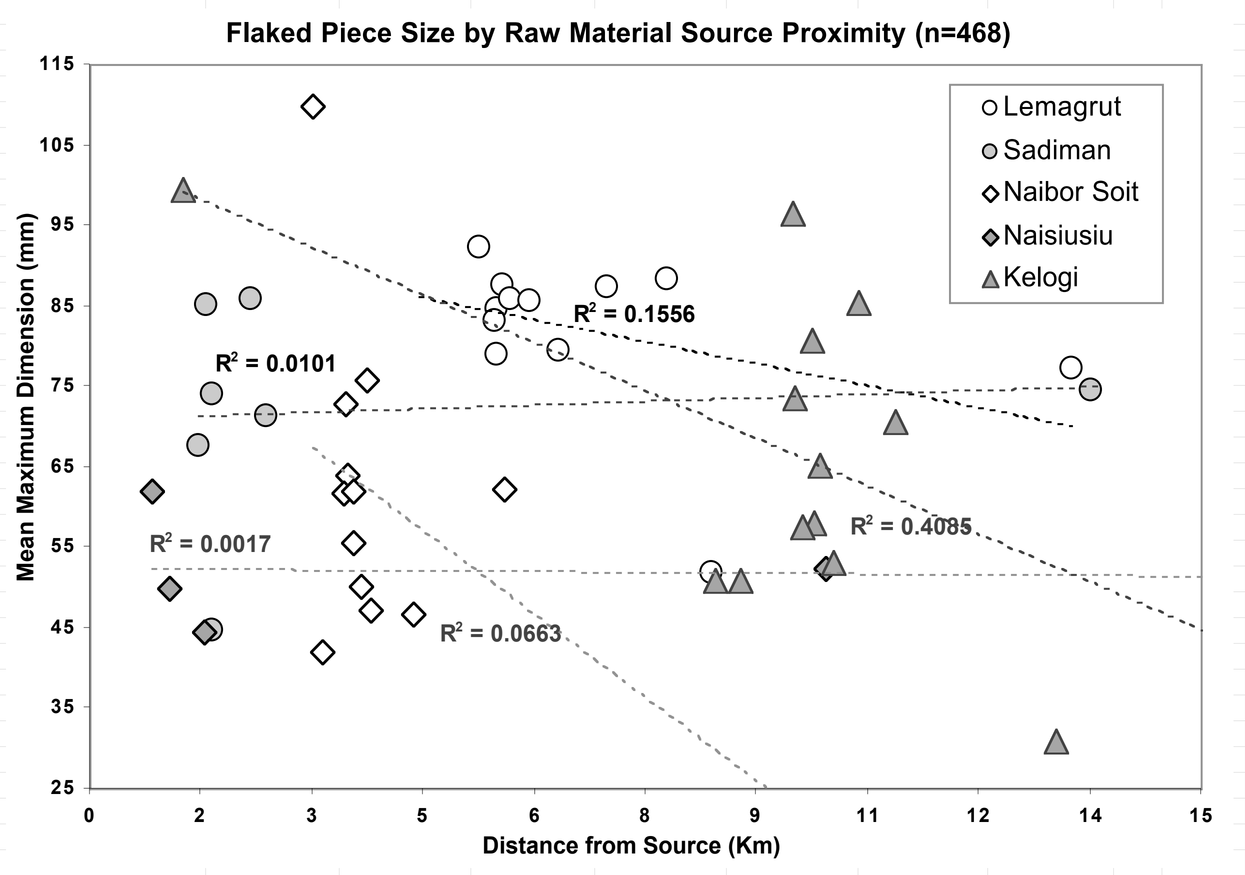


**Fig. 7.2B. Effect of distance to raw material source on Flaked Piece size in a Paleogeographic Locale scale.**

Fig. 7.2C shows the effect of distance from raw material source on the lithic assemblage artifact density in a global raw material grouping. The weak positive correlation seen here ($R^2 =$ 0.0369) does not support the least effort hypothesis as evidenced by the distribution of artifact density values.

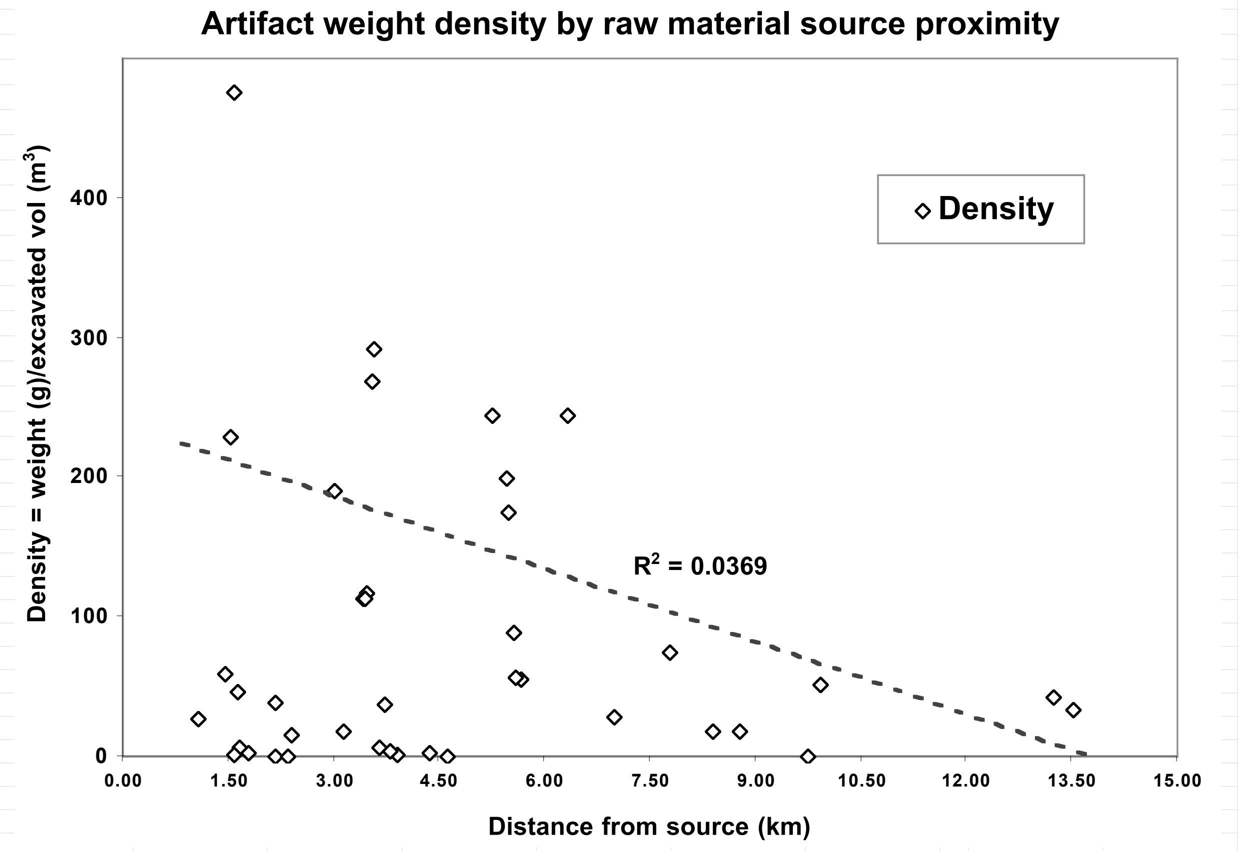


**Fig. 7.2C. Effect of distance from raw material source on artifact density.**

Fig. 7.2D illustrates the effect of distance from the raw material sources upon the artifact weight density for each raw material type in each Paleogeographic Locale. As the model predicts, the *overall* density values exhibit a negative correlation. However, the only strong negative correlation is evident with artifacts of Kelogi gneiss ($R^2$= 0.9914), followed by weak correlations with artifacts of Naisiusiu quartzite ($R^2$= 0.2106), Naibor Soit quartzite ($R^2$= 0.1415), Lemagrut lava ($R^2$= 0.1299), and Sadiman lava ($R^2$= 0.01).

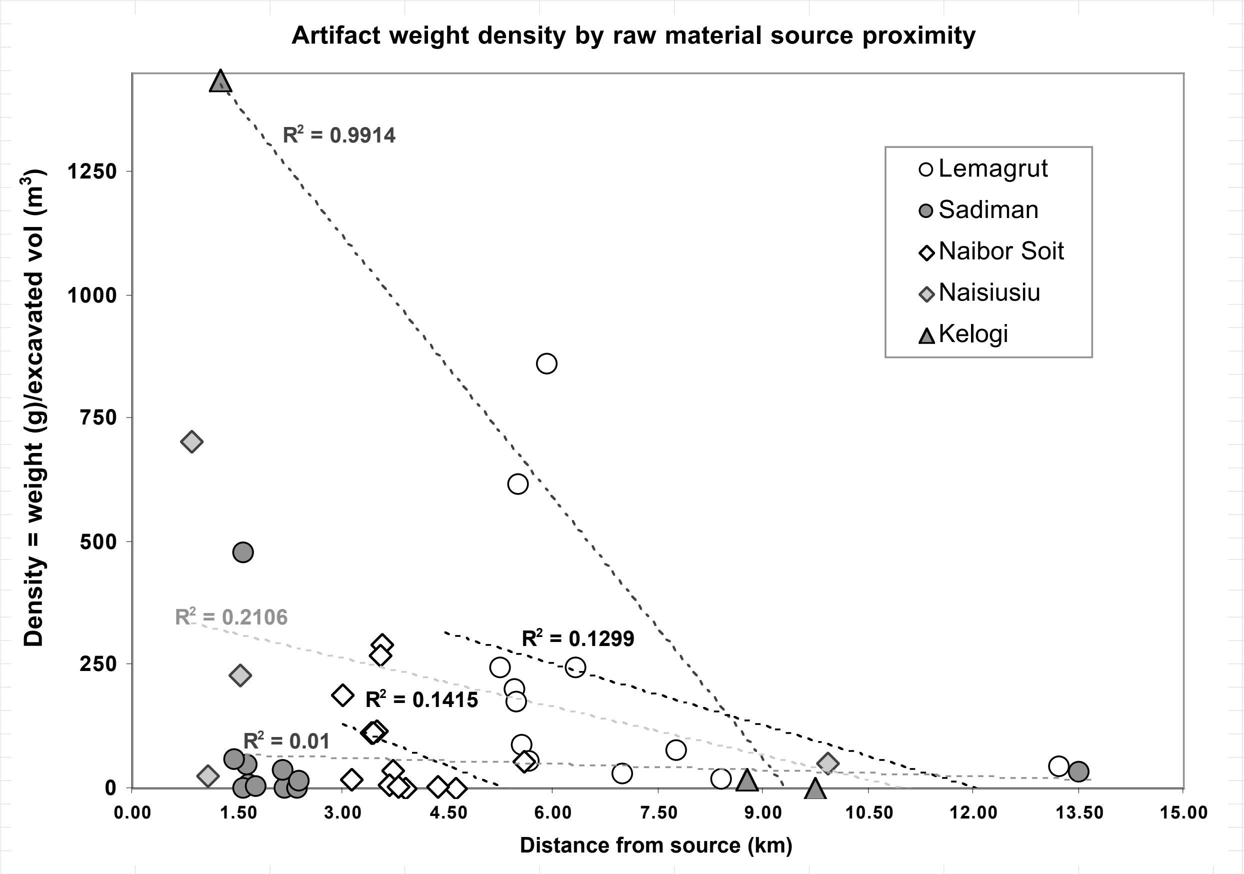


**Fig. 7.2D. Effect of distance from raw material source on artifact weight density in a Paleogeographic Locale scale.**

### *Summary of Implications*

In the first step of the model, the opportunistic strategy, raw material provenience plays the largest role in influencing artifact discard and loss patterns on a landscape. In this strategy it has been stipulated that both the clast size and abundance of available raw material are inversely related to the distance from its source. The high correspondence of the observed relative occurrence of artifact size and density values (73 %) supports the aforementioned stipulation. However, the low correspondence of observed and expected values (37%), does not support the hypothesis that a least effort opportunism was consistently implemented as a technological or behavioral strategy throughout the Olduvai paleolandscape. The examination of the affect of distance on distribution of artifact size and density grouped by raw material also does not support an extensive use of the opportunistic strategy, but rather a limited use in specific areas or with specific raw materials. The Spearman's rank correlation test showed significant correlations between expected and observed density values for all raw materials except Sadiman lava, and between expected and observed maximum dimension values for all raw materials except Sadiman lava and Naibor Soit quartzite. The SWLP is the only Landscape Association where size and density values all occur in conjunction and all expected values correspond with all observed values (except for Sadiman lava). In addition, raw material from Kelogi, which is in closest proximity to the SWLP, conforms to the distributional model as determined by provenience, strongly suggesting that an opportunistic strategy was used in the SWLP. The fact that there is some correspondence with the expected and observed occurrences of artifact size and density in other areas may also suggest that an opportunistic strategy was in effect to a lesser degree in those areas.

These results may imply that raw material selection is influencing artifact assemblage characteristics along with or instead of transport distances. In general, the data examined in this section do support the wholesale argument that as the distance from raw material source increases, size and density of artifacts discarded on the landscape will decrease. However, the hypothesis testing suggests that the affect of distance on artifact size and density does not fully account for the nature of observed lithic artifact discard and loss patterns on the paleolandscape. This does not imply that a least effort strategy was not implemented, but that it was not a spatially homogenous or uniform strategy.

In regards to the question of the scale of investigation, in the higher resolution Paleogeographic Locale grouping, where more data points display greater variation, there is a similar correspondence of observed relative occurrence of artifact size and density (77%) as well as a similar low correspondence of observed and expected values (32%). The scale of investigation appears to have been a factor only when the affect of distance from the raw material sources was plotted against the observed artifact size and density. That effect may be due to the greater number of sampling points, providing more confident correlation coefficients. However, the overall poor fit of the opportunistic strategy model with the observed archaeological data leads to further examination in the following section and the next step in the model, the expedient strategy.

## PART II. Testing the expedient model (Step 2)

Step 2 models a technological strategy whereby the operating hypothesis is that if tool using activities were expedient in nature, then spatial variation in lithic artifact assemblage characteristics would reflect transport and re-use of material, with Flaked Pieces and their associated Detached Pieces in the early stage of reduction occurring in a higher frequency nearer to the raw material source than those in the later stages of reduction (*see* Table 6.5). Thus, the lithic assemblages should vary spatially in composition by raw material type, Flaked and Detached Piece type, and artifact size and density (*see* Table 6.1). The nearer a Landscape Association is to the Naibor Soit inselberg, for example, the higher the percentage of Naibor Soit quartzite Flaked Pieces <50% should be relative to Flaked Pieces <50% of other more distant raw material sources.

The data used in this comparison, the percentages of early reduction stage Flaked and Detached Pieces, are presented first in tabular form below. A total of 556 artifacts from the landscape archaeological sample recovered from Olduvai Gorge Middle-Upper Bed I and lowermost Bed II were identified as Flaked Pieces plus Manuports, and Pounded Pieces. Of this sample, 88 specimens were categorized as ‘Other’ raw material, whose disparate sources are not implemented here, thus reducing the sample used in this comparison to 468 specimens. The early reduction stage Flaked Pieces are presented below by their count and as a percentage of the total Flaked Piece assemblage of each raw material type in each unit (Table 7.5A,B).

**Count and Percentage of Flaked Piece <50% (n = 265)**

| Landscape Association | Lemagrut |  | Sadiman |  | Naibor Soit |  | Naisiusiu |  | Kelogi |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | count | % | count | % | count | % | count | % | count | % |
| **WLP** | 0 | 0 | 2 | 100 | 0 | 0 | 40 | 47.06 | 1 | 100.00 |
| **SWLP** | 19 | 79.17 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 46.15 |
| **ELP** | 98 | 74.81 | 41 | 71.93 | 30 | 28.57 | 0 | 0 | 0 | 0 |
| **ELP/EAP** | 7 | 77.78 | 2 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| **EAP** | 9 | 90.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **NELP** | 2 | 66.67 | 0 | 0 | 2 | 50 | 0 | 0 | 0 | 0 |
| Raw Material Totals | 135 | 76.27 | 45 | 73.77 | 32 | 28.07 | 40 | 44.94 | 13 | 48.15 |

**Table 7.5A. Early reduction stage Flaked Piece distribution in Landscape scale.**

**Percentage of Flaked Piece <50%vs >50% (n = 468)**

| Landscape Association | Lemagrut |  | Sadiman |  | Naibor Soit |  | Naisiusiu |  | Kelogi |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | FP<50% | FP>50% | FP<50% | FP>50% | FP<50% | FP>50% | FP<50% | FP>50% | FP<50% | FP>50% |
| **WLP** | 0 | 0 | 100 | 0 | 0 | 0 | 47.06 | 52.94 | 100.00 | 0.00 |
| **SWLP** | 79.17 | 20.83 | 0 | 0 | 0 | 0 | 0 | 100 | 46.15 | 53.85 |
| **ELP** | 74.81 | 25.19 | 71.93 | 28.07 | 28.57 | 71.43 | 0 | 0 | 0 | 0 |
| **ELP/EAP** | 77.78 | 22.22 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| **EAP** | 90.00 | 10.00 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| **NELP** | 66.67 | 33.33 | 0 | 0 | 50 | 50 | 0 | 0 | 0 | 0 |
| Raw Material Totals | 76.27 | 23.73 | 73.77 | 26.23 | 28.07 | 71.93 | 44.94 | 55.06 | 48.15 | 51.85 |

**Table 7.5B. Comparison of early and later reduction stage Flaked Piece distribution .**

Of the 468 Flaked Pieces examined here, more than half (56.6%) of them are in the early reduction stage (henceforth ERS). Flaked Pieces in the ERS made on Lemagrut and Sadiman lava dominate relative to the later reduction stage (henceforth LRS) in all of the Landscape Associations where they occur. This is almost completely the reverse for Naibor Soit Flaked Pieces (with the exception of the even distribution in the NELP). Naisiusiu and Kelogi Flaked Pieces only occur in WLP and SWLP, the units west of the paleolake, with ERS Flaked Pieces made on Naisiusiu quartzite dominating where they occur. Flaked Pieces made on Kelogi gneiss occur in sparse but varied frequencies. No artifacts made on Naisiusiu quartzite or Kelogi gneiss occur in any of the Landscape Association units to the east of the paleolake. In addition, the ratio of ERS:LRS Flaked Pieces is relatively high for both Lemagrut and Sadiman Lava (~ 3:1), quite low for Naibor Soit quartzite (~ 1:3), and almost even for Naisiusiu quartzite and Kelogi gneiss. This may suggest that not only raw material source proximity but also raw material quality is a factor influencing reduction or transport strategies.

A comparably sized sample of 530 specimens was identified as Detached Pieces to specific Toth Types (*see* Fig. 5.3). Of this sample, 47 specimens were categorized as 'Other' raw material and were excluded from this comparison, reducing the sample size to 483. The count and proportion of ERS Detached Pieces relative to all Detached Pieces are presented below (Table 7.5C,D) for each raw material in each unit.

**Count and Percentage of Type I & II Detached Pieces (n = 84)**

| Landscape | Lemagrut | | Sadiman | | Naibor Soit | | Naisiusiu | | Kelogi | |
|---|---|---|---|---|---|---|---|---|---|---|
| Association | count | % | count | % | count | % | count | % | count | % |
| **WLP** | 0 | 0 | 0 | 0 | 0 | 0 | 43 | 20.00 | 0 | 0 |
| **SWLP** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **ELP** | 6 | 22.22 | 9 | 33.33 | 24 | 12.37 | 0 | 0 | 0 | 0 |
| **ELP/EAP** | 0 | 0 | 0 | 0 | 1 | 14.29 | 0 | 0 | 0 | 0 |
| **EAP** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **NELP** | 0 | 0 | 0 | 0 | 1 | 50 | 0 | 0 | 0 | 0 |
| Raw Material Totals | 6 | 20.69 | 9 | 30 | 26 | 12.81 | 43 | 19.55 | 0 | 0 |

**Table 7.5C. Early reduction stage Detached Piece distribution in Landscape scale**.

**Percentage of Detached Pieces Type I & II vs Type III-VI (n = 483)**

| Landscape | Lemagrut | | Sadiman | | Naibor Soit | | Naisiusiu | | Kelogi | |
|---|---|---|---|---|---|---|---|---|---|---|
| Association | I & II | III - VI | I & II | III - VI | I & II | III - VI | I & II | III - VI | I & II | III - VI |
| **WLP** | 0 | 0 | 0 | 0 | 0 | 0 | 20.00 | 80.00 | 0 | 0 |
| **SWLP** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 |
| **ELP** | 22.22 | 77.78 | 33.33 | 66.67 | 12.37 | 87.63 | 0 | 0 | 0 | 100 |
| **ELP/EAP** | 0 | 100 | 0 | 100 | 14.29 | 85.71 | 0 | 0 | 0 | 0 |
| **EAP** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **NELP** | 0 | 0 | 0 | 0 | 50 | 50 | 0 | 0 | 0 | 0 |
| Raw Material Totals | 20.69 | 79.31 | 30.00 | 70.00 | 12.81 | 87.19 | 19.55 | 80.45 | 0 | 100 |

**Table 7.5D. Comparison of Early and Later Reduction Stages.**

In contrast with the Flaked Piece distribution, only 17.4% of the assemblage is comprised of ERS Detached Pieces. ERS Detached Pieces made on Lemagrut and Sadiman lava occur less frequently relative to LRS. However, the less frequent occurrence of ERS Detached Pieces made on Naibor Soit quartzite does coincide with the Flaked Piece distribution. The same applies for the Naisiusiu Detached Piece distribution. ERS Detached Pieces made on Kelogi gneiss were not observed.

Regarding raw material richness, the Eastern Lacustrine Plain component of the Detached Piece assemblage displays a distributional pattern similar to that seen with Flaked Piece assemblage. In addition, the count of ERS Detached Pieces of quartzite is relatively high, but the ratio of ERS is for the most part, low. In general, whole flakes that are identified to a specific 'Toth Type' are extremely scarce except in the ELP and ELP/EAP, where all raw materials are present except for the more distant source material from Kelogi and Naisiusiu. Interestingly, when the spatial distribution of Detached Pieces is examined, the LRS almost always dominate where they occur (except for Naibor Soit material in the NELP, which is equally distributed). This might imply that the extent of manufacture, transportation, and curation is considerable but not necessarily linearly scaled to distance from the raw material source.

The expedient model implicitly predicts that the relative frequency of ERS Flaked Pieces will occur in conjunction with ERS Detached Pieces according to the distance from raw material source. The data show that 16 of 30 observed occurrences (53%) correspond in this way (Table 7.6),

| Early Reduction Stage Manuports and Flaked Piece <50% | | | | | | Early Reduction Stage Detached Pieces Type I & II | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ranked Relative Occurrence (n= 265) | | | | | | Ranked Relative Occurrence (n = 84) | | | | | |
| Landscape | Lava | | Quartzite | | Other | Landscape | Lava | | Quartzite | | Other |
| Association | LEM | SAD | NS | NAI | KEL | Association | LEM | SAD | NS | NAI | KEL |
| WLP | 1 | 4 | 1 | 3 | 4 | WLP | **1** | 1 | **1** | 5 | 1 |
| SWLP | 5 | 1 | 1 | 1 | 4 | SWLP | 1 | **1** | **1** | **1** | 1 |
| ELP | 5 | 4 | 3 | 1 | 1 | ELP | 3 | **4** | 2 | **1** | 5 |
| ELP/EAP | 4 | 5 | 1 | 1 | 1 | ELP/EAP | 1 | 1 | 5 | **1** | **1** |
| EAP | 5 | 1 | 1 | 1 | 1 | EAP | 1 | **1** | **1** | **1** | **1** |
| NELP | 5 | 1 | 4 | 1 | 1 | NELP | 1 | **1** | 5 | **1** | **1** |

**Table 7.6. Examination of covariation between assumed early reduction stage indicators.**

This may suggest a distance function influencing transport of Flaked Pieces in and out of areas of manufacture, which would obscure or alter the association with discard patterns of Detached Pieces that were not transported.

To begin testing the expedient strategy model, the mean frequency of the critical variables will be examined as they occur in each Landscape Association. If transport and re-use of raw material was being implemented as a conservation or economization measure, then ERS Flaked and Detached Pieces should occur in a higher frequency closer to their raw material source. As the distance to the raw material source increases, so should the relative frequency of LRS Flaked and Detached Pieces.

To test the implications of the second step of the model, the predicted relative values of ERS Flaked Pieces of each raw material are compared with the observed archaeological sample's percentages relative to the distance from each Landscape Association (Table 7.7A). Note that the observed values that correspond with the expected relative frequencies are represented in **boldface** type.

| Landscape Association | Expected Incidence of Flaked Piece <50% (including Manuports, Pounded Pieces, and Split Cobbles) | | | | | Observed Incidence of Flaked Piece <50% as a percentage of all Flaked Pieces | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LEM | SAD | NS | NAI | KEL | LEM | SAD | NS | NAI | KEL |
| Western Lacustrine Plain | low | lowest | med | highest | **high** | 0 | 100 | 0 | 47.06 | **100** |
| Southwestern Lacustrine Plain | high | low | **lowest** | med | highest | 79.17 | 0 | **0** | 0 | 46.15 |
| Eastern Lacustrine Plain | med | highest | high | **lowest** | low | 74.81 | 71.93 | 28.57 | **0** | 0 |
| Eastern Lacustrine Plain/ Eastern Alluvial Plain | med | **highest** | high | **lowest** | low | 77.78 | **100** | 0 | **0** | 0 |
| Eastern Alluvial Plain | med | highest | high | **lowest** | low | 90.00 | 0 | 0 | **0** | 0 |
| Northeastern Lacustrine Plain | med | high | highest | low | **lowest** | 66.67 | 0 | 50.00 | 0 | **0** |

**Table 7.7A. Comparison of expected and observed early reduction stage Flaked Pieces in the economization strategy. Observed data represent the total percentages of each Landscape Association unit.**

In this comparison, only 7 of 30 observed occurrences (23%) correspond with the predictions. The predicted high occurrence of ERS Flaked Pieces in the WLP corresponds with the observed occurrence of artifacts made on Kelogi gneiss. The predicted lowest occurrence in the SWLP corresponds with the absence of those made on Naibor Soit quartzite, as does the predicted lowest occurrence of Kelogi gneiss in the Lake, and of Naisiusiu quartzite in the ELP. The highest and lowest predicted occurrences in the ELP/EAP correspond with the observed occurrences of those made on Sadiman lava and Naisiusiu quartzite (respectively), and the predicted lowest occurrence in the NELP correspond with the absence of those made on Kelogi gneiss.

Next, the predicted relative values of ERS Detached Pieces are compared with the observed archaeological samples' percentages in each Landscape Association (Table 7.7B). Note that the observed values that correspond with the expected relative frequencies are represented in **boldface** type.

| **Landscape Association** | **Expected Incidence of Detached Piece Type I and Type II (*after,* Toth, 1985)** | | | | | **Observed Incidence of Detached Piece Type I and Type II (as a percentage of all Whole Detached Pieces)** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **LEM** | **SAD** | **NS** | **NAI** | **KEL** | **LEM** | **SAD** | **NS** | **NAI** | **KEL** |
| Western Lacustrine Plain | low | **lowest** | med | **highest** | high | 0 | **0** | 0 | **20.00** | 0 |
| Southwestern Lacustrine Plain | high | low | **lowest** | med | highest | 0 | 0 | **0** | 0 | 0 |
| Eastern Lacustrine Plain | **med** | highest | high | **lowest** | low | **22.22** | 33.33 | 12.37 | **0** | 100 |
| Eastern Lacustrine Plain/ Eastern Alluvial Plain | med | highest | high | **lowest** | low | 0 | 0 | 14.29 | **0** | 0 |
| Eastern Alluvial Plain | med | highest | high | **lowest** | low | 0 | 0 | 0 | **0** | 0 |
| Northeastern Lacustrine Plain | med | high | **highest** | low | **lowest** | 0 | 0 | **50.00** | 0 | **0** |

**Table 7.7B. Comparison of expected and observed early reduction stage Detached Pieces in the economization strategy. Observed data represent the total percentages of each Landscape Association unit.**

In the case of ERS Detached Pieces, 9 of 30 observed occurrences (30%) correspond with the predicted occurrences. In the WLP, the predicted highest and lowest occurrences of ERS Detached Pieces correspond with the observed frequency of artifacts made on Naisiusiu quartzite and the absence of those made on Sadiman lava. The predicted lowest occurrences in the SWLP and in the Lake correspond with the absence of artifacts made on Naibor Soit quartzite, and on Kelogi gneiss (respectively). In the ELP the predicted moderate and lowest occurrences of ERS Detached Pieces correspond with the observed frequency of artifacts made on Lemagrut lava and the absence of those made on Naisiusiu quartzite. The predicted lowest occurrences in the ELP/EAP and in the EAP correspond with the absence of artifacts made on Naisiusiu quartzite, and the highest and lowest predicted occurrences in the NELP correspond with the observed frequency of artifacts made on Naibor Soit quartzite and the absence of those made on Kelogi gneiss. When the observed frequencies of ERS Flaked and Detached Piece are combined, 16 of 60 observed occurrences (27%) correspond with the predictions.

In order to further examine the affect of distance from raw material source on the two early reduction stage variables, the percentage of ERS Flaked and Detached Pieces are plotted against distance. The model predicts a negative correlation between the frequency of ERS Flaked Pieces and distance from source. The first graph shows the effect of distance on a global distribution of ERS Flaked Pieces (Fig.7.3A). The positive correlation seen here (*$R^2$* = 0.2815) does not support the economization by transport hypothesis as evidenced by the distribution of ERS Flaked Pieces.

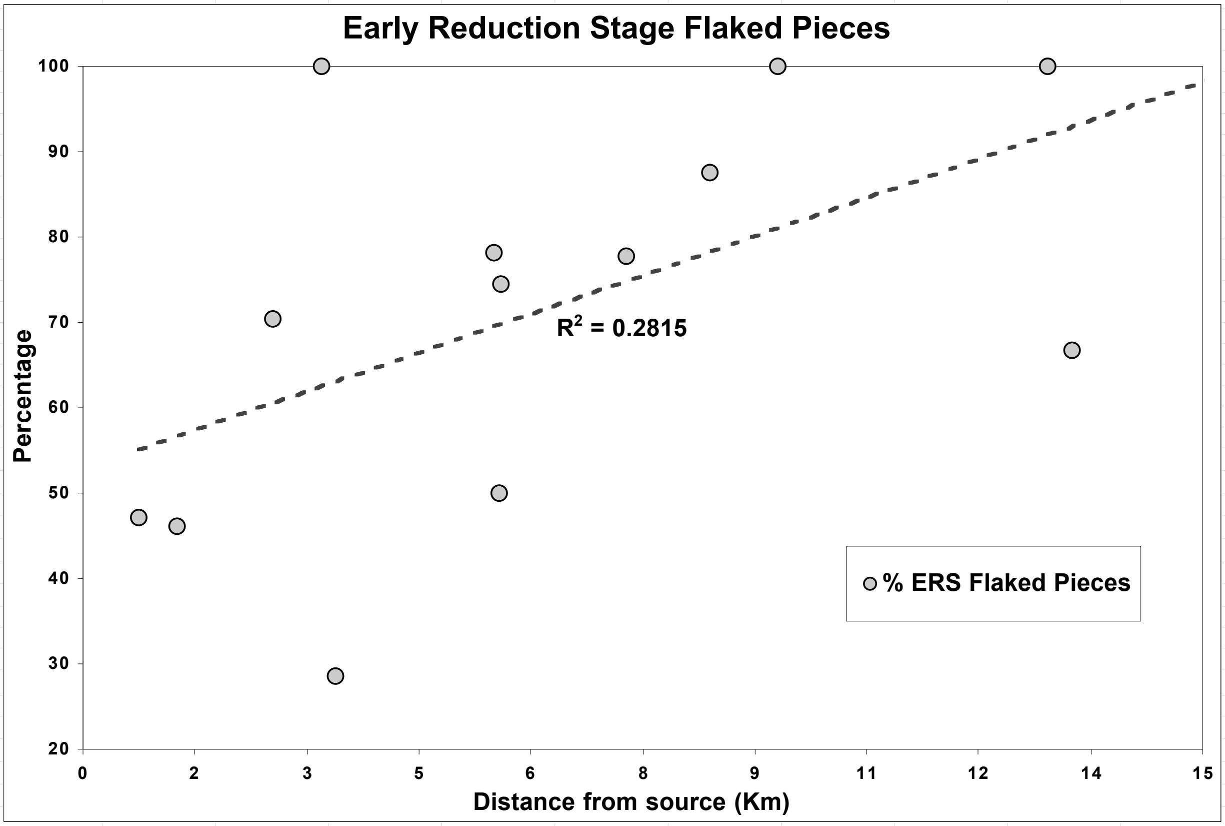


**Fig. 7.3A. Effect of distance from raw material source on early reduction stage Flaked Piece frequencies.**

Fig.7.3B shows the relationship between the percentage of ERS Flaked Pieces of each raw material type from each Paleogeographic Locale, and the distance from the raw material source. Here the data illustrate that only artifacts made on Lemagrut lava display a negative trend, but it is very weak ($R^2 = 0.2475$). A positive correlation is evidenced by Sadiman lava ($R^2 = 0.2987$), but derived from only three data points. Both Naibor Soit quartzite and Kelogi gneiss show perfect positive correlation coefficients but are each derived from only two sample points.

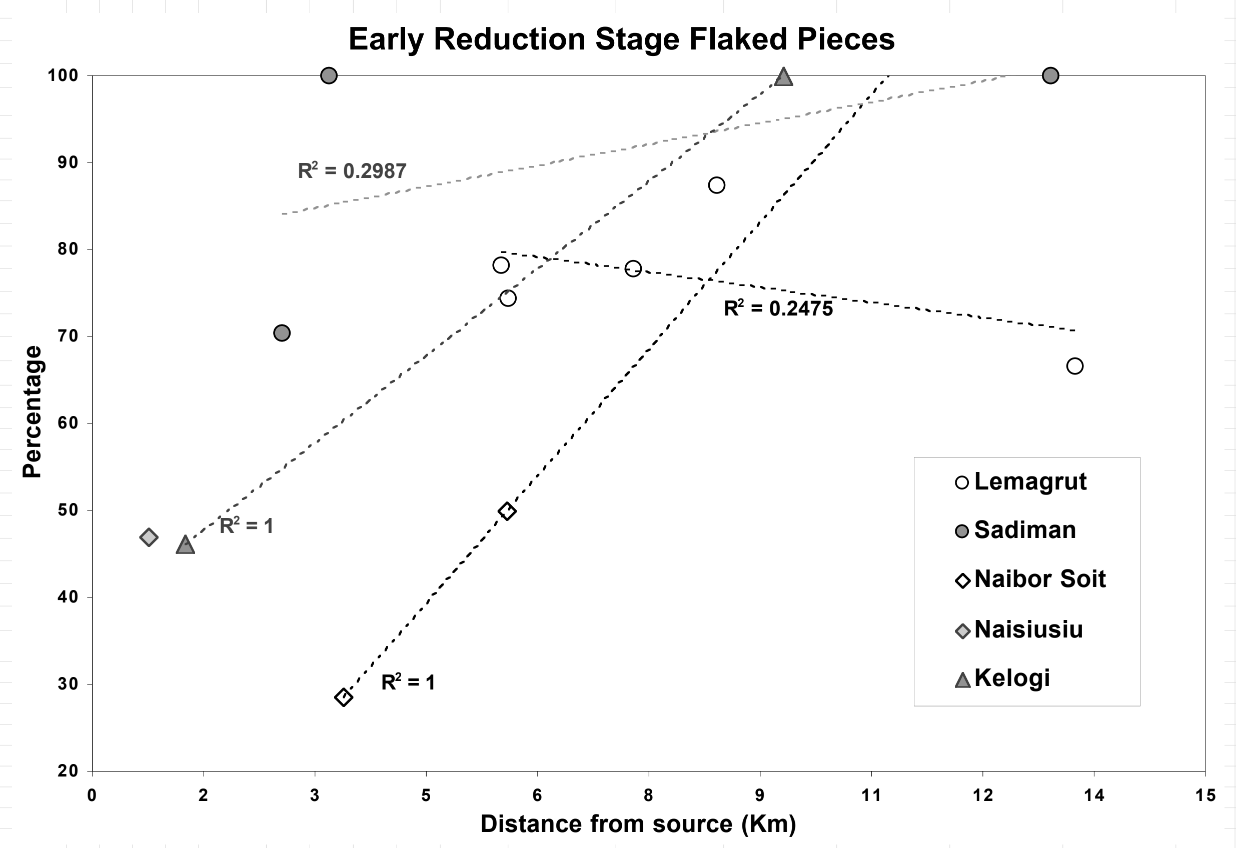


**Fig. 7.3B. Effect of distance on early reduction stage Flaked Piece frequencies by raw material types.**

Fig.7.3C shows the effect of distance on a global distribution of ERS Detached Pieces. The positive correlation seen here ($R^2 = 0.1535$) does not support the economization by transport hypothesis as evidenced by the distribution of ERS Detached Pieces.

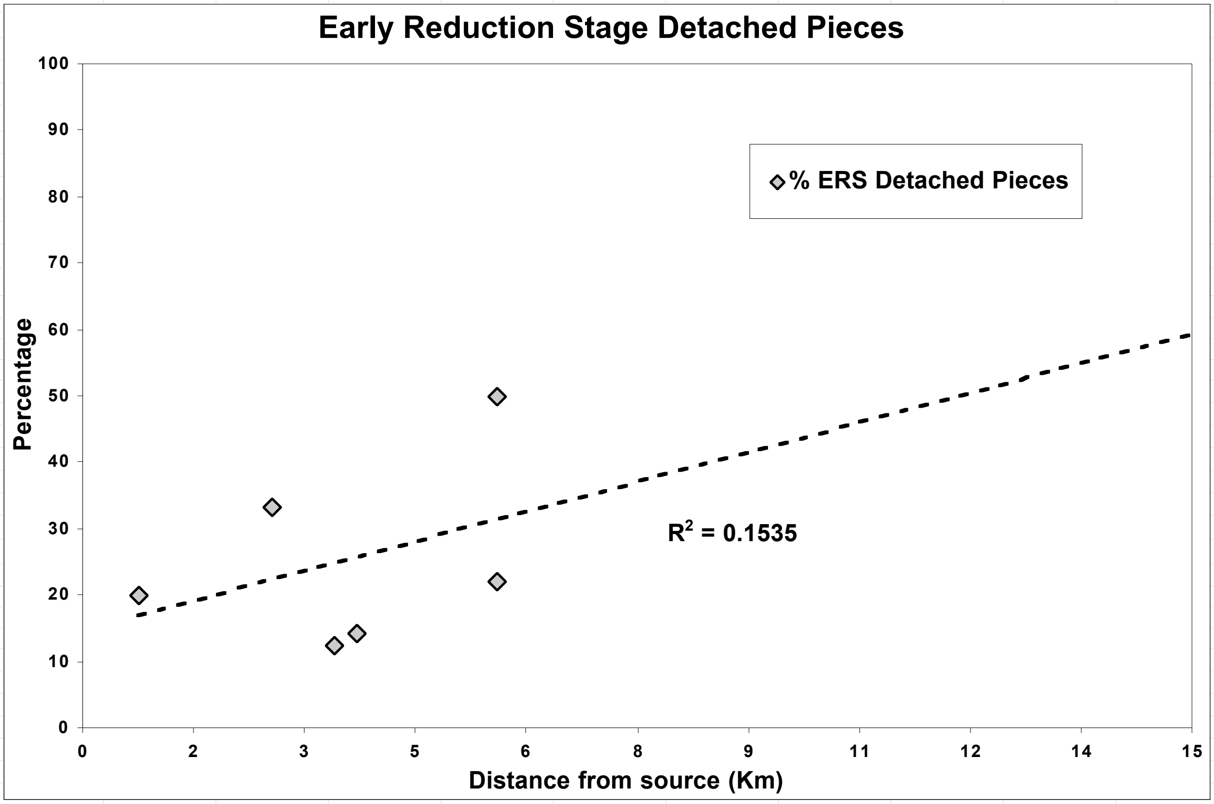


**Fig. 7.3C. Effect of distance from raw material source on early reduction stage Detached Piece frequencies.**

Fig. 7.3D shows the effect of distance on ERS Detached Piece frquencies grouped by raw material types. In this case, there are so few data points for each raw material type that only one raw material source is represented by enough data points to display a trend. Naibor Soit quartzite shows a very strong positive correlation coefficient ($R^2 = .9932$).

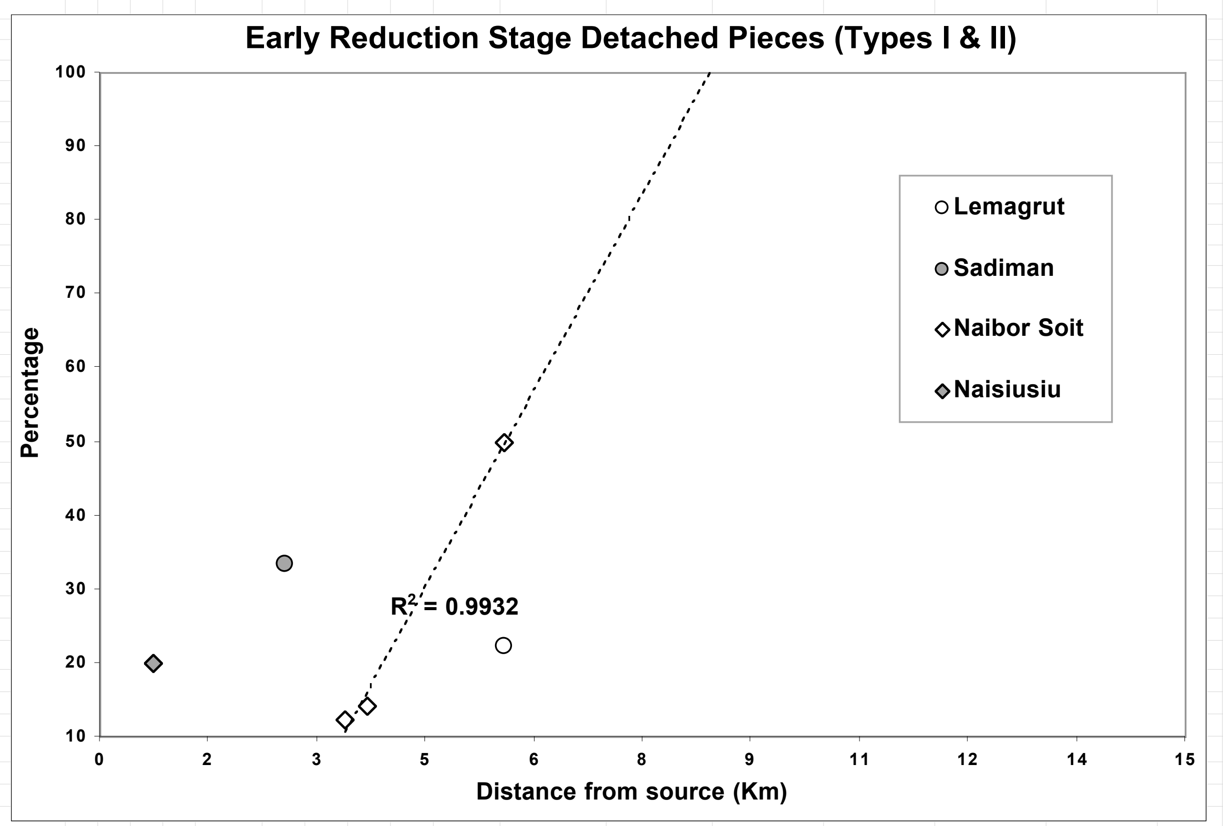


**Fig. 7.3D. Effect of distance from raw material source on early reduction stage Detached Piece frequencies.**

As in the previous section, in order to examine the effect of scale upon the comparisons, I now examine the same data grouped in the higher resolution Paleogeographic Locale scale. The relevant data are presented below by their counts (Table 7.8A,B) and as a percentage of the total artifact assemblage for each raw material type in each unit. Unlike the total dominance of ERS Flaked Pieces seen in the Landscape Association scale, here ERS Flaked Pieces made on Lemagrut lava occur more frequently than LRS Flaked Pieces in only 9 of the 12 Paleogeographic Locales where they occur. FLK and VEK display even distributions and the HWKEE-KK assemblage is dominated by LRS Flaked Pieces.

**Count and Percentage of FP <50%  (n = 265)**

| **Paleogeographic Locale** | **Lemagrut** | | **Sadiman** | | **Naibor Soit** | | **Naisiusiu** | | **Kelogi** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | count | % | count | % | count | % | count | % | count | % |
| Loc. 64 | 0 | 0 | 2 | 100 | 0 | 0 | 27 | 50.94 | 0 | 0 |
| Naisiusiu | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 33.33 | 0 | 0 |
| West-Lake | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 42.31 | 1 | 100 |
| Kelogi | 19 | 79.17 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 46.15 |
| MNK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FLK | 3 | 50.00 | 2 | 100 | 1 | 16.67 | 0 | 0 | 0 | 0 |
| VEK | 5 | 50.00 | 1 | 100 | 4 | 50.00 | 0 | 0 | 0 | 0 |
| HWKW | 9 | 90.00 | 3 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| HWKE | 13 | 100 | 4 | 50.00 | 5 | 17.86 | 0 | 0 | 0 | 0 |
| HWKEE-KK | 1 | 33.33 | 0 | 0 | 2 | 40.00 | 0 | 0 | 0 | 0 |
| MCK | 58 | 80.56 | 31 | 72.09 | 18 | 40.00 | 0 | 0 | 0 | 0 |
| TK-Loc. 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LONGK | 9 | 52.94 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JK-WK | 3 | 60.00 | 2 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| DK-Complex | 4 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| THC-Complex | 9 | 90.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fifth-Fault | 2 | 66.67 | 0 | 0 | 2 | 50 | 0 | 0 | 0 | 0 |
| **Raw material totals** | **135** | **76.27** | **45** | **73.77** | **32** | **28.07** | **40** | **44.94** | **13** | **48.15** |

**Table 7.8A.Early reduction stage Flaked Piece distribution in Landscape scale.**

**Percentage of Early (<50%) and Later (>50%) Reduction Stage Flaked Pieces  (n = 468)**

| **Paleogeographic Locale** | **Lemagrut** | | **Sadiman** | | **Naibor Soit** | | **Naisiusiu** | | **Kelogi** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | FP<50% | FP>50% | FP<50% | FP>50% | FP<50% | FP>50% | FP<50% | FP>50% | FP<50% | FP>50% |
| Loc. 64 | 0 | 0 | 100 | 0 | 0 | 0 | 50.94 | 49.06 | 0 | 0 |
| Naisiusiu | 0 | 0 | 0 | 0 | 0 | 0 | 33.33 | 66.67 | 0 | 0 |
| West-Lake | 0 | 0 | 0 | 0 | 0 | 0 | 42.31 | 57.69 | 100 | 0 |
| Kelogi | 79.17 | 20.83 | 0 | 0 | 0 | 0 | 0 | 100 | 46.15 | 53.85 |
| MNK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FLK | 50 | 50.00 | 100 | 0 | 16.67 | 83.33 | 0 | 0 | 0 | 0 |
| VEK | 50 | 50.00 | 100 | 0 | 50 | 50.00 | 0 | 0 | 0 | 0 |
| HWKW | 90 | 10.00 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| HWKE | 100 | 0 | 50 | 50.00 | 17.86 | 82.14 | 0 | 0 | 0 | 0 |
| HWKEE-KK | 33.33 | 66.67 | 0 | 0 | 40 | 60.00 | 0 | 0 | 0 | 0 |
| MCK | 80.56 | 19.44 | 72.09 | 27.91 | 40 | 60.00 | 0 | 0 | 0 | 0 |
| TK-Loc. 20 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| LONGK | 52.94 | 47.06 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| JK-WK | 60 | 40.00 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| DK-Complex | 100 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| THC-Complex | 90 | 10.00 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| Fifth-Fault | 66.67 | 33.33 | 0 | 0 | 50 | 50 | 0 | 0 | 0 | 0 |
| **Raw material totals** | **76.27** | **23.73** | **73.77** | **26.23** | **28.07** | **71.93** | **44.94** | **55.06** | **48.15** | **51.85** |

**Table 7.8B. Percentages of early and later reduction stage Flaked Pieces on a Paleogeographic locale scale.**

In addition, ERS Flaked Pieces made on Sadiman lava occur more frequently than LRS Flaked Pieces in 6 of the 7 Paleogeographic Locales where they occur, and in HWKE they are evenly distributed. Conversely, where Naibor Soit Flaked Pieces occur, the LRS dominates 10 of the12 Paleogeographic Locales and VEK and the Fifth-Fault assemblages are equally distributed. Naisiusiu and Kelogi Flaked Pieces only occur in the western Paleogeographic Locales. Naisiusiu Flaked Pieces trend toward a higher incidence of LRS, and the few Kelogi Flaked Pieces vary in their distribution.

Raw material richness is greatest in FLK, VEK, HWKW, HWKE, and MCK assemblages, comprised mainly of raw materials from sources located to the east of the paleolake. Naisiusiu quartzite and Kelogi gneiss, located to the west of the paleolake are the only raw materials found in Loc.64, Naisiusiu, and West-Lake assemblages.

Another critical variable that was examined is the ratio of ERS:LRS Detached Pieces. These data are also presented at the higher resolution scale of Paleogeographic Locales by their counts and as percentages (Table 7.8C,D) of the total Whole Detached Piece assemblage for each raw material in each unit.

**Count and Percentage of TYPE I & II Detached Pieces (n = 483)**

| **Paleogeographic Locale** | **Lemagrut** | | **Sadiman** | | **Naibor Soit** | | **Naisiusiu** | | **Kelogi** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | count | % | count | % | count | % | count | % | count | % |
| Loc. 64 | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 17.78 | 0 | 0 |
| Naisiusiu | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 20.00 | 0 | 0 |
| West-Lake | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 33.33 | 0 | 0 |
| Kelogi | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MNK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FLK | 0 | 0 | 0 | 0 | 1 | 7.69 | 0 | 0 | 0 | 0 |
| VEK | 0 | 0 | 0 | 0 | 3 | 12.50 | 0 | 0 | 0 | 0 |
| HWKW | 1 | 50.00 | 0 | 0 | 3 | 11.11 | 0 | 0 | 0 | 0 |
| HWKE | 1 | 100 | 1 | 50.00 | 5 | 10.00 | 0 | 0 | 0 | 0 |
| HWKEE-KK | 0 | 0 | 2 | 66.67 | 6 | 23.08 | 0 | 0 | 0 | 0 |
| MCK | 3 | 15.79 | 6 | 33.33 | 4 | 9.52 | 0 | 0 | 0 | 0 |
| TK-Loc. 20 | 0 | 0 | 0 | 0 | 1 | 20.00 | 0 | 0 | 0 | 0 |
| LONGK | 1 | 33.33 | 0 | 0 | 1 | 50.00 | 0 | 0 | 0 | 0 |
| JK-WK | 0 | 0 | 0 | 0 | 1 | 16.67 | 0 | 0 | 0 | 0 |
| DK-Complex | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| THC-Complex | 0 | 0 | 0 | 0 | 1 | 50.00 | 0 | 0 | 0 | 0 |
| Fifth-Fault | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Raw material totals** | 6 | 20.69 | 9 | 30.00 | 26 | 12.81 | 43 | 19.55 | 0 | 0 |

**Table 7.8C. Early reduction stage Detached Piece distribution on a Paleogeographic locale scale.**

**Percentage of Early (TYPE I & II) and Later (TYPE III-VI) Reduction Stage Detached Pieces (n = 483)**

| **Paleogeographic** | **Lemagrut** | | **Sadiman** | | **Naibor Soit** | | **Naisiusiu** | | **Kelogi** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Locale** | I & II | III-VI | I & II | III-VI | I & II | III-VI | I & II | III-VI | I & II | III-VI |
| Loc. 64 | 0 | 0 | 0 | 0 | 0 | 0 | 17.78 | 82.22 | 0 | 0 |
| Naisiusiu | 0 | 0 | 0 | 0 | 0 | 0 | 20.00 | 80.00 | 0 | 0 |
| West-Lake | 0 | 0 | 0 | 0 | 0 | 0 | 33.33 | 66.67 | 0 | 0 |
| Kelogi | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 |
| MNK | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| FLK | 0 | 0 | 0 | 0 | 7.69 | 92.31 | 0 | 0 | 0 | 0 |
| VEK | 0 | 100 | 0 | 100 | 12.50 | 87.50 | 0 | 0 | 0 | 0 |
| HWKW | 50.00 | 50.00 | 0 | 0 | 11.11 | 88.89 | 0 | 0 | 0 | 100 |
| HWKE | 100 | 0 | 50.00 | 50.00 | 10.00 | 90.00 | 0 | 0 | 0 | 0 |
| HWKEE-KK | 0 | 0 | 66.67 | 33.33 | 23.08 | 76.92 | 0 | 0 | 0 | 0 |
| MCK | 15.79 | 84.21 | 33.33 | 66.67 | 9.52 | 90.48 | 0 | 0 | 0 | 0 |
| TK-Loc. 20 | 0 | 0 | 0 | 100 | 20.00 | 80.00 | 0 | 0 | 0 | 0 |
| LONGK | 33.33 | 66.67 | 0 | 100 | 50.00 | 50.00 | 0 | 0 | 0 | 0 |
| JK-WK | 0 | 100 | 0 | 100 | 16.67 | 83.33 | 0 | 0 | 0 | 0 |
| DK-Complex | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| THC-Complex | 0 | 0 | 0 | 0 | 50.00 | 50.00 | 0 | 0 | 0 | 0 |
| Fifth-Fault | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Raw material totals** | 20.69 | 79.31 | 30.00 | 70.00 | 12.81 | 87.19 | 19.55 | 80.45 | 0 | 100 |

**Table 7.8D. Early and later reduction stage Detached Pieces on a Paleogeographic locale scale.**

Of the 483 Detached Pieces examined here, only 84 of them (17.4%) are in the ERS. This distributional bias may reflect a behavioral strategy, but may also be due to the simple fact that there are a greater number of LRS (Types III-VI) than ERS (Types I-II) classes.

In the seven Paleogeographic Locales where Detached Pieces made on Lemagrut lava occur, the ERS are more frequent than LRS only in HWKE. In HWKW they are evenly distributed. In the seven Paleogeographic Locales where Detached Pieces made of Sadiman lava occur, the ERS is dominant only in HWKEE-KK, and an even distribution is seen in HWKE. In all of the other units, LRS Detached Pieces occur more frequently. Detached Pieces made on Naibor Soit quartzite occur in 12 Paleogeographic Locales, with the LRS dominating in 10 of the12 units. The LongK and THC-Complex Detached Piece assemblages are equally distributed. Naisiusiu Detached Pieces occur only in the western Paleogeographic Locales, and the LRS occurs more frequently in all units they occur. Only one Detached Piece of the LRS made on Kelogi gneiss occurs as an eastern outlier in HWKW. The near absence of whole Detached Pieces made on

Kelogi gneiss may be explained (among other things, like distance or travel routes) by the friable nature of the raw material, resulting in a greater frequency of shattered detached pieces.

To test the implications of the expedient strategy model, the expected incidence of the ERS Flaked and Detached Pieces are compared with the observed archaeological occurrences (Table 7.9A,B). Note that the observed values that correspond with the expected relative frequencies are represented in **boldface** type.

| **Paleogeographic Locale** | **Expected Incidence of Early Reduction Stage Flaked Piece as a percentage of all Flaked Pieces** | | | | | **Expected Incidence of Early Reduction Stage Detached Piece Type I and II (*after* Toth, 1985), as a percentage of all Whole Detached Pieces** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **LEM** | **SAD** | **NS** | **NAI** | **KEL** | **LEM** | **SAD** | **NS** | **NAI** | **KEL** |
| Loc. 64 | low | lowest | medium | highest | high | low | **lowest** | medium | **highest** | high |
| Naisiusiu | low | **lowest** | medium | **highest** | high | low | **lowest** | medium | **highest** | high |
| West-lake | low | **lowest** | medium | highest | high | low | **lowest** | medium | **highest** | high |
| Kelogi | high | low | **lowest** | medium | highest | high | low | **lowest** | medium | highest |
| MNK | medium | highest | high | **lowest** | low | medium | highest | high | **lowest** | low |
| FLK | medium | **highest** | high | **lowest** | low | medium | highest | high | **lowest** | low |
| VEK | **medium** | **highest** | high | **lowest** | low | medium | highest | high | **lowest** | low |
| HWKW | medium | **highest** | high | **lowest** | low | medium | highest | **high** | **lowest** | low |
| HWKE | medium | highest | high | **lowest** | low | medium | highest | high | **lowest** | low |
| HWKEE-KK | medium | highest | high | **lowest** | low | medium | **highest** | **high** | **lowest** | low |
| MCK | medium | highest | high | **lowest** | low | medium | **highest** | high | **lowest** | low |
| TK-Loc.20 | medium | highest | high | **lowest** | low | medium | highest | high | **lowest** | low |
| LongK | medium | highest | high | **lowest** | low | medium | highest | high | **lowest** | low |
| JK-WK | medium | **highest** | high | **lowest** | low | medium | highest | high | **lowest** | low |
| DK-Complex | medium | highest | high | **lowest** | low | medium | highest | high | **lowest** | low |
| THC-Complex | medium | highest | high | **lowest** | low | medium | highest | high | **lowest** | low |
| Fifth-Fault | medium | high | highest | low | **lowest** | medium | high | highest | low | **lowest** |

**Table 7.9A. Expected relative frequency of occurrence of early reduction stage Flaked and Detached Pieces in a Paleogeographic Locale grouping (Flaked Pieces include Manuports, Split Cobbles, and Pounded Pieces).**

| **Paleogeographic Locale** | **Observed Incidence of Early Reduction Stage Flaked Piece (FP <50%) as a percentage of all Flaked Pieces** | | | | | **Observed Incidence of Early Reduction Stage Detached Piece Type I and II (*after* Toth, 1985), as a percentage of all Whole Detached Pieces** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **LEM** | **SAD** | **NS** | **NAI** | **KEL** | **LEM** | **SAD** | **NS** | **NAI** | **KEL** |
| Loc. 64 | lowest | highest | lowest | high | lowest | lowest | **lowest** | lowest | **highest** | lowest |
| Naisiusiu | lowest | **lowest** | lowest | **highest** | lowest | lowest | **lowest** | lowest | **highest** | lowest |
| West-lake | lowest | **lowest** | lowest | high | highest | lowest | **lowest** | lowest | **highest** | lowest |
| Kelogi | highest | lowest | **lowest** | lowest | high | lowest | lowest | **lowest** | lowest | lowest |
| MNK | lowest | lowest | lowest | **lowest** | lowest | lowest | lowest | lowest | **lowest** | lowest |
| FLK | high | **highest** | medium | **lowest** | lowest | lowest | lowest | highest | **lowest** | lowest |
| VEK | **medium** | **highest** | medium | **lowest** | lowest | lowest | lowest | highest | **lowest** | lowest |
| HWKW | high | **highest** | lowest | **lowest** | lowest | highest | lowest | **high** | **lowest** | lowest |
| HWKE | highest | high | medium | **lowest** | lowest | highest | high | medium | **lowest** | lowest |
| HWKEE-KK | high | lowest | highest | **lowest** | lowest | lowest | **highest** | **high** | **lowest** | lowest |
| MCK | highest | high | medium | **lowest** | lowest | high | **highest** | medium | **lowest** | lowest |
| TK-Loc.20 | lowest | lowest | lowest | **lowest** | lowest | lowest | lowest | highest | **lowest** | lowest |
| LongK | highest | lowest | lowest | **lowest** | lowest | high | lowest | highest | **lowest** | lowest |
| JK-WK | high | **highest** | lowest | **lowest** | lowest | lowest | lowest | highest | **lowest** | lowest |
| DK-Complex | highest | lowest | lowest | **lowest** | lowest | lowest | lowest | lowest | **lowest** | lowest |
| THC-Complex | highest | lowest | lowest | **lowest** | lowest | lowest | lowest | highest | **lowest** | lowest |
| Fifth-Fault | highest | lowest | high | lowest | **lowest** | lowest | lowest | lowest | lowest | **lowest** |

**Table 7.9B. Observed relative frequency of occurrence of early reduction stage Flaked and Detached Pieces in a Paleogeographic Locale grouping.**

In the higher spatial resolution grouping, 54 of 85 ERS Flaked Pieces and ERS Detached Pieces occur together (64%). Comparing the expected and observed incidence of ERS Flaked Pieces, 22 of 85 observed occurrences (26%) correspond with the predictions. In Loc. 64, none of the observed values match the predictions. In Naisiusiu, the observed occurrence of artifacts made on Naisiusiu quartzite and the observed absence of those made on Sadiman lava corresponds with the predicted highest and lowest occurrences. The absence of artifacts made on Sadiman lava and Naibor Soit quartzite corresponds with the expected lowest occurrences in the West-Lake and Kelogi (respectively). The observed absence of ERS Flaked Pieces made on Naisiusiu quartzite corresponds with the predicted lowest occurrences in all of the Paleogeographic Locales east of the paleolake except for the Fifth-Fault, where the absence of artifacts made on Kelogi gneiss corresponds with the predictions. The observed highest incidence of ERS Flaked Pieces corresponds with the expected in FLK, VEK, HWKW, and JK-

WK with artifacts made on Sadiman lava. The only observed moderate occurrence that corresponds with the prediction is found with Flaked Pieces made on Lemagrut lava in VEK, which is the only Paleogeographic Locale wherein more than two observed relative values (highest, lowest, and medium) correspond with the predictions.

Comparing the expected and observed incidence of ERS Detached Pieces, 24 of 85 observed occurrences (28%) correspond with the predictions. In Loc.64, Naisiusiu, and the West-Lake the observed occurrence of artifacts made on Naisiusiu quartzite and the observed absence of those made on Sadiman lava correspond with the predicted highest and lowest occurrences. In Kelogi the observed absence of ERS Detached Pieces made on Naibor Soit quartzite and Kelogi gneiss corresponds with the predicted lowest occurrences. The observed absence of ERS Detached Pieces made on Naisiusiu quartzite corresponds with the predicted lowest occurrences in all of the Paleogeographic Locales east of the paleolake except for the Fifth-Fault, where an absence of artifacts made on Kelogi gneiss corresponds with the predicted lowest occurrence. In the HWKEE-KK and MCK Paleogeographic Locales, the observed highest incidence of ERS Detached Pieces made on Sadiman lava corresponds with the expected highest incidence of ERS Detached Pieces. The only correspondence of observed high occurrences of ERS Detached Pieces with that of the predictions is seen with artifacts made on Naibor Soit quartzite in HWKW, and in HWKEE-KK (which is also the only Locale where more than two observations occur in conjunction with the predictions). In the combined cases of observed ERS Flaked and Detached Piece occurrences 46 of 170 (27%) observations match the predictions. In most cases, it is the expected lowest incidence and the observed absence of occurrences that correspond.

The observed ERS Flaked and Detached Piece values in each Paleogeographic Locale are not a perfect match for the expected values, but a Spearman’s rank correlation test shows that there is a significant correlation between expected and observed values of these variables for ERS Flaked Pieces made on Lemagrut lava and for ERS Flaked and Detached Pieces made on Naisiusiu quartzite and Kelogi gneiss

(Table 7.9C)

| **Spearman's rank Correlation** | **P-value (α = .01)** | |
|---|---|---|
| **Raw Material Type** | **Early Reduction Stage Flaked Piece** | **Early Reduction Stage Detached Piece** |
| Lemagrut lava | **.0021** | .0259 |
| Sadiman lava | .0651 | .0124 |
| Naibor Soit quartzite | .0196 | .1005 |
| Naisiusiu quartzite | **.0004** | **.0004** |
| Kelogi gneiss | **.0013** | **.0073** |

**Table 7.9C. Spearman's rank correlation of expected and observed early reduction Stage Flaked and Detached Pieces grouped by raw material type.**

Incorporating all of the diagnostic variables that were hypothesized for the expedient strategy model in the Paleogeographic Locale scale (*see* Table 6.1, 6.7), the lithic artifact assemblages would display the characteristics presented in Table 7.10. The table shows only the observed highest occurrences of raw material and artifact types in two compact categories; availability (size and density) and transport and curation (ERS Flaked and Detached Pieces). Note that the observations that match the predictions are shown in **boldface** type.

| **Observed highest incidences of raw material and artifact types** | | | | |
|---|---|---|---|---|
| | **Availability** | | **Transport and Curation** | |
| **Paleogeographic Locale** | Largest Size | Highest Density | Early Reduction Stage Flaked Pieces, as a percentage of all Flaked Pieces | Early Reduction Stage Detached Pieces as a percentage of all Whole Detached Pieces |
| Loc. 64 | Sadiman Lava | **Naisiusiu Quartzite** | Sadiman Lava | **Naisiusiu Quartzite** |
| Naisiusiu | **Naisiusiu Quartzite** | **Naisiusiu Quartzite** | **Naisiusiu Quartzite** | **Naisiusiu Quartzite** |
| West-Lake | Kelogi Gneiss | Naisiusiu Quartzite | Kelogi Gneiss | Naisiusiu Quartzite |
| Kelogi | **Kelogi Gneiss** | **Kelogi Gneiss** | Lemagrut Lava | No Occurrence |
| Lake | **Naibor Soit Quartzite** | **Naibor Soit Quartzite** | No Occurrence | No Occurrence |
| MNK | Naibor Soit Quartzite | Naibor Soit Quartzite | No Occurrence | No Occurrence |
| FLK | Naibor Soit Quartzite | Naibor Soit Quartzite | **Sadiman Lava** | Naibor Soit Quartzite |
| VEK | Lemagrut Lava | Lemagrut Lava | **Sadiman Lava** | Naibor Soit Quartzite |
| HWKW | Lemagrut Lava | Lemagrut Lava | **Sadiman Lava** | Lemagrut Lava |
| HWKE | Lemagrut Lava | Naibor Soit Quartzite | Lemagrut Lava | Lemagrut Lava |
| HWKEE-KK | Lemagrut Lava | Naibor Soit Quartzite | Naibor Soit Quartzite | **Sadiman Lava** |
| MCK | Lemagrut Lava | Lemagrut Lava | Lemagrut Lava | **Sadiman Lava** |
| TK-Loc. 20 | Naibor Soit Quartzite | Naibor Soit Quartzite | No Occurrence | Naibor Soit Quartzite |
| LongK | Lemagrut Lava | Lemagrut Lava | Lemagrut Lava | Naibor Soit Quartzite |
| JK-WK | Lemagrut Lava | Lemagrut Lava | **Sadiman Lava** | Naibor Soit Quartzite |
| DK-Complex | Lemagrut Lava | Lemagrut Lava | Lemagrut Lava | No Occurrence |
| THC-Complex | Lemagrut Lava | Lemagrut Lava | Lemagrut Lava | Naibor Soit Quartzite |
| Fifth-Fault | Lemagrut Lava | **Naibor Soit Quartzite** | Lemagrut Lava | No Occurrence |

**Table7.10. Observed highest occurrences of the critical artifact type variables of the expedient strategy on a Paleogeographic Locale scale.**

In general, less than a quarter (24%) of the observed highest occurrences match the predictions. Naisiusiu is the only Paleogeographic Locale where observed occurrences of ESR match the expected occurrences in all categories. This otherwise poor fit does not support the hypothesis that an expedient strategy can account for the lithic discard and loss patterns across the paleolandscape.

In further examination the affect of distance from raw material source and the scale of investigation on the two variables, the percentage of ERS Flaked and Detached Pieces, grouped by Paleogeographic Locale are plotted against distance below. According to the model, a negative correlation is expected. Fig. 7.4A shows the effect of distance on the distribution of ERS Flaked Pieces without any raw material differentiation. The weak positive correlation seen here ($R^2 = 0.0962$) does not support the by transport hypothesis as evidenced by the distribution of ERS Flaked Pieces.

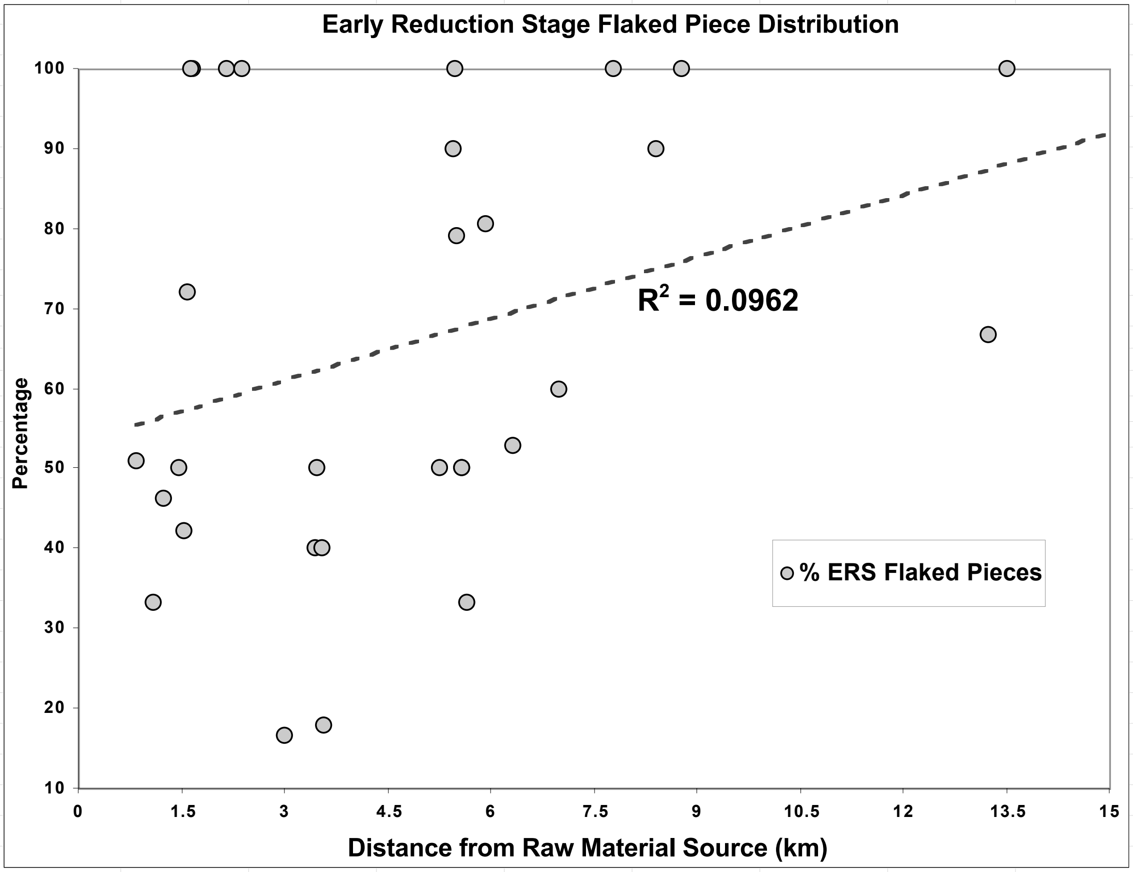


**Fig. 7.4A. Effect of distance on early reduction stage Flaked Piece distribution.**

Fig.7.4B illustrates the relationship between the percentage of ERS Flaked Pieces of each raw material type from each Paleogeographic Locale, and the distance from the raw material source. In this case, a moderate positive correlation is evidenced by Naibor Soit quartzite ($R^2 = 0.3049$), and very weak positive correlations are evidenced by Sadiman lava ($R^2 = 0.0839$) and Lemagrut lava ($R^2 = 0.0103$). Kelogi gneiss shows a positive correlation derived from only two sampling points. Naisiusiu quartzite is the only raw material type to display the negative correlation ($R^2 = 0.1068$) between ERS Flaked Pieces and distance expected of the expedient model.

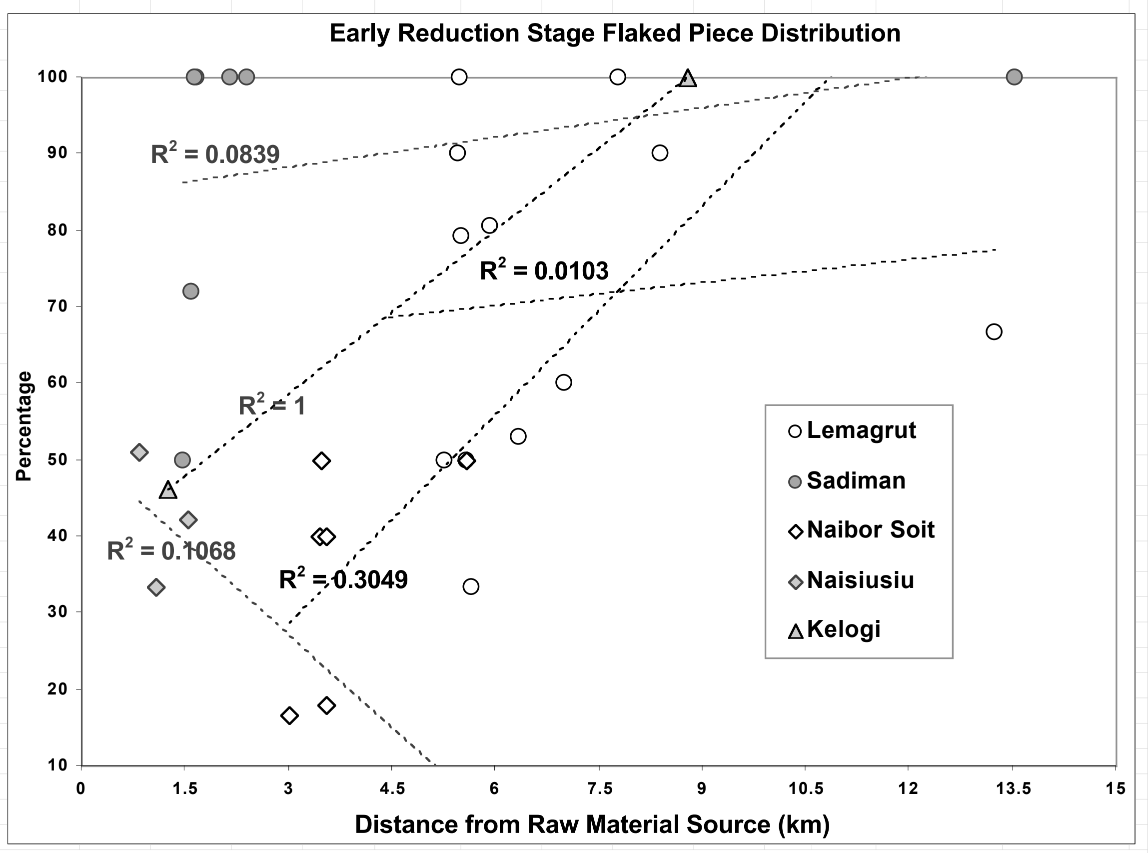


**Fig. 7.4B. Effect of distance on early reduction stage Flaked Piece distribution by raw material type.**

Fig. 74C shows the effect of distance on a distribution of ERS Detached Pieces (without raw material differentiation). The very weak positive correlation seen here (*$R^2$* = 0.0294) does not support the expedient strategy hypothesis (i.e., economization by transport) as evidenced by the distribution of ERS Detached Pieces.

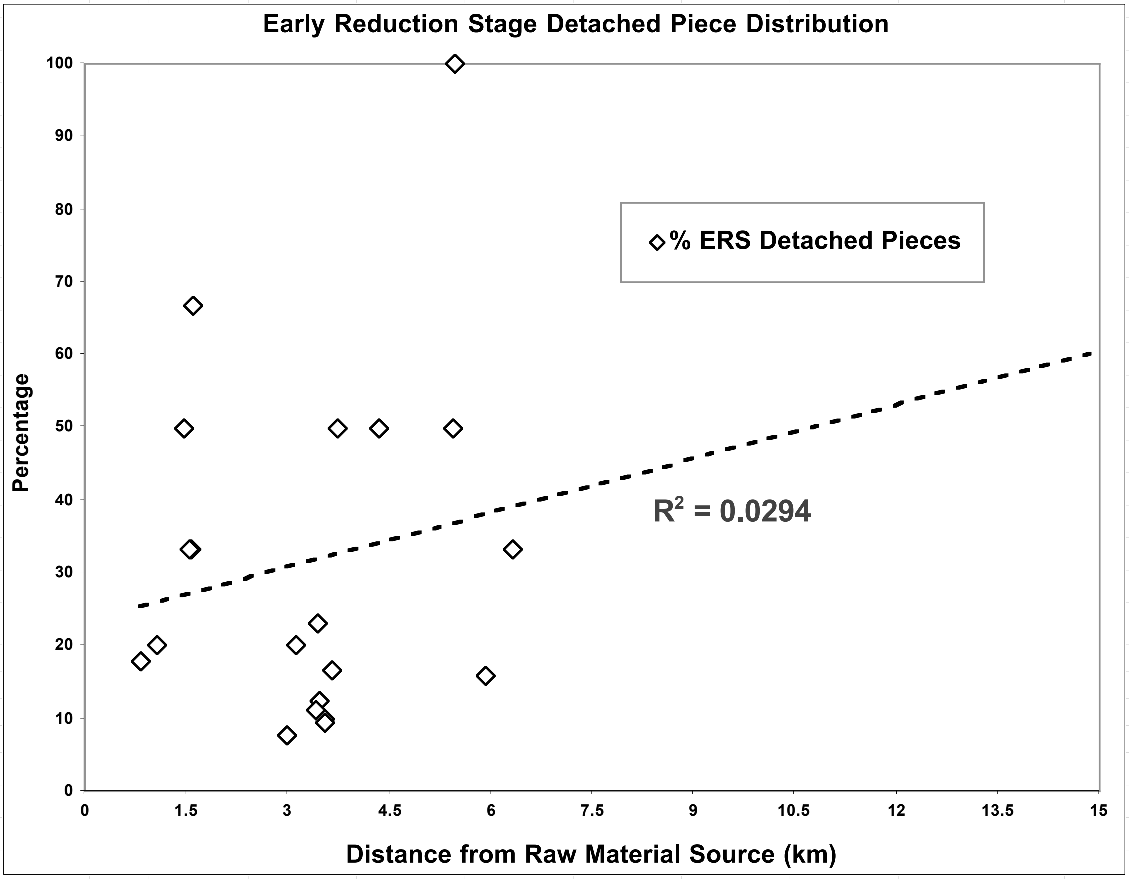


**Fig. 7.4C. Effect of distance on early reduction stage Detached Pieces.**

Fig. 7.4D illustrates the relationship between the percentage of ERS Detached Pieces of each raw material type from each Paleogeographic Locale, and the distance from the raw material source. Although a negative relationship is expected given the expedient strategy hypothesis, most of the raw material types display a positive correlation between percentage of ERS Detached Pieces and distance. The strongest positive correlation is evident with Naisiusiu quartzite ($R^2 = 0.9559$), followed by Naibor Soit quartzite ($R^2 = 0.5044$), and Sadiman lava ($R^2 = 0.5044$). There is a moderately strong negative correlation ($R^2 = 0.408$) between distance and the percentage of ERS Detached Pieces made on Lemagrut lava.

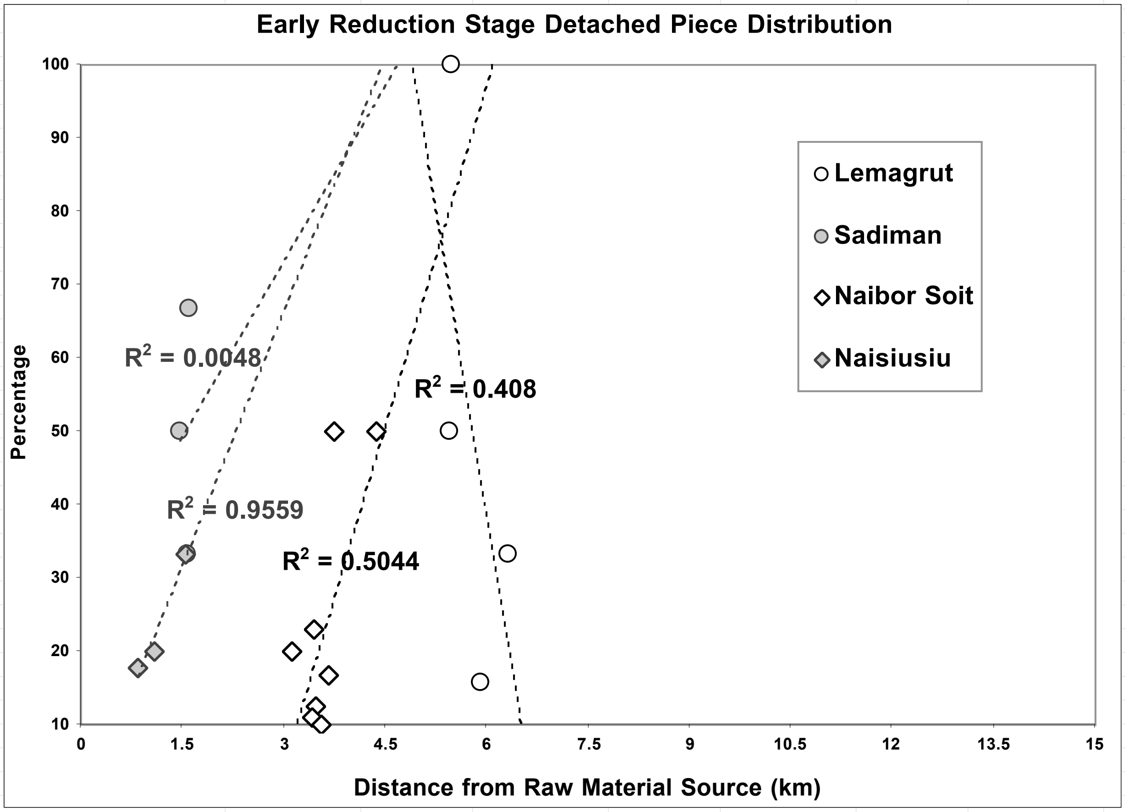


**Fig. 7.4D. Effect of distance on early reduction stage Detached Piece distribution by raw material type.**

### *Summary of Implications*

In the second step of the model, the expedient strategy, raw material provenience, and economization play the largest roles in influencing artifact discard and loss patterns on a landscape. In this strategy it has been stipulated that the proportions of ERS Flaked and Detached Pieces will occur in conjunction in a frequency relative to the raw material source distance. The moderate correspondence of the observed relative occurrence of ERS Flaked and Detached Pieces (60%) supports the aforementioned stipulation but suggests that other factors may be influencing the assemblage composition. It may be that either natural forces or human non-linear transport of Flaked or Detached Pieces to or from an area may have had an impact on the assemblage compositions. I refer to non-linear transport as that which involves the multi-directional transport of raw material (i.e., away from the raw material source, around water obstacles, into and away from activity areas, etc.).

In general, there is a low correspondence of observed and expected values for both ERS Flaked Pieces (23%) and ERS Detached Pieces (29%) and not a single Landscape Association that shows correspondence between expected and observed values in more than two raw material groups in the assemblage. For the most part, the lowest predicted values correspond with an observed absence. This does not support the hypothesis that expediency was consistently implemented as a technological strategy in the Olduvai paleolandscape. However, Spearman's rank correlation tests show that there is a significant correlation between observed and expected values for ERS Flaked and Detached Pieces made on Naisiusiu quartzite and Kelogi gneiss, and ERS Flaked Pieces made on Lemagrut lava. This may imply that although an expedient strategy does not account for the entire assemblage, it may be a strategy used in association with specific raw material. For example, Naisiusiu quartzite and Kelogi gneiss sources are in very close proximity to the WLP and Kelogi (respectively). The material is abundant and easily procured. This may be a scenario conducive to linear, or uni-directional transport as an economization measure. On the other hand, Lemagrut lava shows a significant correlation between observed and expected ERS Flaked Pieces only, suggesting a more selective (non-linear) transport of a Flaked Piece into an area. This may reflect the quality of the raw material as a behavioral determinant as well.

The data examined in this section do not support the contention that as the distance from raw material source increases, the incidence of ERS Flaked and Detached Pieces will decrease consistently. When the expected highest incidence of size, density, ERS Flaked and Detached Pieces were compared to the observed occurrences, Naisiusiu was the only Paleogeographic Locale where all observed values matched all expected values, strongly suggesting that an expedient strategy may have been implemented in that locale. If the ERS Flaked and Detached Pieces occurring in conjunction are an indication of some use of an expedient strategy, then in the Paleogeographic Locales where the frequency of ERS Flaked and Detached Pieces correspond in all raw material groups (Naisiusiu, the Lake, MNK, and HWKE), it is possible that an expedient strategy was being implemented in an limited and area-specific fashion.

Some distributional patterns worth noting are: artifacts made on Naisiusiu quartzite were being more extensively flaked as distance from the source increased. Also ERS Detached Pieces made on Lemagrut lava occur in greater frequency closer to their source. This may be the result of more complex transport behavior, not considered in a uni-directional transport model (which will be addressed in the following section), or it may be that the criterion which have been identified as diagnostic of transport behavior are not as diagnostic as I would have hoped. Many of the corresponding occurrences are evidenced between expected lowest frequencies and absences of observed occurrences, which may be misleading, according to the adage “absence of proof is not proof of absence”. Another factor to consider is that the transport distance is modeled as a uni-directional or linear, flowing in one direction away from the raw material source. Transport difficulty (e.g. the increased cost of transporting material around a body of water, up and/or around a hill or through a high-risk area, or heavy weight for prolonged distances and/or periods of time) was not considered.

In regards to the question of the scale of investigation, in the higher resolution Paleogeographic Locale grouping, there is a similar moderate correspondence of observed occurrences (66%) and as well as a similar low correspondence of observed and expected frequencies of ERS Flaked Pieces (26%) and ERS Detached Pieces (28%). Again, the scale of resolution appears to be a factor only when the distance from the raw material sources are plotted against the frequency of ERS Flaked and Detached Pieces. That may be due to the greater number of sampling points, providing more robust correlation coefficients.

The fact that there is some (albeit weak) correspondence with the expected and observed occurrences of ERS Flaked and Detached Pieces in every Paleogeographic Locale may also suggest that an expedient strategy was implemented to a lesser degree in those areas.

The weak negative correlations and the existence of many positive correlations between distance and ERS Flaked and Detached Pieces suggest that an expedient strategy does fully account for the nature of observed lithic artifact discard and loss patterns on the paleolandscape. This does not imply that an expedient strategy was never implemented, but that it was not a *spatially homogeneous* or universal strategy practiced everywhere and all the time.

The first two steps of the model do not appear to be accurate predictors of archaeological trace distribution to anything more than a moderate degree of accuracy. According to Isaac's original hypotheses, if the two strategies outlined in the model do not adequately explain the artifact assemblage variability across a landscape, then the complexity of the model should be increased. The optimization strategy model incorporates ecological factors to the existing model parameters. Existing theories and modern analog studies have provided ecological data for the third step of the model that are distinguishable only a Paleogeographic Locale scale, so in the following section the third step and highest order of complexity in the model will be presented in the Paleogeographic Locale scale only.

## PART III. Testing the optimization model (Step 3)

Step 3 models an optimization strategy whereby the operating hypothesis is that if tool using activities were carried out in response to eco-functional factors, then spatial variation in lithic artifact assemblage characteristics would reflect resource distribution, degree of predator encounter risk and optimization of tool form. Thus the lithic assemblage composition should vary spatially by raw material type, artifact density and technological diversity, and specific tool form (*see* Table 6.1).

In this more complex behavioral model, the degree of interrelated independent and dependent variables and numerous responses to different task requirements affect the overall pattern of variability in tool discard (Byrne 2004). Spatial variation is not expected to occur as a simple linear function of distance from a raw material source, but rather as the result of a series of influences. The environmental setting determines the availability and distribution of resources and the degree of predator encounter risk, which determines the incidence and nature of anticipated tasks, which determine the specific tool forms (see Tables 6.11A-C). For example, in the Western Lacustrine Plain landscape, in the Loc. 64, Naisiusiu, and West-lake locales, in stream channel/interfluve depositional environments where tree and shrub distribution is expected to be moderate to high, availability of carcass parts is expected to be moderate, predator encounter risk is expected to be high, and limb disarticulation (for transport to a safer area) is expected to be the most highly performed task, followed by a moderate occurrence of defleshing, and low occurrences of skinning or bone pounding. LSR Flaked Pieces (hypothesized as the most efficient tool for limb disarticulation) are expected to occur in a higher frequency than Detached Pieces (defleshing and skinning) or Pounded Pieces (bone pounding).

The degree of artifact density and technological diversity and the incidence of specific tool forms will be examined as they occur in each Paleogeographic Locale. In order to test the validity of the modeled behavioral traces, they will be compared to the observed archaeological traces for goodness of fit.

A total of 3073 artifacts from the archaeological sample that were identified to a specific tool form and raw material type were used in this comparison (unidentified fragments and shatter were excluded). This sample, grouped by raw material and tool type is presented by count (Table 7.11A) and as a percentage of the total artifact assemblage in each Paleogeographic Locale (Table 7.11B).

**Paleogeographic Locale unit artifact distribution by raw material and tool type (excluding shatter)**

| Paleogeographic | Naibor Soit | | | | Naisiusiu | | | | Sadiman | | | | Lemagrut | | | | Kelogi | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Locale | FP<50% | FP>50% | DP | PP/UC | FP<50% | FP>50% | DP | PP/UC | FP<50% | FP>50% | DP | PP/UC | FP<50% | FP>50% | DP | PP/UC | FP<50% | FP>50% | DP | PP/UC | unit total |
| Loc.64 | | | | | 18 | 26 | 902 | 9 | | | | 2 | | | | | | | | | 957 |
| Naisiusiu | | | | | 2 | 4 | 55 | | | | | | | | | | | | | | 61 |
| West-Lake | | | | | 9 | 15 | 185 | 2 | | | | | | | | | 1 | | | | 212 |
| Kelogi | | | | | | 4 | 102 | | | | | | 10 | 5 | 2 | 9 | 9 | 14 | 5 | 3 | 163 |
| MNK | | | 12 | | | | | | | | 1 | | | | | | | | | | 13 |
| FLK | 1 | 5 | 78 | | | | | | 2 | | 2 | | | 3 | 2 | 3 | | | | | 96 |
| VEK | 4 | 4 | 116 | | | | | | | | 4 | 1 | 1 | 5 | 6 | 4 | | | | | 145 |
| HWKW | | 9 | 206 | | | | | | 2 | | | 1 | 4 | 1 | 3 | 5 | | | 4 | | 235 |
| HWKE | 3 | 23 | 347 | 2 | | | | | 3 | 4 | 12 | 1 | 7 | | 14 | 6 | | | | | 422 |
| HWKEE-KK | 2 | 3 | 155 | | | | | | | | 8 | | | 2 | 4 | 1 | | | | | 175 |
| MCK | 13 | 27 | 167 | 5 | | | | | 16 | 12 | 38 | 15 | 18 | 14 | 35 | 40 | | | | | 400 |
| TK-Loc.20 | | 2 | 25 | | | | | | | | 1 | | | | | | | | | | 28 |
| LONGK | | 2 | 31 | | | | | | | | 6 | | 6 | 8 | 6 | 3 | | | | | 62 |
| JK-WK | | 2 | 28 | | | | | | 1 | | 4 | 1 | 2 | 2 | 4 | 1 | | | | | 45 |
| DK-Complex | | 2 | 10 | | | | | | | | | | 2 | | 1 | 2 | | | | | 17 |
| THC-Complex | | 1 | 11 | | | | | | | | | | 3 | 1 | | 6 | | | | | 22 |
| Fifth-Fault | 1 | 2 | 13 | 1 | | | | | | | | | | 1 | | 2 | | | | | 20 |
| Raw Material /Tool type totals | 24 | 82 | 1199 | 8 | 29 | 49 | 1244 | 11 | 24 | 16 | 76 | 21 | 53 | 42 | 77 | 82 | 10 | 14 | 9 | 3 | 3073 |

**Table 7.11A. Artifact count by raw material and tool type (PP/UC = pounded pieces and unmodified cobbles or manuports).**

Paleogeographic Locale raw material and tool types as a percentage of unit total (excluding shatter)

| Paleogeographic | Naibor Soit | | | | Naisiusiu | | | | Sadiman | | | | Lemagrut | | | | Kelogi | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Locale | FP<50% | FP>50% | DP | PP/UC | FP<50% | FP>50% | DP | PP/UC | FP<50% | FP>50% | DP | PP/UC | FP<50% | FP>50% | DP | PP/UC | FP<50% | FP>50% | DP | PP/UC |
| Loc.64 | | | | | 1.88 | 2.72 | 94.25 | 0.94 | | | | 0.21 | | | | | | | | |
| Naisiusiu | | | | | 3.28 | 6.56 | 90.16 | | | | | | | | | | | | | |
| West-Lake | | | | | 4.25 | 7.08 | 87.26 | 0.94 | | | | | | | | | 0.47 | | | |
| Kelogi | | | | | | 2.45 | 62.58 | | | | | | 6.13 | 3.07 | 1.23 | 5.52 | 5.52 | 8.59 | 3.07 | 1.84 |
| MNK | | | 92.31 | | | | | | | | 7.69 | | | | | | | | | |
| FLK | 1.04 | 5.21 | 81.25 | | | | | | 2.08 | | 2.08 | | | 3.13 | 2.08 | 3.13 | | | | |
| VEK | 2.76 | 2.76 | 80.00 | | | | | | | | 2.76 | 0.69 | 0.69 | 3.45 | 4.14 | 2.76 | | | | |
| HWKW | | 3.83 | 87.66 | | | | | | 0.85 | | | 0.43 | 1.70 | 0.43 | 1.28 | 2.13 | | | 1.70 | |
| HWKE | 0.71 | 5.45 | 82.23 | 0.47 | | | | | 0.71 | 0.95 | 2.84 | 0.24 | 1.66 | | 3.32 | 1.42 | | | | |
| HWKEE-KK | 1.14 | 1.71 | 88.57 | | | | | | | | 4.57 | | | 1.14 | 2.29 | 0.57 | | | | |
| MCK | 3.25 | 6.75 | 41.75 | 1.25 | | | | | 4.00 | 3.00 | 9.50 | 3.75 | 4.50 | 3.50 | 8.75 | 10.00 | | | | |
| TK-Loc.20 | | 7.14 | 89.29 | | | | | | | | 3.57 | | | | | | | | | |
| LONGK | | 3.23 | 50.00 | | | | | | | | 9.68 | | 9.68 | 12.90 | 9.68 | 4.84 | | | | |
| JK-WK | | 4.44 | 62.22 | | | | | | 2.22 | | 8.89 | 2.22 | 4.44 | 4.44 | 8.89 | 2.22 | | | | |
| DK-Complex | | 11.76 | 58.82 | | | | | | | | | | 11.76 | | 5.88 | 11.76 | | | | |
| THC-Complex | | 4.55 | 50.00 | | | | | | | | | | 13.64 | 4.55 | | 27.27 | | | | |
| Fifth-Fault | 5.00 | 10.00 | 65.00 | 5.00 | | | | | | | | | | 5.00 | | 10.00 | | | | |
| Tool type total % | 0.78 | 2.67 | 39.02 | 0.26 | 0.94 | 1.59 | 40.48 | 0.36 | 0.78 | 0.52 | 2.47 | 0.68 | 1.72 | 1.37 | 2.51 | 2.67 | 0.33 | 0.46 | 0.29 | 0.10 |

**Table 7.11B. Artifact distribution by raw material and tool type.**

In the Paleogeographic Locales located to the west of the paleolake (Loc. 64, Naisiusiu, and the West-Lake), the assemblages are made up almost entirely of Naisiusiu quartzite, whose raw material source is in very close proximity (except for a small percentage of manuports of Sadiman lava (0.21%) and ERS Flaked Pieces of Kelogi gneiss (0.47). In addition, these western assemblages are all clearly dominated by Detached Pieces. Kelogi is situated at the southwest margin of the paleolake and in close proximity to the source of Kelogi gneiss and a secondary source of Lemagrut lava. Kelogi is dominated by Detached Pieces made on Naisiusiu quartzite (62.58%) but contains a small component of technologically diverse tool forms made on Kelogi gneiss and Lemagrut lava.

The Paleogeographic Locales on the eastern lake margins, the eastern and northeastern lacustrine plains, and the transitional lacustrine/alluvial plain (MNK, FLK, VEK, HWKW, HWKE, HWKEE-KK, MCK, TK-Loc. 20, LongK, JK-WK, DK-Complex, THC-Complex, Fifth-Fault) all contain artifacts whose raw material sources are either directly on the eastern lake margin or to the northeast and southeast of the paleolake (except for an anomalous incidence of

Detached Pieces made on Kelogi gneiss in HWKW). The eastern assemblages are all dominated by Detached Pieces made on Naibor Soit quartzite, with components of Flaked Pieces and Manuports made on Naibor Soit quartzite and Sadiman and Lemagrut lavas. MNK is comprised completely of Detached Pieces, the majority made on Naibor Soit quartzite (92.31%); the remainder is made on Sadiman lava. MNK displays the lowest technological diversity of all the assemblages. MCK is dominated by Detached Pieces made on Naibor Soit quartzite (41.75%), contains a relatively large component of manuports, and is the most technologically diverse of the eastern assemblages. TK-Loc. 20 is comprised mainly of Detached Pieces made on Naibor Soit quartzite (89.29%) and Sadiman lava (3.57), with a fairly high incidence of LRS Flaked Pieces (7.14%). LongK and JK-WK are dominated by Detached Pieces made on Naibor Soit quartzite, but similar to MCK, they are relatively low percentages. LongK and JK-WK have a considerable and fairly technologically diverse component of tools made on Lemagrut lava. DK-Complex is dominated by Detached Pieces made on Naibor Soit quartzite (58.82%) with a high frequency of ESR Flaked Pieces made on Lemagrut lava (11.76%) and LSR Flaked Pieces of Naibor Soit quartzite (11.76%). DK-Complex shows moderate diversity of tool form and raw material type, and has a considerable component of manuports made on Lemagrut lava (11.76%). THC-Complex is comprised mainly of Detached Pieces (50%) with a smaller component of LRS Flaked Pieces made on Naibor Soit quartzite (4.55%). It also contains the highest incidence of all ERS Flaked Pieces (13.64%) and Manuports (27.27%), all made on Lemagrut lava. The Fifth-Fault, the northeastern-most unit, is comprised mainly of Flaked and Detached Pieces and Manuports made on Naibor Soit quartzite with a relatively high frequency of LRS Flaked Pieces and Manuports made on Lemagrut lava.

The highest incidence of ERS Flaked Pieces is evidenced on artifacts made of Lemagrut lava. The highest incidence of LRS Flaked Pieces is seen on artifacts made of Naibor Soit quartzite. In general, the highest incidences of Detached Pieces are made on both Naibor Soit and Naisiusiu quartzite, and the highest incidences of Manuports are from artifacts made of Lemagrut lava.

One of the critical variables to be examined is artifact density. In order to determine artifact density, the total artifact weight (gms) from each Paleogeographic Locale was divided by the excavated volume ($m^3$) of each Paleogeographic Locale. The resulting density indices are shown below (Table 7.12).

| Paleogeographic Locale | Artifact weight (unit total) | Excavated volume (m3) | Unit artifact density |
|---|---|---|---|
| Loc 64 | 13912.10 | 18.86 | 737.80 |
| Naisiusiu | 1016.50 | 37.96 | 26.78 |
| West-Lake | 3880.40 | 15.72 | 246.79 |
| Kelogi | 30552.90 | 14.53 | 2103.16 |
| MNK | 18.10 | 17.46 | 1.04 |
| FLK | 7882.80 | 24.81 | 317.78 |
| VEK | 8285.90 | 22.52 | 368.00 |
| HWKW | 7466.80 | 20.80 | 358.90 |
| HWKE | 11845.70 | 22.55 | 525.22 |
| HWKEE-KK | 3699.90 | 21.76 | 170.02 |
| MCK | 57767.10 | 36.02 | 1603.83 |
| TK-Loc 20 | 380.20 | 20.44 | 18.60 |
| LongK | 6357.90 | 22.46 | 283.04 |
| JK-WK | 2921.00 | 57.59 | 50.72 |
| DK-Complex | 2482.60 | 31.27 | 79.40 |
| THC-Complex | 1175.00 | 56.89 | 20.65 |
| Fifth-Fault | 1872.10 | 19.05 | 98.26 |
| Total | 161517.00 | 460.69 | |

**Table 7.12. Paleogeographic locale unit totals for artifact weight, excavated volume, and density. Artifact density = artifact weight (gm)/excavated volume.**

Another critical variable to be examined is technological diversity. In order to determine technological diversity, a ratio of the number of tool type classes represented and the relative proportion of each type represented ( $-\Sigma p_i \log_{10} p_i$ ) was calculated. The resulting diversity indices are shown below (Table 7.13).

**Technological Diversity**

| Paleogeographic Locale | Observed diversity index |
|---|---|
| Loc.64 | 0.28 |
| Naisiusiu | 0.39 |
| West-lake | 0.42 |
| Kelogi | 0.55 |
| MNK | 0.11 |
| FLK | 0.42 |
| VEK | 0.43 |
| HWKW | 0.38 |
| HWKE | 0.41 |
| HWKEE-KK | 0.32 |
| MCK | 0.58 |
| TK-Loc.20 | 0.32 |
| LongK | 0.51 |
| JK-WK | 0.46 |
| DK-Complex | 0.57 |
| THC-Complex | 0.63 |
| Fifth-Fault | 0.55 |

**Table 7.13. Observed values for technological diversity**
**Diversity = ($-\Sigma p_i \log \chi p_i$)**

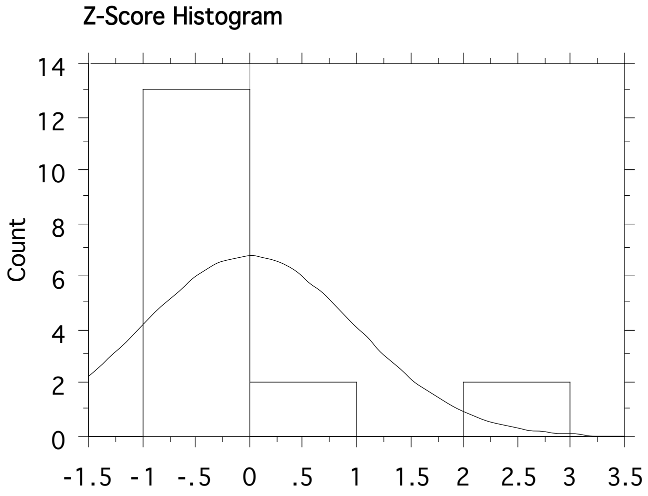
To test the implications of the third step of the model, the variables diagnostic of the optimization strategy, including the expected degree of artifact density and technological diversity as well as the expected incidence of specific tool types, are compared with actual archaeological data.

First, the predicted relative density values are compared with the observed density values (Table 7.14). The actual density values are also converted into ranked relative intervals so that they are comparable to the expected relative values. The variable states range from (1) Lowest, (2) Low, (3) Moderate, (4) High, (5) Very High, to (6) Highest. Those observed values that correspond with the expected values are represented in **boldface** type below.

| **Paleogeographic Locale** | **Artifact Density** | | |
|---|---|---|---|
| | **Expected Relative Value** | **Observed Relative Value** | **Observed Actual Value** |
| Loc.64 | Very High | Moderate | 737.80 |
| Naisiusiu | Moderate | Lowest | 26.78 |
| West-Lake | Moderate | Lowest | 246.79 |
| Kelogi | **Highest** | **Highest** | **2103.16** |
| MNK | **Highest** | **Lowest** | **1.04** |
| FLK | Moderate | Lowest | 317.78 |
| VEK | Moderate | Low | 368.00 |
| HWKW | High | Low | 358.90 |
| HWKE | High | Low | 525.22 |
| HWKEE-KK | High | Lowest | 170.02 |
| MCK | High | Very high | 1603.83 |
| TK-Loc.20 | High | Lowest | 18.60 |
| LongK | High | Lowest | 283.04 |
| JK-WK | Highest | Lowest | 50.72 |
| DK-Complex | Highest | Lowest | 79.40 |
| THC-Complex | Highest | Lowest | 20.65 |
| Fifth-Fault | Moderate | Lowest | 98.26 |

**Table 7.14. Comparison of expected and observed density values. Density = artifact weight (gm)/ excavated volume ($m^3$). Observed relative values are actual values converted into relative ranked intervals.**

Of the 17 Paleogeographic Locales, only Kelogi and MNK (12%) show corresponding expected and observed density values. Interestingly, they are the very highest and the very lowest of the observed values. Kelogi shows the highest density value (2103.16) and MCK shows a very high value (1608.83). Loc. 64 displays a moderate weight density (737.80) and VEK, HWKW, and HWKE show low weight density values. The remaining locales all display the lowest weight densities. In general, the weight density values occur within a narrow range. The weight density values of all but two Paleogeographic Locales (Kelogi, and MCK) fall within one standard deviation from the mean (Fig. 7.5).



| | Weight density |
|---|---|
| Mean | 412.35 |
| Std. Dev. | 585.25 |
| Std. Error | 141.94 |
| Variance | 342520.96 |
| Range | 2102.12 |

**Fig. 7.5. Z-Score distribution and descriptive statistics for artifact weight density on a Palegeographic Locale scale.**

Figure 7.6 further illustrates the spatial distribution of artifact density and the relationship between the expected and observed density values. The actual value scales are also shown as relative values so that they are comparable to the expected relative values. The graph shows that the expected and observed density values differ in their magnitude and spatial patterning.

Except for Kelogi and MCK, all of the Paleogeographic Locales exhibit lower relative density values than expected. There is some similarity in the spatial patterning of artifact density in the Paleogeographic Locales to the west the immediate east of the paleolake, but the observed diversity indices from the Paleogeographic Locales further to the east diverge from the expected and from each other in varying degrees. The model predicts that HWKW, HWKE, HWKEE-KK, MCK, TK-Loc. 20, and LongK will all show identical artifact diversity values. The actual values from these locales vary.

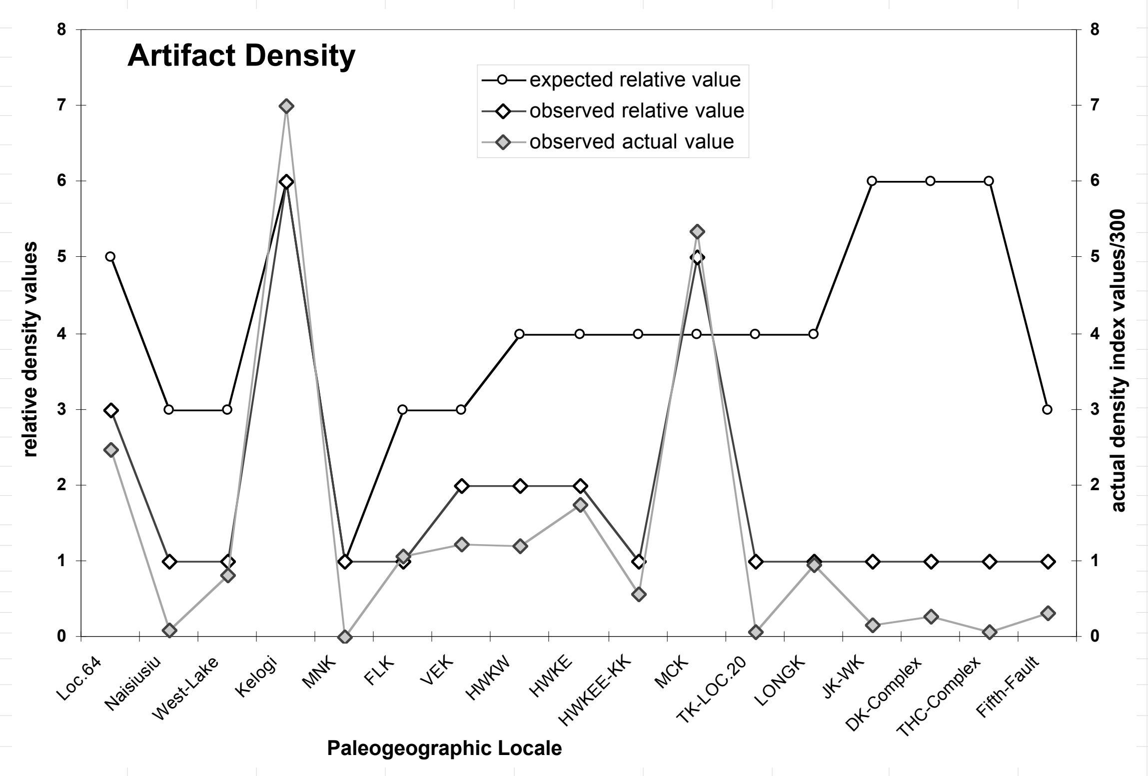


**Figure 7.6. Comparison of expected and observed values and relative and actual values. Density = total artifact weight (gm)/excavated volume ($m^3$).**

In addition, the difference evidenced between observed actual and relative values suggests that the model may not be sensitive enough to show subtle spatial variation. It begs the question, how specific must a model be to accurately describe such variation? This methodology addresses that question by testing a step-wise model of increasing complexity.

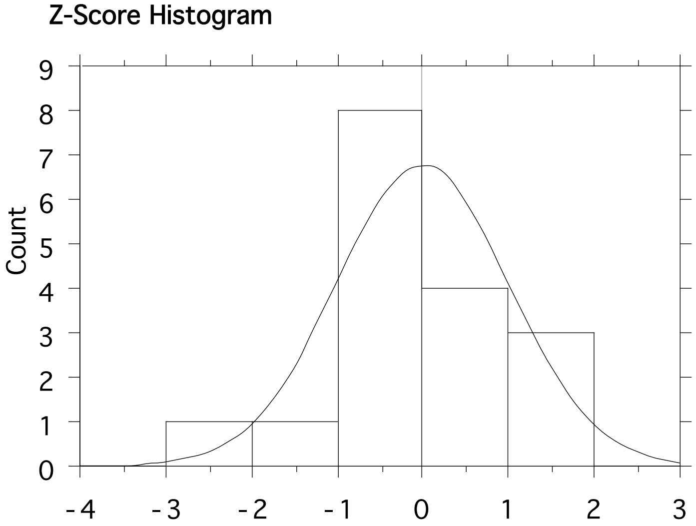
Table 7.15 compares the predicted relative diversity values with the observed diversity values. The actual diversity values are also shown as ranked intervals so that they are comparable to the expected relative values. The variable states range from (1) Lowest, (2) Low, (3) Moderate, (4) High, (5) Very High, to (6) Highest. Those observed values that correspond with the expected values are represented in **boldface** type below.

**Technological Diversity**

| Paleogeographic Locale | Expected relative value | Observed relative value | Observed actual value |
|---|---|---|---|
| Loc.64 | 3 | **3** | **0.28** |
| Naisiusiu | 2 | 4 | 0.39 |
| West-lake | 2 | 4 | 0.42 |
| Kelogi | 3 | 6 | 0.55 |
| MNK | 3 | 2 | 0.11 |
| FLK | 2 | 5 | 0.42 |
| VEK | 2 | 5 | 0.43 |
| HWKW | 1 | 4 | 0.38 |
| HWKE | 1 | 4 | 0.41 |
| HWKEE-KK | 1 | 4 | 0.32 |
| MCK | 1 | 6 | 0.58 |
| TK-Loc.20 | 1 | 4 | 0.32 |
| LongK | 1 | 5 | 0.51 |
| JK-WK | 3 | 5 | 0.46 |
| DK-Complex | 4 | 6 | 0.57 |
| THC-Complex | 4 | 6 | 0.63 |
| Fifth-Fault | 2 | 6 | 0.55 |

**Table 7.15. Comparison of expected and observed diversity values.**

In this case, only 1 Paleogeographic Locale, Loc. 64 (6%) shows corresponding expected and observed diversity values. THC-Complex, MCK, and DK-Complex show the highest diversity values and Loc. 64 shows the lowest diversity value. All the other Paleogeographic Locales show diversity indices within one standard deviation from the mean (Fig.7.7). The observed ranked density and diversity values are a poor match with the expected values.



| | Diversity |
|---|---|
| Mean | .43 |
| Std. Dev. | .13 |
| Std. Error | .03 |
| Variance | .02 |
| Range | .52 |

**Fig.7.7. Z-Score distribution and descriptive statistics for Techno-diversity on a Paleogeographic Locale scale.**

A Spearman's rank correlation shows no significant correlation between expected and observed artifact weight density or technological diversity values (Table 7.15A).

| **Spearman's rank correlation** | **P- value ( a = .01)** |
|---|---|
| Artifact density | .1244 |
| Technological diversity | .2213 |

**Table. 7.15A. Spearman's rank correlation of expected and observed artifact density and technological diversity values.**

Figure 7.8 further illustrates the spatial distribution of artifact diversity and the relationship between the expected and observed diversity values. The actual values are also shown as adjusted relative values so that they are comparable to the expected relative values. The graph shows that the expected and observed density values differ in their magnitude and spatial patterning.

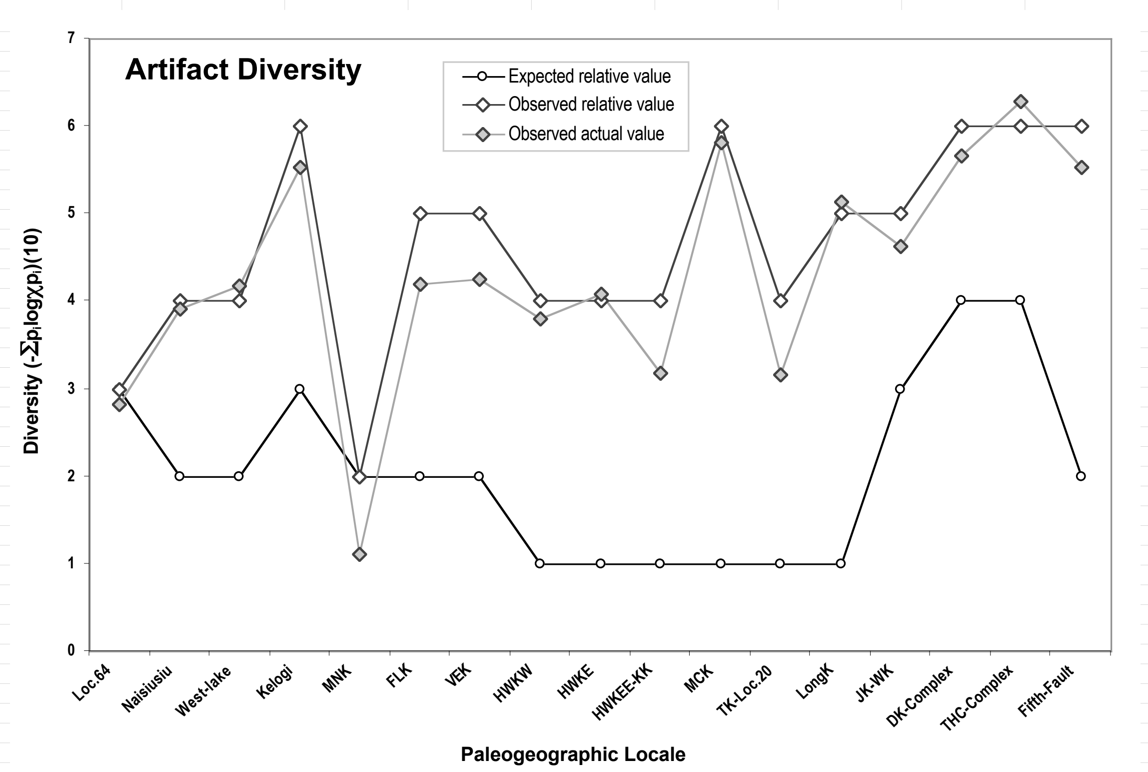


**Fig. 7.8. Comparison of expected and observed and relative and actual diversity values.**

In this case, all of the Paleogeographic Locales except for MNK exhibit higher relative diversity values than expected. There is a slight similarity in the spatial patterning of expected and observed artifact diversity with the exception of MCK, in which the observed values diverge extremely from the expected. The difference between observed actual and relative diversity values is not as pronounced as with density values.

Table 7.16 compares the predicted relative frequencies of specific tool types with the observed archaeological sample. In this case, only 7 of 68 observed occurrences (10%) correspond with the predictions.

| **Paleo-geographic Locale** | Expected ranked incidence of specific tool types | | | | Observed ranked incidence of specific tool types | | | |
|---|---|---|---|---|---|---|---|---|
| | **FP<50%** | **FP >50 %** | **PP/MP** | **DP** | **FP <50%** | **FP >50 %** | **PP/MP** | **DP** |
| Loc.64 | 4 | 1 | 2 | 3 | 2 | 3 | 1 | 4 |
| Naisiusiu | 4 | 1 | 3 | 1 | 1 | 2 | 1 | 3 |
| West-Lake | 4 | 1 | 3 | 1 | 2 | 3 | 1 | 4 |
| Kelogi | 4 | **3** | **1** | 2 | 2 | **3** | **1** | 4 |
| MNK | 3 | **1** | 4 | **1** | 1 | **1** | 1 | **1** |
| FLK | 4 | 3 | 3 | 2 | 1 | 3 | 1 | 4 |
| VEK | 4 | 3 | 3 | 2 | 1 | 3 | 1 | 4 |
| HWKW | 4 | 3 | 3 | 2 | 1 | 3 | 1 | 4 |
| HWKE | 4 | 3 | 3 | 2 | 2 | 3 | 1 | 4 |
| HWKEE-KK | 4 | 3 | 3 | 2 | 2 | 3 | 1 | 4 |
| MCK | 4 | 3 | **3** | 2 | 1 | 2 | **3** | 4 |
| TK-Loc.20 | 4 | 3 | 3 | 2 | 1 | 3 | 1 | 4 |
| LongK | 4 | 3 | 3 | 2 | 2 | 3 | 1 | 4 |
| JK-WK | 4 | 2 | **1** | 2 | 2 | 3 | **1** | 4 |
| DK-Complex | 4 | 2 | **1** | 3 | 1 | 1 | **1** | 4 |
| THC-Complex | 4 | 2 | 1 | 3 | 2 | 1 | 3 | 4 |
| Fifth-Fault | 4 | 1 | 3 | 1 | 1 | 2 | 2 | 4 |

**Table 7.16. Comparison of expected and observed relative frequency of occurrence of specific tool types. Relative frequencies are ranked as (4) high; (3) moderate; (2) Low; (1) lowest-nil. Corresponding observed values are presented in boldface type.**

Spearman's rank correlation test shows that the observed relative occurrence Flaked Piece <50% and Detached Pieces are only slightly above the significance level (Table 7.16A).

| **Spearman's rank correlation** | **P – value ($\alpha = .01$)** |
|---|---|
| **Specific tool type** | |
| Flaked Piece < 50% | **.0124*** |
| Flaked Piece > 50% | .3723 |
| Pounded Piece/Manuport | .1523 |
| Detached Piece | **.0123*** |

**Table 7.16A. Spearman's rank correlation of expected and observed occurrence of specific tool types. * Values are only slightly above the significance level.**

This overall poor fit of the expected and observed relative occurrence of tool forms to the model is underlined by a preponderance of the observed incidence of Detached Pieces. Commensurate with the poor fit of the observed density and diversity values, this may be indicative of the optimization model's inability to accurately predict assemblage compositions, in this case because it fails to take the manufacturing process into account. The reduction process inherent in Flaked Piece manufacture produces Detached Pieces. The model predicts the occurrence of Detached Pieces only as optimal tool forms, not as by-products of Flaked Piece manufacture. In order to account for the incidence of Detached Pieces resulting from the Flaked Piece manufacturing process, I draw upon a previous study carried out by Nick Toth (1982).

In his dissertation research, Toth (1982) used many aspects of Detached Piece morphology and assemblage characteristics as interpretive tools. In particular, Toth argued that conjoining studies could be used to address several types of problems. Among them were:

1. Determining whether flaking occurred on the site and what part of the reduction sequence this flaking represents.
2. Documenting that artifacts have been taken away from (and brought to) an archaeological site.

Using conjoining studies of artifacts from Koobi Fora Toth developed models to explain the reduction sequence patterns at those sites. He then performed experimental replicative studies and compared the results with the archaeological materials in order to validate his model. His reduction model predicts that a cobble/pebble that was first unifacially then bifacially flaked (i.e., FP <50%) would produce 10 Detached Pieces, a cobble flaked to a polyhedron or discoid would produce 14 Detached Pieces (not including retouch or reshaping debitage).

Implementing this projected ratio of Flaked Piece to Detached Piece, I have created a simple formula to correct for the production of Detached Pieces during the manufacturing process:

$$(\Sigma FP<50)10 + (\Sigma FP>50)14 - (\Sigma DP)$$

Ideally, when the resulting value is zero, the Detached Piece count represents the by-product of on-site Flaked Piece reduction. If the resulting value is a larger positive number, that is an indication of transport of Flaked Pieces into a site, or removal of Detached Pieces away from a site. Conversely, if the resulting value is a larger negative number, that is an indication of removal of Flaked Pieces away from the site, or transport of Detached Pieces into a site.

If we apply the formula specified above to the actual data, we arrive at the numbers shown in Table 7.17. The values in **boldface** type illustrate transport of Flaked or Detached Pieces into or away from a site. It is interesting to note that of the raw materials, Lemagrut lava appears to be transported the most. Also interesting is that of the Paleogeographic Locales, Kelogi and MCK show the highest incidence of tool transport into or away from the site.

| Paleogeographic Locale | Naibor Soit | Naisiusiu | Sadiman | Lemagrut | Kelogi |
|---|---|---|---|---|---|
| Loc.64 | | **-358** | | | |
| Naisiusiu | | 21 | | | |
| West Lake | | **115** | | | 10 |
| Kelogi | | **-46** | | **168** | **281** |
| Lake | | | | | |
| MNK | -12 | | -1 | | |
| FLK | 2 | | 18 | **40** | |
| VEK | -20 | | -4 | **74** | |
| HWKW | **-80** | | 20 | **51** | -4 |
| HWKE | 5 | | **74** | **56** | |
| HWKEE-KK | **-93** | | -8 | 24 | |
| MCK | **341** | | **290** | **341** | |
| TK-Loc.20 | 3 | | -1 | | |
| LONGK | -3 | | -6 | **166** | |
| JK-WK | | | 6 | **44** | |
| DK-Complex | 18 | | | 19 | |
| THC-Complex | 3 | | | **44** | |
| Fifth-Fault | **25** | | | 14 | |

**Table 7.17. Detached Piece count corrected for Flaked Piece manufacture**

### *Summary of Implications*

In the third step of the model, the optimization strategy, resource distribution and availability, predation risk, and specific tool utility play the largest predicted roles in influencing artifact discard and loss patterns on a landscape. In this strategy it has been stipulated that anticipated tasks are determined by resource availability and risk associated with an area and that specific tool types, artifact density, and degree of technological diversity will reflect that distribution.

There is a low correspondence of expected and observed density values (17%), evidenced only with the very highest and lowest values. This may be an indication of the model's insensitivity to the narrow range of density values shown by the Z-scores. All of the observed density values except for Kelogi, MNK, and MCK are lower than the expected density values. This may be a function of archaeological sampling, or may be due to an overestimation of the anticipated tasks, but it may simply be due to the fact that Oldowan technological strategies do not conform to the optimization model as it is presented in this thesis.

In this case of technological diversity, the range of values is wider than the density values and there is an even lower correspondence of expected and observed diversity values (11%). This probably attests to the model's inability to predict the spatial distribution of technological diversity on this landscape scale. All of the observed diversity values except for Loc. 64 and MNK are higher than the expected values. This also suggests that the discard and loss patterns do not conform to the optimization model presented in this thesis.

There is a low correspondence of expected and observed occurrence of specific tool types (15%). When an obvious weakness of the model, its failure to account for transport in and out of an area was addressed, the resulting data showed the greatest evidence of transport to occur in Kelogi and MCK. It also showed a greater transport pattern within raw material from Lemagrut than any other. Raw material differentiation, also unaccounted for in the hypothesized optimization strategy would also influence the degree of correspondence of observed data with predictions.

In general, these data do not support the hypothesis that optimization, as it has been modeled here, was consistently implemented as a technological strategy on the Olduvai paleolandscape. In the optimization model there are a large number of hypothesized determinants, many or all of which may not be accurately depicted. Each interrelated set of variables produces the possibility of a wider margin of error. The many reasons for the varying results presented here, not the least of which is the inadequacies of the model, will be discussed in the following summary chapter.

# CHAPTER EIGHT

# THE ADAPTIVE SIGNIFICANCE OF STONE TOOLS

> "Testability lies at the very heart of the scientific enterprise: if we make a statement about how things are...we must be able to make predictions about what we logically should observe in the material world if that statement is true. Repeated failure to confirm predicted observations means we have to abandon an idea--no matter how fondly we cherish it, or how earnestly we may wish to believe it is true."
>
> Niles Eldredge, 2002

## Introduction

This chapter summarizes the research reported in this dissertation and the main conclusions drawn from landscape and experimental perspectives on variability in the Oldowan during Middle-Upper Bed I and lowermost Bed II times at Olduvai Gorge, Tanzania. The objectives of this study are outlined below and will be addressed at length in the following sections in order to bring to light what has been learned from this dissertation research and illustrate its relevance to understanding the adaptive significance of early hominid stone tool use.

## Part I. Objectives of this Study

A. Present a technological description of the first landscape scale lithic artifact assemblage to be recovered from Olduvai Gorge.

B. Compare the landscape scale assemblage with the Oldowan type-assemblage using Leakey typological classifications (Leakey 1971).

C. Introduce an experimental methodology used to examine the relative functional utility of Oldowan tool forms.

D. Offer an alternative approach to explaining spatial variation in artifact distribution. Introduce and test models of lithic assemblage formation processes

E. Interpret the results and discuss their implications for our current understanding of and future research on the Early Paleolithic at Olduvai Gorge

### Technological description

A detailed analytical methodology was formulated and a systematic technological analysis and description of the first landscape sample of lithic artifacts ever to be recovered from Olduvai Gorge was conducted. The archaeological assemblage was recovered from 106 excavated trenches sampling Middle-Upper Bed I and lowermost Bed II deposits across the paleolandscape (see Appendix 3 for the inventory of artifacts recovered from each trench). The artifacts from each trench within the target temporal intervals were combined for analysis into laterally differentiated assemblage groupings in two different scales of spatial resolution. The Landscape Association is a broad spatial classification comprising seven different landscape facets within the Olduvai paleobasin that are identified by their lithology to depositional environments. The Paleogeographic Locale is a higher resolution, narrower spatial classification made up of 18 locales that coincide geographically with modern outcrop groupings and may also coincide with fault compartments resulting from active faulting during Lowermost bed II times (Blumenschine et al, 2004).

On both scales of resolution the OLAPP lithic artifact assemblages illustrate spatial variation in several compositional characteristics. Comparing the artifact count in the different scales shows the range of variation to be higher in the Landscape Association scale. The more even trench distribution of the Paleogeographic Locale results in a lower deviation from the mean count, a lower variance and a shift from the eastern to the western sub basin as the highest count value. This is undoubtedly due to the disparate distribution of the number of trenches in each Landscape Association.

Artifact counts alone may not adequately reflect the actual density of artifacts in a given area, given the disparity that exists in excavated volume per trench, and number of trenches per unit of investigation. In order to better demonstrate the character of the distribution of artifacts across the landscape, artifact weight density was calculated in the following manner: Artifact weights were recorded for individual specimens. The total artifact weight per stratigraphic level and trench were calculated for each Landscape Association and each Paleogeographic Locale. The actual excavated volume (per cubic meter) was recorded for stratigraphic level and trench by OLAPP, and was also calculated for each Landscape Association (see Appendix 4) and Paleogeographic Locale (see Table 7.12). These totals were divided by the respective artifact weight totals to arrive at an artifact weight density. This corrects for disparities in trench sizes, or number of trenches when comparing group artifact assemblage sizes.

In a Landscape Association scale grouping, artifact density is not evenly distributed but dominates in one landscape unit, the SWLP. However, the Landscape Association scale may be too broad a grouping to identify meaningful patterned artifact density distributions as they relate to local land-use patterns.

The artifact weight density is also represented at a higher spatial resolution across the landscape from west to east, grouped according to Paleogeographic Locales. The highest weight densities are shown in Loc. 64, Kelogi, and MCK, and a moderate weight density is seen in Loc. 64. When the distribution of artifact weight density across the landscape is examined on the Paleogeographic Locale spatial scale, a higher spatial resolution than the Landscape Association spatial scale, a less variable distribution is evidenced by a lower standard deviation and lower variance of artifact weight density values (see Chapter 7, Part I).

To further explore the spatial distribution of artifact assemblage characteristics, technological diversity values are examined. To express technological diversity, I use a formula derived from an equation introduced by Shannon and Weaver in 1949 for use in quantitative biology (after Hutchinson, 1957):

$$\text{Diversity} = ( -\Sigma p_i \log_{10} p_i )$$

Technological diversity (henceforth techno-diversity) is determined by calculating the proportion of the number of tool types represented by the number of each type represented in a given assemblage. As with artifact weight density, techno-diversity was also discussed in Chapter 7, Part III, but only as it pertained to the predictive model for techno-diversity values and only on a Paleogeographic Locale scale. The techno-diversity values for each Landscape Association and Paleogeographic Locale across the landscape from west to east were compared.

In the western sub-basin, techno-diversity is similar in both spatial scales of distribution. However, the eastern sub-basin units show more variation in techno-diversity values in the Paleogeographic Locale spatial scale. A comparison of the descriptive statistics for techno-diversity values for the Landscape Association and Paleogeographic Locale scale show a greater range of variation of techno-diversity values in the Paleogeographic Locale scale (see Appendix 6), evidenced by the higher deviation from the mean and higher variance values. Such spatial variability in technological diversity has never been documented in an Oldowan assemblage from Olduvai Gorge.

In the case of raw material distribution, quartzite is by far the dominant raw material and shows a bimodal distribution of Naisiusiu and Naibor Soit quartzite (see Fig. 3.3). Both modes are in close proximity to their respective sources (see Table 3.1). Lava, which comprises a much smaller portion of the assemblage, shows a more normal distribution with the highest frequencies in the Eastern Lacustrine Plain (ELP) and more specifically, MCK, which is not in the closest proximity to known or hypothesized secondary sources of lava. Lateral distribution of raw material appears proportionately similar in both scales of resolution, suggesting again that the scale of investigation may not be affecting the nature of the raw material distribution or that raw material selection occurs more noticeably on a broad spatial scale.

The proportion of different raw material types, or raw material diversity may be an indicator of raw material selection, transport, and preferential tool using behavior. Raw material diversity was examined as it occurs across the landscape from west to east. The distribution of techno-diversity and raw material diversity values across the landscape in both spatial scales was also compared. The Landscape Association scale grouping shows a great range of variation in raw material diversity values, with the highest values evident in the ELP. The Paleogeographic Locale scale shows lower variance between raw material diversity values in general, with the highest values in THC-Complex, MCK, and Kelogi. Comparing the descriptive statistics of raw material diversity in the Landscape Association and the Paleogeographic Locale spatial scales, a higher deviation from the mean and greater variance in diversity values is evident in the broader Landscape Association scale (see Appendix 7).

Differential raw material distribution at Olduvai occurs on a broader spatial scale than does plant and animal resource and risk distribution, and variation in raw material selection is more visible on a broader spatial scale. Techno-diversity values exhibit greater variation in a higher resolution spatial scale than in a lower resolution spatial scale. This may be an indication of the relationship of techno-diversity to resource distribution and that technological selection occurs on a scale commensurate with plant and animal resource and risk distribution.

Data resulting from the systematic technological analysis of the OLAPP lithic artifact assemblage, while not necessarily pertinent to the interpretations discussed in this thesis, are presented in order to further characterize that assemblage. The landscape distribution of artifacts in terms of their maximum dimension (size), and general tool form (shape), on a Landscape Association scale are presented in Appendix 8.

On a Landscape Association scale the artifact counts, in every general technological category, are highest in the ELP. The WLP is second in number for every technological type although the margin is appreciably lower for manuports. In a consistent manner, the SWLP follows in number of every technological type. In the remaining units, the counts are smaller and do not occur in the same uniform proportions. The greatest range of variation in maximum dimension values is seen not between spatial units but within the general tool form categories of Manuport and Flaked Pieces.

### General and specific morphological characteristics:

The general and specific morphological characteristics of a lithic assemblage can be useful in deciphering hominin tool using behavioral traces. Studying their spatial distributional patterns may be helpful in interpreting land use and subsistence strategies. Most of the morphological data are presented in Appendices as tables and graphs, depicting their spatial distribution as they are pertinent to the overarching issues dealt with in this thesis. The data are mostly grouped on a Landscape Association scale due to sample size constraints.

The basic quantitative gross morphological data of artifact weight (g), and technological length, breadth, and width (mm) for each general artifact type are fundamental to questions of technology (manufacturing process), transport, and raw material character and availability The spatial distribution of the various Flaked Piece stages is also useful in understanding technological strategy in terms of reduction sequences (see Appendix 8).

The landscape distribution of various Detached Piece characteristics, such as the striking platform and the cutting edge angle (indicators of flaking technique and type of percussion), the exterior platform angle (indicator of the knapper's level of skill), and the 'Toth type' (Toth, 1982), or type of platform preparation relative to the percentage of cortical surface (indicator of the relative reduction sequence) are presented in Appendix 9.

Discerning whether an artifact is in primary context or an assemblage is palimpsestic or resulting from associated natural agents is of utmost importance to behavioral interpretations. In addition to morphological data, surface modification due to weathering can be informative as to the archaeological integrity of an assemblage. The distribution of weathering stages is shown (Appendix 10) in the Landscape Association scale.

### *Summary of observations*

This section provided very basic summary description of the OLAPP archaeological assemblage recovered during the 1989-2000 excavations at Olduvai Gorge, Tanzania. Artifact counts and density data were presented grouped by two different spatial units of investigation. In both spatial scales, spatial variability in the artifact assemblages is evident.

Lithic artifact assemblage characteristics vary considerably when examined in Landscape Association groupings. The highest artifact counts are seen in the ELP, but the greatest density is seen in the SWLP. The greatest technological diversity is seen in the EAP. The ELP/EAP and

NELP are relatively meager assemblages containing few manuports on low quality lava. The NELP assemblages are dominated by chert. Some of the chert pieces are flaked and modified but many are unmodified nodules found in massive waxy clays and may be considered authigenic, not manuports. The SWLP assemblages are dominated by Kelogi gneiss, which is extremely friable and many specimens are extremely weathered and there are a relatively large number of whole flakes, cores and other fragments, even quite a few made on Lemagrut lava. There are considerably less core fragments in the western assemblages than in the ELP, and they are generally larger than those in the eastern assemblages. This is probably due to the higher quality of Naisiusiu quartzite than the more friable, lower quality Naibor Soit quartzite.

The Paleogeographic Locale grouping provides a more even distribution of excavated units and the assemblage characteristics display less variability in artifact count distribution. While the range of variation is narrower in higher spatial resolution, variation between Paleogeographic Locales is evident. The highest artifact counts are seen in Loc. 64 but the greatest density is seen in Kelogi. The greatest techno-diversity is seen in THC-Complex. The West-Lake artifacts are rolled and weathered, in many cases displaying an original cortical surface and a worked surface, which has been extremely weathered appearing almost cortical and pebble-like. The Naisiusiu artifacts are dominated by Naisiusiu quartzite and of that assemblage, detached pieces are most prevalent, many of which are uncharacteristically divergent in planform, with a high dorsal ridge much like a rejuvenation flake.

## Typological comparison

Addressing a basic question of whether the Leakey's geographically restricted Oldowan type-site assemblages represent a homogenous Industrial Complex that occurs over a broad landscape, the OLAPP landscape archaeological sample was classified using the Leakey typology for the Oldowan (1971) and its typological distribution was compared and contrasted with the Leakey Oldowan type-site assemblages.

The Oldowan type-site assemblages are geographically limited but do represent a homogenous typological composition that is evidenced also on a broader spatial scale. While it can be said that the broad landscape OLAPP sample does indeed fall within the typological composition of the Oldowan, it appears that factors such as sample bias, resolution, and geographic scale may have some impact on the distributional characteristics that might describe spatial variation within the Oldowan. The proportionate occurrences of the different tool types were shown to vary depending upon the spatial scale or resolution of the assemblage examined.

On a smaller geographic scale, the Oldowan type-site assemblage showed a decrease in variance when certain types were removed. On the contrary, when the same types were removed from the OLAPP landscape sample (in both scales of resolution), the variance increased. It may simply be so that the broader the geographic scale of the sample, the more variation will be introduced into that sample. In this case it appears that the geographic scale is affecting the character of the typological distribution more than the resolution is.

Typological classifications are descriptive and the specific categories are distinct enough to differentiate between general morphological characteristics. Thus they are suited to addressing broad human evolutionary issues such as tool-culture traditions, anatomical functional morphology, diet, cognition, encephalization, etc. However, when approaching issues such as behavioral ecology, land-use, and technological strategies, typological classifications have not been empirically linked to function or shown to identify behaviorally meaningful patterns of distribution or diagnostic characteristics of lithic technological organization. To identify such behavioral characteristics a middle range methodology was devised that might link static archaeological traces with the dynamic behavioral processes that created them.

## Experimental methodology

A methodology was developed that would explore the feasibility of using Oldowan tool forms for specific tasks. I simulated the technological forms and raw material component of the Oldowan Industry and carried out 168 experimental trials using various replicated Oldowan tool forms on various subsistence related tasks. From this experimentation, I was able to create a relative utility index by which Oldowan tool forms were ranked according to their efficiency at performing specific tasks. Using time as a currency, I assessed the relative costs of carrying out different subsistence related tasks. Those tasks are grouped into main categories of woodworking and butchery, and their results and observations are summarized as follows:

I found that for woodworking tasks such as chopping wood, large lava pieces flaked on less than 50% of their surface were the most efficient. For procuring a stick, small lava flaked pieces or medium sized detached pieces were most efficient. For sharpening a stick, small pieces of lava or quartzite flaked on less than 50% of their surface were most efficient. In the case of chopping wood, tool size seemed to be the most important factor, whereas in procuring and sharpening sticks, tool form, raw material, and size all affected efficiency.

In butchery tasks such as limb disarticulation, the most efficient tool was a medium sized quartzite piece flaked on less than 50% of its surface. Small to medium sized pieces of quartzite or lava flaked on less or more than 50% of their surfaces were efficient as well. In skinning and defleshing trials small, detached pieces of quartzite were unquestionably most efficient, but other raw materials of the same size and form did quite well also.

In pounding bone, size and form seemed to have the greatest impact with flaked pieces on more than 50% of their surface or unmodified cobbles being the most efficient.

In general, lava seemed to be a better material for working wood and quartzite for butchery.

Woodworking was observed to cause greater edge damage to tools than butchery. This may also be surmised from the mineral content of the raw materials, given that quartzite contains more silica than basalt does. Additional observations about raw material characteristics were made during the experimentation may shed some light on this differentiation.

Sadiman and Lemagrut lavas do not shatter much during tool manufacture. Cutting edges wear down and become dull or break off in microfractures, resulting in an overall decrease in cutting edge efficiency. Cortical lava flakes were observed to hold their edge longer than non-cortical flakes. This may also be due o the cutting edge morphology, whereas the smoother cortical surface exerting less abrasive drag on the material being cut, preserving the cutting edge longer. The structural nature of quartzite causes the material to shatter during tool manufacture and use. Naibor Soit is more friable than Naisiusui. Quartzite cutting edges were observed to be more durable than lava. These observations have implications related not only to tool manufacture and use, but also to the ensuing discard and loss patterns.

Another outcome of the experimental trials was the resulting assessment of relative time needed to perform specific tasks. Accessing bone marrow (pounding bone) was by far the least time consuming of all the tasks, followed by sharpening a stick, limb disarticulation, defleshing, skinning, procuring a stick, and chopping wood. Being able to differentiate between tasks and the hypothesized amount of time needed too perform them made it possible to speculate on which tasks would be carried out in which areas, depending on available resources and associated predation risks.

Unfortunately, the experimental trials evaluated tool efficiency using only time as a currency. Tool use as an optimization strategy would undoubtedly involve other currencies as well. The expenditure of energy for instance, in raw material acquisition, tool manufacture, tool use, and transport is another factor to be considered.

## Models

In an attempt to explain the variability evidenced by the spatial distribution of Oldowan artifacts on a landscape scale, a distributional model was formulated. That model was based on a hypothetical method for explaining variability in artifact assemblages proposed by Isaac *et al.* (1981). The model predicted the landscape distribution of artifacts using critical variables associated with different technological strategies. The model predictions were used to test the following hypotheses concerning land use and technological strategies in the Oldowan:

- There is no spatial variability in Oldowan lithic assemblages during Middle Bed I and Lowermost Bed II times.
- There is spatial variability in Oldowan lithic assemblages that can be accounted for by raw material determinism or an opportunistic technological strategy.
- There is spatial variability in Oldowan lithic assemblages that can be accounted for by curation and conservation or an expedient technological strategy.
- There is spatial variability in Oldowan lithic assemblages that can be accounted for by resource availability and risk management or an optimization technological strategy.
- The spatial variability in Oldowan lithic assemblages evidenced by a landscape grouping does not reflect any single behavioral model proposed thus far.

The first strategy is opportunistic, and raw material provenience is the primary determinant of the expected discard and loss patterns on a landscape. The critical variables associated with raw material provenience are artifact size and density. An average 75% concurrence of observed archaeological artifact size and density values suggests an association between the two variables, but the observed archaeological occurrences corresponded with the predicted on average 35% of the time. The Landscape Association that fits the model predictions best is the Southwestern Lacustrine Plain (SWLP) where all the artifact size and density values correspond to the model (except for Sadiman lava). In the Western Lacustrine Plain (WLP) and the SWLP density values are the highest, conforming to the distributional model as determined by provenience, as they are located in the closest proximity to the dominant raw materials in their assemblages. Artifacts made on Naisiusiu quartzite correspond with the predictions almost 65% of the time, Kelogi and Naibor Soit each 50%, and Lemagrut less than 15% of the time. These results suggest that a least effort strategy was not a uniform behavior across the landscape and/or that raw material quality may have been influencing when and where it did apply. In other words, where the raw material was abundant, or quality was sufficient, it was used opportunistically.

The second strategy is expedient, and raw material provenience and availability are the primary determinants of expected discard and loss patterns. The critical variables that are associated with raw material provenience and availability are transport proxies, the extent of manufacture as indicated by the early and later reduction stages of Flaked and associated Detached Pieces. An average 59% concurrence of observed archaeological occurrences of these two variables' values suggests a moderate production association between them.

An archaeological association between the accumulated proportions of Flaked and Detached Pieces is also indicated by a comparison of their weathering stages. Flaked and Detached Pieces occur in a fresh, non-weathered stage in the highest percentages and similar proportions, in all of the Landscape Associations except the Eastern Alluvial Plain, and the extremely weathered SWLP assemblages. A weak association between Flaked and Detached Piece values could also be accounted for by a low level of skill (Toth 1987; Ludwig and Harris 1998; Schick et al. 1999), whereby the manufacture of Flaked Pieces results in more shattered or split pieces, whose percentages have not been examined in this comparison. It might also be due to a differential natural or human transport of Flaked or Detached Pieces into or away from an area.

The observed archaeological occurrences corresponded with the predicted a combined total of only 27% of the time, suggesting that an expedient strategy involving transport was also not a uniform strategy across the landscape, but an occasional one.

It is interesting to note that in general, only the observed highest and lowest occurrences match the predictions. This may reflect the model's inability to predict moderate levels of transport behavior (as it is related to raw material availability) because it is too general. The availability of raw material may be further qualified by two characteristics that can also influence the effect of distance on the degree of reduction. Those characteristics are the distribution and accessibility to the raw material (i.e., quarrying exposed outcrops vs. harvesting river cobbles), and the quality of the raw material in terms of knappability (i.e., brittleness, homogeneity, and isotropism) (Cotterell and Kamminga, 1990). Some possible variations within the realm of a raw material source and their possible implications in terms of degree of reduction are discussed and displayed graphically below (Fig. 8.1).

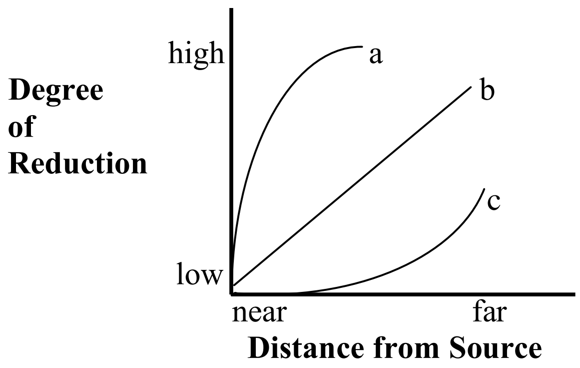


**Fig. 8.1. Graphic representation of hypothetical variations on the degree of reduction relative to distance in the economization strategy.**

a) Raw material is difficult to access or the best quality material is rare. This scenario represents high-end expediency, where economization and conservation (re-use) of material is at a premium. Here a high degree of reduction is expected relative to transported distance. Within the expedient strategy, this particular response to circumstances can be thought of as cost-effective.

b) Relatively easy access to good quality raw material. This is where transported distance should be fairly consistent with the degree of reduction. Within the expedient strategy, this particular response to circumstances can be thought of as common stone flow.

c) Good quality raw material may be easily accessible and common. In this case of easily renewable resources, disposal may be more efficient than transport and re-use. Within the expedient strategy, this particular response to circumstances can be thought of as disposable.

Another factor related to raw material availability is transport range. Only one raw material type in each of the Landscape Association units fits the transport model except for the transitional ELP/EAP, where two raw material types fit. In general, raw material does not occur in an assemblage from a source further than 10 kilometers away, which may suggest that the range of transport distance in the Oldowan is quite low.

Not more than two types of raw material fit the transport model in any Landscape Association. This may suggest that raw material differentiation is a greater factor than technological decisions determined by transport distance. The fact that approximately 73% of the observed percentage values of early reduction stage Detached Pieces do not match the predictions for an expedient strategy as outlined in this thesis suggests that something other than economization and curation tactics were affecting the spatial variability in artifact discard and loss patterns, and supports the contention that linear transport was not universally implemented as an economization measure in the Oldowan.

In terms of the scales of resolution, the Paleogeographic Locale scale does reveal some distributional variation in the early-to-later reduction stage ratio that was not evident in the lower resolution Landscape Association scale. The higher resolution scale also shows a higher percentage of correspondence between expected and observed ERS Flaked and Detached Pieces than the lower resolution does. Since the frequency of occurrence of ERS Flaked Pieces is considered a critical variable in the expedient model, the Paleogeographic Locale scale of investigation may prove to be more sensitive to the archaeological traces of linear transport behavior.

In general, the results indicate that while an expedient strategy was not a uniform behavior across a landscape, it was implemented in association with specific raw materials, such as Lemagrut lava. In this case raw material selection may not have been based on availability but rather on quality.

The third strategy is optimization, and resource availability and predation risk are the primary determinants of expected discard and loss patterns. The critical variables that are associated with optimization are behavioral proxies, and include artifact density and technological diversity as they relate to resource availability, and the specific tool types considered as the optimal form for specific tasks. Here we see the lowest correspondence of all with expected and observed archaeological occurrences with density, diversity, and specific tool types corresponding 12%, 6%, 10%, (respectively). This low correspondence is not surprising, considering that the modeled artifact distribution was contingent upon nested levels of “inferential confidence” (Gifford-Gonzalez 1991) or three other associated levels of influencing factors. The first level and independent variable was depositional environment and raw material proximity. The second level and dependent variable was availability and distribution of vegetation and scavengeable carcasses, as well as predation risk. The third level and dependent (and newly hypothesized) variable was frequency and type of anticipated task. Each level infers a relationship that increases the possibility of error in the ultimate model predictions.

The overall poor fit of the model predictions may also reflect the model’s insensitivity to the variability in resource distribution. If we consider the effect of resource distribution and distance from raw material source on artifact discard and loss patterns across a landscape, there are several possible variations. Here are but a few:

a) The resource availability is high, the distribution of resources is uniformly high, and predation risk is low. In this case, where abundant resources allow for a high level of resource exploitation activity, the density and diversity of artifact discard and loss patterns are expected to be high relative to distance from raw material source. This particular response to circumstances might be thought of as extensive exploitation.

b) The availability of resources is low, distribution is patchy, and predation risk is moderate. In this case, where resource exploitation would occur in interrupted concentrations of activity, the artifact density is expected to fluctuate relative to resource availability and distance from raw material source, and diversity of artifact discard and loss patterns are expected to be low relative to distance from raw material source. This particular response to circumstances might be thought of as moderate exploitation.

c) The resource availability is low, distribution of resources is uniformly sparse, and the predation risk is high. In this case, where sparse resources and time constraints indicate limited resource exploitation activity, the artifact density and diversity are expected to be very low relative to distance from raw material source. This particular response to circumstances might be thought of as restrained exploitation.

These scenarios are generalizations of multiple possible responses to different task requirements and situations, and numerous variations on these themes that may contribute to the overall pattern of variability (Byrne 2004:362). The various hypothetical artifact density and diversity (Fig. 8.2) patterns discussed are portrayed graphically below.

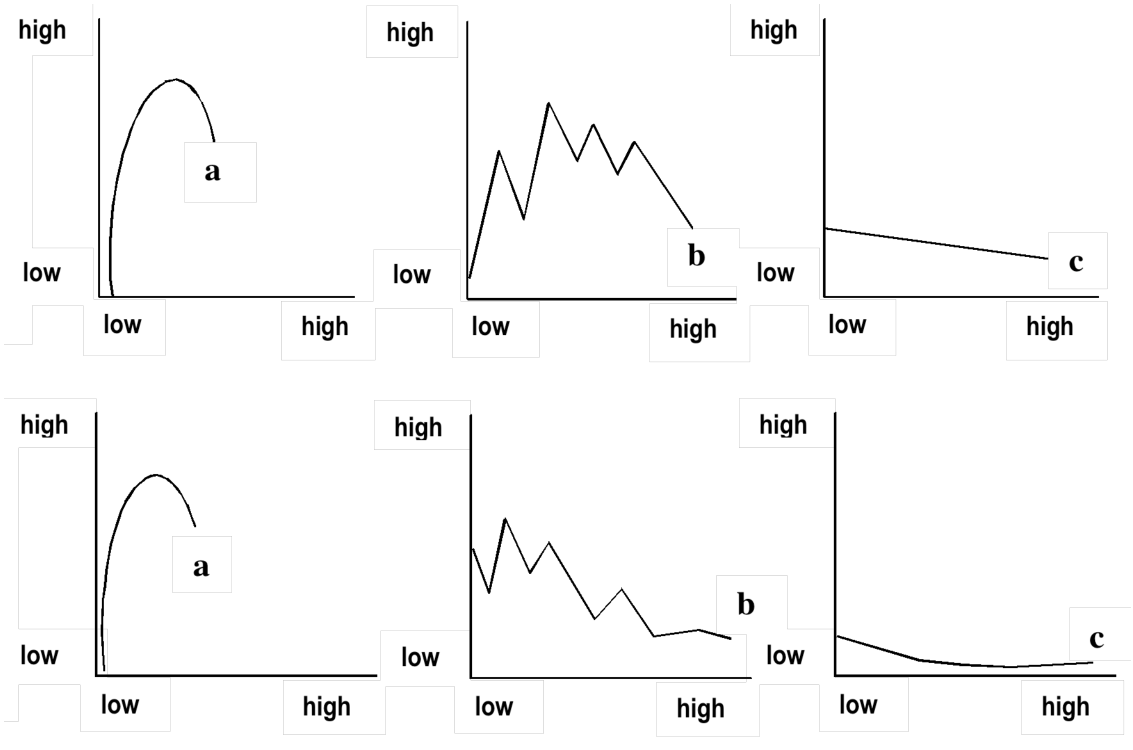


**Fig. 8.2. Graphic representation of hypothetical variations on the density and diversity of discard and loss patterns in the optimization strategy.**

The optimization model predictions were accurate on an average 10% of the occurrences. In Kelogi, later reduction stage Flaked Pieces occurred in a relative high frequency corresponding with the model. Interestingly, these artifacts were made on raw materials not found in close proximity. This same phenomenon is evidenced with Pounded Pieces and Manuports in MCK. The majority of the artifacts corresponding to the model are from Lemagrut, not the closest raw material source. This may indicate that optimization involved the occasional transport of higher quality or raw material better suited to a specific task. In general, the test results suggest than an optimization strategy was not a uniform behavior by far, but may have been in a more restricted temporal and/or spatial sense than expediency was. It could also be that the model is not adequate at predicting such behavioral trace distributions given the variables used. It could also be that behavior like raw material selection occurs on a broader scale commensurate with raw material distribution. Technological differentiation, or using specific tools for certain tasks may occur on a narrower scale and be determined by more proximate factors because plant and animal resources and predation risk occur on a narrower scale.

## Discussion

There are many factors that contribute to the formation and modification of lithic artifact assemblages. This thesis focuses on the hominin agent and the possible ecological determinants in the primary formation processes of those assemblages. Isaac (1981) cautioned that only those lines of movement along which durable items are discarded would be represented by artifactual traces. This sort of restricted trace evidence may not provide the entire human behavioral ecological narrative, that being said, the absence of traces can inform us as well as the presence, as to what sort of behavior was done where. Studies like this one, using landscape scale data to examine not just areas where activity traces are the most prevalent, but areas where they are scarce or even nonexistent, provides us with a means to better understand early human land-use and tool using behavior. Isaac (1981) also mentioned that secondary transport by natural or human agencies would obscure original points in that movement. This will be a problem until we learn how to fully comprehend behaviorally meaningful artifactual traces and incorporate that with site formation process studies. We may have gained insights into the manufacturing process involved in Oldowan technology, but there is a great deal about the complexities of the oldest stone technology known that we have yet to understand. Stern (1994) cautions us about the effects of time averaging and the shortcomings of applying interpretive models derived from short time scale observations to time-averaged assemblages (1995). The effect of time averaging on the OLAPP lithic assemblages could possibly render the assumption of coincidental assemblage formation untenable. However, this thesis is examining behavioral trends, as opposed to “short time scale behaviors”. In this case, time averaging may serve to boost a behavioral signal that is repeated over time in the same depositional environment so that it is more recognizable.

The results and conclusions drawn from this study have immediate implications regarding Oldowan technology, and broader implications as well. For instance, spatial variation in Oldowan assemblage characteristics was identified. This variation may be a reflection of regional variation within the Oldowan Industrial Complex. Regional variation within the Oldowan Industrial Complex had not been identified previously at Olduvai Gorge because the original type assemblages were derived from a restricted geographic area that may have not been broad enough to encompass regional variants.

Although Lithic Industrial Complexes refer to a grouping of Industries considered to represent part of the same whole, they are often characterized by the frequency of various morphological attributes or by recognizable landmarks on artifacts (Tactikos 2003). Since the Oldowan is an unstandardized technology that is not bound by design constraints, typical recognizable morphological attributes may be difficult to identify, and may lead to misinterpretations, especially if a lithic industry were to be described purely by its production mode and technique, and the tools produced (Roche 2000). Unlike the proposed temporally static production techniques (Ludwig 1998), different production modes and production techniques have been identified in synchronous lithic assemblages in the Olduvai Sub-basin, suggesting that variable production modes and production techniques are part of what defines behavioral or regional variants within an Industrial Complex. The Karari Industry (Harris 1978) is a prime example of a regional variant whose production mode and production technique made it distinct from the Oldowan Industry, but not separate from the Oldowan Industrial Complex. While Industrial ‘facies’ such as those recognized from the Shungura Formation, in the Omo Valley, Ethiopia (Chavaillon 1976) have been identified, other regional variants of the Oldowan Industrial Complex like the Karari Industry have not yet been identified.

Early Pleistocene lithic production is hardly confined to a single vast technological complex but rather defined by one. Unfortunately we have not yet fully described the driving forces behind the technical choices made in different tool production strategies that occur within an Industrial Complex. In other words, we recognize the Oldowan Industrial Complex as being a sum of its parts, but have not yet fully identified all of those parts. The ecological mechanisms that influence tool manufacture and tool assisted activities creating the static remains we attempt to interpret are still poorly defined. The morphological variables that are diagnostic of specific technological strategies are even more poorly defined.

Traditional approaches to studying the Oldowan have been focused upon human physical and behavioral evolution in terms of identifying the ‘evolution’ of stone tool cultures. These studies often addressed issues of diet, encephalization, and cognition, cultural complexity, etc. that involve the identification of the technological abilities of the toolmaker. They typically do not deal with the spatial or ecological context of the stone artifacts and have only hypothesized technological strategies. A successful evolutionarily stable strategy is a behavior or adaptation that improves reproductive viability. To understand technological strategies we need to understand the driving forces behind the specific tool-assisted exploitation of resources. Instead of looking to a patchwork of interpretations on levels of technological skills, tool-maker intelligence and the manufacturing techniques used in a particular area to understand early hominid tool-using behavior, we might consider the combined hominid decision making capability evidenced by differentiation in raw material selection and procurement, manufacturing technique, tool use, and transport on a landscape; in short, the technological organization (Nelson 1988). This is the theoretical bridge between identifying technology and technological strategies. Missing the link between these two concepts may be the reason for the many different technological signals that are perceived in examining geographically disparate lithic assemblages. Geographically limited foci may lead to errant conclusions about early hominid technological strategies and may be a case of not seeing the forest for the trees.

Multivariate analysis has been undertaken in order to recognize patterns in diachronous Oldowan artifact assemblages (Binford 1989). In that study, diachronous patterned variation was identified and interpreted as resulting from different technological strategies in Beds I and II. However, the criteria for the variables were typological categories, which have not been proven to be behaviorally meaningful categories. This study has shown that synchronously patterned variation exists and has attempted to identify the underlying influencing factors of that variation. The patterns are complex and vary temporally as well as spatially. Unlike much of the previous work done on the Oldowan, in this landscape archaeological approach, the behavioral and ecological contexts are the keys to identifying those influencing factors.

Another line of exploration regarding early hominid tool using behavior is the distribution of vegetation as both plant food and refuge. Sikes (1994) stated that $\delta^{13}C$ values indicate that the Olduvai Gorge Basal Bed II paleosol supported a relatively closed riverine forest to grassy woodland habitat. This is based upon data from the Eastern Lacustrine Plain Landscape Association. Unfortunately, between a riverine forest and grassy woodland there are countless combinations of resource distributions and costs and benefits. In order to link more specific habitats with specific activities, the local vegetation mosaic, which can be quite complex, would have to be available in a higher resolution.

In her dissertation thesis, Cushing (2002) pointed out that “stone tool discard should closely relate to the degrees of carnivore competition so that the lower the competition, the higher the discard/density of stone tools. This should indicate early hominids' adaptive strategy of avoiding becoming prey while incorporating high quality nutrient-yielding larger mammal foods into their diets.” According to Cushing (2002), both hominid stone tool marks and carnivore tooth marks co-exist on vertebrate fossil specimens in several Plio-Pleistocene localities. This indicates that hominids and carnivores experienced some type of interaction at this time and denotes that a common resource was shared between the two taxa (Cushing, 2002). A simple comparison of artifact and faunal distributions across the landscape support this theory (see Appendix 11).

This coincidence of stone tool distribution and faunal remains suggests an activity related stone tool discard and loss pattern. This illustrates the importance of a behavioral ecological perspective on lithic artifact analysis and interpretation. A landscape scale assemblage can demonstrate just how integrated tool using behavior was with the environment by revealing behavioral patterns that co vary with resource distributions. In the paleo-Olduvai Basin, the Western and Eastern Lacustrine Plains are dense assemblages. This may imply that the lacustrine plains offer not only more food and raw material resources, but more refuge to carry out more tasks. However, the proximity of various raw material sources impacts the raw material diversity greatly. Even in an area of high raw material availability, transport of specific raw material into the area occurs. This implies an optimal raw material is selected for specific areas that perhaps necessitate specific tasks.

Previous research that examined trends in Plio-Pleistocene tool using behavior at Lake Turkana and Olduvai Gorge (Kimura 2002, Rogers et al, 1994) compared various localities over time, but not *the same* localities over time. Rogers et al (1994) found that over an 800,000 year time span, the earlier hominid land use and tool using behavior was restricted in its range and artifact diversity and density, whereas the later hominid land and tool use was given to geographic and technological expansion. Kimura (2002) concluded that over a 600,00 year time span Bed I hominids at Olduvai were employing a least effort opportunistic strategy manufacturing Oldowan style tools, whereas the makers of the Developed Oldowan A and B were given to higher skill levels and greater transport ranges. A landscape scale assemblage like the OLAPP lithic assemblage provides the opportunity to compare various localities in different depositional environments to assess the presence of diverse strategies. The OLAPP landscape assemblage showed evidence of a least-effort strategy, a transport strategy, and an optimization strategy, occurring during the same 50,000-year period. It also showed different production techniques not only during the same time period but also in the same excavation unit (trench).

Testing the behavioral models proposed in this thesis provided the insight that the Oldowan, typically known as a simplistic technological industry, is potentially more complex than was previously thought or could be explained by rudimentary models. In the western sub-basin it appears that raw material proximity determined much of the technological organization. Raw materials were procured and used extensively in a limited geographic range and the opportunistic use of raw material appears to have been the primary strategy. In the eastern sub-basin, a combination of expedient technology involving transport of lava and optimization of specific tools appears to have been the strategy. Specific locales such as MCK show a high diversity of tool types and raw materials that do not conform to the more simplistic behavioral models of opportunism or ‘stone flow’ transport. However, an optimization strategy, as was modeled in this study, does not account for the assemblage characteristics either. At the 1% significance level ($\alpha = .01$), the test implications do not provide sufficient evidence to conclude that any of the models will accurately predict artifact distribution across the landscape. However, many of the predicted raw material components of the model do exhibit significant correlations with the actual archaeological data. This suggests that while neither the opportunistic, expedient, nor optimization models can totally account for artifact distribution, they each can account for some of the distributional characteristics.

The Oldowan technological organization can be seen as a mosaic of behavioral strategies integrated with a mosaic of paleoenvironments and, just as the resources are distributed in different temporal and spatial scales across a landscape, so are the behaviors.

I conclude that simplistic behavioral models such as those presented here are inadequate to explain the tool using behavior evidenced by the variation displayed in the Oldowan assemblage characteristics over a broad landscape scale. This study has attempted to tease apart several aspects of tool-using behavior by experimentally identifying and modeling what the archaeological traces of particular behaviors might look like. Ultimately, if specific behaviors could be identified by their archaeological traces and those traces could be isolated, then accumulated assemblages could be understood in the manner that they were accumulated. It may be so that the critical variables used in my distributional models are oversimplifications of the complex nature of the driving forces behind the decision-making and manufacture and use of stone tools on a landscape. This study demonstrates the need for extensive experimental archaeology, whereby the diagnostic variables of manufacturing process, and transport and reuse are addressed in greater detail.

### *Future research directions and goals*

This study illustrates the need for further research to be done to facilitate the behavioral interpretation of landscape scale assemblages and to better understand the technological organization of the Oldowan hominids. Identifying the ecological variables (distance from raw material source, raw material quality, availability, and distribution, cost of procurement, risk of procurement, etc.) that have the greatest impact on technological strategies is a logical next step. This should be approached in two ways: experimentally generating data and statistically manipulating that data. In order to do that, the critical variables assigned to a technological strategy need to be well defined. While a holistic approach to that task is necessary for understanding technological organization, it is also important to be able to isolate each variable in the manufacturing process. In order to understand the behavioral adaptations involved in various strategies, extensive experimental archaeological studies that can identify the effect of different land use patterns on archaeological assemblages are needed. For instance transport costs and reduction sequences for various raw material types must be more clearly articulated through experimentation.

Although the models presented and tested were not completely accurate in predicting assemblage distribution, they did demonstrate patterned correlations with various ecological factors. Those patterned correlations must also be quantified, that is to say, archaeological and experimentally generated data such as that presented here must be subjected to more stringent statistical analyses that can isolate influencing factors and principal components of behavior.

In conclusion, reporting on the new landscape sample of Oldowan artifacts from Olduvai Gorge was not done with the intention of describing a new lithic Industry, or associating the Oldowan with a particular hominid species, but discerning whether existing behavioral models could be used to identify the technological strategy used by the Oldowan hominids on a broad landscape scale. The OLAPP landscape scale sample provided a comprehensive database with which to carry out such a study. The data suggest that Oldowan technological organization is more complex than is generally acknowledged. Based upon morphological characteristics of Oldowan style tools, the technology may seem rudimentary, but considering the spatial pattern of resource use (Potts 1991) and how the technology is integrated with early hominid land use strategies, the technological organization is much more complex than what is portrayed in a least effort strategy. This thesis asserts that the adaptive significance of Oldowan technology lies in how the complexity of the Oldowan technological organization is integrated into the landscape, so that tool-using strategies can be adapted to the fit the local ecological constraints or benefits.

In the foreword to *Excavations in Beds I and II, Olduvai Gorge 1960-1963* (Leakey 1971), J. D. Clark, speaking on the "embarrassment of riches" that were the lithic, faunal, and hominid remains recovered from Olduvai, said that they "…form the very basis for understanding the way of life and capabilities of the hominids, once we are able to interpret the evidence correctly." My goal in completing this study has been to improve our understanding of that evidence.

# APPENDIX 1

**Appendix 1. Artifact counts from each trench and specific excavation level**

| Trench | Level | Count | Trench | Level | Count | Trench | Level | Count | Trench | Level | Count | Trench | Level | Count | Trench | Level | Count |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 1 | 26 | 1 | 10 | 35 | 5 | 2 | 46 | 4 | 6 | 62 | 6 | 6 | 84 | 1 | 2 |
|  | 3 | 5 |  | 2 | 8 | 36 | 5 | 25 |  | 9 | 2 |  | 7 | 10 |  | 2 | 5 |
| 3 | 3 | 49 |  | 3 | 1 | 37 | 4 | 2 |  | 11 | 1 |  | 10 | 5 |  | 3 | 2 |
| 4 | 3 | 10 |  | 4 | 3 |  | 5 | 2 |  | 12 | 1 | 63 | 12 | 2 |  | 4 | 1 |
| 5 | 3 | 9 |  | 5 | 8 |  | 6 | 2 |  | 13 | 1 | 64 | 3 | 1 | 85 | 2 | 5 |
| 6 | 3 | 9 | 27 | 2 | 7 |  | 7 | 4 | 47 | 3 | 5 |  | 4 | 23 |  | 5 | 1 |
| 7 | 3 | 14 |  | 3 | 26 | 38 | 4 | 2 |  | 4 | 18 | 65 | 3 | 339 | 86 | 1 | 5 |
| 8 | 3 | 23 |  | 5 | 59 |  | 8 | 2 | 48 | 2 | 50 |  | 4 | 6 |  | 2 | 4 |
| 9 | 3 | 8 |  | 6 | 8 |  | 11 | 2 |  | 3 | 5 | 66 | 7 | 1 |  | 4 | 2 |
| 10 | 2 | 2 |  | 7 | 14 | 39 | 6 | 1 |  | 4 | 5 | 67 | 6 | 7 | 88 | 1 | 103 |
|  | 3 | 18 |  | 9 | 1 |  | 7 | 3 |  | 7 | 4 |  | 7 | 9 |  | 2 | 30 |
| 11 | 3 | 5 |  | 11 | 1 |  | 9 | 3 |  | 9 | 4 | 68 | 2 | 22 |  | 4 | 60 |
| 12 | 3 | 28 |  | 12 | 3 | 40 | 1 | 2 | 49 | 2 | 2 | 70 | 2 | 4 |  | 5 | 9 |
| 14 | 3 | 4 | 28 | 1 | 6 |  | 2 | 6 |  | 3 | 4 |  | 3 | 40 |  | 10 | 1 |
| 15 | 3 | 10 |  | 2 | 2 | 41 | 1 | 5 | 50 | 4 | 3 |  | 4 | 1 |  | 11 | 6 |
| 16 | 3 | 1 | 29 | 4 | 1 |  | 4 | 16 |  | 5 | 5 |  | 5 | 1 |  | 12 | 23 |
| 18 | 3 | 8 |  | 6 | 1 |  | 7 | 7 |  | 6 | 2 | 71 | 1 | 41 |  | 13 | 3 |
| 19 | IS | 14 |  | 7 | 11 |  | 1A | 2 |  | 7 | 1 |  | 2 | 32 |  | 14 | 1 |
| 20 | 2 | 7 | 30 | 2 | 1 |  | 1B | 3 |  | 8 | 1 |  | 3 | 9 | 92 | 1 | 1 |
| 21 | 1 | 64 |  | 4 | 4 | 43 | 7 | 34 | 51 | 3 | 11 |  | 4 | 4 | 94 | 1 | 8 |
|  | 2 | 28 |  | 5 | 2 |  | 9 | 20 |  | 4 | 22 |  | 5 | 1 |  | 2 | 133 |
| 22 | 6 | 8 |  | 6 | 1 |  | 11 | 49 |  | 6 | 3 | 72 | 14 | 21 | 95 | 2 | 2 |
|  | 7 | 12 |  | 8 | 5 |  | 12 | 92 |  | 8 | 2 |  | 15 | 87 | 96 | 3 | 17 |
|  | 9 | 28 |  | 11 | 5 | 44 | 4 | 100 | 52 | 13 | 2 |  | 23 | 5 | 97 | 9 | 3 |
|  | 10 | 3 |  | 12 | 1 |  | 5 | 34 |  | 14 | 2 | 73 | 13 | 1 |  | 10 | 3 |
|  | 13 | 3 |  | 13 | 1 |  | 6 | 44 | 53 | 2 | 9 | 74 | 3 | 1 |  | 11 | 7 |
|  | 14 | 2 | 31 | 3 | 6 |  | 7 | 8 |  | 3 | 6 |  | 4 | 2 | 98 | 4 | 1 |
| 23 | 1 | 2 | 32 | 6 | 1 |  | 8 | 33 |  | 4 | 13 |  | 6 | 1 |  | 5 | 4 |
|  | 4 | 21 |  | 7 | 2 |  | 9 | 17 |  | 7 | 1 | 75 | 3 | 7 |  | 7 | 2 |
|  | 2+3 | 2 | 34 | 1 | 96 |  | 10 | 13 | 56 | 2 | 4 |  | 10 | 2 | 99 | 5 | 5 |
| 24 | 1 | 9 |  | 1A | 17 |  | 11 | 8 |  | 7 | 2 |  | 11 | 3 | 100 | 4 | 15 |
|  | 2 | 57 |  | 1B | 9 |  | 12 | 14 | 57 | 2 | 625 |  | 12 | 3 |  | 5 | 4 |
|  | 4 | 1 |  | 1C | 9 |  | 11EXT | 22 |  | 3 | 187 | 79 | 1 | 1 | 103 | 4 | 27 |
| 25 | 2 | 13 |  | 1D | 3 | 45 | 3 | 6 | 58 | 1 | 7 |  | 3 | 5 |  | 5 | 24 |
|  | 3 | 5 |  | 1F | 14 |  | 4 | 1 | 59 | 2 | 4 |  | 4 | 5 | 104 | 1 | 45 |
|  | 4 | 4 |  | 1G | 22 |  | 5 | 12 | 60 | 1 | 3 |  | 5 | 1 |  | 2 | 198 |
|  | 5 | 22 |  | 1H | 47 |  | 6 | 5 |  | 11 | 8 | 80 | 7 | 1 |  | 3 | 14 |
|  | 6 | 7 |  | 1I | 17 |  | 7 | 2 | 61 | 1 | 5 |  | 8 | 1 | 105 | 1 | 7 |
|  | 7 | 20 |  | 1J | 47 |  |  |  |  | 2 | 58 | 81 | 1 | 2 |  | 2 | 9 |
|  |  |  |  | 1K | 61 |  |  |  |  | 3 | 3 |  | 2 | 1 |  | 4 | 32 |
|  |  |  |  |  |  |  |  |  |  |  |  |  | 4 | 1 | 106 | 8 | 2 |
| sub totals |  | 536 |  |  | 541 |  |  | 605 | sub totals |  | 1097 |  |  | 715 |  |  | 826 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | **Grand Total** |  | **4320** |

**Grand Total = only those artifacts used in analysis.**

**33 artifacts were omitted as they lacked some critical variable data.**

# APPENDIX 2. THE RESULTS OF THE EXPERIMENTAL TRIALS.

| no. | spec # | Task | Form | Material | Mass | Time(.10/min) | # Strikes |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 5 | 1 | 1 | 3 | ineffective | 60 |
| 2 | 2 | 5 | 3 | 1 | 2 | ineffective | 300 |
| 3 | 3 | 5 | 3 | 1 | 3 | 5.50 | 156 |
| 4 | 4 | 3 | 2 | 5 | 1 | 3.08 | - |
| 5 | 4 | 5 | 3 | 1 | 3 | 5.75 | 172 |
| 6 | 5 | 5 | 3 | 4 | 3 | ineffective | 250 |
| 7 | 6 | 1 | 3 | 2 | 2 | 4.50 | 120 |
| 8 | 7 | 1 | 3 | 1 | 2 | 4.17 | 180 |
| 9 | 8 | 1 | 3 | 2 | 2 | 2.97 | 120 |
| 10 | 9 | 1 | 2 | 1 | 2 | 2.67 | 109 |
| 11 | 10 | 1 | 3 | 3 | 2 | 2.98 | 62 |
| 12 | 11 | 1 | 4 | 2 | 1 | 2.75 | 206 |
| 13 | 12 | 1 | 2 | 2 | 1 | 3.83 | 240 |
| 14 | 13 | 1 | 3 | 4 | 2 | 2.97 | 123 |
| 15 | 14 | 1 | 2 | 4 | 1 | ineffective | 30 |
| 16 | 15 | 1 | 2 | 4 | 1 | ineffective | 159 |
| 17 | 16 | 1 | 3 | 1 | 1 | 0.50 | 49 |
| 18 | 17 | 1 | 2 | 1 | 1 | ineffective | 250 |
| 19 | 18 | 1 | 4 | 5 | 1 | 2.97 | 94 |
| 20 | 19 | 4 | 2 | 2 | 1 | 3.42 | 90 |
| 21 | 20 | 4 | 2 | 2 | 1 | 3.37 | 85 |
| 22 | 21 | 4 | 2 | 1 | 1 | 3.20 | 78 |
| 23 | 22 | 4 | 3 | 1 | 2 | 7.00 | <200 |
| 24 | 23 | 4 | 4 | 2 | 1 | ineffective | 60 |
| 25 | 24 | 4 | 4 | 1 | 3 | 11.00 | 213 |
| 26 | 25 | 4 | 2 | 1 | 1 | 18.00 | 387 |
| 27 | 26 | 3 | 2 | 1 | 1 | 5.00 | 108 |
| 28 | 27 | 3 | 2 | 1 | 1 | 7.00 | 231 |
| 29 | 28 | 7 | 2 | 1 | 1 | 7.00 | 378 |
| 30 | 29 | 7 | 2 | 1 | 1 | 6.00 | 397 |
| 31 | 30 | 7 | 2 | 2 | 1 | 4.00 | 403 |
| 32 | 31 | 7 | 2 | 1 | 1 | 12.00 | 714 |
| 33 | 32 | 7 | 2 | 2 | 1 | 25.00 | 80 |
| 34 | 33 | 7 | 2 | 2 | 1 | 29.00 | 120 |
| 35 | 34 | 3 | 2 | 2 | 1 | 6.00 | 460 |
| 36 | 35 | 7 | 3 | 2 | 2 | ineffective | <200 |
| 37 | 36 | 7 | 3 | 5 | 2 | 9.00 | 519 |
| 38 | 37 | 7 | 2 | 5 | 1 | 36.00 | - |
| 39 | 38 | 8 | 3 | 5 | 1 | 2.00 | 18 |
| 40 | 39 | 3 | 2 | 2 | 1 | 5.00 | 387 |
| 41 | 40 | 7 | 3 | 2 | 2 | 16.00 | 510 |
| 42 | 41 | 7 | 2 | 1 | 1 | 11.50 | - |
| 43 | 42 | 7 | 2 | 2 | 1 | 3.50 | - |
| 44 | 45 | 3 | 3 | 1 | 1 | 9.00 | 382 |
| 45 | 46 | 7 | 2 | 1 | 1 | 7.50 | - |
| 46 | 47 | 7 | 2 | 1 | 1 | 28.00 | - |
| 47 | 48 | 8 | 1 | 4 | 1 | 0.33 | 7 |
| 48 | 49 | 8 | 1 | 4 | 1 | 0.20 | 13 |
| 49 | 50 | 8 | 1 | 4 | 1 | 0.25 | 12 |
| 50 | 51 | 3 | 4 | 5 | 1 | ineffective | 75 |
| 51 | 52 | 3 | 3 | 1 | 1 | ineffective | 80 |
| 52 | 53 | 3 | 3 | 1 | 1 | 11.00 | - |
| 53 | 54 | 7 | 2 | 3 | 1 | 20.50 | - |
| 54 | 55 | 7 | 4 | 1 | 1 | 24.75 | - |

| no. | spec # | Task | Form | Material | Mass | Time(.10/min) | # Strikes |
|---|---|---|---|---|---|---|---|
| 55 | 56 | 8 | 1 | 5 | 3 | 0.07 | 2 |
| 56 | 56 | 8 | 1 | 5 | 3 | 0.33 | 11 |
| 57 | 56 | 8 | 1 | 5 | 3 | 0.23 | 7 |
| 58 | 57 | 4 | 4 | 1 | 1 | 2.78 | - |
| 59 | 58 | 3 | 3 | 4 | 1 | 6.83 | - |
| 60 | 59 | 3 | 3 | 5 | 2 | 7.93 | - |
| 61 | 59 | 7 | 2 | 5 | 1 | 7.92 | - |
| 62 | 59 | 7 | 2 | 5 | 1 | 3.08 | - |
| 63 | 60 | 7 | 2 | 5 | 1 | 13.08 | - |
| 64 | 60 | 7 | 2 | 4 | 1 | 3.08 | - |
| 65 | 60 | 3 | 4 | 5 | 1 | 7.42 | - |
| 66 | 62 | 7 | 3 | 3 | 2 | 5.42 | - |
| 67 | 62 | 3 | 2 | 3 | 1 | 2.78 | - |
| 68 | 62 | 3 | 2 | 3 | 1 | 5.00 | - |
| 69 | 62 | 3 | 2 | 3 | 1 | 5.17 | - |
| 70 | 62 | 7 | 2 | 3 | 1 | 2.67 | - |
| 71 | 63 | 7 | 3 | 5 | 1 | 6.70 | - |
| 72 | 63 | 4 | 2 | 5 | 1 | 2.17 | - |
| 73 | 64 | 3 | 4 | 5 | 1 | 10.50 | - |
| 74 | 65 | 4 | 2 | 4 | 1 | 2.17 | - |
| 75 | 65 | 7 | 2 | 3 | 1 | 3.70 | - |
| 76 | 66 | 4 | 3 | 3 | 1 | 2.62 | - |
| 77 | 67 | 8 | 1 | 5 | 2 | 1.16 | 16 |
| 78 | 69 | 4 | 3 | 4 | 1 | 5.02 | - |
| 79 | 70 | 4 | 3 | 4 | 2 | 6.45 | - |
| 80 | 71 | 3 | 4 | 5 | 2 | 6.08 | - |
| 81 | 72 | 2 | 3 | 1 | 2 | 5.17 | <300 |
| 82 | 73 | 2 | 4 | 1 | 1 | 4.50 | 339 |
| 83 | 74 | 2 | 3 | 1 | 1 | 2.78 | 245 |
| 84 | 75 | 2 | 4 | 5 | 2 | 4.00 | 450 |
| 85 | 76 | 2 | 3 | 5 | 1 | 4.50 | 345 |
| 86 | 77 | 2 | 4 | 5 | 1 | 6.25 | <300 |
| 87 | 78 | 2 | 3 | 5 | 1 | 8.00 | <400 |
| 88 | 79 | 2 | 3 | 3 | 1 | 4.75 | 362 |
| 89 | 80 | 2 | 3 | 4 | 1 | 3.00 | 316 |
| 90 | 81 | 2 | 4 | 2 | 1 | 5.58 | 361 |
| 91 | 82 | 2 | 3 | 2 | 2 | 4.75 | 306 |
| 92 | 83 | 2 | 3 | 2 | 2 | 5.00 | 403 |
| 93 | 84 | 2 | 2 | 1 | 1 | 8.33 | <500 |
| 94 | 85 | 2 | 2 | 3 | 1 | 15.00 | <1000 |
| 95 | 86 | 2 | 4 | 1 | 2 | 4.67 | 260 |
| 96 | 87 | 8N | 3 | 4 | 1 | - | 19 |
| 97 | 87 | 8N | 3 | 4 | 1 | - | 1 |
| 98 | 88 | 8N | 3 | 5 | 1 | - | 9 |
| 99 | 88 | 8N | 3 | 5 | 1 | - | 1 |
| 100 | 89 | 8N | 4 | 5 | 1 | - | 10 |
| 101 | 89 | 8N | 4 | 5 | 1 | - | 1 |
| 102 | 90 | 8N | 3 | 2 | 3 | - | 5 |
| 103 | 90 | 8N | 3 | 2 | 3 | - | 1 |
| 104 | 91 | 8N | 4 | 2 | 3 | - | 6 |
| 105 | 91 | 8N | 4 | 2 | 3 | - | 2 |
| 106 | 92 | 8N | 3 | 1 | 1 | - | 3 |
| 107 | 92 | 8N | 3 | 1 | 1 | - | 2 |
| 108 | 93 | 8N | 4 | 1 | 2 | - | 4 |
| 109 | 93 | 8N | 4 | 1 | 2 | - | 1 |
| 110 | 94 | 8N | 3 | 5 | 1 | - | 14 |
| 111 | 94 | 8N | 3 | 5 | 1 | - | 1 |
| 112 | 95 | 8N | 3 | 2 | 1 | - | 5 |
| 113 | 95 | 8N | 3 | 2 | 1 | - | 2 |

| no. | spec # | Task | Form | Material | Mass | Time(.10/min) | # Strikes |
|---|---|---|---|---|---|---|---|
| 114 | 96 | 8N | 2 | 3 | 1 | ineffective | <10 |
| 115 | 96 | 8N | 2 | 3 | 1 | - | 1 |
| 116 | 97 | 8N | 2 | 3 | 1 | ineffective | <50 |
| 117 | 97 | 8N | 2 | 3 | 1 | - | 5 |
| 118 | 98 | 8N | 4 | 5 | 2 | - | 13 |
| 119 | 98 | 8N | 4 | 5 | 2 | - | 2 |
| 120 | 99 | 8N | 2 | 3 | 1 | ineffective | <50 |
| 121 | 99 | 8N | 2 | 3 | 1 | - | 2 |
| 122 | 100 | 8N | 2 | 2 | 1 | ineffective | <70 |
| 123 | 100 | 8N | 2 | 2 | 1 | - | 4 |
| 124 | 101 | 8N | 1 | 5 | 1 | ineffective | <20 |
| 125 | 101 | 8N | 1 | 5 | 1 | - | 2 |
| 126 | 102 | 8N | 1 | 5 | 1 | - | 4 |
| 127 | 102 | 8N | 1 | 5 | 1 | - | 1 |
| 128 | 103 | 8N | 1 | 5 | 1 | - | 3 |
| 129 | 103 | 8N | 1 | 5 | 1 | - | 1 |
| 130 | 104 | 8N | 1 | 5 | 1 | - | 2 |
| 131 | 104 | 8N | 1 | 5 | 1 | - | 1 |
| 132 | 105 | 8N | 1 | 5 | 2 | - | 2 |
| 133 | 105 | 8N | 1 | 5 | 2 | - | 1 |
| 134 | 106 | 8N | 1 | 2 | 2 | - | 2 |
| 135 | 106 | 8N | 1 | 2 | 2 | - | 1 |
| 136 | 107 | 6 | 5 | 5 |  | 0.50 | - |
| 137 | 108 | 6 | 5 | 5 |  | 0.17 | - |
| 138 | 109 | 6 | 5 | 5 |  | 0.52 | - |
| 139 | 110 | 6 | 2 | 4 | 1 | 0.33 | - |
| 140 | 111 | 3 | 4 | 2 | 1 | 11.90 | - |
| 141 | 112 | 3 | 4 | 4 | 2 | ineffective | - |
| 142 | 113 | 3 | 2 | 2 | 1 | 8.92 | - |
| 143 | 114 | 3 | 2 | 3 | 1 | 4.67 | - |
| 144 | 116 | 4 | 3 | 4 | 2 | 0.22 | - |
| 145 | 117 | 4 | 4 | 3 | 1 | 0.35 | - |
| 146 | 118 | 4 | 2 | 4 | 1 | 1.60 | - |
| 147 | 119 | 4 | 3 | 1 | 2 | 0.77 | - |
| 148 | 120 | 7 | 3 | 4 | 1 | 8.58 | - |
| 149 | 121 | 7 | 3 | 4 | 1 | 9.05 | - |
| 150 | 122 | 7 | 4 | 3 | 1 | 5.12 | - |
| 151 | 123 | 7 | 3 | 2 | 1 | 8.88 | - |
| 152 | 124 | 8 | 4 | 2 | 2 | 0.33 | 7 |
| 153 | 127 | 8 | 1 | 4 | 2 | 0.30 | 7 |
| 154 | 128 | 8 | 1 | 5 | 2 | 0.28 | 6 |
| 155 | 129 | 8 | 1 | 5 | 2 | 0.08 | 3 |
| 156 | 130 | 8 | 0 | 5 | 2 | 0.08 | 3 |
| 157 | 133 | 8 | 1 | 4 | 2 | 0.20 | 5 |
| 158 | 134 | 8 | 1 | 5 | 2 | 0.10 | 10 |
| 159 | 135 | 8 | 1 | 5 | 2 | 0.08 | 10 |
| 160 | 136 | 8 | 1 | 5 | 2 | 0.32 | - |
| 161 | 137 | 8 | 3 | 2 | 2 | 0.05 | - |
| 162 | 138 | 8 | 3 | 2 | 2 | 0.48 | - |
| 163 | 139 | 7 | 2 | 5 | 1 | 11.25 | - |
| 164 | 140 | 8 | 3 | 2 | 2 | 0.20 | - |
| 165 | 141 | 8 | 1 | 5 | 1 | 0.37 | - |
| 166 | 142 | 8 | 3 | 2 | 2 | 0.13 | - |
| 167 | 143 | 8 | 1 | 5 | 2 | 0.08 | - |
| 168 | 144 | 8 | 1 | 5 | 2 | 0.27 | - |

**Task**: (1) Procuring Stick; (2) Sharpening Stick; (3) Skinning; (4) Limb Disarticulation; (5) Chopping Wood; (6) Digging; (7) Defleshing; (8) Pounding Bone; (8N) Pounding Nut
**Form:** (1) Unmodified Cobble; (2) Detached Piece; (3) Flaked Piece <50%; (4) Flaked Piece >50%; (5) Sharpened Stick.
**Material:** (1) Lava [Lemagrut]; (2) Lava [Sadiman]; (3) Quartzite [Naibor Soit]; (4) Quartzite [Naisiusiu]; (5) Other.
**Mass:** (1) Small; (2) Medium; (3) Large size classes.
Time: Recorded in real numbers to the .10 of a minute.
**# Strikes:** Number of strikes or blows necessary to complete the task.

# APPENDIX 3. NUMBER OF ARTIFACTS BY EXCAVATED UNIT (TRENCH).

| Trench | No. Artifacts | Trench | No. Artifacts | | Trench | No. Artifacts |
|---|---|---|---|---|---|---|
| 1 | 6 | 37 | 10 | | 73 | 1 |
| 2 | – | 38 | 19 | | 74 | 4 |
| 3 | 49 | 39 | 8 | | 75 | 15 |
| 4 | 10 | 40 | 8 | | 76 | – |
| 5 | 9 | 41 | 33 | | 77 | – |
| 6 | 9 | 42 | -- | | 78 | – |
| 7 | 15 | 43 | 195 | | 79 | 12 |
| 8 | 23 | 44 | 294 | | 80 | 2 |
| 9 | 8 | 45 | 26 | | 81 | 4 |
| 10 | 20 | 46 | 11 | | 82 | – |
| 11 | 5 | 47 | 23 | | 83 | – |
| 12 | 28 | 48 | 68 | | 84 | 10 |
| 13 | – | 49 | 6 | | 85 | 6 |
| 14 | 4 | 50 | 12 | | 86 | 11 |
| 15 | 10 | 51 | 38 | | 87 | – |
| 16 | 1 | 52 | 4 | | 88 | 237 |
| 17 | – | 53 | 29 | | 89 | – |
| 18 | 8 | 54 | -- | | 90 | – |
| 19 | 14 | 55 | -- | | 91 | – |
| 20 | 7 | 56 | 6 | | 92 | 1 |
| 21 | 92 | 57 | 812 | | 93 | – |
| 22 | 56 | 58 | 7 | | 94 | 141 |
| 23 | 25 | 59 | 4 | | 95 | 2 |
| 24 | 67 | 60 | 11 | | 96 | 17 |
| 25 | 71 | 61 | 66 | | 97 | 13 |
| 26 | 30 | 62 | 21 | | 98 | 7 |
| 27 | 119 | 63 | 2 | | 99 | 5 |
| 28 | 8 | 64 | 24 | | 100 | 19 |
| 29 | 13 | 65 | 346 | | 101 | – |
| 30 | 21 | 66 | 1 | | 102 | – |
| 31 | 6 | 67 | 16 | | 103 | 51 |
| 32 | 3 | 68 | 22 | | 104 | 271 |
| 33 | – | 69 | – | | 105 | 48 |
| 34 | 342 | 70 | 46 | | 106 | 2 |
| 35 | 2 | 71 | 87 | | | |
| 36 | 25 | 72 | 113 | **Total** | **106** | **4353** |

Note: some of the artifacts shown above were omitted from the analysis.

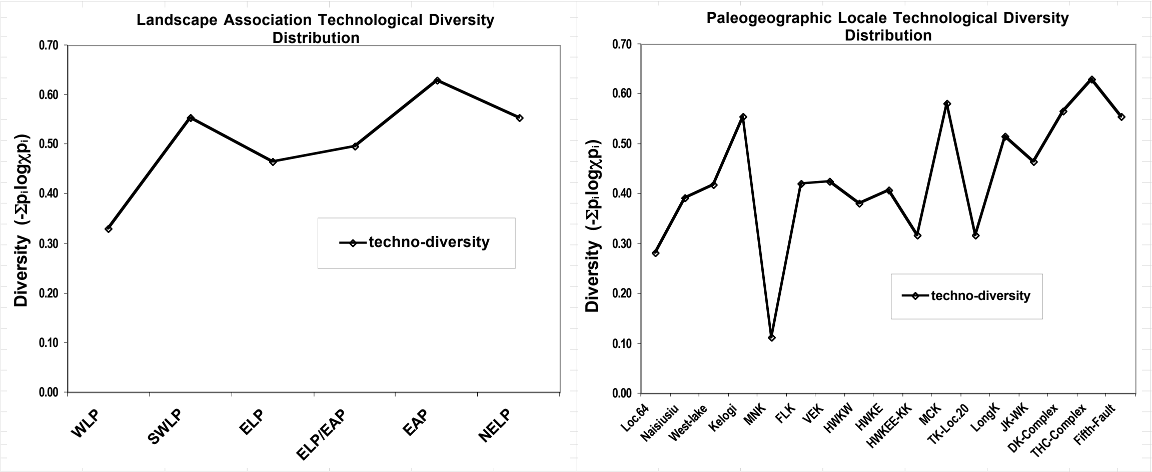
# APPENDIX 4. ARTIFACT WEIGHT DENSITY AND EXCAVATED VOLUME IN A LANDSCAPE ASSOCIATION SCALE GROUPING.

| **Landscape Association** | **Total artifact weight (grams)** | **Total excavated volume ($m^3$)** | **Density** |
|---|---|---|---|
| Western Lacustrine Plain | 23250.30 | 72.54 | 320.52 |
| Southwestern Lacustrine Plain | 32226.40 | 14.53 | 2217.92 |
| Eastern Lacustrine Plain | 122481.20 | 208.82 | 586.54 |
| Eastern Lacustrine Plain/Eastern Alluvial Plain (transitional) | 5436.30 | 88.85 | 61.19 |
| Eastern Alluvial Plain | 1250.80 | 56.89 | 21.99 |
| Northeastern Lacustrine Plain | 2026.80 | 19.05 | 106.39 |
| **Total** | **186674.90** | **469.47** | **397.63** |

Artifact weight density

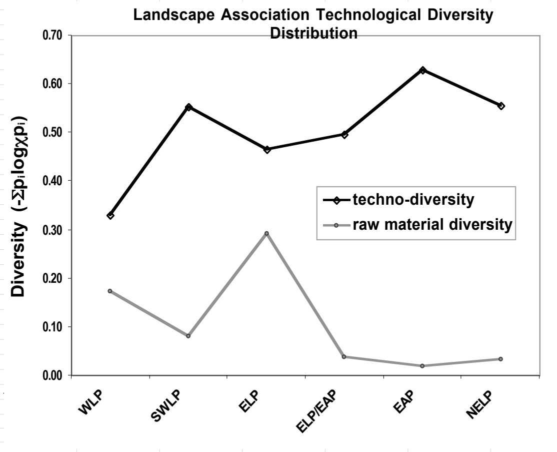
| | Mean | Std. Dev. | Std. Error | Variance | Range |
|---|---|---|---|---|---|
| Landscape Association | 506.465 | 801.484 | 327.204 | 642376.649 | 2082.510 |
| Paleogeographic Locale | 412.352 | 585.253 | 141.945 | 342520.956 | 2102.120 |

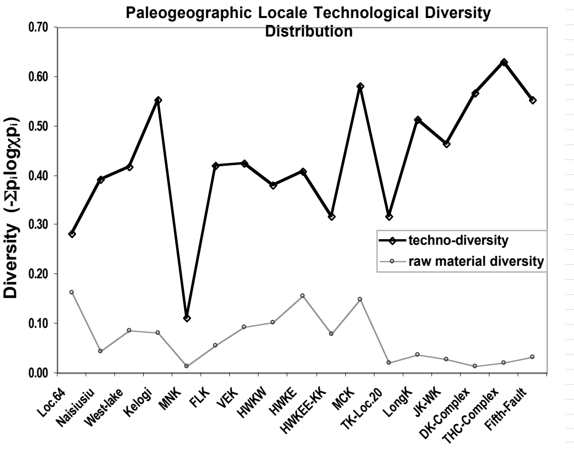
# APPENDIX 5. COMPARISON OF TECHNOLOGICAL DIVERSITY ON A LANDSCAPE ASSOCIATION AND A PALEOGEOGRAPHIC LOCALE SCALE.



| Techno-diversity | Mean | Std. Dev. | Std. Error | Variance | Range |
|---|---|---|---|---|---|
| Landscape Association | .505 | .102 | .041 | .010 | .300 |
| Paleogeographic Locale | .431 | .130 | .032 | .017 | .520 |

# APPENDIX 6. COMPARISON OF TECHNOLOGICAL DIVERSITY AND RAW MATERIAL DIVERSITY ON A LANDSCAPE ASSOCIATION AND A PALEOGEOGRAPHIC LOCALE SCALE.





**Raw Material Diversity**

| | Mean | Std. Dev. | Std. Error | Variance | Range |
|---|---|---|---|---|---|
| Landscape Association | .106 | .107 | .044 | .011 | .271 |
| Paleogeographic Locale | .069 | .050 | .012 | .003 | .150 |

# APPENDIX 7. THE SPATIAL DISTRIBUTION OF THE GENERAL ARTIFACT TYPES BY COUNT AND MAXIMUM DIMENSION.

| Landscape Association | Flaked Piece | | | Detached Piece | | | Manuport | | | Split Cobble | | | Pounded Piece | | | unit total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | count | max dim | s.d. | count | max dim | s.d. | count | max dim | s.d. | count | max dim | s.d. | count | max dim | s.d. | count |
| **WLP** | 88 | 57.13 | 23.12 | 1197 | 23.48 | 9.79 | 18 | 64.76 | 27.61 | 316 | 22.47 | 8.80 | | | | 1619 |
| **SWLP** | 45 | 91.14 | 33.78 | 117 | 23.36 | 14.38 | 13 | 88.61 | 27.35 | 37 | 25.18 | 12.92 | | | | 212 |
| **ELP** | 231 | 72.85 | 24.55 | 1400 | 21.08 | 12.20 | 115 | 83.66 | 20.45 | 558 | 20.22 | 13.05 | 2 | 90.70 | 17.25 | 2306 |
| **ELP/EAP** | 11 | 66.64 | 23.40 | 50 | 25.12 | 13.79 | 3 | 101.33 | 15.30 | 17 | 20.42 | 12.80 | 1 | 91.40 | | 82 |
| **EAP** | 3 | 61.37 | 16.57 | 15 | 18.28 | 12.00 | 7 | 49.31 | 16.61 | 10 | 23.20 | 9.60 | | | | 35 |
| **NELP** | 6 | 54.82 | 16.29 | 40 | 27.26 | 17.71 | 2 | 78.70 | 1.13 | 16 | 20.96 | 9.42 | 1 | 70.80 | | 65 |
| Tool Type totals | 384 | 70.88 | 27.07 | 2819 | 22.34 | 11.56 | 158 | 80.67 | 23.45 | 954 | 21.20 | 11.75 | 4 | 85.90 | 14.17 | 4319 |

| Paleogeographic Locale | Flaked Piece | | | Detached Piece | | | Manuport | | | Split Cobble | | | Pounded Piece | | | unit total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | count | max dim | s.d. | count | max dim | s.d. | count | max dim | s.d. | count | max dim | s.d. | count | max dim | s.d. | count |
| Loc 64 | 51 | 65.35 | 24.61 | 941 | 23.18 | 9.81 | 15 | 64.72 | 29.75 | 171 | 21.50 | 8.83 | | | | 1178 |
| Naisiusiu | 10 | 52.37 | 21.06 | 63 | 21.65 | 12.44 | 1 | 66.70 | | 44 | 18.31 | 7.56 | | | | 118 |
| West-Lake | 27 | 43.67 | 12.09 | 193 | 25.59 | 8.38 | 2 | 64.10 | 23.76 | 101 | 25.92 | 8.08 | | | | 323 |
| Kelogi | 45 | 91.14 | 33.78 | 117 | 23.36 | 14.38 | 13 | 88.61 | 27.35 | 37 | 25.18 | 12.92 | | | | 212 |
| MNK | 1 | 50.90 | | 21 | 16.33 | 6.35 | | | | 1 | 10.30 | | | | | 23 |
| FLK | 11 | 98.23 | 24.90 | 90 | 21.48 | 14.70 | 4 | 83.38 | 20.15 | 32 | 20.17 | 11.07 | | | | 137 |
| VEK | 15 | 76.25 | 33.62 | 138 | 17.78 | 8.74 | 5 | 86.08 | 30.16 | 129 | 17.13 | 8.17 | | | | 287 |
| HWKW | 20 | 71.26 | 22.51 | 240 | 18.20 | 8.05 | 9 | 83.04 | 14.14 | 86 | 19.41 | 11.21 | | | | 355 |
| HWKE | 44 | 59.88 | 22.46 | 407 | 20.33 | 11.50 | 13 | 77.67 | 21.32 | 171 | 18.88 | 9.91 | | | | 635 |
| HWKEE-KK | 7 | 75.11 | 50.60 | 172 | 18.04 | 8.92 | 3 | 57.90 | 36.14 | 61 | 16.67 | 6.33 | | | | 243 |
| MCK | 112 | 75.14 | 20.21 | 258 | 28.30 | 15.40 | 76 | 86.03 | 19.79 | 60 | 34.43 | 24.52 | 2 | 90.70 | 17.25 | 510 |
| TK-Loc 20 | 2 | 41.95 | 21.43 | 29 | 21.81 | 13.23 | | | | 8 | 26.09 | 8.56 | | | | 39 |
| LongK | 19 | 77.25 | 18.39 | 43 | 24.21 | 14.61 | 5 | 77.52 | 13.1 | 10 | 22.82 | 14.34 | | | | 77 |
| JK-WK | 7 | 68.80 | 27.06 | 37 | 27.90 | 14.39 | 2 | 99.45 | 21.14 | 12 | 23.12 | 14.31 | | | | 58 |
| DK-Complex | 4 | 62.85 | 18.18 | 15 | 17.21 | 7.97 | 1 | 105.10 | | 5 | 13.96 | 4.25 | 1 | 91.40 | | 24 |
| THC-Complex | 3 | 61.37 | 16.57 | 15 | 18.28 | 12.00 | 7 | 49.31 | 16.61 | 10 | 23.20 | 9.60 | | | | 35 |
| Fifth-Fault | 6 | 54.82 | 16.29 | 40 | 27.26 | 17.71 | 2 | 78.70 | 1.13 | 16 | 20.96 | 9.42 | 1 | 7.80 | | 65 |
| Tool Type totals | 384 | 70.88 | 27.07 | 2819 | 22.34 | 11.56 | 158 | 80.67 | 23.45 | 954 | 21.20 | 11.75 | 4 | 85.90 | 14.17 | 4319 |

Note: Maximum dimensions are represented in millimeters.

# APPENDIX 8. THE BASIC QUANTITATIVE GROSS MORPHOLOGICAL DATA:

Artifact weight, technological length, breadth, and width for each general artifact type and each specific flaked piece type by landscape association grouping.

| Landscape Association | General Tool Type | weight (gm) mean | weight (gm) s.d. | length (mm) mean | length (mm) s.d. | breadth (mm) mean | breadth (mm) s.d. | width (mm) mean | width (mm) s.d. | unit total Count |
|---|---|---|---|---|---|---|---|---|---|---|
| WLP | Flaked Piece | 140.54 | 210.44 | 56.90 | 23.09 | 45.67 | 19.49 | 32.67 | 15.15 | 88 |
|  | Detached Piece | 4.66 | 9.43 | 22.63 | 9.40 | 17.23 | 8.40 | 7.92 | 3.86 | 1197 |
|  | Manuport | 187.55 | 191.37 | 64.76 | 27.61 | 50.19 | 27.13 | 34.00 | 19.10 | 18 |
|  | Split Cobble | 6.12 | 9.73 | 22.40 | 8.90 | 16.45 | 6.59 | 11.15 | 4.89 | 316 |
| SWLP | Flaked Piece | 550.83 | 887.61 | 93.14 | 38.20 | 72.30 | 24.78 | 53.69 | 23.28 | 45 |
|  | Detached Piece | 12.47 | 51.71 | 22.87 | 13.56 | 16.82 | 11.72 | 9.18 | 7.04 | 117 |
|  | Manuport | 424.67 | 339.76 | 88.61 | 27.35 | 69.95 | 14.19 | 51.15 | 9.62 | 13 |
|  | Split Cobble | 12.42 | 28.76 | 25.18 | 12.92 | 18.48 | 10.97 | 12.61 | 7.11 | 37 |
| ELP | Flaked Piece | 286.43 | 261.92 | 72.83 | 24.58 | 59.98 | 20.59 | 45.74 | 18.63 | 231 |
|  | Detached Piece | 5.80 | 20.78 | 20.26 | 11.29 | 15.50 | 9.95 | 7.93 | 5.06 | 1400 |
|  | Manuport | 356.13 | 225.66 | 86.01 | 40.89 | 65.98 | 16.52 | 50.97 | 15.41 | 115 |
|  | Split Cobble | 10.37 | 41.56 | 20.34 | 13.39 | 15.15 | 10.29 | 10.68 | 6.92 | 558 |
|  | Pounded Piece | 727.10 | 571.77 | 90.70 | 17.25 | 81.10 | 25.17 | 70.40 | 28.00 | 2 |
| ELP/EAP | Flaked Piece | 184.25 | 165.75 | 66.55 | 23.57 | 56.49 | 24.92 | 37.15 | 18.43 | 11 |
|  | Detached Piece | 7.78 | 10.17 | 24.21 | 12.82 | 19.15 | 11.14 | 9.93 | 5.61 | 50 |
|  | Manuport | 777.03 | 497.14 | 101.33 | 15.30 | 80.30 | 13.00 | 68.77 | 19.40 | 3 |
|  | Split Cobble | 6.79 | 11.63 | 20.43 | 12.79 | 14.82 | 9.89 | 11.32 | 6.71 | 17 |
|  | Pounded Piece | 574.00 |  | 91.40 |  | 88.20 |  | 75.30 |  | 1 |
| EAP | Flaked Piece | 125.73 | 84.50 | 61.37 | 16.57 | 51.57 | 8.11 | 35.93 | 1.50 | 3 |
|  | Detached Piece | 3.97 | 7.62 | 17.59 | 12.00 | 14.59 | 12.40 | 6.69 | 3.81 | 15 |
|  | Manuport | 105.33 | 125.90 | 49.31 | 16.61 | 43.07 | 16.21 | 31.53 | 13.63 | 7 |
|  | Split Cobble | 7.68 | 8.23 | 23.19 | 9.59 | 16.92 | 6.95 | 13.12 | 5.36 | 10 |
| NELP | Flaked Piece | 97.88 | 110.95 | 54.82 | 16.29 | 40.13 | 15.37 | 27.18 | 16.62 | 6 |
|  | Detached Piece | 12.44 | 46.45 | 25.84 | 13.56 | 20.52 | 14.61 | 8.83 | 6.37 | 40 |
|  | Manuport | 277.55 | 68.52 | 78.70 | 1.13 | 72.45 | 8.13 | 46.90 | 9.76 | 2 |
|  | Split Cobble | 6.66 | 8.77 | 20.96 | 9.42 | 16.04 | 6.77 | 11.80 | 4.48 | 16 |
|  | Pounded Piece | 280.30 |  | 70.80 |  | 59.90 |  | 52.10 |  | 1 |
| Total Average |  | 43.21 |  | 28.15 |  | 21.74 |  | 13.33 |  | 4319 |

| Landscape Association | Specific Flaked Piece Type<br>unifacial <50% count | % | bifacial <50% count | % | unfacial >50% count | % | bifacial >50% count | % | multidirectional count | % | split cobble count | % | unit total count |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WLP | 25 | 33.33 | 5 | 6.67 | 9 | 12.00 | 22 | 29.33 | 14 | 18.67 |  |  | 75 |
| SWLP | 10 | 23.81 | 8 | 19.05 | 5 | 11.90 | 14 | 33.33 | 4 | 9.52 | 1 | 2.38 | 42 |
| ELP | 44 | 21.36 | 33 | 16.02 | 7 | 3.40 | 78 | 37.86 | 39 | 18.93 | 5 | 2.43 | 206 |
| ELP/EAP | 5 | 45.45 |  |  | 1 | 9.09 | 4 | 36.36 | 1 | 9.09 |  |  | 11 |
| EAP | 1 | 20.00 |  |  |  |  | 2 | 40.00 |  |  | 2 | 40.00 | 5 |
| NELP | 1 | 25.00 |  |  |  |  | 3 | 75.00 |  |  |  |  | 4 |
| Grand Total | 86 | 25.07 | 46 | 13.41 | 22 | 6.41 | 123 | 35.86 | 58 | 16.91 | 8 | 2.33 | 343 |

Note: Morphological data are represented in kilograms and millimeters.

# APPENDIX 9. LANDSCAPE ASSOCIATION SCALE DISTRIBUTION OF THE DETACHED PIECE CHARACTERISTICS.

Striking platform breadth, cutting edge angle, exterior platform angle, and the ‘Toth type’ (Toth, 1982), or type of platform preparation relative to the percentage of cortical surface.

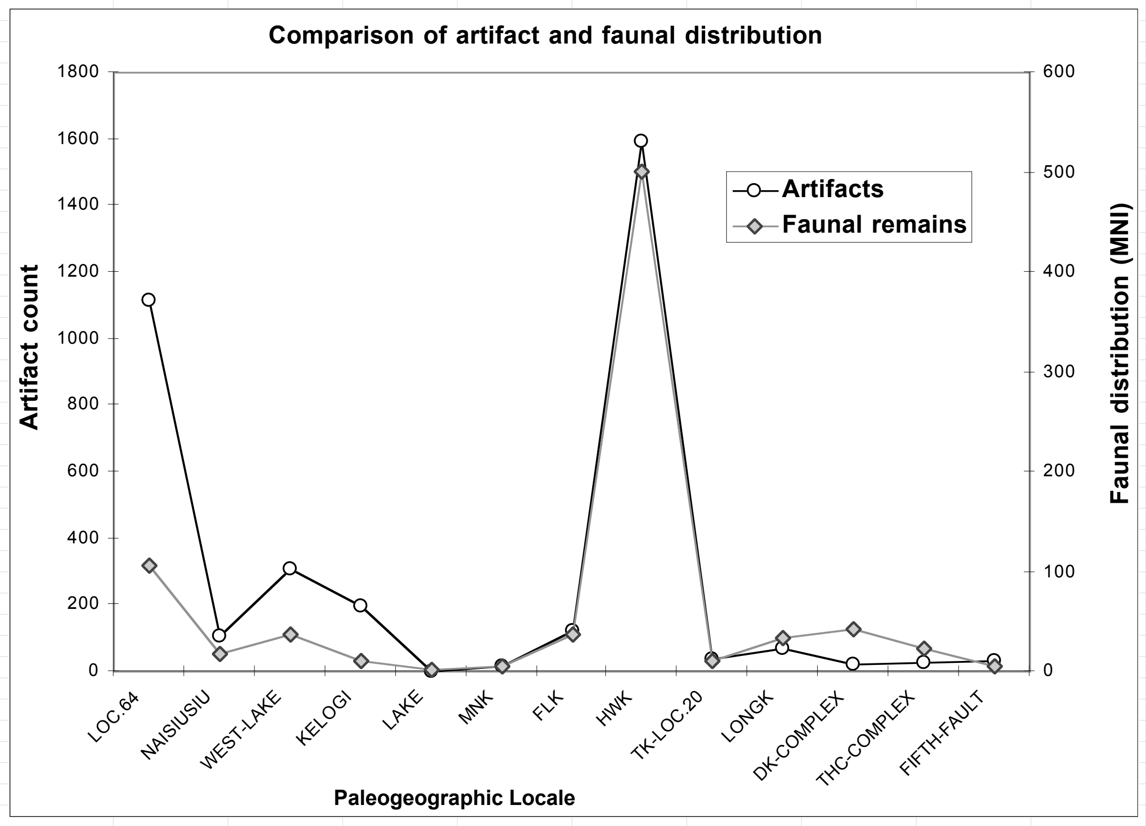
| | **Detached Piece Characteristics** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Landscape Association** | **striking platform breadth (mm)** | | **striking platform width (mm)** | | **cutting edge angle** | | **exterior platform angle** | | **technological length (mm)** | |
| | **mean** | **s.d.** | **mean** | **s.d.** | **mean** | **s.d.** | **mean** | **s.d.** | **mean** | **s.d.** |
| WLP | 17.98 | 8.31 | 8.18 | 3.83 | 49° | 11.51 | 74° | 9.15 | 22.63 | 9.40 |
| SWLP | 22.86 | 19.79 | 11.82 | 12.18 | 60° | 11.91 | 78° | 7.31 | 22.87 | 13.56 |
| ELP | 18.87 | 12.06 | 9.15 | 5.94 | 53° | 13.16 | 74° | 12.02 | 20.26 | 11.29 |
| ELP/EAP | 16.66 | 7.25 | 10.05 | 5.23 | 53° | 5.52 | 78° | 10.06 | 24.21 | 12.82 |
| EAP | 17.45 | 1.06 | 9.45 | 1.06 | 57° | 12.02 | 70° | 23.33 | 17.59 | 12.00 |
| NELP | 25.92 | 16.75 | 10.43 | 4.60 | 60° | 13.05 | 70° | 17.24 | 25.84 | 13.56 |

| | **Toth Type** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Landscape** | **I** | | **II** | | **III** | | **IV** | | **V** | | **VI** | | unit total |
| **Association** | **count** | **%** | **count** | **%** | **count** | **%** | **count** | **%** | **count** | **%** | **count** | **%** | **count** |
| WLP | 14 | 6.19 | 32 | 14.16 | 14 | 6.19 | 5 | 2.21 | 43 | 19.03 | 118 | 52.21 | 226 |
| SWLP | | | 1 | 12.50 | 1 | 12.50 | | | 2 | 25.00 | 4 | 50.00 | 8 |
| ELP | 20 | 7.41 | 30 | 11.11 | 24 | 8.89 | 25 | 9.26 | 28 | 10.37 | 143 | 52.96 | 270 |
| ELP/EAP | | | 1 | 10.00 | | | | | 2 | 20.00 | 7 | 70.00 | 10 |
| EAP | 1 | 50.00 | 1 | 50.00 | | | | | | | | | 2 |
| NELP | 1 | 11.11 | 3 | 33.33 | | | | | 1 | 11.11 | 4 | 44.44 | 9 |
| totals | 36 | 6.86 | 68 | 12.95 | 39 | 7.43 | 30 | 5.71 | 76 | 14.48 | 276 | 52.57 | 525 |

# APPENDIX 10. LANDSCAPE ASSOCIATION SCALE DISTRIBUTION OF WEATHERING STAGES.

| | | **Weathering Stage** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Landscape Association** | **General Artifact Type** | None | | Slight | | Extreme | | |
| | | count | % | count | % | count | % | unit total |
| WLP | Flaked Piece | 55 | 62.50 | 24 | 27.27 | 9 | 10.23 | 88 |
| | Detached Piece | 837 | 69.98 | 265 | 22.16 | 94 | 7.86 | 1196 |
| | Manuport | 12 | 66.67 | 1 | 5.56 | 5 | 27.78 | 18 |
| | Split Cobble | 144 | 45.57 | 105 | 33.23 | 67 | 21.20 | 316 |
| SWLP | Flaked Piece | 7 | 15.56 | 16 | 35.56 | 22 | 48.89 | 45 |
| | Detached Piece | 54 | 46.15 | 49 | 41.88 | 14 | 11.97 | 117 |
| | Manuport | 6 | 46.15 | 1 | 7.69 | 6 | 46.15 | 13 |
| | Split Cobble | 6 | 16.22 | 24 | 64.86 | 7 | 18.92 | 37 |
| ELP | Flaked Piece | 189 | 81.82 | 36 | 15.58 | 6 | 2.60 | 231 |
| | Detached Piece | 1091 | 78.49 | 278 | 20.00 | 21 | 1.51 | 1390 |
| | Manuport | 102 | 88.70 | 6 | 5.22 | 7 | 6.09 | 115 |
| | Split Cobble | 314 | 56.27 | 220 | 39.43 | 24 | 4.30 | 558 |
| | Pounded Piece | 2 | 100 | | | | | 2 |
| ELP/EAP | Flaked Piece | 9 | 81.82 | 2 | 18.18 | | | 11 |
| | Detached Piece | 41 | 82.00 | 7 | 14.00 | 2 | 4.00 | 50 |
| | Manuport | 3 | 100 | | | | | 3 |
| | Split Cobble | 9 | 52.94 | 6 | 35.29 | 2 | 11.76 | 17 |
| | Pounded Piece | | | 1 | 100 | | | 1 |
| EAP | Flaked Piece | 2 | 66.67 | | | 1 | 33.33 | 3 |
| | Detached Piece | 7 | 46.67 | 7 | 46.67 | 1 | 6.67 | 15 |
| | Manuport | 7 | 100 | | | | | 7 |
| | Split Cobble | 7 | 70.00 | 2 | 20.00 | 1 | 10.00 | 10 |
| NELP | Flaked Piece | 4 | 66.67 | | | 2 | 33.33 | 6 |
| | Detached Piece | 30 | 75.00 | 3 | 7.50 | 7 | 17.50 | 40 |
| | Manuport | 2 | 100 | | | | | 2 |
| | Split Cobble | 11 | 68.75 | 4 | 25.00 | 1 | 6.25 | 16 |
| | Pounded Piece | | | 1 | 100 | | | 1 |
| Material Totals | | 2951 | 1684.58 | 1058 | 685.08 | 299 | 330.34 | 4308 |

# APPENDIX 11. A COMPARISON OF ARTIFACT AND FAUNAL DISTRIBUTIONS ACROSS THE OLDUVAI PALEOLANDSCAPE



(faunal data from Cushing 2002).

# REFERENCES CITED

Aiello, Leslie C, and Peter Wheeler

1995 The expensive-tissue hypothesis: the brain and digestive system in human and primate evolution. *Cur. Anth.* 36(2):199-221.

Andrefsky, William Jr.

2001 Lithic Debitage. Context, form, meaning. Salt Lake City: University of Utah Press.

Andrews, Peter, and Lawrence Martin

1991 Hominoid dietary evolution. *Philosophical Transactions of the Royal Society of London (B).* 334:199-209.

Ashmore, Wendy, and Robert J Sharer

2000 Discovering Our Past: Mayfield Publishing Company.

Bamforth, Douglas B.

1986 Technological Efficiency and Tool Curation. *American Antiquity* 51(1):38-50.

Barbetti, Mike

1986 Traces of fire in the archaeological record, before one million years ago? *Journal of Human Evolution*. Pp. 771-781, ill, Vol. 15, no. 8: London.

Bartholomew, G., and J. Birdsell

1953 Ecology and the protohominids. *Am. Anthropologist* 55:481-498.

Barton, C.M

1988 Lithic variability and Middle Paleolithic behavior: new evidence from the Iberian Peninsula. Oxford.

Behrensmeyer, Anna K.

1983 Human evolution and the environments of the Plio-Pleistocene. *In* Interim evidence. Pp. 1-3, ill, Vol. 5, no. 1: New York.

Bellomo, Randy V.

1994 Methods of determining early hominid behavioral activities associated with the controlled use of fire at FxJj 20 Main, Koobi Fora, Kenya. *Journal of Human Evolution,* Vol. 27, no. 1-3. Pp. 173-195: London.

Bernick, Kathryn

1983 A Site Catchment Analysis of the Little Qualicum River Site. *In* A wet site on the east coast of Vancouver Island, B.C. Ottawa: National Museums of Canada.

Binford, Lewis R

1967 Smudge pits and hide smoking: the use of analogy in archaeological reasoning. *American Antiquity*. 32:1-12.

—

1973 Interassemblage Variability- The Mousterian and the "functional" argument. *In* The Explanation of Culture Change. C. Renfrew, ed. Pp. 227-254. London: Duckworth Press.

—

1977 Forty-seven Trips - A Case Study in the Character of Some Formation Processes of the Archaeological Record. *In* Contributions to Anthropology: The Interior Peoples of Northern Alaska. E.S. Hall, ed. Pp. 299-351. Ottawa: National Museum of Canada.

—

1978 Nunamuit Ethnoarchaeology. New York: Academic Press.

—

1979 Organization and formation processes: looking at curated technologies. *Journal of Anthropological Research* 35(3):255-273.

—

1983 In Pursuit of the Past. London: Thames and Hudson.

—

1992 Seeing the Present and Interpreting the Past-and keeping things straight. *In* Space, Time, and Archaeological Landscapes. J. Rossignol and L. Wandsnider, eds. Pp. 43-59. New York: Plenum Press.

Binford, Lewis R.

1980 Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formations. *American Antiquity* 45(1):1-20.

—

1981 Bones: ancient men and modern myths. New York: Academic Press.

—

1984 Faunal remains from Klasies River Mouth. New York: Academic Press.

—

1985 Human ancestors: changing views of their behavior. *Journal of Anthropological Archaeology* 4:292-327.

—

1989 Technology of Early Man: An organizational Approach to the Oldowan. Debating Archaeology. New York, Academic Press: 437-463.

Bleed, P

1995 Content as Variability, Result as Selection: Toward a Behavioral Definition of Technology. *Archaeological Papers of the American Anthropological Association* Rediscovering Darwin: Evolutionary Theory and Archaeological Explanation (no. 7):95-104.

Blumenschine, R.J., and Curtis W. Marean

1993 A Carnivore's View of Archaeological Bone Assemblages. *In* From Bones to Behavior: Ethnoarchaeological and Experimental Contributions to the Interpretations of Faunal Remains. J. Hudson, ed. Pp. 273-300. CAI Occasional paper No. 21. Carbondale: University of Southern Illinois Press.

Blumenschine, R.J*., et al.*

2003 Late Pliocene Homo and hominid land use from western Olduvai Gorge, Tanzania. *Science* 299:1217-1221.

Blumenschine, Robert J

1988 An experimental model of the timing of hominid and carnivore influence on archaeological bone assemblages. *Journal of Archaeological Science* 15:483-502.

—

1989 A landscape taphonomic model of the scale of prehistoric scavenging opportunities. *Journal of Human Evolution* 18:345-371.

—

1991a Breakfast at Olorgesailie: the natural history approach to Early Stone Age archaeology. *Journal of Human Evolution* 21:307-327.

—

1991b Hominid carnivory, foraging strategies, and the socio-economic function of early archaeological sites. *Philosophical Transactions of the Royal Society of London B.* 334:211-221.

Blumenschine, Robert J*, et al.*

1994 Competition for Carcasses and early hominid behavioral ecology: A case study and conceptual framework. *Journal of Human Evolution* 27:197-213.

Blumenschine, Robert J, and T.C. Madrigal

1993 Variability in long bone marrow yields of East African ungulates and its zooarchaeological implication. *Journal of Archaeological Science* 20:555-587.

Blumenschine, Robert J, and F T Masao

1995 Landscape Ecology and Hominid Land Use in the Lowermost Bed II Olduvai Basin: Research Proposal to the National Science Foundation.

Blumenschine, Robert J, and F.T. Masao

1991 Living sites at Olduvai Gorge, Tanzania. Preliminary landscape archaeology results in the basal Bed II lake margin zone. *Journal of Human Evolution* 21:451-462.

—

1997 Preliminary results of the 1996 field season of the Olduvai Landscape Paleoanthropology Project: Tanzania Antiquities Division. Report to the Tanzania Commission for Science and Technology, Ngorongoro Conservation Area Authority, Tanzania National Museums, L.S.B. Leakey Foundation, National Science Foundation.

Blumenschine, Robert J, and Charles R Peters

1998 Archaeological predictions for hominid land-use in the paleo-Olduvai Basin, Tanzania, during lowermost Bed II times. *Journal of Human Evolution* 34:565-607.

Blumenschine, Robert J.

1986a Carcass consumption sequences and the archaeological distinction of scavenging and hunting. *Journal of Human Evolution*. Pp. 639-659, Vol. 15, no. 8, 1986: London.

—

1986b Early Hominid Scavenging Opportunities: Implications of Carcass Availability in the Serengeti and Ngorongoro Ecosystems. Oxford: BAR International Series 283.

Bordes, F., and D. de Sonneville-Bordes

1970 The significance of variability in Paleolithic assemblages. *World Archaeology* 2(1):61-73.

Bordes, Francois

1961 Mousterian Cultures in France. *Science* 134(3482):803-810.

Bradbury, Andrew P, and Phillip J Carr

1999 Examining Stage and Continuum Models of Flake Debris Analysis: An Experimental Approach. *Journal of Archaeological Science* 26:105-116.

Bradbury, Andrew P., and Philip J. Carr

1995 Flake typologies and alternative approaches: an experimental assessment. *Lithic Technology* 20:100-115.

Bradley, Bruce A

1975 Lithic Reduction Sequences: A Glossary and Discussion. *In* Lithic Technology; Making and Using Stone Tools. E. Swanson, ed. Pp. 5-13. World Anthropology. The Hague: Mouton.

Bunn, H. T.

1981 Archaeological evidence for meat-eating by Plio-Pleistocene hominids from Koobi Fora and Olduvai Gorge. *Nature* 291:574-577.

Bunn, H.T.

1982 Meat-eating and human evolution: studies on the diet and subsistence patterns of Plio-Pleistocene hominids in East Africa. Ph.D., University of California.

Bunn, Henry T.*, et al.*

1980 FxJj50: an Early Pleistocene site in northern Kenya. *World archaeology* 12(2):109-136.

Butzer, K.W.

1982 Archaeology as Human Ecology: Method and Theory for Contextual Approach. Cambridge: Cambridge University Press.

Butzer, Karl

1971 Environment & Archaeology. An Ecological Approach to Prehistory. New York: Aldine/ Atherton.

Byrne, Louise

2004 Lithic tools from Arago cave, Tautavel (Pyreness-Orientales, France): behavioral continuity or raw material determinism during the Middle Pleistocene? *Journal Archeological Science* 31:351-365.

Camilli, E. L., and J. I. Ebert.

1992 Artifact Reuse and Recycling in Continuous Surface Distributions and Implications for Interpreting Land Use Patterns. *In* Space, Time, and Archaeological Landscapes. J. Rossignol and L. Wandsnider, eds. Pp. 113-136, Vol. Chapter 6. New York: Plenum Press.

Chavaillon, J.

1976 Evidence for the technical practices of early Pleistocene Hominids, Shungura Formation, Lower Omo Valley, Ethiopia. In Earliest Man and Environments in the Lake Rudolf Basin. Y. Coppens, F.C. Howell, G.L. Isaac, and R.E.F. Leakey, eds. Pp. 565-573. Chicago: University of Chicago Press.

Clark, Desmond J

1982 The Transition from Lower to Middle Paleolithic in the African Continent. *In* The transition from Lower to Middle Paleolithic and the origins of modern man. A. Ronen, ed. Pp. 235-255, Vol. 151. Cambridge: BAR International Series.

—

1985 Microlithic industries of Africa: their antiquity and possible economic implications. *In* Recent advances in Indo-Pacific prehistory. V. N. Misra and Peter Bellwood, eds. Pp. 95-103, ill: New Delhi : Oxford & IBH Publishing, 1985.

Clark, Desmond J*, et al.*

1966 Precision and definition in African Archaeology. *South African Archaeological Bulletin* 21(83):114-121.

Collins, Michael B

1975 Lithic Technology as a means of Processual Inference. *In* Lithic Technology: Making and Using Stone Tools. Pp. 15-34. The Hague: Mouton.

Copeland, Sandi Rae

2004 Paleoanthropological implications of vegetation and wild plant resources in modern savanna landscapes, with applications to Plio-Pleistocene Olduvai Gorge, Tanzania. Doctoral Thesis, Rutgers University.

Cotterell, Brian, and Johan Kamminga

1986 Finials on stone flakes. *Journal of Archaeological Science.* Pp. 451-461, ill, Vol. 13, no. 5: London.

—

1990 Mechanics of pre-industrial technology. Cambridge: Cambridge University Press.

Crabtree, Don E

1975 Comments on Lithic Technology and Experimental Archaeology. *In* Lithic Technology; Making and Using Stone Tools. E. Swanson, ed. Pp. 105-114. World Anthropology. The Hague: Mouton.

Cushing, Amy E

2002 The Landscape Zooarchaeology and Paleontology of Plio-Pleistocene Olduvai, Tanzania and Their Implications For Early Hominid Ecology. Doctoral Dissertation, Rutgers University.

DeVore, Irven, and S. L. Washburn

1963 Baboon ecology and human evolution. *In* African Ecology and Human Evolution. F.C. Howell and F. Bouliere, eds. Pp. 335-367. Chicago: Aldine.

Dibble, Harold L.

1985 Technological aspects of flake variation. A comparison of experimental and prehistoric flake production. *American archeology* 5(3):236-240.

—

1997 Platform variability and flake morphology: comparison of experimental and archaeological data and implications for interpreting prehistoric lithic technological strategies. *Lithic Technology* 22(2):150-170.

Dunnell, Robert C.

1992 The Notion Site. *In* Space, Time, and Archaeological Landscapes. J. Rossignol and L. Wandsnider, eds. Pp. 21-42. New York: Plenum Press.

Dunnell, Robert C, and William S Dancey

1983 The Siteless Survey: A Regional Scale Data Collection Strategy. *In* Advances in Archaeological Method and Theory. M.B. Schiffer, ed. Pp. 267-287, Vol. vol. 6. New York: Academic Press.

Ebert, James I.

1992 Distributional Archaeology: Albuquerque.

Evans, John G.

1978 An Introduction to Environmental Archaeology. Ithaca: Cornell University Press.

Feibel, Craig S.

1988 Paleoenvironments from the Koobi Fora Formation, Turkana Basin, northern Kenya. Ph. D. Dissertation, University of Utah.

Feibel, Craig S*., et al.*

1991 Palaeoenvironmental context for the late Neogene of the Turkana Basin. *In* Koobi For Research Project. The fossil ungulates: geology, fossil artiodactyls, and palaeoenvironments. J.M. Harris, ed. Pp. 321-370, Vol. 3. Oxford: Clarendon Press.

Fleischer, Robert*, et al.*

1965 Fission track dating of Bed I, Olduvai Gorge. *In* Cur. Anth. Pp. 389-390. illus: Chicago, 1965.

Flenniken, J. Jeffrey, and Anan W. Raymond

1986 Morphological projectile point typology: replication experimentation and technological analysis. *American Antiquity.* Pp. 603-614, ill, Vol. 51, no. 3, 1986: Washington, D.C.

Foley, R.

1981 Off-site archaeology: an alternative approach for the short-sited. *In* Patterns of the Past. I. Hodder, G. Isaac, and N. Hammond, eds. Pp. 157-183. Cambridge: Cambridge University Press.

Frison, G.C.

1968 A Functional Analysis of Certain Chipped Stone Tools. *American Antiquity* 33(2):149-155.

Gamble, Clive, and James Steele

1999 Hominid Ranging Patterns and Dietary Strategies. *In* Hominid Evolution; Lifestyles and Survival Strategies. H. Ulrich, ed. Pp. 396-409: Edition Archaea.

Gerresheim, K.

1974 The Serengeti Landscape Classification (with accompanying 1:250,000 scale map). Vol. 165. Nairobi: Africa Wildlife Leadership Foundation.

Gifford, Diane P.

1981 Taphonomy and paleoecology: a critical review of archaeology's sister disciplines. *Advances in Archaeological Method and Theory* 4:365-438.

Gifford-Gonzalez, Diane P.

1991 Bones Are Not Enough: Analogues, Knowledge, and Interpretive Strategies in Zooarchaeology. *Journal of Anthropological Archaeology* 10:215-254.

Gowlett, J.A. J*., et al.*

1981 Early archaeological sites, hominid remains and traces of fire from Chesowanja, Kenya. *Nature* 294(5837):125-129.

—

1982 Early hominids and fire at Chesowanja, Kenya [Reply]. *Nature* 296:870.

Grayson, Donald K.

1989 Bone transport, bone destruction, and reverse utility curves. *Journal of Archaeological Science* 16:643-652.

Grine, Fred E*., et al.*

1996 Phenetic affinities among early *Homo* crania from east and South Africa. *submitted to Journal of Human Evolution* 30:189-225.

Groves, Colin

1975 An approach to the taxonomy of the Hominidae: Gracile villafranchian hominids of Africa. *Casopis Pro Mineralogii a Geologii* 3:225-246.

Hardy, Bruce L, and Gary T Garufi

1998 Identification of Woodworking on Stone Tools through Residue and Use-Wear Analyses: Experimental Results. *Journal of Archaeological Science* 25:177-184.

Harris, John William Kendal

1978 The Karari Industry, its place in East African Prehistory. Anthropology. Berkeley, University of California, Berkeley**:** 608.

Harris, John William Kendal, and Salvatore D Capaldo

1993 The earliest stone tools: Their implications for an understanding of the activities and behaviour of late Pliocene hominids. *In* The Use of Tools by Human and Non-human Primates. A. Berthelet and J. Chavaillon, eds. Pp. 196-220. Oxford: Clarendon Press.

Harris, John William Kendal, and Ingrid Herbich

1978 Aspects of early Pleistocene hominid behaviour east of Lake Turkana, Kenya. *In* Geological background to fossil man. Pp. 529-547. Edinburgh: Scottish Academic Press.

Harris, John William Kendal, and Glynn Ll. Isaac

1976 The Karari Industry: Early Pleistocene Archaeological Evidence from the terrain, east of Lake Turkana. *Nature* 262:102-107.

Hay, Richard L

1963 Stratigraphy of Bed I through IV, Olduvai Gorge, Tanganyika. *Science* 139:829-833.

—

1976 Geology of the Olduvai Gorge. A study of sedimentation in a semi-arid basin. Berkeley: University of California Press.

—

1990 Olduvai Gorge. A case history in the interpretation of hominid paleoenvironments in East Africa. *In* Establishment of a Geologic Framework for Paleoanthropology. L.F. LaPorte, ed. Pp. 23-37. Boulder: Geological Society of America.

—

1996 Stratigraphy and lake-margin Paleoenvironments of Lowermost Bed II in Olduvai Gorge. *Kaupia: Darmstadter Beitrage zur Naturgeschichte* 6(15, October):223-230.

Henry, Donald O.

1989 Correlations between Reduction Strategies and Settlement Patterns. Alternative Approaches to Lithic Analysis, 1989. Vol. 1, pp. 139-155. American Anthropological Association.

Holloway, Ralph L.

1980 The O.H.7 (Olduvai Gorge, Tanzania) hominid partial brain endocast revisited. *American Journal of Physical Anthropology.* Pp. 267-274, ill, Vol. 53, no. 2, 1980.

Hurtado, Magdalena A, and Kim Hill

1989 Experimental Studies of Tool Efficiency Among Machiguenga Women and Implications for Root-digging Foragers. *Journal of Anthropological Research* 45:207-217.

Hutchinson, G. E.

1957 Concluding remarks. *Quant. Biol.* 22:415-427.

Isaac, Glynn Ll

1968 Traces of Pleistocene Hunters: an East African example. *In* Man the Hunter. R.B. Lee and I. DeVore, eds. Pp. 253-261. Chicago: Aldine.

—

1971 The diet of early man: aspects of archaeological evidence from Lower and Middle Pleistocene sites in Africa. *World Archaeology* 2:278-299.

—

1976 The activities of early African hominids: a review of archaeological evidence from the time span two and a half to one million years ago. In Human Origins: Louis Leakey and the East African Evidence. G.L. Isaac and E. McCown, eds. Pp. 483-514. Menlo Park, California: W. A. Benjamin.

—

1978a The archaeological evidence for the activities of early African hominids. *In* Early hominids of Africa. Pp. 219-254, ill., diagrs., tables: New York : St Martin's Press, c1978.

—

1978b Food sharing and human evolution: archaeological evidence from the Plio-Pleistocene of East Africa. Journal of Anthropological Research 34:311-325.

—

1980 Casting the net wide: a review of archaeological evidence for early hominid land-use and ecological relations. *In* Current Argument On Early Man (Conference), Karlskoga, 1978. Current argument on early man. Pp. 226-251, ill: Oxford, Eng. : Pergamon Press, 1980.

—

1981 Stone Age Visiting Cards; approaches to the study of early land use patterns. *In* Patterns of the Past: Studies in honour of David Clarke. I. Hodder, G.L. Isaac, and N.D.C. Hammond, eds. Pp. 131-155. Cambridge: Cambridge University Press.

—

1982 Early hominids and fire at Chesowanja, Kenya. *Nature* 296:870.

—

1983a Bones in contention: competing explanations for the juxtaposition of early Pleistocene artifacts and faunal remains. *In* Animals and Archaeology: 1. Hunters and Their Prey. J. Clutton-Brock and C. Grigson, eds. Pp. 3-19. British Archaeological Reports International Series, Vol. 163.

—

1983b Early stages in the evolution of human behavior: the adaptive significance of stone tools. *Zesdekroon-voordraft gehouden voor die Stichting Nederlands Museum voor anthropologie en praehistorie* (22 April):5-43.

—

1984 The Archaeology of Human Origins: Studies of the Lower Pleistocene in East Africa 1971-1981. *In* Advances in World Archaeology. F. Wendorf and A.E. Close, eds. Pp. 1-87. New York: Academic Press.

—

1986 Foundation stones: early artefacts as indicators of activities and abilities. *In* Stone Age Prehistory. G.N. Bailey and P. Callow, eds. Pp. 221-241. Cambridge: Cambridge University Press.

—

1989 Aspects of Human Evolution. *In* The Archaeology of Human Origins: Papers by Glynn Isaac. G.L. Isaac, ed. Pp. 96-119. Cambridge: Cambridge University Press.

Isaac, Glynn, Ll, and John W. K. Harris

1975 The scatters between the patches. *In* Kroeber Anthropological Society: Univ. California, Berkeley.

—

1980 A method for determining the characteristics of artefacts between sites in the upper member of the Koobi Fora formation, east Lake Turkana. *In* Proceedings of the 8th Panafrican Congress of Prehistory and Quaternary Studies. Pp. 19-22, ill, Vol. 8: Nairobi.

Isaac, Glynn Ll., *et al.*

1981 Small is Informative: The application of the study of mini-sites and least effort criteria in the interpretation of the early Pleistocene archaeological record at Koobi Fora, Kenya. X Congresso, Union Internacional de Ciencas Prehistoricas Y Protohistoricas, Mexico City, 1981, pp. 258-268.

Jarman, M.R.

1972 A Territorial Model for Archaeology: a behavioral and geographical approach. *In* Models in Archaeology. D.L. Clarke, ed. Pp. 705-733. London: Methuen.

Jelinek, A.J.

1976 Form, Function, and Style in Lithic Technology. *In* Cultural Change and Continuity: Essays in Honor of James B. Griffin. C.E. Cleland, ed. Pp. 19-33. New York: Academic Press.

Jochim, Michael A

1976 Hunter-Gatherer Subsistence and Settlement: A Predictive Model.

—

1983 Optimization Models in Context. *In* Archaeological Theories and Hammers. J.A. Moore and A.S. Keene, eds. Pp. 157-172. New York: Academic Press.

Johanson, Donald C., *et al.*

1987 New partial skeleton of Homo habilis from Olduvai Gorge, Tanzania. *Nature* 327:205-209.

Jones, George T, *et al.*

1989 Measures of diversity and expedient lithic technologies. *In* Quantifying Diversity in Archaeology. R.D. Leonard and G.T. Jones, eds. New Directions in Archaeology. Cambridge: Cambridge University Press.

Jones, K.T., and D. Metcalfe

1988 Bare bones archaeology: bone marrow indices and efficiency. *Journal of Archaeological Science* 15:415-423.

Jones, Peter R

1979 Effects of raw material on biface manufacture. *Science* 204:835-836.

—

1981 Experimental implement manufacture and use: A case study from Olduvai Gorge. *Philosophical Transactions of the Royal Society, London (B)* 292:189-195.

—

1994 Results of Experimental Work in Relation to the Stone Industries of Olduvai Gorge. *In* Olduvai Gorge Vol. 5. M.D. Leakey, ed. Pp. 254-298, Vol. 5. Cambridge: Cambridge University Press.

Kappelman, John

1984 Plio-Pleistocene environments of Bed I and Lower Bed II, Olduvai Gorge, Tanzania. *Palaeogeography, Palaeoclimatology, Palaeoecology* 48:171-196.

Kappelman, John, *et al.*

1997 Bovids as indicators of Plio-Pleistocene paleoenvironments in East Africa. *Journal of Human Evolution* 32(2-3):229-256.

Keeley, Lawrence E

1980 Experimental determination of stone tool uses. Chicago: University of Chicago Press.

Kibunjia, Mzalendo

2000. Doctoral dissertation, Rutgers University.

Kimura, Yuki

2002 Examining time trends in the Oldowan technology at Beds I and II, Olduvai Gorge. *Journal of Human Evolution* 43: 291-321.

Kuhn, S.

1993 Mousterian Technology as Adaptive Response: A Case study. *Archaeological Papers of the American Anthropological Association* 4(Hunting and Animal Exploitation in the Later Paleolithic and Mesolithic of Eurasia):25-31.

LaPorte, Leo F.

1968 Ancient Environments. 2 vols. Volume 1. Englewood Cliffs: Prentice-Hall.

Leakey, Louis Seymour Bazett

1926 A new classification of the bow and arrow in Africa. *In* Royal anthropological institute of Great Britain and Ireland. Journal. Pp. 259-299, illus., pl. XXXI-XXXIII, 5 maps, Vol. LVI: London, 1926.

—

1954 Olduvai Gorge. *Scientific American* 190(1):66-71.

—

1957 Preliminary report on a Chellean I living site at B.K.II, Olduvai Gorge, Tanganyika Territory. *In* Pan-African Congress on Prehistory 3rd, Livingstone, 1955. Actes. Pp. 217-218: London, 1957.

—

1959a From the taung skull to "nutcracker man": Africa as the cradle of mankind and the primates--discoveries of the last thirty-five years. *In* Illustrated London news. Pp. [41], 44. illus: London, 1959.

—

1959b The newly-discovered skull from Olduvai: first photographs of the complete skull. *In* Illustrated London news. Pp. 288-289. illus: London, 1959.

—

1959c Zinjanthropus. *In* Philadelphia Anthropological Society, Bulletin. Pp. 20-24: Philadelphia, 1959.

—

1961a New Finds at Olduvai Gorge. *Nature* 189:649-650.

—

1961b New links in the chain of human evolution: three major new discoveries from the Olduvai Gorge, Tanganyika. *In* Illustrated London news. Pp. 335, 346-348, Vol. 238.

—

1963 Very early East African Hominidae and their ecological setting. *In* African ecology and human evolution. F.C. Howell and F. Bourliere, eds. Pp. 448-457. New York: Aldine.

—

1967 Olduvai Gorge 1951-61. A Preliminary Report on the Geology and Fauna. 5 vols. Volume 1. Cambridge: Cambridge University Press.

Leakey, Louis Seymour Bazett, and Kenneth Oakley

1959 'The first men': recent discovery in East Africa. *Antiquity* 23(132):285-287.

Leakey, Louis Seymour Bazett*, et al.*

1968 Age of bed V, Olduvai Gorge, Tanzania. *Science* 162(3853):559-560.

Leakey, Mary Douglas

1971 Excavations in Beds I and II, Olduvai Gorge 1960-1963. Volume 3. Cambridge: Cambridge University Press.

—

1975 Cultural Patterns in the Olduvai Sequence. *In* After the Australopithecines: Stratigraphy, Ecology, and Culture Change in the Middle Pleistocene. K.W. Butzer and G.L. Isaac, eds. The Hague: Mouton.

—

1976a The early stone industries of Olduvai Gorge. International Congress of Prehistoric and Protohistoric Sciences, 9th, Universite de Nice, 1976. Paris, 1976a. Vol. 5, pp. 24-41. Centre national de la recherche scientifique, 1976.

—

1976b A summary and discussion of the archaeological evidence from bed I and bed II, Olduvai Gorge, Tanzania. *In* Perspectives on human evolution. Pp. 431-459: graphs, Vol. 3, 1976: New York.

Lee, Richard B

1965 Subsistence ecology of the !Kung Bushmen. Ph.D., University of California.

Lee, Richard B, and Irven DeVore, eds.

1968 Man the Hunter. Chicago: Aldine.

Lemonick, M.D., and A. Dorfman

2002 Up From The Apes. *In* Time.

Leroi-Gourhan, Andre

1964 Le Geste et la Parole. Paris: M.I.T. Press.

Lieberman, Daniel E, and John J Shea

1994 Behavioral Differences between Archaic and Modern Humans in the Levantine Mousterian. *Am. Anthropologist* 96(2):300-332.

Ludwig, Brian V., and J. W. K. Harris

1998 Towards a technological reassessment of East African Plio-Pleistocene lithic assemblages. *In* Early Human Behavior in Global Context: The Rise and Diversity of the Lower Paleolithic Record. R. Korisettar and M.D. Petraglia, eds. Pp. 84-107. One World Archaeology, Vol. 28. London: Routledge.

Lyman, R. L.

1984 Bone density and differential survivorship of fossil classes. *Journal of Anthropological Archaeology* 3:259-299.

Madrigal, T. Cregg

2000 Preferential Processing of High Return Rate Marrow Bones by Oldowan Hominids: a Comment on Lupo. *Journal of Archaeological Science* 27:739-741.

Marean, C.W.

1992 Implications of Late Quaternary mammalian fauna from Lukenya Hill (south-central Kenya) for paleoenvironmental change and faunal extinctions. *Quaternary Research* 37:239-255.

Mauldin, Raymond P., and Daniel S. Amick

1989 Investigating patterning in debitage from experimental bifacial core reduction. *In* Experiments in Lithic Technology: Oxford: B.A.R.

Mellars, P

1989 Technological Changes Across the Middle-Upper Paleolithic Transition: Economic, Social, and Cognitive Perspectives. *In* The Human Revolution; behavioral and biological perspectives in the origins of modern humans. P. Mellars and C. Stringer, eds. Pp. 338-365. Princeton: Princeton University Press.

Napier, John Russell*, et al.*

1962 Olduvai Gorge and human origins. *Antiquity* 36(141):41-47.

Nelson, M.C.

1988 The Study of Technological Organization. *In* Archaeological Method and Theory. M. Schiffer, ed. Pp. 57-100. Tucson: University of Arizona Press.

Newcomer, Mark

1980 Experimental Flake Scatter Patterns: a new interpretive technique. *Journ. Field Arch.* 7(3):345-352.

Odell, George H.

1996 Economizing Behavior and the concept of "Curation". *In* Stone Tools: Theoretical Insights into Human Prehistory. G.H. Odell, ed. Pp. 51-80. Interdisciplinary Contributions to Archaeology, Vol. 22. New York, London: Plenum Press.

Ohel, M.Y.

1977 Patterned Concentrations on Living Floors at Olduvai, Beds I and II: Experimental Study. *Journ. Field Arch.* 4:423-433.

Ohnuma, Katsuhiko

1995 Analysis of debitage pieces from experimentally reduced "classical Levallois"and "discoidal"cores. *In* Definition and Interpretation of Levallois Technology. Pp. 257-266: Madison: Prehistory Press.

Oliver, J.S.

1994 Estimates of hominid and carnivore involvement in the FLK Zinjanthropus fossil assemblage: some socioecological implications. *Journal of Human Evolution* 27:267-294.

Oliver, J.S.*, et al.*

1994 new looks at old questions: Intro to early hominid behavioral ecology. *Journal of Human Evolution*:1-5.

Parkington, John

1972 Seasonal mobility in the Late Stone Age. *African Studies* 31:223-243.

Pearce, T.H.

1971 Short Distance Fluvial Rounding of Volcanic Detritus. *Journal of Sedimentary Petrology* 41(No. 4):1069-1072.

Pelcin, Andrew W.

1997 Formation of flakes: the role of platform thickness and exterior platform angle in the production of flake initiations and terminations. *Journal of Archaeological Science* 24(12):1107-1113.

Peters, C.R., and R.J. Blumenschine

1995 Landscape perspectives on possible land use patterns for early hominids in the Olduvai Basin. *Journal of Human Evolution* 29:321-362.

---

1996 Landscape perspectives on possible land use patterns for early hominids in the Olduvai Basin, Tanzania: Part II, Expanding the Landscape Models. *Kaupia* 6:175-221.

Potts, Richard

1984 Home base and early hominids. *American Scientist* 72:338-347.

—

1988 On an early hominid scavenging niche. *In* Cur. Anth. Pp. 153-155, Vol. 29, no. 1, 1988: Chicago.

—

1989 Olorgesailie: new excavations and findings in Early and Middle Pleistocene contexts, southern Kenya rift valley. *Journal of Human Evolution* 18:477-484.

—

1991 Why the Oldowan?: Plio-Pleistocene toolmaking and the transport of resources. *Journal of Anthropological Research* 47(2):153-176.

—

1994 Variables versus models of Early Pleistocene hominid land use. *Journal of Human Evolution* 27(1-3):7-24.

Prins, H.H.T.

1988 Plant phenology patterns in Lake Manyara National Park, Tanzania. *Journal of Biogeography* 15:465-480.

Prins, H. H. T., and Henk P. van der Jeugd

1993 Herbivore population crashes and woodland structure in East Africa. *Journal of Ecology* 81:305-314.

Roche, H.

2000 Variability of Pliocene Lithic Productions in East Africa. ACTA Anthropologica Sinica **19 (supplement)**: 98-103.

Rogers, Michael J

1996 Lithic analysis in landscape archaeology: evidence from East Turkana. *In* Aspects of African Archaeology. G. Pwiti and R. Soper, eds. Papers from the 10th congress of the Pan African Association for Prehistory and Related Studies. Harare: University of Zimbabwe Publications.

Rogers, Michael J*, et al.*

1994 Changing patterns of land use by Plio-Pleistocene hominids in the Lake Turkana basin. *Journal of Human Evolution* 27:139-158.

Sahnouni, Mohamed*, et al.*

1997 Experimental investigation into the nature of faceted limestone "spheroids" in the Early Palaeolithic. *Journal of Archaeological Science*, Vol. 24, no. 8, Pp. 701-713: London.

Schick, Kathy D

1987 Modeling the Formation of Early Stone Age Artifact Concentrations. *Journal of Human Evolution* 16:789-807.

Schick, Kathy D, and Nicholas Toth

1993 Making Silent Stones Speak: Human Evolution and the Dawn of Technology. New York: Simon and Schuster.

Schick, K. D., N. Toth, et al.

1999 Continuing Investigations into the Stone Tool-making and Tool-using Capabilities of a Bonobo (Pan paniscus). *Journal of Archaeological Science* 26: 821-832.

Schiffer, Michael B

1975 The Effects of Occupation Span on Site Content. *In* The Cache River Archaeological Project: An Experiment in Contract Archaeology. M.B. Schiffer and J.H. House, eds. Pp. 265-269. Research Series B. Fayetteville: Arkansas Archaeological Survey.

—

1976 Behavioral Archaeology. New York: Academic Press.

—

1983 Toward the identification of formation processes. *American Antiquity* 48:675-706.

Semaw, Sileshi*, et al.*

2003 2.6 Million-year-old stone tools and associated bones from OGS-6 and OGS-7, Gona, Afar, Ethiopia. *Journal of Human Evolution* 45:169-177.

Shea, John J

1998 Neandertal and Early Modern Human Behavioral Variability: a Regional-Scale Approach to Lithic Evidence for Hunting in the Levantine Mousterian. *Cur. Anth.* 39(supplement, June 1998):S45-S78.

—

1991 The Behavioral Significance of Levantine Mousterian Industrial Variability. Doctoral dissertation, Harvard University.

Shipman, Pat, and John M. Harris

1988 Habitat Preference and Paleoecology of *Australopithecus boisei* in East Africa. *In* Evolutionary History of the "Robust" Australopithecines. F.E. Grine, ed. Pp. 343-381. New York: Aldine de Gruyter.

Shott, Michael

2003 Chaine Operatoire and Reduction Sequence. *Lithic Technology* 28(2):95-105.

Shott, Michael J.

1989 On tool-class use lives and the formation of archaeological assemblages. *In* American Antiquity, Vol. v. 54, no. 1, 1989. Pp. 9-30: Washington, D.C.

—

1994 Size and form in the analysis of flake debris: review and recent approaches. *Journal of Archaeological Method and Theory* 1:69-110.

—

1996 Stage versus continuum in the debris assemblage from production of a fluted biface. *Lithic Technology* 21(1):6-22.

Speth, John

1979 Experimental Investigations of Hard-Hammer Percussion Flaking. *Tebrile* 17(1):7-36.

Speth, John D.

1989 Early hominid hunting and scavenging: the role of meat as an energy source. *Journal of Human Evolution* 18:329-343.

Stafford, C. Russell, and E. R. Hajic

1992 Landscape Scale. Geoenvironmental Approaches to Prehistoric Settlement Strategies. *In* Space, Time, and Archaeological Landscapes. J. Rossignol and L. Wandsnider, eds. Pp. 137-161. New York: Plenum Press.

Stephens, D. W., and J. R. Krebs

1986 Foraging Theory. Princeton: Princeton University Press.

Stern, Nicola

1994 The implications of time-averaging for reconstructing the land-use patterns of early tool-using hominids. *Journal of Human Evolution* 27:89-105.

—

1995 The 'blu' tuff locality at Koobi Fora in northern Kenya: archaeological time and the record of past human behavior. *The Artefact* 18:49-59.

Steward, Julian H.

1938 Basin-plateau aboriginal sociopolitical groups. *Bureau of American Ethnology Bulletin no. 120.*

—

1955 Theory of Culture Change; the methodology of multilinear evolution. Urbana: University of Illinois Press.

Tactikos, Joanne C.

*in press*. Experimental Archaeology and New Perspectives on Tool-Using Strategies of the Oldowan Hominids. XIVe Congres De L'Union Internationale Des Sciences Prehistoriques et Protohistoriques, Liege, Belgium, 2001.

—

2002 Typology, Technological Organization, and the Landscape Perspective. *Presentation to* The Society of Africanist Archaeologists Conference. Tucson, Arizona.

—

2003 A Re-evaluation of Paleolithic Stone Tool Cutting Edge Production Rates and their Implications. *In* Lithic Analysis at the Millennium. N. Maloney and M. Shott. London, Archetype. Pp. 151-162.

Thomas, David H.

1973 An empirical test for Steward's model of Great Basin settlement patterns. *American Antiquity* 38:155-176.

—

1975 Nonsite Sampling in Archaeology: Up the Creek Without a Site? *In* Sampling in Archaeology. J. Mueller, ed. Pp. 61-81. Tucson: University of Arizona Press.

Tinbergen, Niko

1963 On Aims and Methods of Ethology. *Zeitschrift fur Tierpsychologie* 20:410-433.

Torrence, R

1989a Retooling: towards a behavioral theory of stone tools. *In* Time, Energy, and Stone Tools. R. Torrence, ed. Pp. 57-66. Cambridge: Cambridge University Press.

Torrence, Robin

1983 Time Budgeting and hunter-gatherer technology. *In* Hunter-gatherer economy in prehistory: A European perspective. G.N. Bailey, ed. Pp. 11-22. New Directions in Archaeology. Cambridge: Cambridge University Press.

—

1989b Tools as optimal solutions. *In* Time, Energy and Stone Tools. R. Torrence, ed. Pp. 1-6. Cambridge: Cambridge University Press.

Toth, Nicholas

1982 The Stone Age Technology of Early Hominids at Koobi Fora, Kenya: an experimental approach. Doctoral dissertation, University of California.

—

1985 The Oldowan Reassessed: A Close Look at Early Stone Artifacts. *Journal of Archaeological Science* 12(2):101-120, ill.

—

1987 Behavioral Inferences from Early Stone Artifact Assemblages: an experimental model. *Journal of Human Evolution* 16:763-787.

—

1991 Importance of experimental replicative and functional studies in Palaeolithic archaeology. *In* Cultural Beginnings: Approaches to Understanding Early Hominid Life-ways in the African Savanna. J.D. Clark, ed. Pp. 109-124. Bonn: Rudolf Habelt Verlag.

Ugan, Andrew*, et al.*

2003 When is Technology Worth the Trouble? *Journal of Archaeological Science* 30:1315-1329.

Villa, Paola

1978 The stone artifact assemblages from Terra Amata. Doctoral, University of California, Berkeley.

Villa, Paola, and Marie Soresi

2000 Stone Tools in Carnivore Sites: The Case of Bois Roche. *Journal of Anthropological Research* 56.

Vita-Finzi, C., and E.S. Higgs

1970 Prehistoric Economy in the Mount Carmel Area of Palestine: site catchment analysis. *Proceedings of the Prehistoric Society* 36:1-37.

Walter, R.C.*, et al.*

1991 Laser-fusion $^{40}$Ar/$^{39}$Ar dating of Bed I, Olduvai Gorge, Tanzania. *Nature* 354:145-149.

Wandsnider, LuAnn

1992 Archaeological Landscape Studies. *In* Space, Time, and Archaeological Landscapes. J. Rossignol and L. Wandsnider, eds. Pp. 285-292. New York: Plenum Press.

Whittaker, John C

1994 Flintknapping: making and understanding stone tools. Austin: University of Texas Press.

Winterhalder, B.

1977 Foraging strategy adaptations of the boreal forest Cree: an evaluation of theory and models from evolutionary ecology. PhD dissertation, Cornell University.

—

1980 Environmental Analysis in Human Evolution and Adaptation Research. *Hum. Ecol.* 8:135-155.

Yellen, J.E.

1977 Cultural patterning in faunal remains: evidence from the !Kung Bushmen. *In* Experimental Archaeology. D.W. Ingersoll and J.E. Yellen, eds. Pp. 271-331. New York: Columbia University Press.

Zipf, George Kingsley

1965 Human Behavior and the Principle of Least Effort: an introduction to human ecology. Volume facsimile of 19 edition. New York: Hafner Publishing Co.

# Joanne C. Tactikos

*Supervisory Archaeologist/Lithic Analyst*

**Archaeological Consulting Services, Ltd.**
**424. W. Broadway Rd., Tempe, AZ 85282**
**(480) 894-5477**

## EDUCATION

| | |
|---|---|
| 2005 | PhD. Anthropology Graduate Program, Rutgers University, NJ. |
| 2003 | Certificate in Quaternary Studies, Graduate School, New Brunswick, Rutgers University, NJ. |
| 2002 | M.A. in Anthropology, Rutgers University, NJ. |
| 1994 | B.A. in Anthropology, *cum laude*, State University of New York at Stony Brook. |

## PROFESSIONAL EXPERIENCE

*ARCHAEOLOGICAL CONSULTING SERVICES, LTD., Tempe*

Field Director/Supervisory Archaeologist/Lithic Analyst

**2005 to present**

- Field director responsibilities included supervising the archaeological testing of the Hayden Flour Mill project (historic and prehistoric components), Tempe, Arizona.
- Analyst responsibilities included analyzing and reporting on chipped and ground stone artifacts from testing and data recovery projects in Arizona. Projects included the Crismon ruin project, SR88–us 60 to Wheatfields section, and San Xavier farm rehabilitation project for reclamation.
- Archaeological monitoring and excavation for valley metro light rail project, cities of Phoenix and Tempe; monitoring for the Yuma gateway park improvement project for ADOT and City of Yuma, and monitoring and burial removal for the San Xavier farm rehabilitation project construction phase.
- Survey for Arizona public service company, Don Luis extension between Bisbee and Don Luis.
- Archaeological excavation for wilderness school project, GEC-SAB.

*GRAY & PAPE, INC., Cinn. OH.*

Field Director

- (2005) Supervised Phase I testing and Phase II data recovery on the Millennium Pipeline Project, NY.

*RUTGERS UNIVERSITY, New Brunswick, NJ.*

Supervisory Archaeologist/Field Archaeologist

**Grand Canyon Foundation Internship, Grand Canyon National Park (2004)**

- Assisted with site relocation and reporting, and data recovery in the Grand Canyon National Park.

**Olduvai Landscape Paleoanthropology Project (1996-2000)**
- Supervised archaeological excavations at the Plio-Pleistocene site of Olduvai Gorge, Tanzania.
- Curated and analyzed Oldowan lithic archaeological assemblages at the Arusha Human Origins Laboratory, Tanzania.

**Rutgers University Center for Public Archaeology (1995)**
- Assisted in the Phase III data recovery at the Gabor Prehistoric Occupation, Delaware.
- Assisted in the Phase III data recovery at the Revolutionary War Occupation, West Point, NY.

*John Milner Associates, NJ.*

Field Archaeologist

- Assisted with Phase III data recovery of the Indian Queen Tavern (Rt 18/27) Data Recovery (2003).

*Los Alamos National Laboratory, Los Alamos, NM*

Field Archaeologist

- Assisted in Phase III data recovery of Ancestral Pueblo Occupation (2002).

*Hartgen Archaeological Assoc., NJ.*

Field Archaeologist

- Assisted in Raritan Landing Data Recovery Project (2001).

*Gannet Fleming. NJ*

Field Archaeologist

- Assisted in the Phase III data recovery at the Trenton Steelworks, Route 29 (1997-1999).
- Assisted in various Prehistoric and Historic Phase I-III projects (1997-1999).

*STATE UNIVERSITY OF NEW YORK at STONY BROOK*

Crew Chief/Field Technician

- Crew chief for data recovery at the Middle Stone Age site of Die Kelders Cave, South Africa (1995).

**Harvard University/SUNY Stony Brook (1994)**
- Assisted in data recovery at the Pleistocene site of ‘Ubeidiya, Israel.

**Institute for Long Island Archaeology, SUNY at Stony Brook (1992-19994).**
- Assisted in various Phase I-II Prehistoric projects.

**University of Arizona Field School (1992)**
- Assisted in Phase III data recovery at Pottery Hill, AZ.

## SELECTED ACADEMIC POSITIONS

- Instructor, Rutgers University, Study Abroad Program. Koobi Fora Field School, Kenya. (2005).
- Instructor, Rutgers University, Lithic Analysis: Advanced Undergraduate/Graduate Seminar (2004).
- Instructor, Rutgers University, Lithic Analysis: Advanced Undergraduate Seminar and Lab; Introduction to Archaeology (2001-2002).
- Co-lecturer, Lithic Analysis: Advanced Undergraduate Seminar and Lab (1997).

## CONFERENCE PRESENTATIONS

| | |
|---|---|
| 2006 | Effects of Proximity to Stone Material Source on the Landscape Distribution of Oldowan Stone Artifacts in the Plio-Pleistocene Olduvai Basin, Tanzania. R.J. Blumenschine, F.T. Masao, C.R. Peters, J.C. Tactikos, R.M. Albert, P. Andrews, M.K. Bamford, J.I. Ebert, R.I. Hay, J.K. Njau, I.G. Stanistreet, H. Stollhofen. Presented at the *Paleoanthropology Society* annual meeting. San Juan, Puerto Rico. |
| 2003 | Quantifying Oldowan Lithic Reduction Sequences: Theoretical and Methodological Considerations. Presented at the *Paleoanthropology Society* annual meeting. Tempe, Arizona. |
| 2002 | New Insights on Typology, Technological Organization, Landscape and Experimental Perspectives. *Presented at brown bag seminar.* Los Alamos National Laboratories, New Mexico. |
| 2002 | Landscape and experimental perspectives on the Technological Organization of the Early Oldowan Hominids at Olduvai Gorge, Tanzania. Presented at *the Society of Africanist Archaeologists* conference. Tucson, Arizona. |
| 2002 | Typology, Technological Organization, and the Landscape Perspective. Presented at *the Society of Africanist Archaeologists* conference. Tucson, Arizona. |
| 2001 | Experimental Archaeology and New Perspectives on Tool-Using Strategies of the Oldowan Hominids, presented at the *XIVe Congres De L'Union Internationale Des Sciences Prehistoriques et Protohistoriques*, Liege, Belgium. |
| 2001 | Experimental archaeology and experimental perspectives on Oldowan tool-use. Workshop presented at New York University. NY. |
| 1999 | Experimental Perspectives on Tool-Using Strategies of the Oldowan Hominids. Presented at *Changing Paradigms and Interdisciplinary Approaches to Anthropology*, at Rutgers University, New Brunswick, NJ. |
| 1998 | A Paleoecological Approach to Lithic Analysis. Presented at *Multidisciplinary Approaches to Anthropology* at Rutgers University, New Brunswick, NJ. |
| 1998 | A re-evaluation of Paleolithic Stone Tool Cutting Edge Production Rates and their Implications, presented at *Lithic and Groundstone Analysis in the 1990s* at the Institute of Archaeology, University College London. |

## Reports/Publications

| | |
|---|---|
| *In prep* | Experimental Perspectives on Tool-Using Strategies of the Oldowan Hominids. *Proceedings from the XIVe Congres De L'Union Internationale des Sciences Prehistoriques et Protohistoriques,* Liege, Belgium. |
| 2006 | Chapter 6: Material Culture. In *Results of Data Recovery at Crismon Ruin, AZ U:9:173(ASM), as Part of the CEMEX USA Lehi Expansion Project, Lehi, Maricopa County, Arizona*, edited by Lourdes Aguila, pp. 125–141. ACS Project Number 01-045-07A. Archaeological Consulting Services, Ltd., Tempe. |
| *In prep.* | Lithic Analysis and Interpretation Section of *Final Report of Intensive Testing for the San Xavier District Farm Rehabilitation Project, Tohono O'odham Nation, Pima County, Arizona. Archaeological Consulting Services, Tempe.* Robert J. Stokes (Editor), Linda M. Schilling, Kristin L. Fangmeier, Michael S. Droz, Andrea R. Gregory, and Teresa L. Pinter |

*In prep.* Lithic Analysis and Interpretation Section of *Settlement History along SR 188 from the Globe Highlands to Tonto National Monument,* edited by Teresa L Pinter, *pp. tbd.* Cultural Resources Report No. 140. Archaeological Consulting Services, Tempe.

2006 Contextualizing Oldowan lithic strategies: a biological perspective. J. Ferraro, D.R. Braun, and J.C. Tactikos. Manuscript for the Society of American Archaeology Electronic Symposium: *Core Reduction, Chaine Operatoire and Other Methods: the Epistemologies of Different Approaches to Lithic Analysis*. San Juan, Puerto Rico.

2005 Flake recovery rates and inferences of Oldowan hominin behavior: a response to Kimura, 1999 and Kimura, 2002. D.R. Braun, J.C. Tactikos, J.V. Ferraro, and J.W.K. Harris. *Journal of Human Evolution,* 48:525-531.

2003 Late Pliocene *Homo* and hominid land use from western Olduvai Gorge, Tanzania. Blumenschine, R.J, Peters, C.R, Masao, F.T, Clarke, R.J, Deino, A.L, Hay, R.L, Swisher, C.C, Stanistreet, I.G, Ashley, G.M, McHenry, L.J, Sikes, N.E, van der Merwe, N.J, Tactikos, J.C, Cushing, A.E, Deocampo, D.M, Njau, J.K, Ebert, J.I. ***Science***. 299:1217-1221.

2003 A Re-evaluation of Paleolithic Stone Tool Cutting Edge Production Rates and their Implications. Proceedings from *Lithics and Groundstone Analysis in the 1990s* conference, University College, London. In Lithic Analysis at the Millennium. Institute of Archaeology. *Archetype*, London. 151-162.

1999 A Paleoecological Approach to Lithic Analysis. *Crosscurrents* (11): 32-47.

### Selected Professional Affiliations

Paleoanthropology Society
Society of Africanist Archaeologists
Center for Human Evolutionary Studies, Dept of Anthropology. Rutgers University
Research Associate of the Dept of Anthropology. Rutgers, the State University of New Jersey.
Reviewer for the Journal of Human Evolution.