University of Alberta

Characterization of Middle and Later Stone Age Lithic Artifacts from two Rockshelter sites in Iringa Region, southern Tanzania

by

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Abstract

Stone tools have a critical role to play in our understanding of the behavior of early humans. In particular, the types of raw materials that are present in stone tool assemblages, and the sources from which they are acquired, provide information relating to decision making processes, planning, organization of technology, and group mobility. The characterization of Stone Age lithic artifact assemblages from two rockshelter sites in southern Tanzania, Magubike and Mlambalasi, allowed for the evaluation of inter- and intra-assemblage variability. Raw material characterization was conducted using macroscopic and microscopic analyses.

Numerous raw material sourcing studies have been undertaken on Stone Age lithic assemblages recovered from sites in Tanzania and the rest of East Africa. Generally these studies have concentrated on identifying the sources of a particular type of stone raw material such as chert, obsidian, and basalt; however, rarely are the attributes of the whole assemblage examined. Furthermore, few archaeologists describe stone materials in terms of their basic petrographic characteristics. Both of these weaknesses are the direct result of the lack of a standardized methodology for describing lithic raw materials, thus this dissertation outlines a strategy for raw material sourcing, with a focus on description and grounded in geoarchaeological theory. When combined with typological and technological analyses, the results of the raw material analyses suggests the exclusive use of locally acquired lithics.

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Chapter 1: Introduction

> Most of the marks that man has left on the face of the earth during his 2-million-year career as a litterbugging, meddlesome, and occasionally artistic animal have one aspect in common: they are things, they are not deeds, ideas or words. Thus for better or for worse archaeologists are involved along with natural scientists in the study of objects and materials.
>
> G.Ll. Isaac 1971:397

1.1 Introduction

Stone tools have a critical role to play in our understanding of the origins and evolution of modern humans. They are a crucial key for interpreting the behavior of those who conceived of, created, used, and discarded them. The intent of this dissertation is to establish raw material utilization strategies for the Stone Age assemblages from two rockshelter sites in southern Tanzania, Mlambalasi and Magubike. This was done using macroscopic and microscopic (petrographic) analyses. Through the analysis of the lithic assemblages, in terms of raw material availability and organization of technology, I will illustrate Stone Age technological behavior and group mobility which will assist in our understanding of the origins of modern behavior.

The theoretical framework for this research is constructed from the fossil and genetic evidence which places the origin of our own species *Homo sapiens,* soon after 200,000 years ago in East Africa. The earliest moderns dating to around 200 kya were recovered at Omo-Kibish, Ethiopia (McDougall et al., 2004). Beginning at this time and continuing until approximately 30,000 – 40,000 years ago, these anatomically modern hominids in sub-Saharan Africa were creating assemblages with distinctive kinds of flaked stone tools. The associated artifacts from this period (200 – 30 kya) in sub-Saharan Africa are referred to as Middle Stone Age (MSA) (Goodwin and van Riet Lowe 1929). These stone tools, including points and scrapers generally made by prepared core techniques or by retouching flakes, are virtually indistinguishable from those created by the Neandertals in Europe at the same time where they are referred to as Middle Palaeolithic. After 40,000 years ago, MSA technologies were replaced by the blade and bladelet industries of the Later Stone Age (LSA). It is only then that these modern humans dispersed out of Africa to Eurasia where they either replaced or interbred with local Middle Palaeolithic populations and became the ancestors of all human populations today. This suggests that modern anatomy developed well before modern or Upper Palaeolithic culture and technology, which is considered the earliest modern behavior by most archaeologists. Researchers such as Richard Klein (1999) suggest that it is only when these anatomically modern humans developed Upper Palaeolithic culture (i.e., art, figurines, composite tools, used bone, etc.) that they can be considered behaviorally modern.

1.2 Research Questions

The major theoretical questions I will examine in this dissertation are (1) what are the characteristics of modern behavior, and (2) whether or not the MSA tools, and the artifacts found in the associated assemblages at Mlambalasi and Magubike rockshelter, demonstrate these attributes. This dissertation will also address several questions pertaining to raw material use and organization of technology:

- *What technological (lithic tool production) strategies were utilized at each site as represented in the lithic artifacts recovered?*
- *How was technology organised?*
- *Can technological change be used to explain raw material variability?*
- *Which sources (local, non-local, exotic) were utilized? How were raw materials acquired?*

- *Who were the agents of raw material acquisition, transportation, and utilization? Is their inferred behavior "modern"?*

Note that herein the term lithic is used to describe "materials and artifacts made from rocks or minerals" (Rapp 2002:63).

Raw material analysis will include macroscopic and microscopic analyses. The intent of these analyses is to determine accurately the raw material type, and ultimately, the source for the artifact. Additionally, this will serve to illustrate some of the limitations and strengths of the use of macroscopic and microscopic techniques in MSA/LSA raw material sourcing. This will be one of the first comprehensive lithic raw material studies conducted on Tanzanian MSA and LSA assemblages. My main raw material research questions are:

- *How many types of raw material were utilized at each site?*
- *How were the raw material types utilized?*
- *Were the different raw material types utilized differently?*

1.3 Summary of Chapters

Chapter 2 contains a discussion of the environmental context of Tanzania in general, and of Iringa Region specifically. Changes in the landscape and climate over time are presented as having a significant impact on the evolution of hominids. A brief overview of archaeological and palaeoanthropological research that has been conducted in Tanzania is provided. I also detail the 2006, 2008, and 2010 archaeological fieldwork I conducted in Iringa Region.

It would be difficult to conduct Stone Age research in Africa without addressing one of the most significant topics of discussion in African archaeology – the origins of modern humans. For the last twenty years, palaeoanthropologists and Stone Age archaeologists have been trying to determine the time and place of the origin of our species. Although the question of anatomically modernity has been mostly resolved, we still have the more abstract and convoluted issue of behavioral modernity to contend with. Indeed one of the biggest questions facing our discipline is how did anatomically modern *Homo sapiens* become behaviorally modern? In order to examine this question, one must examine how we define "modern." Further emphasis is placed on MSA assemblages in Tanzania. A discussion of the MSA-Later Stone Age (LSA) transition, and analogies to the Middle to Upper Palaeolithic "revolution", will provide a means of exploring features that are suggested to be indicative of modern behavior. I provide some examples of models of behavioral modernity which demonstrate that modern behavior was present in the MSA. Chapter 3 demonstrates a clear picture of the MSA and LSA in East Africa must be established, as this has serious implications in terms of our understanding of the origins of modern humans and behavioral modernity.

Chapter 4 begins with an overview of the Middle and Later Stone Ages. Particular emphasis is made on defining and examining the key attributes of MSA and LSA lithic assemblages. The transition between the MSA and LSA is explored in the context of similarities to and divergences from the European Middle and Upper Palaeolithic model. With the content of the previous chapter concerning behavioral modernity in mind, I next scrutinize the technological indicators used in behavioral inference by: (1) exploring archaeological attempts to resolve typological and classification issues; (2) examining the role of fracture mechanics and debitage analysis in the interpretation and determination of these indicators; and (3) describing the lithic production strategies associated with these indicators. The final section of Chapter 4 focuses on presenting the core, debitage, and tool attributes which will be utilized in the technological analysis of the assemblages from Mlambalasi and Magubike. These topics will form the framework for the discussion on organization of technology presented in Chapter 5.

Although a number of theoretical approaches have been posited as a means of examining technological organization, Chapter 5 focuses on three: design theory, the material culture approach, and *chaîne opératoire*. Several hypotheses are presented that attempt to connect the attributes of artifacts with production technique and technological strategy so that a larger picture of group mobility and raw material acquisition can be inferred. Portions of this chapter are derived from my earlier work (Miles 2005).

Chapter 6 examines the theoretical and methodological framework used by archaeologists in lithic raw material provenance studies. A few East African studies are presented to demonstrate toolstone sourcing in practice. Provenance studies involve two stages: first, one must characterize the raw materials found in an assemblage and any potential raw material sources, and second, one must match the visual, microscopic, and chemical signatures of the rocks in the artifacta assemblages with those of the sources. The methodology employed here utilises two aspects of raw material characterization – petrology (lithography) and petrography. Although both involve the detailed study and description of rocks, petrology or lithography focuses on the macroscopic hand-sample or outcrop description while petrography is the speciality that examines microscopic properties via thin sections. The macroscopic and microscopic properties, or attributes, of stone in general, and of those specific to the Iringa Region, will be discussed. These properties relate, not just to methodology, but also to why particular tool stones were selected. The specific types of raw materials selected for use in all aspects of craft and tool production reflect the planning and decisions of individuals in the past.

Chapter 7 outlines the sampling methodology employed in the selection of artifacts for macroscopic and microscopic analyses. These analyses resulted in a system of lithic raw material classification, and detailed descriptions of each raw material type are provided, emphasizing indicators of possible source locations. The results of the raw material analyses are correlated with the technological analysis and the implication of these results follows in Chapter 8.

In Chapter 8, the results of both the technological and raw material analyses are discussed in order to present a picture of technological organization at Magubike and Mlambalasi. Intersite versus intrasite variations in raw material use and organization of technology will be discussed. A detailed interpretation of lithic toolstone use at each site will also be provided, which will be used to construct a regional perspective on raw material selection and use. These results will also be compared and contrasted with data from sites in northern Tanzania.

Chapter 9 provides a statement of the major findings of the study, the implications of these results, and the problems and/or limitations of this research. Ongoing and future research are also addressed.

Chapter 2: Archaeological Research in Tanzania

2.1 Environmental Context

This discussion of the environmental context includes a description of the landscape, climate, and palaeoclimate of Tanzania and Iringa Region. By understanding the environmental context, archaeologists are better equipped to interpret archaeological materials found and to infer the behaviors of past populations. Furthermore, changes in the East African environment over time have been proposed to have significant impact on the evolution of hominids.

Landscape

The Iringa Region is located in the south central portion of Tanzania within the Southern Highlands. Iringa town itself is located on a high-level plateau (approximately 4600 ft above sea level). Within this region, there are numerous villages, interspersed between large, granitic outcrops and cut through by rivers and ephemeral streams. The Little Ruaha River, a tributary of the Rufiji River traverses the region. Frequently sites are located within erosional gullies (*makorongo*) as is the case with the Isimila Acheulian site (Cole and Kleindienst 1974). The current vegetation of Iringa is characterized as miombo woodland – a moist savannah type dominated by tall, densely spaced tress, found in areas with an annual rainfall of 75 – 100 mm rainfall and a long dry season (Hamilton 1982:19). The Iringa Region has dry montane forest on and around the hills and mountains with patches of savannah on the plains. The cultivation of crops and cattle and goat herding are the primary economic activities for local peoples.

The most prominent feature of the landscape of Iringa is the numerous kopjes (koppies) or castle kopjes. A kopje is a “steep-sided pile of massive crystalline boulders” (Buckle 2007:141). They are formed by the collapse of bornhardts or inselbergs (Figure 2.1). Inselbergs, high steep-sided dome or table-shaped hills, are formed via pediplanation in arid and semi-arid areas or by deep weathering and stripping in forest and savannah regions. Cycles of subsurface weathering creates weathered rock debris which is stripped away. This weathering and stripping process leaves behind fresh unweathered rock called inselbergs (more specifically bornhardts). While deep weathering continues, surface erosion begins to attack joint systems and cracks within the unweathered rock. If the joint system and weathering are extensive enough, then the bornhardt may collapse into kopjes; therefore, kopjes are "thought to evolve both directly by deep weathering and indirectly by the collapse of bornhardts" (Buckle 2007:143). Kopjes are of high archaeological potential as they form natural rockshelters and are prominent, highly visible features of the landscape which would have appealed to people as shelters while providing a view of the surrounding landscape.

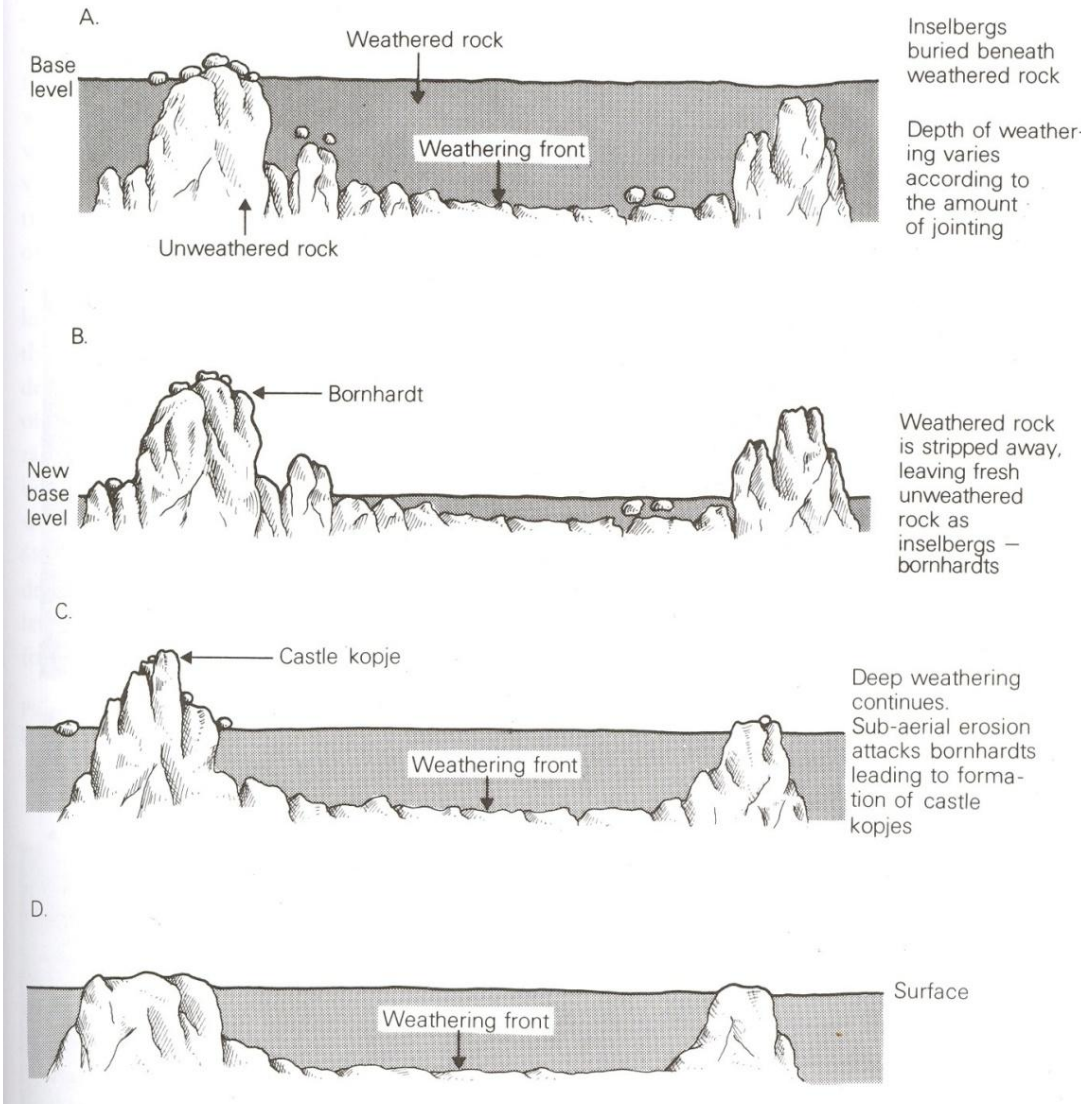


Figure 2.1: Kopje formation sequence (after Buckle 2007:143, Figure 7.4).

Climate & Climatic Change: Monsoonal cycles

The modern climate of East Africa is generally dry-subhumid or semiarid, typified by a "general decrease in the duration of the rainy seasons and in the total amount of rainfall from west to east and with distance from the equator" (Figure 2.2; Street-Perrott and Perrott 1993:328). In Figures 2.2 and 2.3, the star represents the approximate location of Iringa Region.

There are two rainy seasons centering on March-May and September-November (Figure 2.3). These are caused by the position and seasonal migration of the Intertropical Convergence Zone (ITCZ). The ITCZ, the zone of maximum rainfall, follows the latitudinal position of the overhead sun with a time lag of approximately 4 – 6 weeks (Trauth et al., 2001:499). Monsoon circulation is driven by the "ocean-land temperature and pressure gradient that develops between the subtropical oceans of the 'winter' hemisphere and land of 'summer' hemisphere" (Barker and Gasse 2003:825). The rainy seasons of the ITCZ coincide with periods of transition between the southeast Indian and northeast/South African monsoonal flows.

Changes in the monsoonal cycle and ITCZ will affect precipitation. Monsoonal cycle transformations have been inferred using a variety of sources of data. Williamson et al., (1993) use progressive changes in gram size and concentration of magnetic particles to suggest a progressive weakening of the monsoonal cycles during the Younger Dryas event.

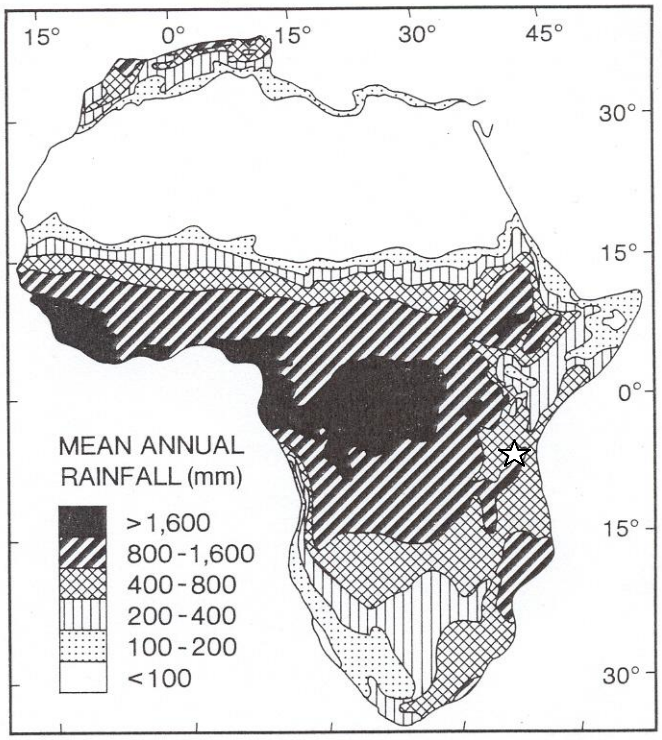


Figure 2.2: Rainfall map of Africa (adapted from Street-Perrott and Perrott 1993:318, fig.1).

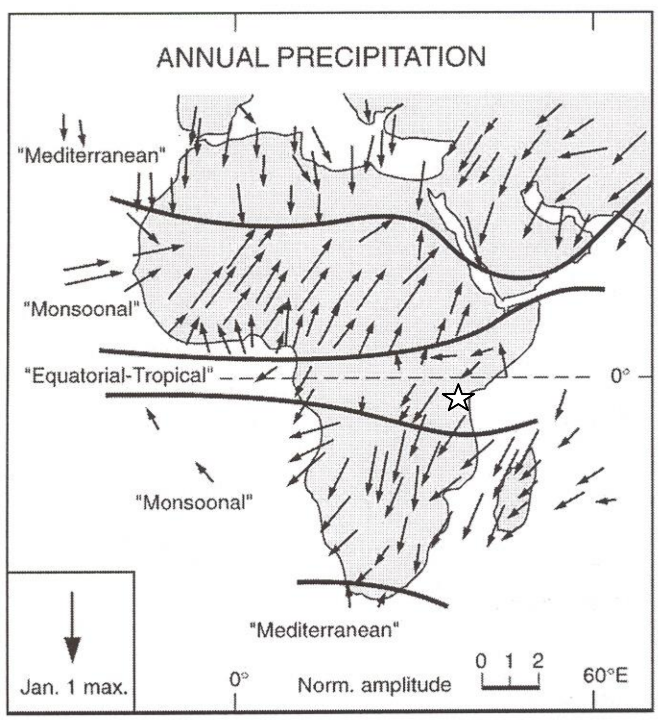


Figure 2.3: African precipitation regimes. The vector length indicates normalized amplitude; vector direction indicates month of maximum precipitation. Southward-pointing vectors indicate January 1 rainfall maximum; westward vectors indicate April 1 maxima (adapted from Gasse 2000:192, fig.2).

Climatic Change: Orbital Forcing & Milankovitch cycles

Although monsoonal cycles are responsible for regional climate change in East Africa, it is well established that Milankovitch cycles of the Earth's orbital variations have driven the major climatic changes over the course of the Pleistocene and Holocene. Briefly, there are three Milankovitch cycles: precession of the equinoxes, angle of ecliptic, and eccentricity of orbit. The equinox shifts throughout time so that the point closest to the sun, perihelion, changes. This precession of the equinoxes occurs on a 23 ky cycle. The angle of ecliptic – the tilt on the axis of rotation of the Earth – shifts from 68°21' (minimum tilt) to 65°24' (maximum tilt) in a 41 ky cycle. The Earth's orbit around the sun is variable; this is referred to as the eccentricity of orbit. On a scale of 100 ky, the shape of the orbit changes from almost a perfect circle to an ellipse. These three cycles all operate at the same time; although each cycle dominates at different times (the importance of each cycle varies). This means that there are different combinations of multiplying and negation effects. For example, the coincidence of the cycles can cause periods where the Earth is closest to the sun in the summer, furthest at its winter, and at maximum tilt resulting in exaggeration of the seasons. Milankovitch cycles therefore have a significant impact on Earth's climate and the nature of climate change, primarily because of their impact on insolation.

The orbital parameters of eccentricity, procession, and obliquity combine to produce changes in the seasonal cycle of solar radiation; i.e., insolation (Figure 6.8; Kutzbach and Webb 1993:6). Compared to the present, the "seasonality of solar radiation was considerably greater" from 12 to 6 kya, reaching a maximum around 9 kya when solar radiation was greatest in northern summer (Kutzbach and Webb 1993:6). The response of climate to insolation variations is based on the difference between the heat capacities (albedo) of land and water. Increase in solar radiation during the northern summer warms land surface, relative to ocean. This difference reinforces the monsoonal circulation as wind fields and P–E are altered (Figure 2.4; Kutzbach and Street-Perrott 1985; Kutzbach et al., 1993).

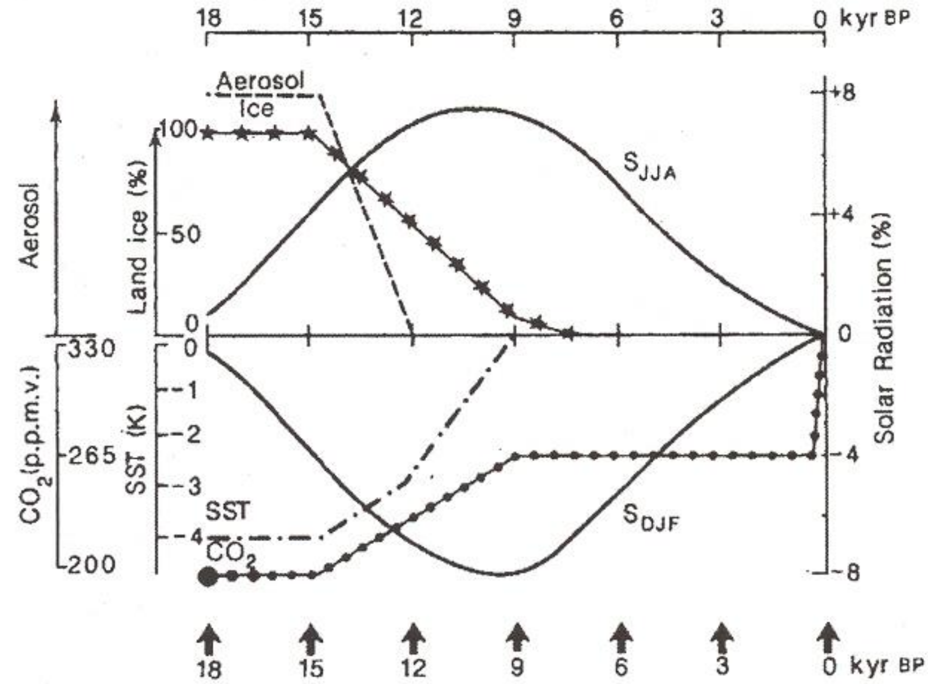


Figure 2.4: Schematic diagram of major changes since 18 ky BP in external forcing (Northern Hemisphere solar radiation in June-August [S_{JJA}] and December-February [S_{DJF}] as per cent difference from present) and internal boundary conditions (land ice, global mean annual SST, excess glacial aerosol, and atmospheric CO_2) (from Kutzbach and Street-Perrott 1985:130, fig.1).

Influence of Environmental Change on Hominid Evolution

As lake basins have long been looked to as an important source of archaeological and climatic data in East Africa I will use them to illustrate the complex, dynamic interrelation between hominids and their environment, and the implications environmental change may have had on hominid evolution. East African lake basins provided the basis for the stratigraphic sequence of "pluvials" and "interpluvials" proposed by the first Pan-African Congress on Prehistory (see Resolution 14, Leakey 1952). In the 1920s Louis Leakey established a succession of industries linked to a pluvial sequence primarily based on their correlation with ancient high lake-levels in the Gregory Rift (Phillipson 1982:428). The Nakuran – Makalian – Gamblian – Kamasian – Kageran pluvial scheme was seen as equivalent to the Sub-Alpine glacial chronology of Europe (Leakey 1952:6). The pluvials were thought to represent glacial periods. Although this climatostratigraphic approach was later dismissed when the lithostratigraphic criteria on which the sequence had been based was deemed unsatisfactory (Cooke 1958; Flint 1959), it shows early comprehension of a complex relationship between climate, lakes, and archaeology.

This association of archaeology with lacustrine environments is not surprising. Humans require a source of fresh water, as do all of the animals from which we subsist. Bishop (1966:247) correlates the "prevalence of artifacts and hominid fossils in deposits of former lakes" in dense concentrations along lake-edge environments with the simple "need of a water supply for hunter and hunted." Important to archaeologists is the simple fact that lake sediments must be of a "particular character" (Bishop 1966:247) in order for preservation and fossilization to occur. It is this suitability of environment for preservation of archaeological remains that lake-level change becomes important again. Even small changes in lake-level expose large areas of lake flat. These lake flats are used as occupational surfaces, such as at the Early Stone Age site of Olorgesailie, Kenya. Any "bone or stone" left on that surface would be "stratified and entombed" by the continual process of lake-level rise and fall (Bishop 1966:248).

Thus, understanding East African lake-level changes, as driven by climatic change, could be significant in terms of the suitability of the lakes for both occupation by hominids and preservation of their physical and cultural remains.

There is a great deal of archaeological data associated with East African lakes, both within and without the Rift Valley, which is often referred to as the cradle of humanity. The majority of Miocene hominoid sites are around/on East African Rift Valley sites. During the Quaternary, large quantities of hominid fossil sites are also associated with the Rift Valley. Although Acheulian sites are widely dispersed throughout East Africa, their occurrences tend to show the exploitation of only a narrow range of ecological contexts or opportunities – namely former alluvial or lakeshore locations coinciding with periods of wetter climate (Butzer and Cooke 1982:54). However, one must also consider that the association of sites with this narrow range of contexts such as the rift valley may not reflect patterns of hominid use, but may be the indirect result of the process of rifting itself which has exposed sites and fossils making them more visible and easier to find.

The first Middle Stone Age (MSA) artifacts found in East Africa were recovered from the Naivasha-Nakuru basin in the Kenya Rift Valley by Louis Leakey in the 1930s (Clark 1982). This MSA technology is interstratified with layers of volcanic ash – a promising situation for chronostratigraphy as $^{39}Ar/^{40}Ar$ dating is appropriate for both the substrate and the time period in question. Another MSA occupation locality has also been excavated at Enderit Drift in the Nakuru-Elementeita basin. Considered to be temporary camps used for hunting and butchery, these sites occur in a "channel fill cut, when the lake-level was low, into older sediments of a high level Upper Pleistocene lake" (Clark 1982:282). Interestingly these occurrences often contain heavy concentrations of obsidian artifacts, the source of which is over 100 km away.

Obsidian outcrops near Lake Zwai, in the Galla Lakes area of the Ethiopian Rift, are associated with Mode 3 technology (Middle Stone Age/Middle Palaeolithic) (Clark 1982; Phillipson 2005). These assemblages have been potassium/argon dated to 180 – 150 kya. From Lake Ayasi/Eyasi, Sangoan-like lithics, a regional MSA industry, have been recovered with a fragmentary cranium akin to the Broken Hill, Kabwe *Homo heidelbergensis* (Clark 1982; Phillipson 2005).

Lake Turkana has produced a significant amount of archaeological data. With the exception of one at Lake Edward, all Holocene sites relating to the beginnings of permanent settlement are from Lake Turkana (Phillipson 2005). Phillipson (2005:157) suggests this may be linked with Turkana's fluctuating high levels. As discussed above, around 10 kya, water levels rapidly rose to ca. 80 m above its modern surface giving the lake nearly twice its present area (Phillipson 2005:157). Bone harpoons from 10 – 8 kya have been recovered from its shores indicating that fishing technology developed before ceramic technology in this region. Perhaps more significant is the number of fossil sites that Turkana has generated. The Lake Victoria basin "preserves a long record of cultural activity and the several stages that can be recognised there help to emphasise the length of time during which the 'Middle Stone Age' tradition was being practiced" (Clark 1982:286). The Ugandan waters of Lake Victoria have yielded microlithic industry dated to ca. 20 kya.

Phillipson (1982:427) suggests that the great variability in "geology, resulting in a diversity of the materials available for stone implement manufacture, and climate of eastern Africa have been at least partially responsible for the wide range of distinctive Later Stone Age industries." One of the earliest microlithic Later Stone Age (LSA) industries comes from Munyama Cave on Buvuma Island, Lake Victoria (Phillipson 1982:429).

To contextualise, the information that can be derived from lake-level records has significant implications in terms of understanding hominid evolution. The development of bipedal locomotion, a critical attribute used to define a fossil as a hominid, has been suggested as an adaptation to changing climate and environmental conditions. The anatomical differences between *Australopithecus* and *Homo erectus* have been interpreted in relation to climate and thermoregulation (Rightmire 1995). Even the nose has been explained as adaptation to climate. The thin and plate-like nose with low nasal bridge in *Homo sp.* is suggested to be adapted to life in an arid environment, while the wide, flat nose of Neandertals is supposed to represent cold adaptation.

Trauth et al., (2005) were able to reconstruct three periods of humid climate during the Cenozoic in East Africa from Rift Valley Lakes in Ethiopia, Kenya, and Tanzania. They postulate that these events at 2.7 – 2.5 mya, 1.9 – 1.7 mya, and 1.1 to 0.9 mya could have had significant impact on speciation events and the dispersal of hominids (Trauth et al., 2005:2051). Indeed a number of key events in hominid evolution, such as the origin of the genus *Homo* and the appearance of *Homo erectus,* occurred in East Africa at these times. Bar-Yosef (1995:507) suggests that humans did not survive in arid zones during glacial conditions in northern latitudes, therefore, movements out of Africa would have occurred at times that were more humid (Isotope stage 5d and early stage 3). He further argues that the appearance of *Homo erectus* during this time represents an adaptation to the environment during or immediately after the Olduvai subchron (1.95 – ca. 1.84 mya) which resulted in major ecological changes. *Homo erectus* is posited to have the "necessary social and technical skills and biological capacities to colonize" the new regions opened up by palaeoclimatic and palaeoecological changes at this time (Bar-Yosef 1995:517). Furthermore, evidence supports the regional evolution of *Homo erectus* under the constraints of local climate conditions following their dispersal out of Africa (Stringer 1995).

Partridge et al., (1995) examine the regional mechanisms that may influence global climate changes in the context of potential relationships between regional and global climatic change and the pattern of mammalian evolution during the African Neogene. Importantly, they avoid the tautological reasoning that archaeologists often fall into by clearly recognising that faunal evidence cannot be used "both as evidence of the effect of changes in palaeoclimate and to demonstrate that palaeoclimatic change had taken place" (Partridge et al., 1995:331). Wesselman (1995) examines the relationship between palaeoecology and human evolution in the Turkana basin, an important region for archaeology and palaeoanthropology as noted above. He concludes that the late Pliocene climate shift "created conditions of lowered primary production and lessened climatic stability, which, combined with increased seasonality and spatial heterogeneity…must have subjected to diversifying hominid types to considerable stress" (1995:366). This is evidenced in the morphological divergences of the genus *Homo* from their australopithecine counterparts. Bar-Yosef (1995:571) proposes that both the Middle to Upper Palaeolithic transition and the Neolithic revolution may have been the result of "dramatic changes" within human populations triggered by climatic and environmental change in a certain region.

It is difficult to find archaeological evidence anywhere in Africa between 40 kya and 18 kya. This is a crucial time period for the origins of behaviorally modern humans. In places like North Africa, it has been suggested that humans entirely abandoned the region owing to the effects of full glacial conditions. Only the Neanderthals show anatomical adaptations suitable for cold environments (Stringer 1995). During the Last Glacial Maximum (LGM), desert and semi-desert conditions expanded across tropical Africa, and the tropical rainforest was greatly reduced. This resulted in a net decrease in plant cover, and increases in albedo and in infrared radiation (Street and Grove 1976:387). The pollen record indicates the presence of high altitude flora at low altitudes – likely the result of expanding ice gaps/glaciers.

Parts of East Africa have been suggested as regions that may have remained hospitable during full glacial conditions; Iringa Region is possibly one of these (Fitch et al., 2009; Fitch and Marchant 2011). The palaeoclimatic data inferred from lake-level records, as discussed above, illustrate that significant changes were occurring in this region. Lake-levels dropped, decreasing the amount of fresh water available to humans and animals in the region. Lake Victoria dried out at the close of the last glacial (Stager et al., 2002) but lakes in Iringa Region did not. As previously noted, humans and animals alike have heavy requirements for fresh water; thus, lakes serve as important sites for subsistence and occupation. This drastic loss of water from the region could have forced the movement of people out of the region. People could have moved towards the coast, which would have moved seaward with glaciation. As sea level increased with deglaciation, these coastal sites would have been abandoned then lost to archaeologists under sea water. This model is often proposed as an explanation for the seeming disappearance of humans from South Africa; a model I would argue is fair to apply to East Africa as well.

However, if East African lakes still maintained more water relative to other lakes in adjacent regions, there could have been significant movement of people and animals into the region trying to find fresh water sources off which they could live. Barker et al., (2002) state that although Lake Rukwa experienced low levels during the LGM, likely driven by a low precipitation to evaporation (P–E) ratio, there was sufficient water to avoid desiccation. Although speculative, these points do demonstrate the importance of lake-level reconstructions and the palaeoclimatic and palaeoecological conditions derived from it.

2.2 Archaeological Research in Tanzania

Tanzania has a rich culture, and contains a wealth of archaeological and heritage resources. Since the 1940s, Tanzania has been an important center for archaeology and palaeoanthropology in East Africa. Its sites contain the entire cultural sequence from the Early Stone Age through the Pastoral Neolithic. Fossil hominid finds, which have changed our understanding of human evolution and our relationship to living apes, have been found in the eastern or Gregory branch of the famous East African Rift Valley which runs along the northern and western part of the country.   Some of the terminology used in this chapter, i.e., Middle Stone Age (MSA) and Later Stone Age (LSA), will be explained in additional detail in the next chapter (Chapter 2).

MSA and LSA Sites in Tanzania

Tanzania is the ideal region to examine the research questions posited herein as Klein (1992:12) suggests that the conditions best suited to finding the earliest behaviorally modern humans are "best met in equatorial east Africa." Most of the Stone Age research conducted in Tanzania has been conducted in the north, while the rest of the country has "hardly been studied at all" (Willoughby 2007:259). Sites in the north have been found at Olduvai Gorge, Laetoli, and in the Lake Eyasi basin, such as Nasera and Mumba. MSA artifacts, mostly "olivine basalt flakes with faceted platforms and radial or convergent dorsal scar patterns…associated with discoidal and Levallois cores, as well as a few retouched tools" (Willoughby 2007:260), are found in the Ndutu Beds of Olduvai (Clark 1988; Merrick 1975). LSA assemblages are contained in the overlying Naisiusiu Beds. These include backed blades and geometric microliths in obsidian and chert (Brooks and Robertshaw 1990). MSA lava and quartz artifacts have been collected from the Ngaloba beds at Laetoli in association with the LH-18 skull, which has been assigned to *Homo heidelbergensis* (Clark 1988:275).

The Skull Site, Mumba Höhle, and Nasera Rockshelter, three sites located together at Lake Eyasi, contain a long cultural sequence – from Sangoan to protohistoric times – which has become the standard for the Middle and Later Stone Age cultural record in Tanzania (Brooks and Robertshaw 1990; Clark 1988; Mabulla 1996; Mehlman 1979, 1989, 1991). In order of age, from oldest to most recent, it is composed of the Njarasan, Sanzako, Kisele, Mumba, Naseran, Lemuta, and Silale Industries. The oldest, assigned to the Njarasan Industry, is only found at the Skull site. It is estimated to have been produced 200 kya, and includes core axes, radial cores, and large, non-facetted flakes made on volcanic rocks and quartz (Mabulla 1996; Mehlman 1989). The Sanzako Industry is present in Bed VI-B at Mumba. It contains side and notched scrapers, concave scrapers, bifacially modified pieces, and small bifaces and choppers. Ninety-five percent of the artifacts are made of quartz (Mabulla 1996:162). The Kisele Industry is present in Bed VI-A at Mumba (ca. 90 kya), and Nasera (ca. 56 kya).

It contains disc and part peripheral cores, few radial and Levallois cores, few bifacial and unifacial points, and convex end-scrapers mainly produced from quartz (Mabulla 1996; Mehlman 1989). The Mumba Industry, present in Bed V, contains large backed flakes (“knives”), blades, trapezes, short bifacial and unifacial points, and bipolar cores (Willoughby 2007:262). The Naseran Industry, estimated to be between 23,000 and 27,000 years old, includes small concave and convex end scrapers of quartz (97%). Points increase over time, and the few backed pieces present are small (Mehlman 1989:318). The Lemuta Industry is dated between 14,800 and 21,600 years old, and is found in levels 4 and 5 at Nasera; it is absent at Mumba (Mehlman 1989). Radial and Levallois cores, and retouched points are missing. Most tools are medium sized (20 to 30 mm long) backed tools, end scrapers, and small convex scrapers. The Silale Industry represents the Holocene Later Stone Age.

New excavations have been undertaken at Mumba rockshelter by Diez-Martín et al. (2009). There they unearthed an “unbiased” lithic sample from Bed V that permitted a reinterpretation of the Mumba Industry. It has been argued that the earlier excavations of Mumba by the Kohl-Larsons were biased as analysis of their back dirt piles demonstrated that debitage and smaller lithic artifacts were discarded. A combined technological and typological analysis of this sample suggests that all of Bed V should be classified as LSA as continuity is the main technological characteristic of the series (Diez-Martín et al., 2009:147). Continued work is needed at this very important site as past research has been proven to be problematic especially regarding the assemblages collected during early excavations and subsequent studies of them.

Other sites include Loiyangalani (HcJd-1) and Kisese II. Loiyangalani is an open-air MSA site located in Serengeti National Park, which contains scrapers, borers, a few bifaces or points, and disc and Levallois cores produced from quartzite, quartz, and obsidian (Bower 1977, 1981). Kisese II is a nearby rockshelter containing paintings and a series of occupation horizons including early LSA levels with outils écaillés and convex scrapers (Brooks and Robertshaw

1990:147). In northern Tanzania, during the MSA, obsidian was more readily available owing to exchange and/or social networks with populations in the Central Rift Valley and Lake Victoria basin of Kenya. Few coastal sites have been reported as the majority of archaeology conducted along the coast is more focused on Swahili culture sites.

As previously stated, in southern Tanzania and near the city of Iringa, numerous kopjes are scattered across the hilly landscape. These frequently were utilized by people as rockshelters. In Iringa town it is not uncommon to find modern structures built against or adjacent to kopjes. There are also many open-air MSA and LSA localities. In the Mbeya Region, some of these open-air sites are associated with the ancient terraces of the Songwe River. In the Mbeya/Songwe Region, approximately half of the material collected from MSA assemblages is quartz/quartzite (Willoughby 1993:13). Other raw materials utilized include silicates (chert/flint/cryptocrystalline silica) and volcanic. These are restricted to specific areas, thus reduction strategies vary with the raw material (Willoughby 1996b). Volcanic material use in the southern MSA is highest in sites that are closer to the volcanic highlands (Willoughby 1993:13); thus while MSA people in southern Tanzania utilized local materials, the presence of distinctive lithic types shows they also transported raw materials or finished tools over significant distances (Willoughby 2001b:14). These lithic raw materials would have been relatively abundant and easily obtainable. Conversely, to southern LSA peoples, cryptocrystalline silica (CCS) was either so highly prized, or so difficult to obtain owing to raw material scarcity or other constraints, they extracted CCS formed in small vesicles in the volcanic rock shelter walls (Willoughby 2001b:14).

During the LSA the tendency is towards the utilization of more exotic raw materials suggesting a significant change in mobility strategies including the development of long distance trade and exchange networks for raw material procurement. This pattern differs from that found in southern Tanzania. Along the Songwe River in Mbeya, LSA sites show a high reliance on quartz, approximately 92% (Willoughby 1993:13). Preference is for quartz pebbles that were reduced using bipolar technique then subsequently flaked and retouched (Willoughby 1996a, 1996b). This is a similar pattern to that seen in the Middle Pleistocene of France, where local quartz and sedimentary pebbles were transported whole and reduced by a variety of techniques including discoid, unipolar, and bipolar flaking (Byrne 2004). Ultimately, further investigation of raw material utilization and acquisition during the MSA and LSA in Tanzania is desperately required.

2.3 Archaeological Fieldwork in Iringa Region

Prior to 2006, very little archaeological field work had been conducted in Iringa Region. The focus of this past research has either been on the ESA (Howell et al., 1962) or Iron Age periods (e.g., Sutton 1969, 1973. In 2002, Dr. Paul Msemwa, Director of the National Museum in Dar es Salaam, undertook fourteen days of fieldwork. The overall objective of his work was to “come up with sites that could help build up the general chronology” and to understand the cultural history of the region (Msemwa 2002:1); however, strong emphasis was placed on Iron Age sites owing to a theoretical emphasis on understanding the factors which may have led the southern populations of Tanzania to interact with coastal peoples much later in time than interior peoples (Msemwa 2002:1). Figure 2.5 illustrates the locations of archaeological sites recorded in Iringa Region during the 2006 and 2008 fieldwork season. Swahili terms for artifacts and landscape features are italicized when provided.

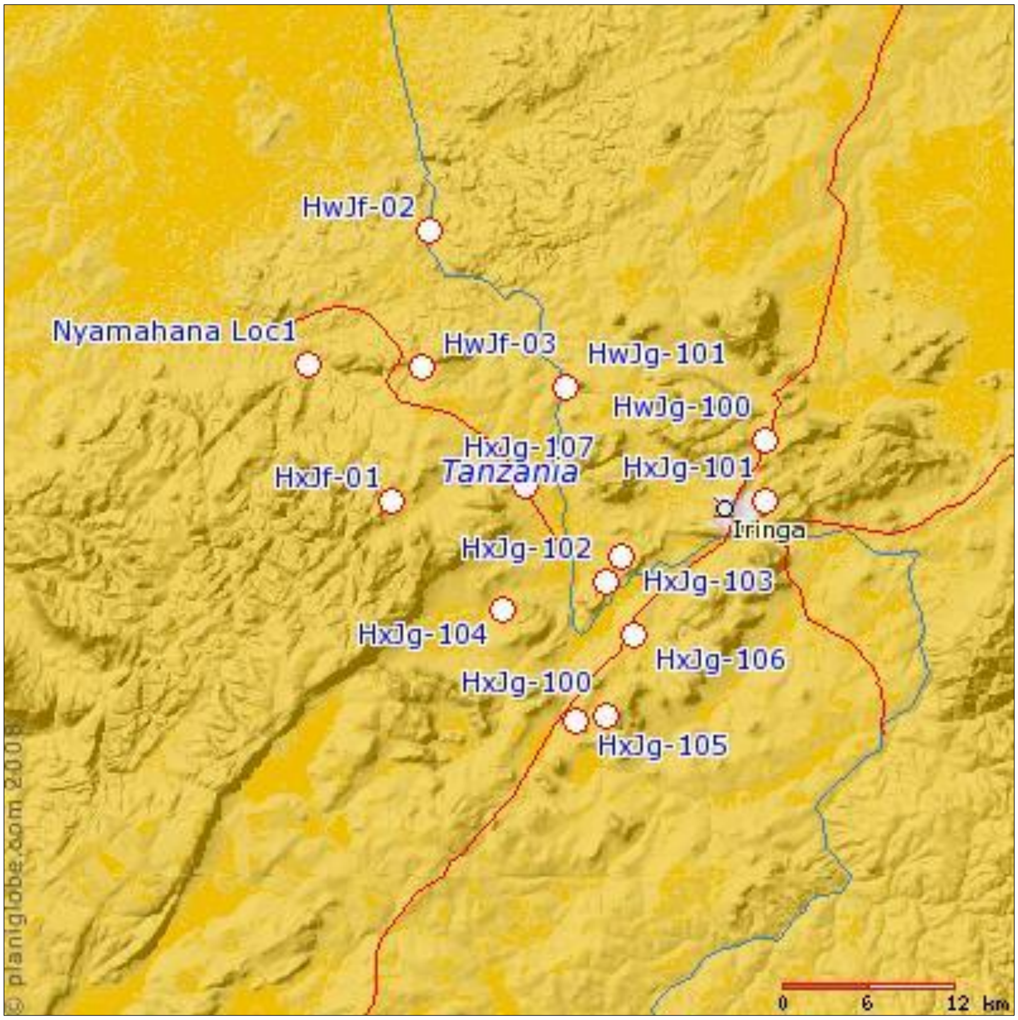


Figure 2.5: Map of Iringa Region indicating location of sites. Constructed using www.planiglobe.com/omc_set.html.

2006 Fieldwork

For eight weeks during July and August of 2006, test excavations were conducted by the Iringa Region Archaeology Project research team at two rockshelter sites, Magubike and Mlambalasi, in the Iringa Region of southern Tanzania. A surface collection was also made at a third site, Kitelewasi. The purpose of this preliminary study was to determine the archaeological potential, artifact density and stratification of rockshelter sites in the region. This was the first research in the Iringa Region to examine MSA and LSA assemblages, as previous research in the area focused on earlier (Acheulean) assemblages at sites as Isimila and Mgongo (Cole and Kleindienst 1974; Omi 1988; Hansen and Keller 1971; Howell 1961, 1972; Howell et al., 1962).

Mlambalasi (HwJf-02), located 50 km west of Iringa town, is a large multi-component *pango* (rockshelter) (Figure 2.6). The site is best known as the burial place of Chief Mkwawa (1855-1898) of the Hehe people; the tomb containing his body and a monument erected to commemorate the 100th anniversary is located adjacent to, and below, the rockshelter. Rather than surrender to the colonizing Germans Chief Mkwawa killed his servant before committing suicide. His head was cut off, as a bounty had been placed on it, and sent to the Bremen Anthropological Museum where it remained until 1954 when it was finally returned to his family. It is currently on display at the museum in his capital Kalenga along with other personal belongings and items representing the cultural and economic activities of local people.

The rock shelter contains two main rooms connected by a small, but still passable, fissure in the rocks. Artifacts, including shell (*konokono*), bones (*mifupa*), iron and iron slag (*chuma*) and smelting debris (including tuyere and other furnace fragments), lithic artifacts (*zana za mawe*), and pottery (*vyungu*) are observed on the surface at, around, and on the paths leading to the shelter – a sample of which was collected. Two 1m x 1m test pits were excavated. Test pit #1 (TP #1), positioned centrally in room 1, was excavated to a depth of 120 cm (Figure 2.7). It contained a well defined Iron Age to LSA stratigraphic sequence

(Figure 2.8). It is possible that there are two LSA levels representing Holocene and Pleistocene occupations, and that these overlay a MSA component. Excavation of TP#1 stopped when progress could no longer be made owing to a large number of boulders which could not be readily moved. Whether these boulders had fallen from the roof of the rockshelter or were placed there by people, possibly in association with a burial, could not be determined.

The remnants of an Iron Age furnace were located in the southwest corner of the unit. Human remains were recovered in this same corner from a depth of approximately 70 – 90 cm below surface, in association with a single shell bead (*shanga*) and potential LSA lithics. Three radiocarbon dates were acquired from TP #1. One taken from the ash layer associated with the furnace dates the Iron Age occupation to around 500 years ago. The burial and associated LSA artifacts date to around 11,800 to 13,000 years old. The burial could be intrusive into older sediments which would account for the discrepancy in the dates (the older date above, and the younger date below, the burial).

Test pit #2 (TP #2) was excavated to a depth of 160 cm at the top of a slope just outside of the modern shelter overhang (Figure 2.9). While TP# 2 contained Iron Age, LSA and MSA materials, they had been disturbed by erosion and bioturbation so no clear stratigraphic sequence could be established.

In 2002, Dr. Msemwa excavated a single 1m x 2m unit to a depth of 60 cm in what he considered to be the middle of the rockshelter (Room 1) at Mlambalasi. Photographs of this excavation unit show that it is located to the south-east corner of TP#1 on the diagonal (Msemwa 2002:11, Plate 3). Materials his team recovered include pottery, lithics, bones, iron slag, iron metal sheet, shells, and beads (Msemwa 2002:11-14). Both worked tools and un-retouched flakes were recovered throughout the unit, and are made primarily of “clear quartz” and chert (Msemwa 2002:13).

Figure 2.6: Mlambalasi rockshelter. Regional Cultural Officer Ms. Joyce Nachilima stands at the opening of the rockshelter.

Figure 2.7: Location of Test Pit #1. Pictured from left to right: Thomas, myself, Antiquities Officer Mr. Peter Abwalo, and Mr. Marungu.

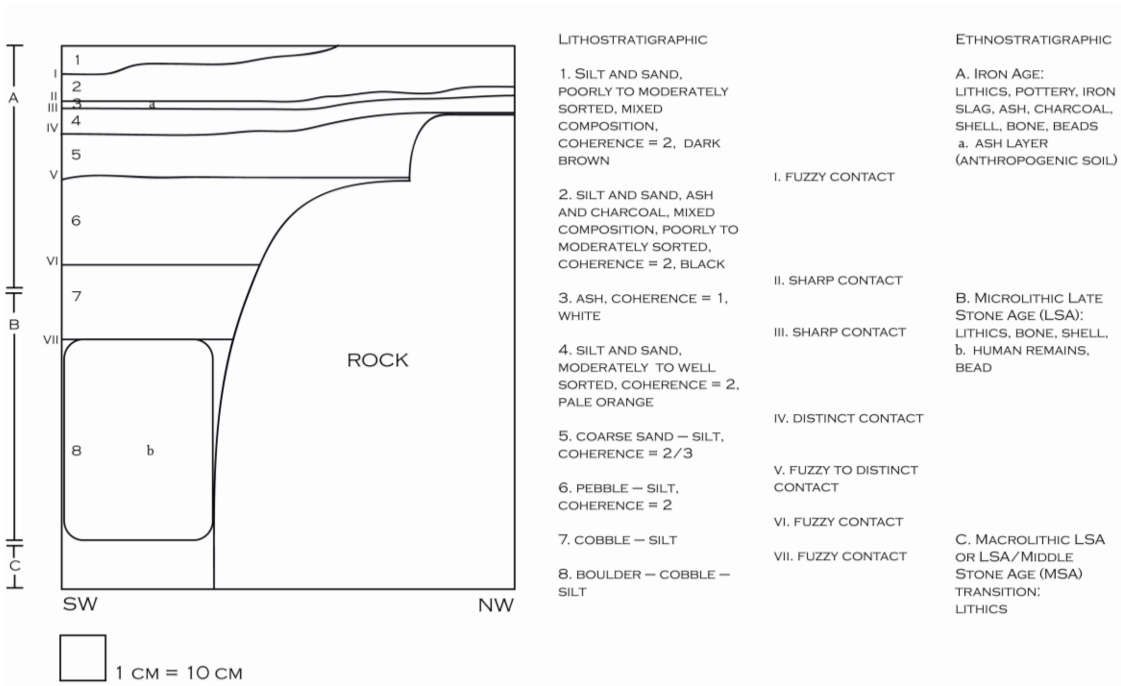


Figure 2.8: Stratigraphic profile of HwJf-02 Test Pit #1, West Wall. 8 August 2006.

Figure 2.9: Location of Test Pit #2 near slope. Antiquities officer Mr. Peter Abwalo discusses excavation progress with local worker Thomas and Maasai visitors.

Fragmentary human bones were also recovered and it is interesting to note that they were exclusively cranial while the remains recovered by our team in 2006 are post-cranial. The close proximity and general orientation of Msemwa's excavation unit to our TP#1 does suggest that the remains recovered from both seasons belong to the same burial. Sawchuk's (2008) analysis of the TP#1 remains revealed that two individuals are present in the sample, one of which is a juvenile. However, Sawchuk was unable to establish an age at death for the juvenile individual as the juvenile remains comprised a single, incomplete manubrium fragment (Sawchuk 2008:36). The gender and age of the adult specimen were also not determined owing to the poor preservation and the absence of the necessary diagnostic skeletal elements. Thus owing to unknown site formation processes and the limited sample, Sawchuk (2008:36) concluded that it is "unclear whether or not these two individuals are part of a greater collection resulting from cultural practices, such as the creation of a cemetery or burial ground." Further large-scale horizontal excavation of Mlambalasi is required in order to determine the context of these remains in the site as a whole; this was accomplished during field work in 2010.

We returned to Mlambalasi rockshelter in June through August 2010. We excavated a 2m x 3m trench in room 1 (Figure 2.10). Using a total station, a datum and site baseline was established. Excavations revealed the locations of Msemwa's 2002 test pit and our 2006 Test pit #1 (Figure 2.11). We recovered the rest of the individual originally found in 2006, as Feature B1, and were able to establish that its context was undisturbed by Msemwa's 2002 test excavation. These remains are currently being investigated. Additionally we recovered a large number of ostrich eggshell, glass, and plastic beads. Although analysis of the lithic and faunal materials has not yet been undertaken, initial impressions confirm our 2006 interpretation of the cultural sequence at Mlambalasi rockshelter.

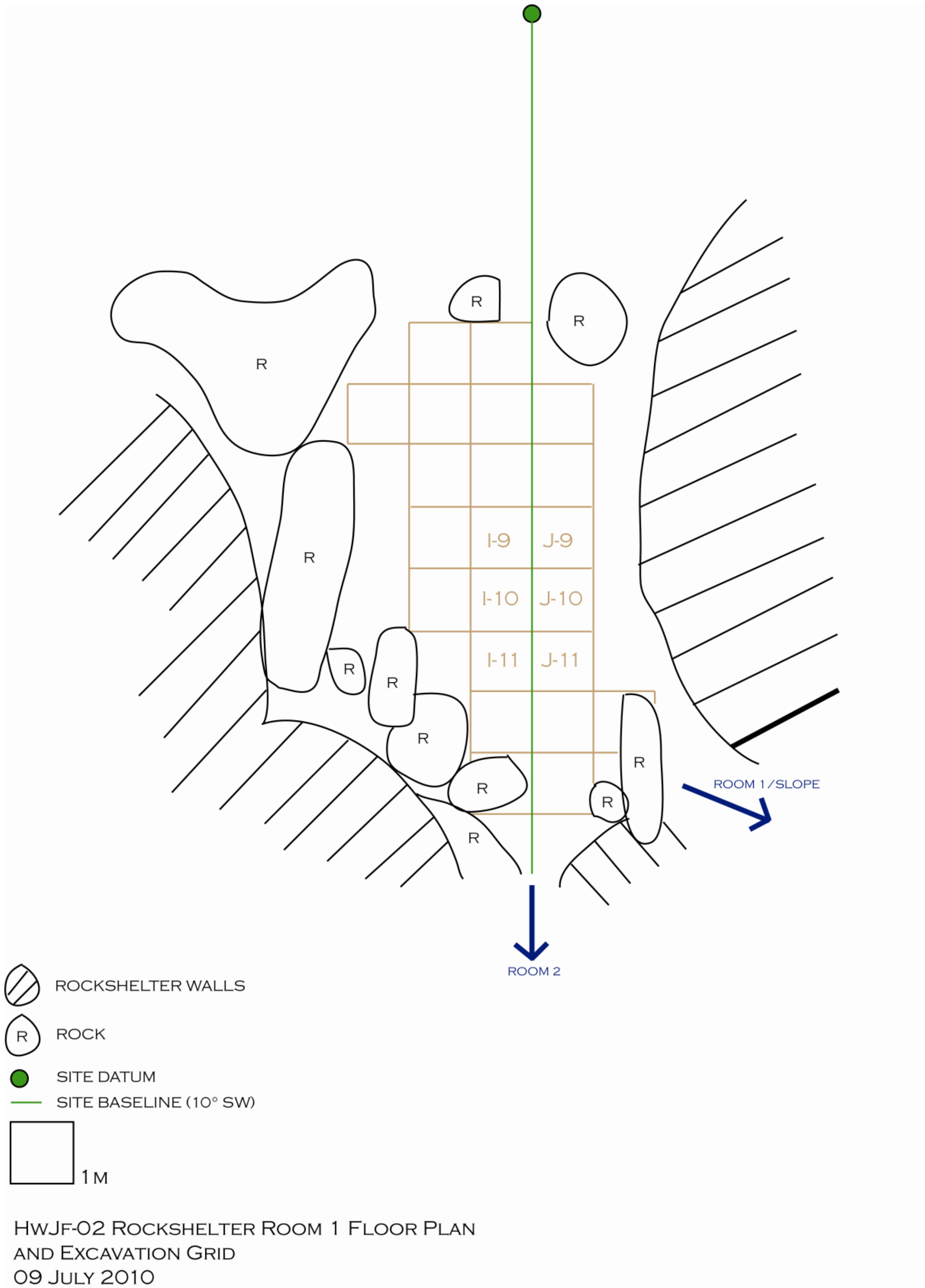


Figure 2.10: HwJf-02 floor plan showing excavation grid. 09 July 2010.

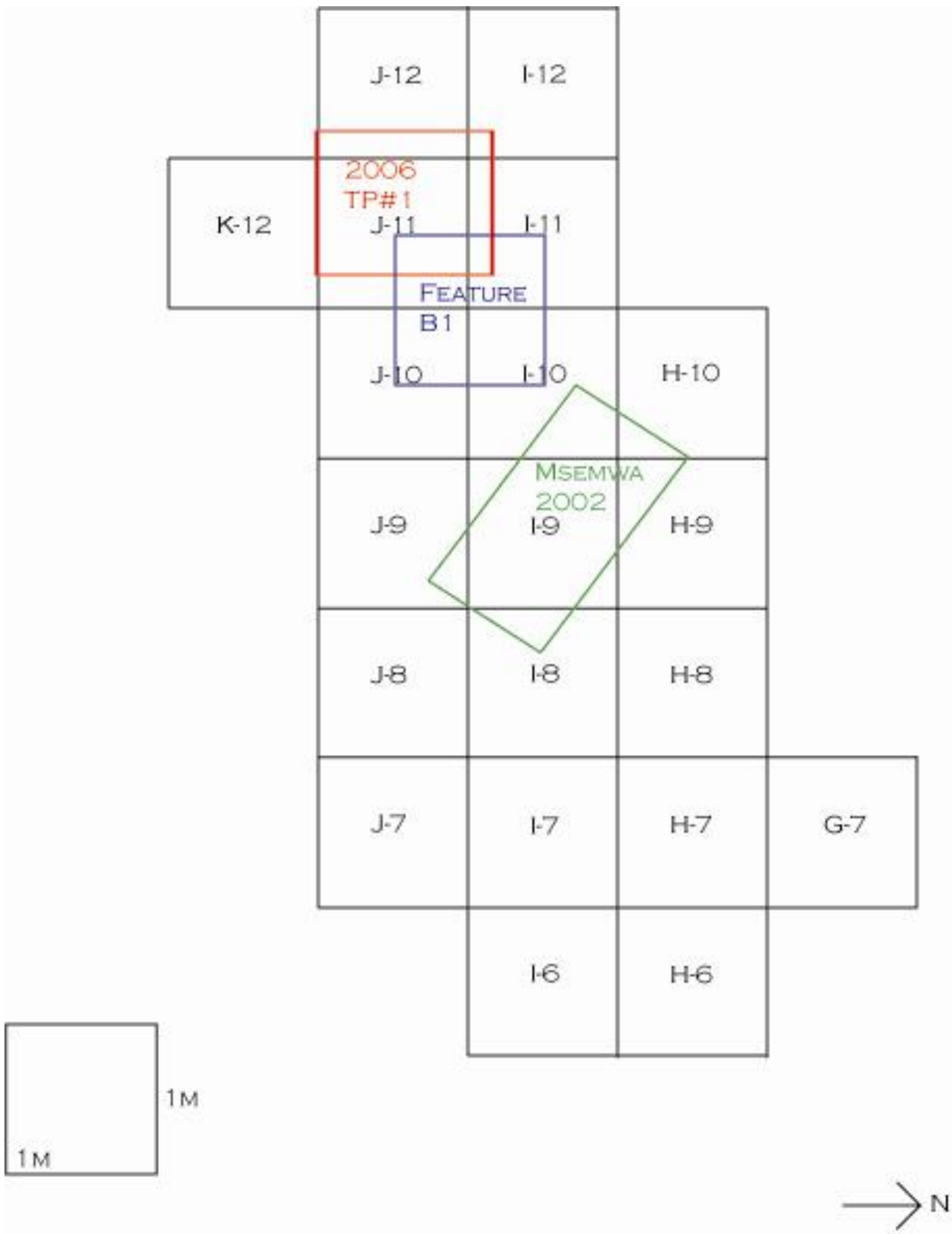


Figure 2.11: Location of Msemwa's (2002) excavation unit and TP#1 relative to the 2010 excavation grid. 27 July 2010.

Two sites are located adjacent to the village of Magubike. Three one meter square test pits were excavated at the rockshelter (HxJf-01) (Figure 2.12). TP#1, excavated within a crevice, was extended to a depth of 180 cm (Figure 2.13). Few artifacts were recovered from the first meter, however, a dense, approximately 50 cm thick layer of large MSA lithics started at approximately 110 cm below surface (Figure 2.14). TP #2 and TP#3 were excavated under the modern shelter overhang (Figure 2.15). When large rocks, possibly roof fall, were reached at a depth of 60 cm in TP #2, TP #3 was placed adjacent to the east wall of TP#2. This was excavated to a depth of 210 cm below surface. Both TP #2 and #3 contain Iron Age materials in the top 40 cm (Figure 2.19).

The rest of the deposits appear to belong solely to the MSA. In TP #3, MSA artifacts are associated with fossilized animal bones and shells, six and a half fossil human teeth, and a single shell bead. It is extremely rare to recover fossil animal bones in association with MSA artifacts in East Africa; therefore these sites are significant to our understanding of this period in human evolution. Additionally, the fossil human teeth represent the first fossil hominin remains recovered in Tanzania outside of the northern sites (which include Olduvai Gorge, Laetoli, and Mumba). The fossil teeth are currently being investigated by Dr. Chris Stringer and his associates at the Natural History Museum, London.

Figure 2.12: Magubike rockshelter.

Figure 2.13: Test Pit #1 located within a crevasse in the kopje. Dr. Pastory Bushozi takes photos while local workers look on.

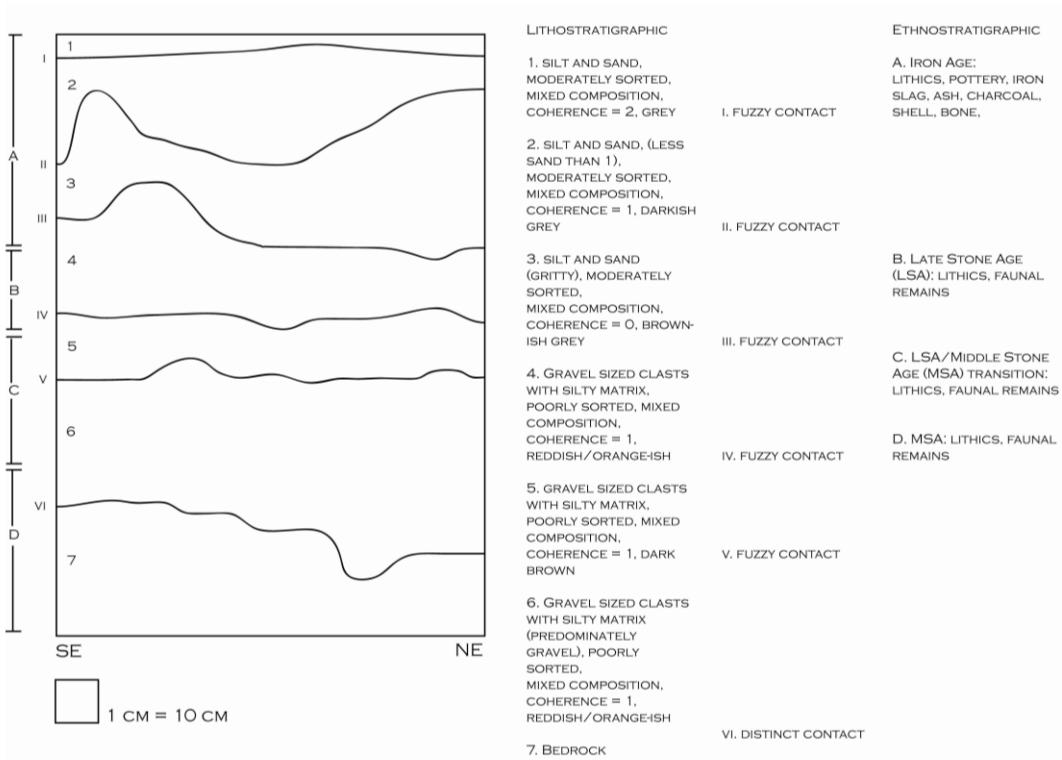


Figure 2.14: Stratigraphic profile for Magubike Test Pit #1, East Wall. 16 August 2006.


Figure 2.15: Location of Test Pit #2 and #3.

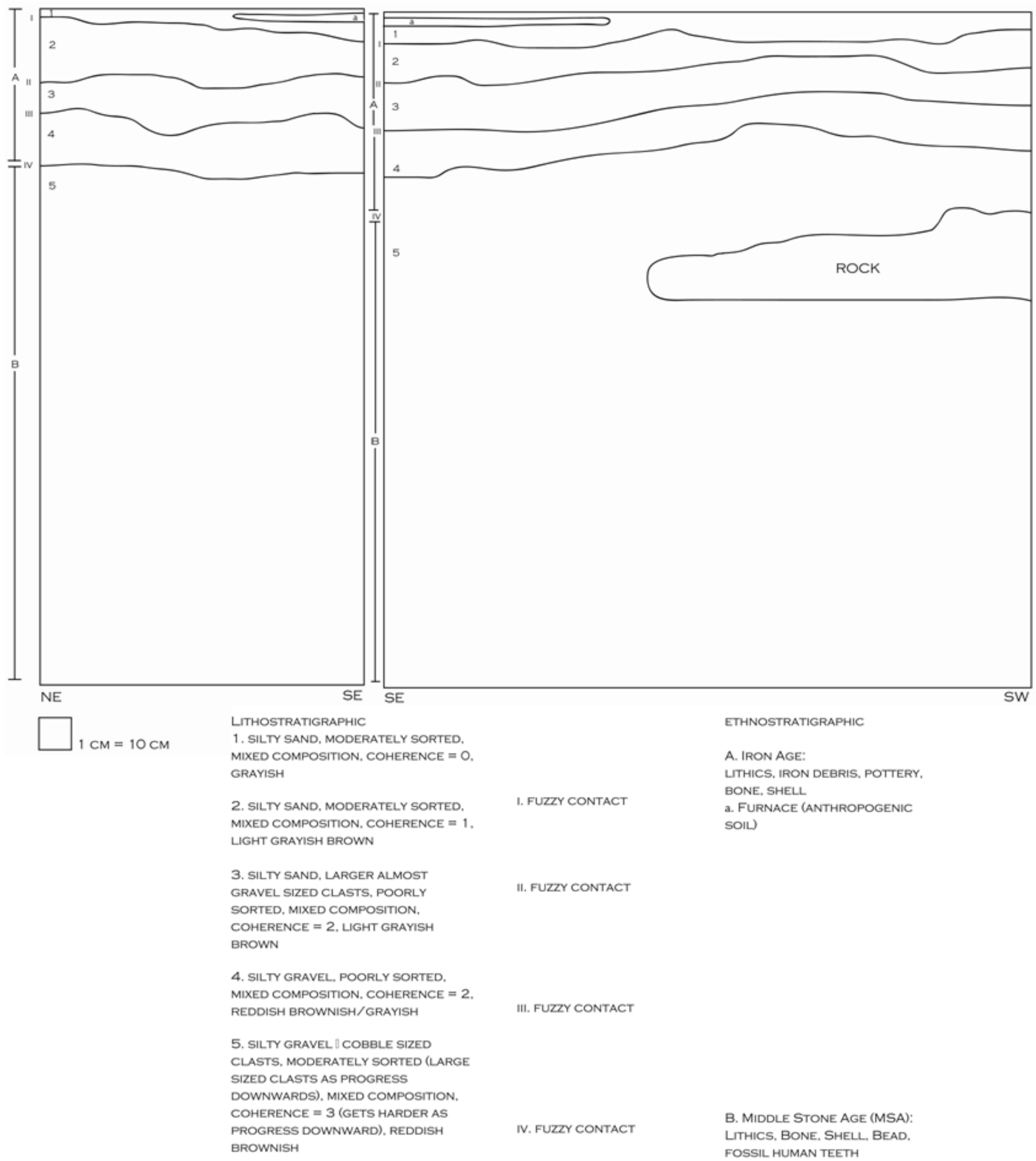


Figure 2.16: Stratigraphic profile of Magubike Test Pits #2 and #3.

Below the rockshelter, in a tobacco field (Figure 2.17), are a number of larger artifacts in cryptocrystalline silica/quartzite. These possibly represent an MSA occupation, but one different from that inside the rockshelter – the raw materials for stone tools are very different from that found in the shelter. As such it was designated with another site number (HxJf-03), and a surface collection was made of this material.

Kitelewasi (HxJh-01) (Figure 2.18), bearing the local name of Mangayawatwe, is located off the main highway east of Iringa, in the village of Ibofwe or Ilangomoto, high on an escarpment. Surface collection of predominantly stone artifacts (mainly quartz/quartzite) was conducted. Some artifacts, including fossilized bone, are found in a cemented soil or breccia located on the ground at edge of the modern shelter overhang; a sample of this material was also collected.

Figure 2.17: Tobacco and corn field, site HxJf-03 at Magubike.

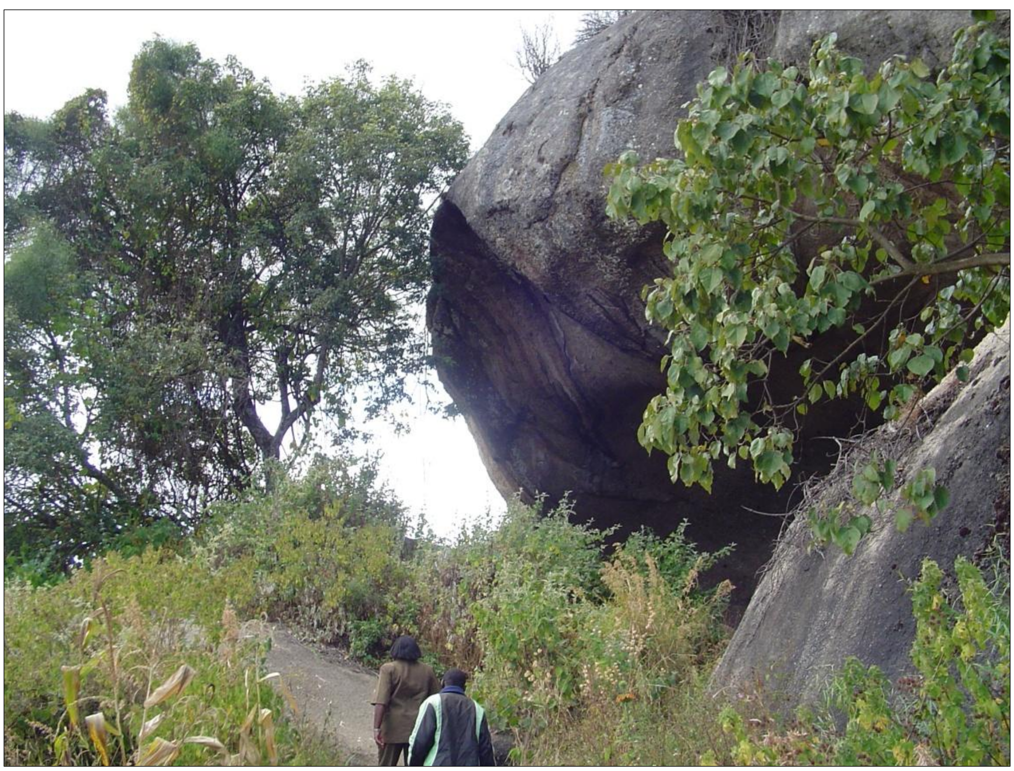


Figure 2.18: Kitelewasi rockshelter.

2008 Fieldwork: Survey of potential source materials and archaeological sites

In 2008, our research team returned to Iringa. The goal was to undertake a large-scale regional survey in order to document the distribution of sites and stone raw material sources. Following Msemwa (2002), four field techniques were used: (1) enquiry of the local communities on the location of *korongo* (gorges) and *mapongo* (caves/rockshelters); (2) visiting known/previously recorded archaeological and cultural heritage sites; (3) carrying out surface surveys; and (4) surface collection of both local stone raw materials and artifacts. Survey forms (Appendix D) were constructed following Lavin (1983) and Wilson (2007). Surface collection occurred at twelve different locations including at several previously unrecorded archaeological sites, two well-known Acheulian sites, and various rocky outcrops (Table 2.1).

Isimila (HxJg-06) is a Stone Age site with abundant Acheulian tools (handaxes, cleavers) and some fossilized faunal remains (Figure 2.19). It is located within a prominent feature on the landscape, a gorge that is visible from some distance. The gorge sediments do not appear to contain any raw material sources, however, we sampled various pieces of debitage focusing on volcanic, cryptocrystalline silicate (CCS), and chert materials (mainly those that appeared to be similar and different from those recovered in 2006 season at Mlambalasi and Magubike). The artifacts demonstrate an extremely wide variety of raw materials including high quality quartz (crystal) and quartzite, and the chert varieties are mostly milky white with white-rusty cortex, with a few pieces of a caramel-brown with white cortex variety. This last type described is similar to some of the chert from Mlambalasi and Magubike but generally one does not have the same range of diversity in chert types. The volcanics are very fine grained with lots of inclusions.

Table 2.1: Summary of sites and potential raw material sources recorded during 2008 survey of Iringa Region.

Site Name &/or SASES Designation	Previously Recorded	Cultural components	Artifacts	Lithic Artifacts & Samples Collected
Isimila HxJg-06	Cole & Kleindienst 1974; Hansen & Keller 1971; Howell 1961, 1972; Howell et al., 1962	Acheulian – LSA	Abundant handaxes	86
Kessakilolo Rock Art Site HwJg-100	Unknown	MSA?-Iron Age	Lithics, pottery, iron slag, bone	19
Mgongo HwJg-02	Omi 1986	Acheulian – LSA	Lithics, shell	6
Mlambalasi Creek bed	N/A	None	None	2
Nyamahana River Location #1	N/A	None	Single flake	13
HwJf-03	No		Lithics, pottery, iron slag, nail	58
Tungamalenga HxJe-01	Unknown		Lithics, pottery, iron, glass	15
Black Stones at Ruaha		LSA?	Lithics, pottery	5
Kigwambimbi HxJg-103	Unknown	MSA – LSA	Lithics, pottery, shell	227
HxJg-102	No	LSA?	Lithics	8
Gully sample	N/A			1
Modern quarry	N/A			1
Kibebe HxJg-104	No	LSA?	Lithics	20
Lisindavanu	No	LSA?	Lithics	3
Isimila River HxJg-105	Unknown	Acheulian – LSA	Lithics, pottery, glass, porcelain	170
HxJg-107	No	LSA	Lithics, pottery, iron slag	1
Total				634

Our survey included the area immediately adjacent to Isimila focusing on two major topographic features: Lukingi and Kikombwe Hills (seen in the background of Figure 2.19). Approximately 4 km^2 was surveyed. Surface visibility varied from poor to moderate to good. A footpath, which eventually turned into a newly constructed gravel road from Isimila to Kikombwe Hill, crosses cultivated fields (corn and cassava) thus there was poor ground visibility. A single new site Lukingi Hill (HxJg-100) consisting of LSA quartzite surface scatter adjacent to large rocky outcrop was recorded (Figure 2.20).

The area to the southwest of Isimila was also examined. Isimila River (HxJg-105) is an Acheulian and MSA site located on west side of road just south of Isimila along a creek bed (Figure 2.21). The artifacts are made from various raw materials, mostly cryptocrystalline silica (CCS) varieties. The site is disturbed owing to water erosion and pedestrian traffic in and across the creek bed. Handaxes and large flakes were recovered from the footpath that leads down into the creek bed. This site may be connected to Isimila proper.

HxJg-106 is located on a large rocky outcrop on east side of the highway from Iringa to Mbeya, a couple of kilometres north of Isimila River site (Figure 2.22). LSA and Iron Age artifacts, predominantly quartz/quartzite, are scattered across the surface. A few pottery fragments we recovered but they are likely recent.

Figure 2.19: Isimila Stone Age site.

.Figure 2.20: LSA site at Lukingi Hill.

Figure 2.21: Pastory Bushozi, Pamela Willoughby, and Benjamin Collins surveying along the ephemeral creek bed at Isimila River (HxJg-105).

Figure 2.22: LSA site HxJg-106.

The kopjes located within the limits of Iringa town proper were also examined; first, by revisiting a potential site identified by Willoughby in 1989, the Iringa Girls School or Church Site (HxJg-101). As its name suggests, it is located adjacent to the Iringa Girls Secondary School and a large church. This location consists of a large amount of quartzite debris surrounding a granite kopje; however, as there has been extensive cultivation around the rockshelter it is difficult to ascertain if this debris is cultural. As quartzite is ubiquitous and there is an absence of other artifacts/cultural activity at the locality and in the immediate surrounding area, this suggests that it is not likely a Stone Age site after all, thus no samples were collected.

Shabaha Hill is the major topographic feature within Iringa Region proper. Approximately 1 km^2 was surveyed. Although there were kopjes on the hillside, no archaeological materials were found. In one area, a deep crevasse had been excavated by individuals treasure hunting; it may have been a natural trap and could have contained artifacts and fossils at some point. Interestingly, some of the rockshelters towards the bottom of the hill had houses and other buildings built directly underneath them. The field to the north of Shabaha Hill (owned by nearby Mkwawa University College) was closely examined but it contained very sparse, scattered lithic debris. No materials were collected, and no potential raw material sources identified. Overall the ground visibility was high owing to cultivation.

Just outside of Iringa town to the north-west, we found a modern quarry site on Ipamba Hill, a major topographic feature in the region. The material is quarried for construction (crushed for gravel, road fill). This material is not suitable for tools but interesting stone outcrop nonetheless as the rock type is different from usual metamorphic outcrops. The rest of hillside is littered with eroding quartzite and dark metamorphic rocks characteristic of the region. To the east of the quarry/hill is Ruaha river, a low swampy/marshy area of low archaeological potential (Figure 2.23).

Mgongo (HwJg-02) is another previously recorded Acheulian site located within Iringa Region. Located to the northeast of Iringa town proper (Figure 2.24), Mgongo is not as famous as the nearby site Isimila. In 1986, a Japanese team excavated three 2 m x 2 m blocks at Mgongo (Omi 1988). They recovered Acheulian, MSA, and LSA artifacts and state there is a very clear age difference between the Acheulian tools excavated and those found toward the surface. However, they found that much of the artefact-bearing layers had been lost and many artifacts had been brought to the surface and washed away. They note that microlithic quartz artifacts are dominant for the LSA. Today the surface scatter is not as abundant; very few handaxes/bifaces remain, and some small quartzite debitage were found.

Kessakilolo Rock Art Site (HwJg-100) is located on a rocky outcrop in the Igareke Mountains (Figure 2.25). It is a rockshelter with red ochre and charcoal rock art with extensive surface scatter including pottery, iron, and lithics (quartzite, chert, and volcanics of MSA, LSA, and Iron Age). According to Mr. Emmanuel Bwasiri M.A., our Antiquities Officer for 2008 who wrote his Master's thesis on Tanzanian rock art, the images are typical Iron Age, bantu-style rock art (Figure 2.26). The images include anthropomorphic and zoomorphic figures including giraffes, and stylized lines (the meaning of which is unclear).

Figure 2.23: Ruaha River southwest of Iringa town.

Figure 2.24: Mgongo Acheulian site showing signs of water erosion.

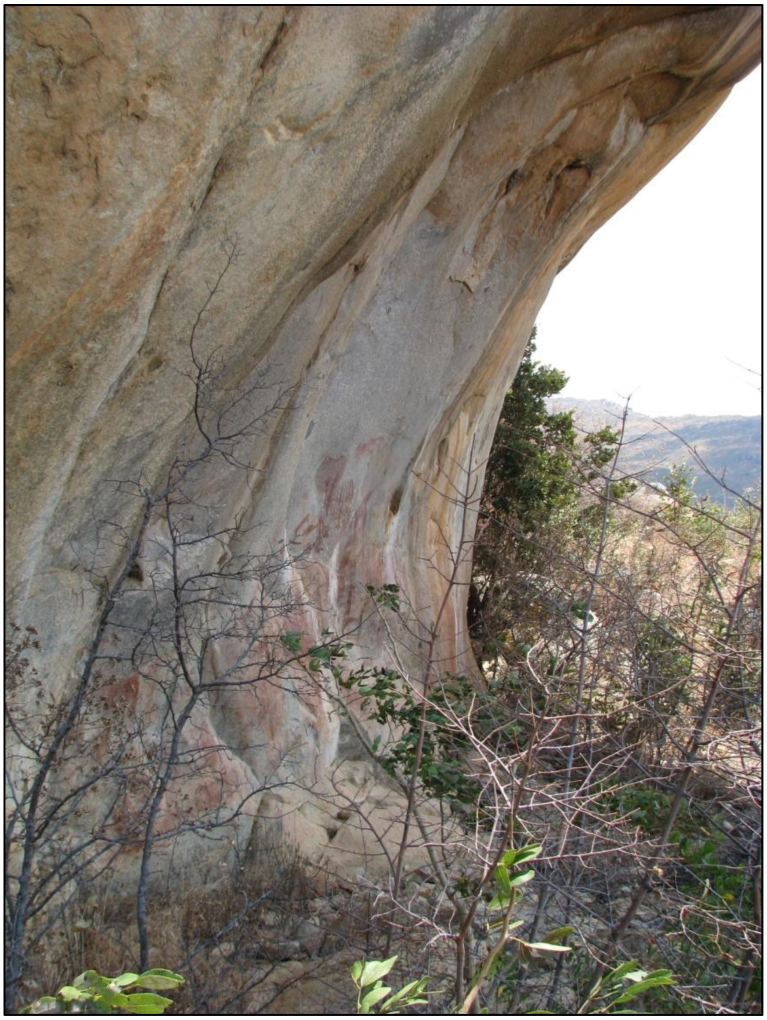


Figure 2.25: Kessakilolo rock art site.

Figure 2.26: Bantu-style red ochre art work on the rockshelter wall at HwJg-100. Various animals and anthropomorphic figures can be identified.

Both Mlambalasi and Magubike were revisited in 2008. At Mlambalasi there was evidence of continued erosion down slope and abundant artifacts were visible on its surface. The rockshelter itself appears to be undisturbed with the exception of little new graffiti. The ephemeral creeks bed to the south and west of the rockshelter proper were examined and a few samples were taken. The rest of the landscape surrounding the site is flat to undulating; no major rocky outcrops or other topographic features are visible beyond a few ephemeral creeks.

Nyamahana River is a tributary of the Little Ruaha River, which is the major river system in Iringa Region, and it is used as contemporary primary water source by people of Nyamahana village for washing clothes, watering animals, and irrigating crops. Owing to its relatively close proximity to both Mlambalasi and Magubike, surveying included a segment of the Nyamahana River as a potential secondary raw material source. Raw material samples were taken from an eroded exposure with gravel deposit in river bed (17.7 m in length) which contained pebble to cobble sized clasts, and a few (less than 5%) good quality clasts of chert and chert-like material. Throughout the metamorphic bedrock of the river there are numerous quartz/quartzite outcrops (10-20 cm across), which include a lot of plagioclase and a green mineral that could not be identified in the field.

HwJf-03 is a newly recorded site located on the east side of the Iringa-Ruaha road (Figure 2.27). It consists of a surface scatter across an abandoned corn field. Artifact density is moderate to high but highly disturbed by extensive cultivation. Large rocky outcrops are nearby but no artifacts were found in direct association (i.e., nothing found directly under them – this could be the result of the cultivation and normal erosional processes). The artifacts consist largely of Iron Age pottery and iron slag, and a significant number of quartzite artifacts (MSA? LSA?). There is also some chert that demonstrates the macroscopic properties similar to those recovered from Magubike and Mlambalasi. The abandoned modern buildings contain artifacts in clay walls (Figure 2.28);

residents must have quarried clay from area surrounding rock shelter to form bricks.

A single site (HxJe-01) was recorded near the village of Tungamalenga. Distributed throughout a cultivated (corn) field, quartz and quartzite lithic artifacts were scattered along with some pottery and iron slag (Figure 2.29). This area was investigated because of reports of old human footprints in the rock. The "footprint" is an isolated feature on stone which is not likely made by human activity, in part because it is not in sediment like clay or ash that would allow for the creation and preservation of footprints (Figure 2.30); however, this feature is important to note as locals are convinced of its authenticity. Future discussions with local peoples concerning the background stories of the footprint would be a good start for conducting a cultural heritage site survey of Iringa Region.

Another site of local importance is Kikongoma or the "Black Stones of Ruaha River." Located adjacent to Ruaha river, Kikongoma is a large spring and creek site running through large "black" stones that are metamorphic, typical for the region but darker and well-weathered (Figure 2.31). Very few artifacts were recovered, and those found were likely washed in with seasonal change in river level. No potential raw material sources noted (including no quartz/quartzite veins or any other such nodules or inclusions but a few iron stone inclusions). However, the site is of cultural significance. Kikongoma is the location of the death of Chief Mkwawa's mother. Offerings of leaves or branches are left near at this location (Figure 2.32). It is surprising that no archaeological sites are located within close proximity as is rapid flowing fresh water source; the natural spring in particular is warm. This could be because it may be relatively recent feature on the landscape, thus was not a resource available to Stone Age peoples.

We met with the *Mtendaji wa Kijiji* (village chairperson) of Kalenga who agreed to take us to two *makorongo* in the area. Two new sites were recorded. HxJg-102 is a low density, LSA/Iron Age lithic scatter in gravel bed with lots of deflation (Figure 2.33). The artifacts are mainly quartzite.

The other new site Kigwambimbi (HxJg-103) is located in a large gorge off another ephemeral branch of Ruaha River (Figure 2.34). It is a medium to high density of artifacts including large flakes and tools, and a few pieces of pottery. There are various lithic raw materials (mostly quartzite/quartz) representing the MSA, LSA, and Iron Age. There is some evidence of erosion or weathering from the fields on top down into the bottom of the gorge.

A survey along the Ruaha River was made to check for potential raw material sources. The river bed is clay to sandy clay with very few clasts (some areas contain no clasts); its banks are extensively quarried to make bricks. Some soil color change is evident in the form of darker bands which may be organic rich, and were produced during a dry period when the river level dropped significantly for an extended period of time. However we only examined approximately 1 km^2 as the river is likely to young to have been available to Stone Age peoples.

Another new site, Kibebe (HxJg-104), is located along the Kihesa river tributary/seasonal swamp (Figure 2.35). There were few artifacts; however the surface scatter was interesting because the assemblage was comprised of mostly non-quartzite artifacts.

Figure 2.27: Abandoned field containing extensive surface scatter.

Figure 2.28: Artifacts incorporated into mud-brick structures at abandoned farm.


Figure 2.29: Active corn field where various artifacts were found.

Figure 2.30: The Tungamalenga footprint.


Figure 2.31: The Black Stones of Ruaha River.


Figure 2.32: Mr. Emmanuel Bwasiri listens to a description of the offerings left in honour of Chief Mkwawa's mother.


Figure 2.33: HxJg-102.


Figure 2.34: Kigwambimbi.


Figure 2.35: Confluence of two branches of the Kihesa river tributary where artifacts were recovered.


Figure 2.36: HxJg-107.

HxJg-107 is an Iron Age (and possible LSA) site. Like most sites in Iringa Region, it is located within a rocky outcrop with a few slight overhangs (Figure 2.36). There were few quartzite lithics, as the majority of the assemblage consisted of abundant pottery and iron. The site is heavily disturbed by cultivation. There were 634 stone artifacts and raw material samples were collected from Iringa Region during the 2009 field season.

Of the numerous *makorongo* in Iringa Region, many of them, like Lisindavanu, are formed into medium grained, dark red deposits and contain no archaeological deposits (Figure 2.37). Lisindavanu was the exception and it contained only three quartz artifacts. They could have easily washed into the area from elsewhere as there was evidence of water erosion along the sides and bottom of the gully. Interestingly these deposits could be connected with the Red Sandstone Group deposits in the Rukwa Rift Basin in Mbeya Region. These deposits have recently been studied (Roberts et al., 2004; O'Connor et al., 2006) as they contain dinosaur fossils. Future palaeontological investigation of the Iringa Region red sandstone gullies may prove fruitful.

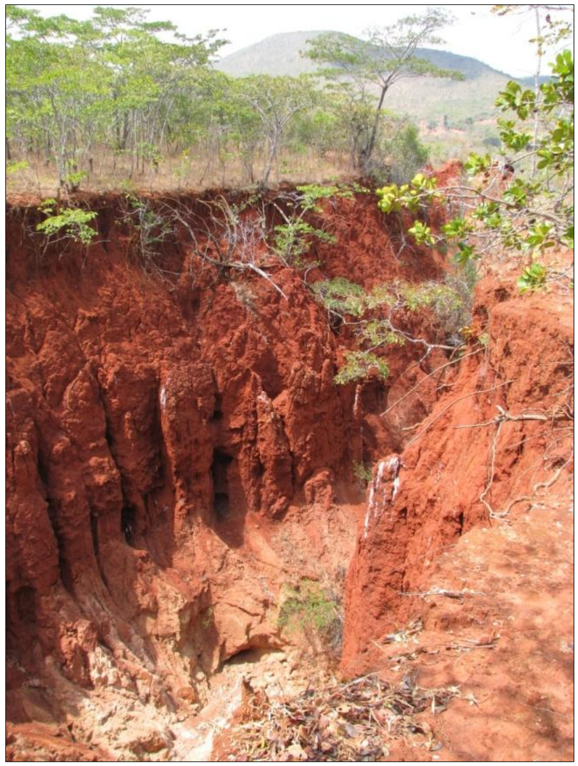


Figure 2.37: The red sediments at Lisindavanu are typical of a number of *makorongo* throughout Iringa Region.

Extension of Survey to Mbeya Region

Geological maps for Iringa Region and out-of-print monographs were obtained from the Geological Survey of Tanzania (GST) in Dodoma. Mr. Fadhiri, a geologist with GST who has worked in Iringa and Mbeya Regions suggested surveying for potential raw material sources in Mbeya Region as chert outcrops are located along Chafukwa Hill. Figure 2.38 illustrates the sites visited in the 2008 survey. Table 2.2 provides a summary of these sites and the samples taken.

In 1990, Willoughby (1992:32) recovered "great numbers" of chert flakes, blades and finished tools spread out in all directions over a kilometre from a small chert butte called Chamoto Hill. Chamoto Hill (IdIx-01) is located approximately 50 km east of Mbeya town, and north of Igurusi village (Figure 2.39). It was first identified by E.G. Haldermann in the 1950s. A large number of lithics, notably chert, are eroding out of the sedimentary deposit and down into a nearby gorge (Figures 2.40 & 2.41). From this site, 122 artifacts and lithic samples were collected for analyses.

Not too far from Chamoto Hill at Chafukwa Hill, surface survey was undertaken (Figure 2.42). Fadhiri recalled identifying amygdaloidal lava outcrops which contained small cherts at this locality. We were unsuccessful in locating these outcrops. A single outcrop of some fissile chert was identified and samples were collected for analyses (Figure 2.43). However, the material is very brittle and would not be adequate for stone tool manufacture and use.

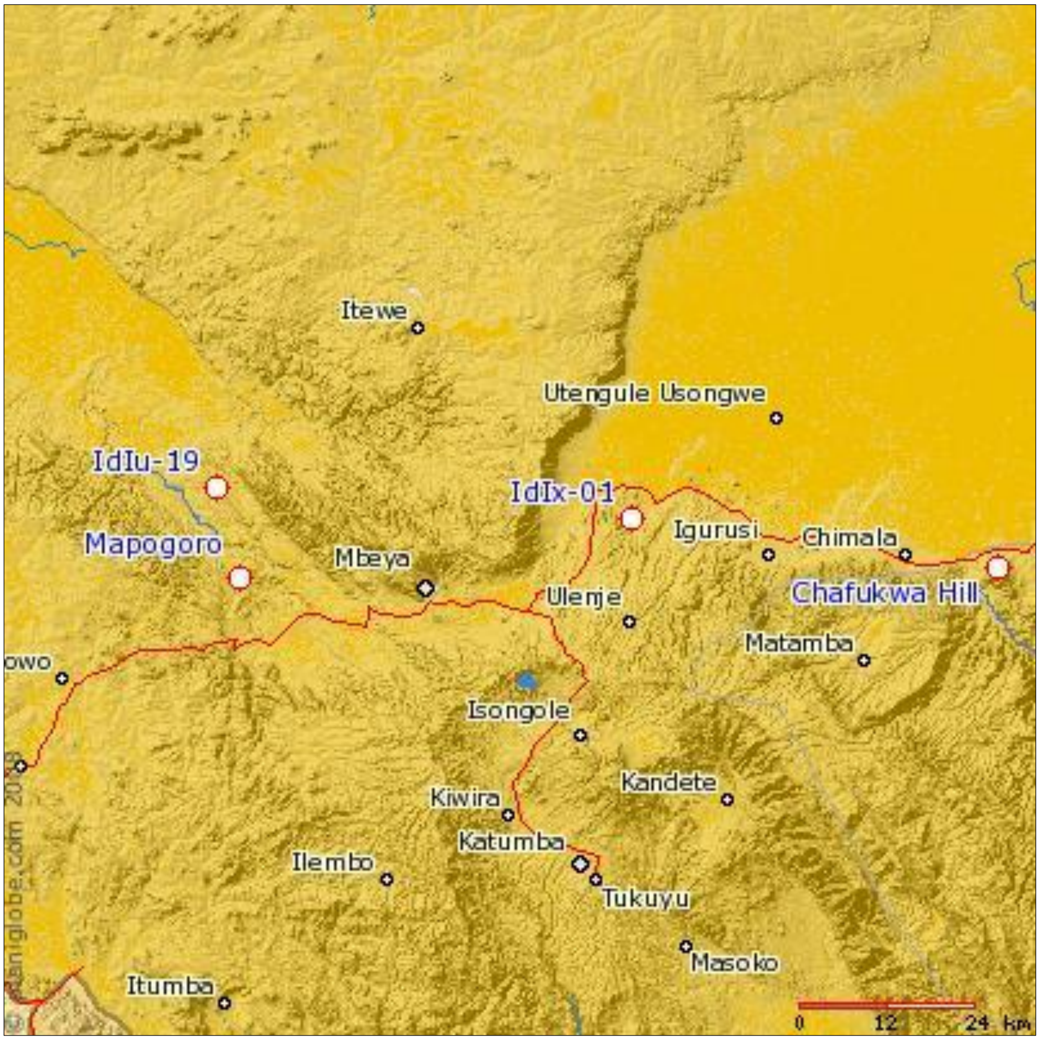


Figure 2.38: Location of archaeological sites in Mbeya Region. Constructed using www.planiglobe.com/omc_set.html.

Table 2.2: Summary of sites and potential raw material sources recorded during 2008 survey of Mbeya Region.

Site Name &/or SASES Designation	Previously Recorded	Cultural components	Artifacts	Lithic Artifacts &/or Samples Collected
Chafukwa Hill	No	None	None	30
Mapogoro Site No.1	Unknown	?	Lithics, pottery	15
Chamoto Hill IdIx-01		MSA – LSA	Lithics	122
IdIu-19	Willoughby 1993, 1996, 2001	MSA – LSA	Lithics	166
Total				333

Figure 2.39: Chamoto Hill.

Figure 2.40: Gully adjacent to Chamoto Hill.

Figure 2.41: Cobbles of chert located within gully at Chamoto Hill.

Figure 2.42: View of Chafukwa Hill from highway.


Figure 2.43: Fissile chert outcrop on Chafukwa Hill.


Figure 2.44: Mapogoro rockshelter.

Mapogoro Site No.1 is a rockshelter with very sparse lithics and pottery on the surface (Figure 2.44). All of the artifacts are heat-altered; as with most regions in southern Tanzania, slash-and-burn agriculture is practiced. This activity would produce heat sufficient to visibly alter the artifacts. No cherts were found despite the numerous vesicles in the volcanic rocks comprising the rockshelter (Figure 2.45). Mapogoro is located within walking distance (less than 1 km) from IdIu-17 (Njelenje 6), an LSA site identified by Willoughby in 1990. The site was revisited and revealed significant disturbance. The entire area underneath the rockshelter overhang had been dug out by local peoples. Human skeletal material and lithic artifacts were strewn about the area adjacent to the excavated area.

In 1990 Willoughby recorded and excavated IdIu-19 (Njelenje 8). IdIu-19 is an MSA site located within a steep-walled valley (Figure 2.46). A capping layer over several metres of fine grained volcanic deposits is formed by small quartz pebbles interspersed with tabular slabs of cryptocrystalline silica (cherts) and cobbles of volcanic rocks (Willoughby 2001b:7) (Figure 2.47). Willoughby's (1993:13; 1996a:64) analysis of these artifacts found a high percentage of whole flakes manufactured from a variety of raw materials suggesting that it was a site for primary core reduction. Willoughby (1993:13) further argues that the site was used as a quarry as the "quartz pebbles were used as cores, as were small slabs of locally available chert, and possibly transported volcanic materials as well."


Figure 2.45: Vesicles in the volcanic rockshelter.


Figure 2.46: Overview of IdIu-19.


Figure 2.47: Surface scatter at IdIu-19.

2.4 Summary and Conclusions

There were 967 lithic artifacts and stone raw material samples collected for analyses during the 2008 field season in addition to the 31,175 artifacts recovered in 2006 from Magubike, Mlambalasi, and Kitelewasi. The nature of these assemblages, the sample taken, and the attributes used in this study during analysis are discussed in the following chapters.

The importance of understanding the environmental context of one's study region has herein been made clear. The strong emphasis placed particularly on climate is the result of numerous studies that argue a connection between climatic change events and hominid evolution, specifically the context of modern human origins. East Africa, and Tanzania in particular, may have had the ideal conditions amenable to human life and perhaps may even represent a refuge of sorts during the period(s) of both the rise of modern behavior and the establishment of modern human anatomy. This means that archaeological research focusing on the Middle and Later Stone Ages in this key region may be our only way to fully understand the origin of *Homo sapiens*.

The 2006 and 2008 fieldwork undertaken in Iringa Region was conducted first and foremost to find sites from this crucial period. Archaeological materials, including lithics, faunal and human remains, were collected for analyses so that research questions relating to the behavior of the people could be, hopefully, reconstructed and understood. As stated in previous chapters, the goal of this study is to examine lithic raw material acquisition and utilization and technological organization in part to reconstruct the human-landscape interaction. Thus understanding changes to/in the landscape itself, and the factors which affect the ability for humans to exploit resources, is imperative.

Chapter 3: Modernity Examined

3.1 Background: The Stone Age Africa Scheme

Before addressing modernity, it is imperative that the framework in which most Stone Age African archaeology is conducted is explained. In order to emphasise the distinctiveness of the African archaeological record from the European Palaeolithic model (Lower, Middle and Upper Palaeolithic), the Stone Age Africa scheme was devised (Goodwin and van Riet Lowe 1929). Based on material from South Africa, the Earlier, Middle, and Later Stone Ages (ESA, MSA, and LSA respectively) were first defined using typological and technological attributes of lithic artifacts (Goodwin 1928; Goodwin and van Riet Lowe 1929). The ESA includes both the Oldowan and the Acheulian. The MSA is characterized by flake and blade tools produced using a prepared core technique or by retouching flakes struck from radial cores; whereas the LSA features predominantly microlithic blade technology. The specific attributes of the lithic MSA and LSA assemblages are presented in Chapter 4.

3.2 Modern Human Origins

The how and when questions of modern human origins are becoming clearer as chronologies are refined and more evidence is found throughout the world; but it seems as though the more discoveries that are made, and the more data that is collected, the more unclear the question “what is modern” becomes. The term modern is applied to both anatomical and behavioral/cultural traits, but not without assumptions and problems. The problem of anatomical modernity can be traced back to the lack of a definitive type specimen for *Homo sapiens sapiens* (Chazan 1995; Ingold 1995). It also has its roots in how palaeoanthropology has borrowed techniques and methodologies for defining species from the biological sciences.

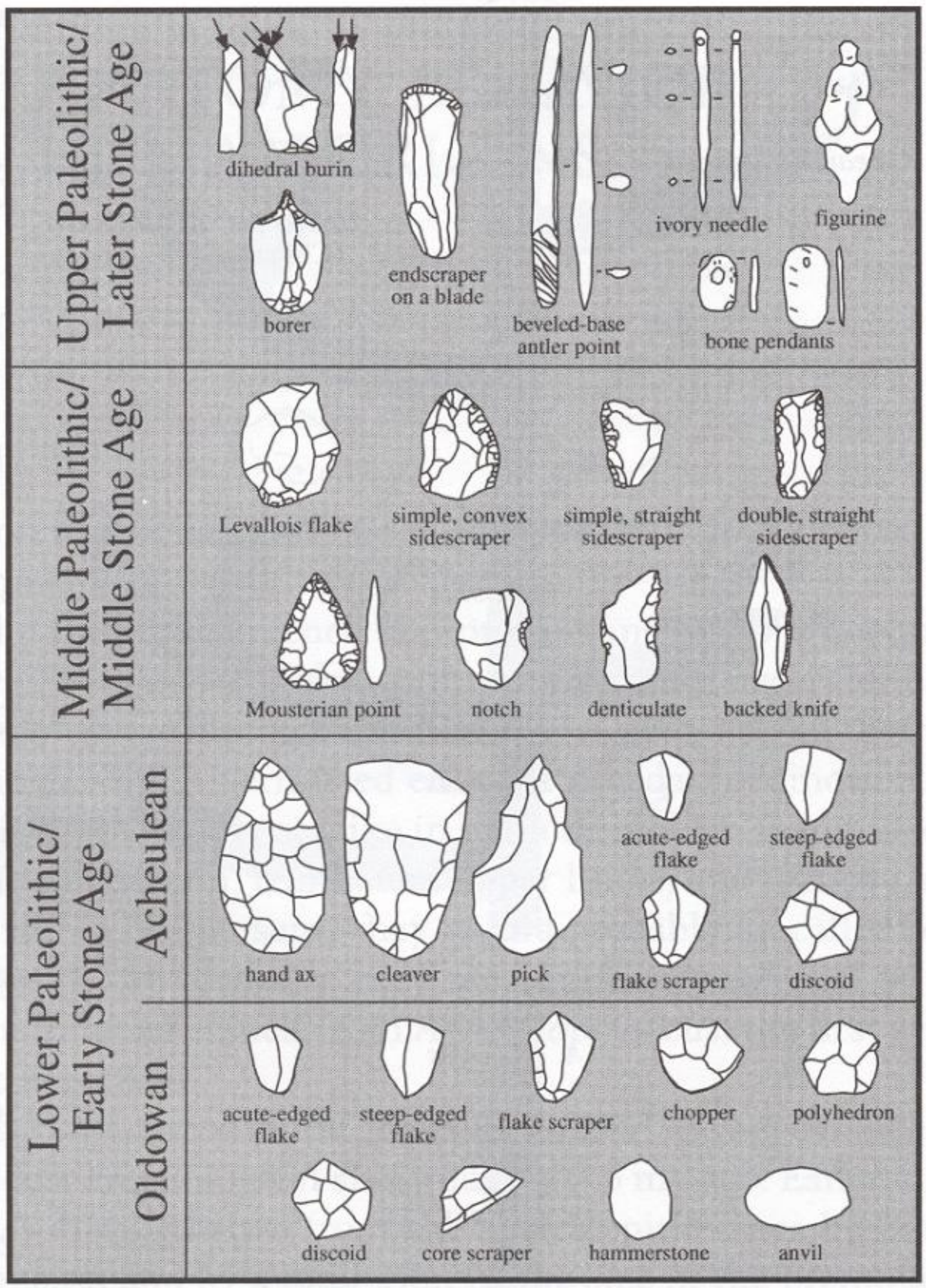


Figure 3.1: The African Stone Age Scheme (adapted from Klein 1999:576, Figure 8.2).

For example, although cladistic analysis is frequently used in developing hominid evolutionary sequences and in representing relatedness of hominid species, it is often done incorrectly; i.e., autapomorphies (derived traits unique to a group, not found in any other groups nor present in the last common ancestor) are used instead of synapomorphies (a derived character trait shared by two or more groups, thus inherited from a common ancestor for which it was an autapomorphy) (Gilbert and Burian 2003). Other problems are the result of this "crucial period of human prehistory" lying outside the range of reliability for standard dating techniques (McBrearty 1990:130). Here I will focus on the other application of the term modern – behavioral modernity. I will address the question what is modern behavior in order to deal with the larger question of how did anatomically modern humans become behaviorally modern?

The fossil evidence is clear that by at least 190 kya modern humans (*H. sapiens sapiens*) are present in Africa (McDougall et al., 2004). Modern humans do not appear outside of Africa anywhere, with the exception of Australia at ca. 63 kya (and that is if the dates are acceptable), before ca. 40 kya (McBrearty and Brooks 2000). The question of the origins of modern humans has led to the formation of several contrasting theoretical models (Aiello 1993:73-74; Stringer 2001, 2002a): the Recent African Origin, the African Hybridisation and Replacement, the Assimilation, and the Multiregional Evolution models (Figure 3.2 a-d). As all models accept Africa as our ancestral homeland, the debate lies in operational time scale (late Pleistocene versus Pleistocene in its entirety), how many migrations out of Africa occurred (just *H. erectus* during Out of Africa I or multiple migrations), and geography (one region of evolutionary origin for modern humans or many).

Recent African Origins or Replacement Model

The Recent African Origin, Replacement, Out of Africa II, or Mitochondrial Eve model argues that modern humans arose first in Africa by 100 kya and subsequently spread from there throughout the world (Figure 3.2a). Indigenous human populations were replaced by the migrating population with little, if any, hybridisation between the groups. This model has received considerable support from mitochondrial and nuclear DNA research (Cann et al.,1987; Cavalli-Sforza and Feldman 2003; Ingman et al., 2000; Stoneking and Cann 1989; Wilson and Cann 1992). Proponents of this model include Bar-Yosef (Bar-Yosef and Belfer-Cohen 2001), Deacon (1992, 2001), Klein (1992, 1995, 1999, and 2000), Rightmire (2001), Stringer and Gamble (1993), and Stringer (1992, 2001, 2002a, and 2002b). Following Clark (1992, 1997), advocates for replacement ignore grade/clade distinctions, emphasise cladogenic speciation, invoke splitter taxonomies (make a distinction between archaic *H. sapiens* and Neanderthals), and claim there was complete replacement of archaic *H. sapiens*, Neanderthals, and *H. erectus* with no admixture.

Multiregional or Regional Continuity Model

The Multiregional Evolution model denies a recent African origin for modern humans (Figure 3.2d). It stresses the role of genetic continuity over time and gene flow between contemporaneous populations, arguing that modern humans arose not only out of Africa but also in Europe and Asia from their Middle Pleistocene forbears. Developed primarily by Thorne and Wolpoff (Hawks and Wolpoff 2001; Kramer et al., 2001; Thorne and Wolpoff 1981, 1992; Wolpoff 1989, 1992; Wolpoff and Caspari 1997; Wolpoff et al., 2000, 2004), this model argues that the fossil record and archaeological record demonstrates regional continuity and that Africa had no special role in the later Pleistocene or influence in the process of modern human origins (Stringer 2001:71). Proponents of multiregionalism/continuity argue that genetic evidence does not support an out of Africa origin for anatomically modern *H. sapiens*. Instead it demonstrates the single, prolonged radiation out of African by *H. erectus* (following Nei's [1995] slower mtDNA substitution rate). In contrast to replacement advocates, continuity supporters emphasise glade/clade distinctions and anagenic speciation, invoke lumper taxonomies, and claim substantial genetic admixture between archaic and modern populations (Clark 1992, 1997).

Intermediate Models

The African Hybridisation and Replacement, and Assimilation models represent middle range models. The African Hybridisation and Replacement model is similar to the Recent African Origin model except it allows for a greater extent of hybridisation between migrating and indigenous pre-modern populations (Figure 3.2b). Bräuer's (1982) model, in essence, suggests the genes of living humans are virtually all derived from populations that lived only in Africa ca. 150 kya.

The Assimilation model concurs with an African origin for modern humans but it denies replacement, or population migration, as a major factor in the appearance of modern humans (Figure 3.2c). Rather, it emphasizes the importance of gene flow, admixture, changing selection pressures, and the resulting directional morphological change. It is an outgrowth of the Multiregional model (Smith et al., 1989). It is highly adaptationalist. Supporters of this model stress the key to understanding the evolution of modern humans is the study of adaptive advantages of modern human body form over that of our archaic predecessors (Aiello 1993). The rapid transformation from archaic to modern *H. sapiens* is explained from the selection for modern, gracile morphology (in genes already present in archaic populations from gene flow out of Africa) over the archaic, hyper-robust skeleton once the necessary technological stage was reached (Aiello 1993:79; Smith 1991). The most recent version of the Assimilation model, relying on the presence of a small amount of Neanderthal DNA in living Europeans and Asians is called "leaky replacement" (Gibbons 2011).

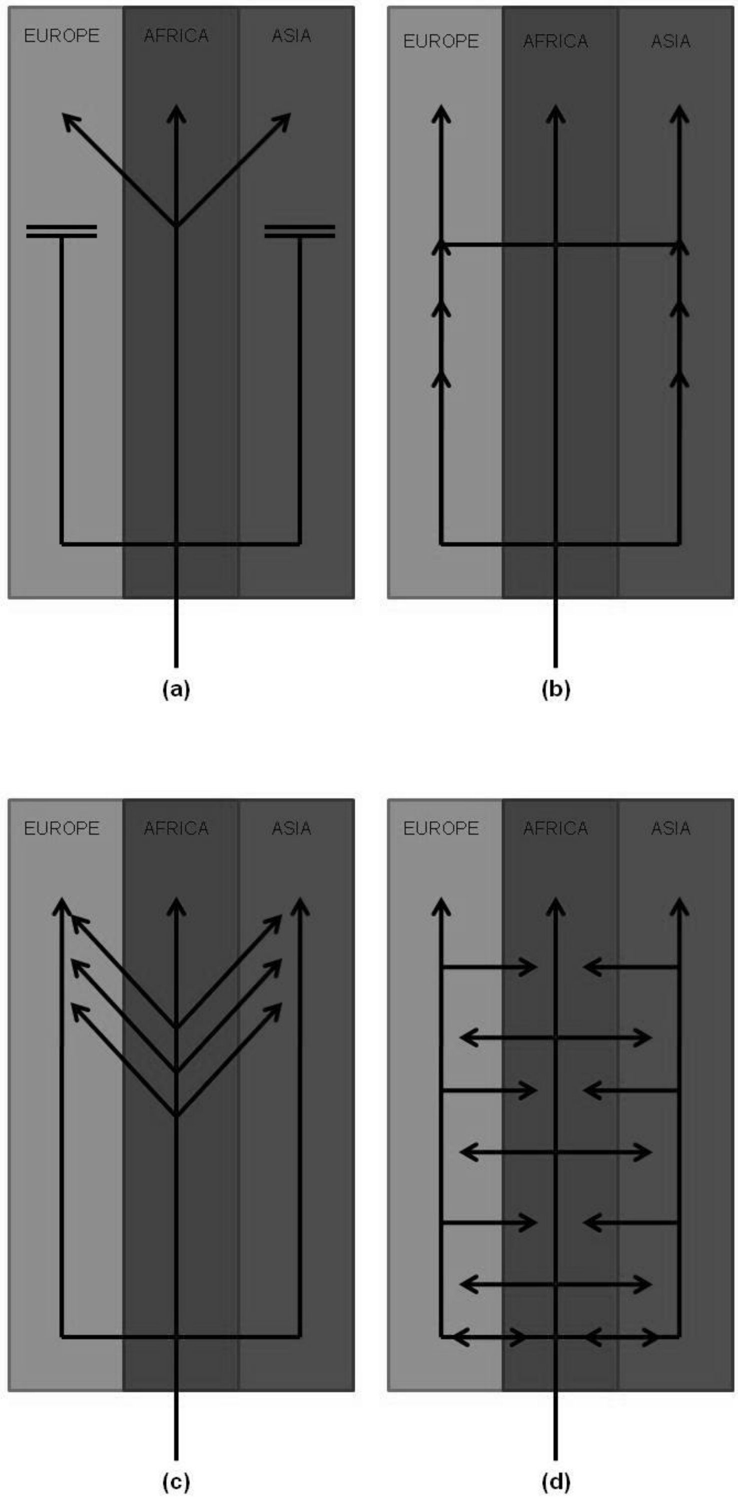


Figure 3.2: Models of Human Evolution: (a) African Replacement Model, (b) African Replacement with Hybridisation Model, (c) Assimilation Model, and (d) Multiregional Evolution Model.

Models of Modern Human Origins and Bias in Interpretation

An understanding of these differing models of modern human origins is necessary as the model to which a researcher ascribes creates a bias in their interpretation; i.e., Willermet and Clark's (1995) "paradigm crisis" in modern human origins research. Differences in the paradigms of modern human origins researchers result in a biased selection of specimens and/or variables used in the analysis (Willermet and Clark 1995:488). The bias in selection is extremely high. Most researchers from one paradigm are not using the same data to test their hypotheses as researchers from the other paradigm. The variables that a researcher chooses to measure tend to be weighted based on preconceptions of what is important. This is a long-standing problem in lithic analysis that is frequently debated. Sampling can also be biased; non-random sampling occurs when specimens are emphasised because of preconceived importance, especially those that support a particular theoretical position. Unfortunately, these paradigm-related biases are unavoidable. Data have no meaning independent of "a paradigm that defines and contextualises them" (Willermet and Clark 1995:488). Collection of additional data will likely just further complicate the issue. The only option is to make these biases explicit.

3.3 The rest of the world: The Middle to Upper Palaeolithic "Revolution"

The Middle to Upper Palaeolithic Revolution is a model that links behavioral innovation to a "cultural revolution" by anatomically modern humans in Europe around 40 kya (D'Errico 2003:188). It assumes behavioral modernity arose only in a single species as a result of a sudden change within anatomically modern humans in a limited area. The nature of this revolution is hotly debated (White 1982; Mellars 1989a; Bar-Yosef 1998a; Clark 1997; Klein 1999; McBrearty and Brooks 2000). Some propose a more gradual change over time, (Clark 1997; McBrearty and Brooks 2000), while others argue for an even earlier late Middle Palaeolithic appearance of innovations and shifts in social structure (Straus 2001) – thus both, effectively, are arguing against the idea of a revolution.

Revolution or not, the Upper Palaeolithic shows more rapid development in cultural and technological traits, and population growth, emergence of self-awareness and group identity, and distinct global effects in comparison to the slow pace of the Middle Palaeolithic (Bar-Yosef 2002:365). For example, while flake tools are the norm during the Middle Palaeolithic, blades are ubiquitous during the Upper Palaeolithic. Researchers often look for these traits in MSA assemblages as a means of establishing behavioral modernity during that period. I will return to a discussion of these traits shortly.

Important to this discussion, traits seen as diagnostic of behavioral modernity are those of the European Cro-Magnons and the Upper Palaeolithic. Mousterian (Middle Palaeolithic) assemblages are attributed to the Neanderthals (*H. neanderthalensis* or *H. sapiens neanderthalensis*). The Mousterian is parallel to the MSA, which was produced by anatomically modern *H. sapiens* in Africa at approximately the same time but are said to lack the hallmarks of modernity. This introduces the problem of the Neanderthals and their relationship to anatomically modern humans. I believe it is difficult to compare outright the assemblages attributed to the Neanderthals versus those produced by anatomically (and eventually behaviorally) modern *H. sapiens*. There is always the problem of who produced the tools that are recovered. Associations between fossils and assemblages are often tenuous at best. As of yet archaeologists have not recovered any hominid with a tool clutched in its hand. Further, whenever Neanderthals enter the discussion the issue of cognition always arises. Positions on the cognitive capacity of Neanderthals are strongly biased by the underlying modern human origins model of the researcher. The "paradigm bias" makes its appearance in this issue as well. Views have changed significantly in the past fifty years. Neanderthals are no longer seen as dumb brutes; instead they are argued to have cognitive skills comparable to modern *H. sapiens* (Speth 2004; Wolpoff et al., 2004).

Evidence that Neanderthals were present at the same time as anatomically modern humans, but on different continents, is considered unequivocal; further, there is also the potential for numerous species to be present in the same regions at the same time. As mentioned previously in the outline of modern human origins models, the number of hominid dispersals out of Africa into Europe is debated. The number of dispersals with successful colonisations ranges between a single event (e.g., Wolpoff 1989), through two events involving *H. ergaster/erectus* and *H. sapiens* (e.g., Klein 1999), up to four involving *H. ergaster/erectus*, *H. heidelbergensis*, *H. helmei*, and *H. sapiens* (Foley and Lahr 1997). Finlayson (2004:58), using an ecological and evolutionary perspective, suggests there are major climatic episodes that correlate with colonisation and extinction events. This correlation supports theories suggesting at least three colonising events occurred involving *H. antecessor (H. erectus)*, *H. heidelbergensis*, and *H. heidelbergensis/helmei* (anatomically modern *H. sapiens*).

Problems with Correlating the African Stone Age and the European Palaeolithic Models

The MSA-LSA transition and the Middle to Upper Palaeolithic "revolution" are important because they coincide with the appearance of anatomically modern *H. sapiens* throughout the world. If one subscribes to the Recent African Origins model of modern human origins than this time period is when anatomically modern *H. sapiens* expands out of Africa to replace, with or without hybridisation, pre-modern populations in the rest of the world. If Multiregional Continuity is to be accepted, then this is the period when the first anatomically modern humans appear, having evolved from pre-modern populations native to that region. The significance of the revolution/transition has been maintained in the literature based on the rapid rate of innovation and change that is argued to be indicated in the archaeological record. Prior to the revolution/transition human anatomy and behavior developed hand-in-hand, very slowly over a long time (around 150 kya during the MSA for example); whereas following the revolution/transition, evolution of anatomy all but stops, while behavioral and cultural change accelerated drastically (Klein 1992:12).

The problem, one with great ramifications for the issue of behavioral modernity, is that the “revolution” that occurs in Europe and the rest of the Old World at approximately 40,000 B.P. did not take place in Africa. Instead a more continuous technological change is evident; but because a fully developed signature of modern human behavior is present in the LSA, the MSA-LSA transition is correlated with the Middle to Upper Palaeolithic and the emergence of modern human behavior (McBrearty and Brooks 2000:457). However, this rapid rate of change may only be an artifact of a more refined chronology because sites and artifacts from this time period can be easily, and more reliably, dated. Further these sites may be more visible because they are more recent and better preserved.

Nonetheless, the MSA-LSA transition cannot be equated with the Middle to Upper Palaeolithic “revolution.” The models that are derived from the “unique” record of European prehistory do not (and cannot) explain events in Africa where the origin of modern humans “actually occurred” (McBrearty and Brooks 2000:454). Not only do anatomically modern humans appear in Africa at least 60,000 years before the MSA-LSA transition, they are associated with both industries suggesting they were behaviorally indistinguishable from their non-modern Eurasian counterparts, the Neanderthals (Klein 1995; Reynolds 1991). In terms of the archaeology of these periods, the European Middle Palaeolithic/Upper Palaeolithic distinction is made on the basis of flake versus blade technology. African MSA assemblages, as discussed above, have both flake and blade tools (Willoughby 1993:6). Moreover, blades have been recovered from the Kapthurin Formation at Lake Baringo, Kenya that date to the late Acheulian (McBrearty 1999). The large number and careful design of retouched points, and the relative lack of emphasis on scrapers, are major differences between African MSA and European Mousterian assemblages (McBrearty and Brooks 2000:496). As a consequence, Middle Palaeolithic typologies (such as that of Bordes) can be of limited use in describing some MSA assemblages. Additionally, the Middle to Upper Palaeolithic transition in Europe is a change from mode 3 (flake tools) to mode 4 (blade tools from prepared cores) technology, whereas in Africa, modes 3, 4, and 5 (microliths and composite tools) are already present in the MSA. Discussion of these modes occurs in Chapter 4. Finally, the MSA-LSA transition may have occurred as much as 25 ky later than the MP/UP revolution (Stringer 2002).

3.4 Discussion: What is modern behavior?

Anatomical versus behavioral modernity

According to Bräuer (1989) and McBrearty and Brooks (2000), the anatomical evolution of *H. sapiens* is divided into three grades: (1) Early archaic *H. sapiens* – 'developed *H. erectus*' which exhibits primitive features as well as derived features of *H. sapiens* including *H. erectus, H. ergaster, H. louisleakeyi* and *H. rhodesiensis;* (2) Late archaic *H. sapiens* – intermediary phase between early archaic *H. sapiens* and early anatomically modern *H. sapiens* including *H. heidelbergensis, H. helmei* or *H. sapiens;* and (3) Anatomically modern *H. sapiens*. Anatomically, the emergence of modern humans in sub-Saharan Africa is documented by reduction in overall facial projection and brow size, change in elevation of the frontal profile, increase in parietal length, and changes in the shape of the occipital (Rightmire 1989). These changes do not parallel those occurring in Europe (Rightmire 1984; Trinkaus 1986). Figure 3.3 illustrates the correlation of fossil and archaeological evidence throughout the Old World. As previously stated, the fossil evidence is clear that by as early as 190 kya anatomically modern humans are present in Africa, but do not leave Africa until between 60 to 40 kya. Thus, features diagnostic of anatomical modernity appear in conjunction with the start of MSA technologies (McBrearty and Brooks 2000:486). This lack in the coincidence between the first appearance of modern anatomy and the first appearance of the LSA/UP raises the question of whether early anatomically modern *H. sapiens* were actually fully modern (Aiello 1993:81). Klein (1999:512) argues:

> Based on what early near-modern Africans did and did not do, it seems reasonable to conclude that they were cognitively human, but not cognitively modern in the sense that all living people are. It was only when they became cognitively modern, with the fully modern capacity for culture, that they obtained an adaptive advantage over their archaic Eurasian contemporaries.

The relationship between anatomical and behavioral modernity is posited in two main ways: (1) that the appearance of modern behaviors preceded or accompanied the appearance of modern anatomy – including suggestions that these modern behaviors perhaps directed anatomical change (Eswaran 2002; Klein 2000; McBrearty and Brooks 2000), or (2) that there is no connection between anatomical and behavioral modernity – that they happened independently with neither one influencing the other. Recent genetic data suggests there are few correlations between genetics and behavior, which therefore, supports the second hypothesis. However, morphological change can have behavioral implications. Harrold (1992:220-221) lists six morphological changes across the Middle to Upper Palaeolithic transition. He then gives for each its broad behavioral implications, the cultural innovations suggested to account for the behavior change, and the archaeological correlates for the innovations (Table 3.1). This correlation fails to account for what would necessitate morphological changes in the first place. Behavioral changes act as catalysts for morphological change, but the catalysts for the behavioral adaptation are not taken into account.

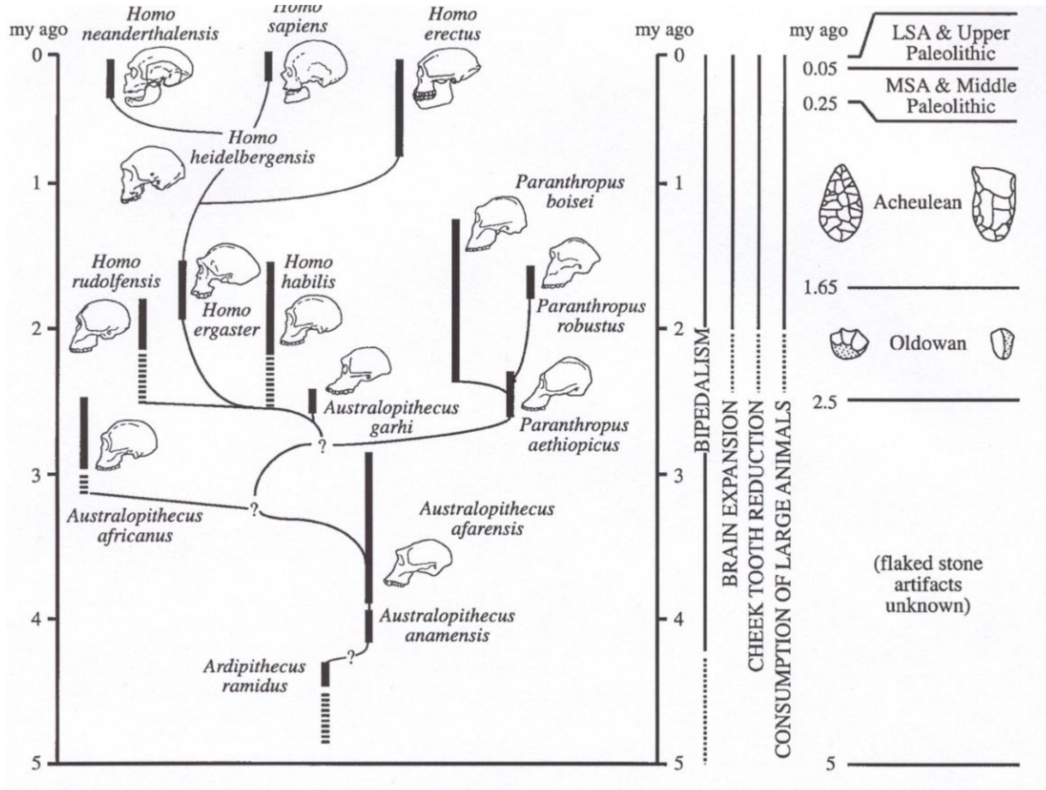


Figure 3.3: Correlation of fossil and archaeological evidence (adapted from Klein 2000:18, Figure 1).

Table 3.1: Inferred links between morphological changes, behavioral and cultural developments, and archaeological evidence (adapted from Harrold 1992:220, Table 1).

Morphological Changes	*Behavioral Implications*	*Suggested Cultural Developments*	*Proposed Archaeological Correlates*
1. Reduced anterior dentition, facial prognathism/massiveness, and nuchal and related structures	Less use of anterior teeth as tools Less forceful and repetitive chewing	a) More efficient, task specific tools b) Improved food processing facilities and tools	a) Greater typological and technological diversity b) More efficient hearths
2. Reduced upper body massiveness	Less strength habitually used in manipulative tasks	a) As in 1a b) Tools and techniques for 'stand-off' hunting	a) As in 1a b) Projectile points, atlatls; occurrence in archaeofaunas of species usually snared or trapped
3. Changed thumb phalangeal proportions and less hand robusticity	More use of precision grip, less use of power grip	a) As in 1a (especially in tools requiring fine manipulative ability)	a) As in 1a above (especially blades and bladelets)
4. Reduced lower limb robusticity	Lower levels of sustained locomotor activity	a) More systematic, less opportunistic foraging, based on extensive environmental knowledge, facilitated by more complex social organization	a) Evidence from faunal and spatial analysis of logistically-organised procurement systems b) Evidence of higher populations c) Notational systems, art; complex burials; artifact style zones
5. Longer legs and longer distal segments	Cultural substitutes for anatomical adaptations to cold	Better heat conservation through improved clothing, hearths, shelters	Bone pins; more efficient and complex hearths; more numerous and thermally efficient shelters
6. Higher, rounded cranium	Longer period of learning; greater amount of acquired cultural information	Information storage and transmission systems; more complex social organization	Notational systems, art; complex burials; artifact style zones

Behavioral and Technological Modernity

As both the MSA and LSA are associated with *H. sapiens* in Africa, and there is at no time an indication of a sudden change of the magnitude of the European Middle/Upper Palaeolithic transition, one must ask if the transition between the MSA and the LSA is a technological or a behavioral one (Willoughby 2002)? Arguments of significance of particular attributes aside, a number of general characteristics or traits have been accepted as indicators of modern behavior (Henshilwood and Marean 2003; Klein 1995; McBrearty and Brooks 2000; Reynolds 1991):

- new lithic technologies – including blades, microblades, backing, as well as, hafting and composite tools;
- innovation rate – the "substantial growth in the diversity and standardization of artifact types (and) rapid increase in the rate of artifactual change through time and degree of diversity through space" (Klein 1995:168); includes special purpose tools, geographic and formal variation in formal categories;
- diversification in the materials used to produce tools beyond lithics – bone, antler, ivory, shell;
- portable and parietal art;
- site phenomena – reoccupation, greater size, frequency, complexity/structured use (spatial organization of floors including hearths and structural ruins);
- economy, exchange and mobility – procurement, exchange and transportation of large quantities of high quality raw materials over large distances (hundreds of kilometres);
- symbolic behavior as expressed through ceremony and ritual (art and elaborate burials), group and self identification, regional artifact styles, use of pigment, ornamentation, jewellery and personal adornment, representation of humanoid and animal forms;

- range extension to previously unoccupied regions indicating adaptation to diverse environments – intensification of resource extraction (aquatic and vegetable resources), increase in diet breadth, scheduling, and seasonality in resource exploitation.

I should note that although some of these characteristics can be found in the MSA, a subject that will be subsequently discussed, they are still Upper Palaeolithic attributes. D'Errico (2003) has reservations concerning the creation of lists of archaeological signatures of behavioral modernity. He is critical of the "criteria to find the criteria" claiming they are rarely made explicit, and often demonstrate the creation of a theory to "fit one's expectations" (2003:189). However, I argue that these lists are a useful way of discussing modernity and a means to better understand the appearance of modern behavior. Following McBrearty and Brooks (2000:492), I will correlate these characteristics under four main categories:

- abstract thinking – "the ability to act with reference to abstract concepts not limited in time or space",
- planning depth – "the ability to formulate strategies based on past experience and to act upon them in a group context",
- behavioral, economic and technological innovativeness,
- symbolic behavior – "the ability to represent objects, people and abstract concepts with arbitrary symbols, vocal or visual, and to reify such symbols in cultural practice."

These characteristics leave "tangible traces" in the archaeological record (Table 3.2).

Table 3.2: Archaeological signatures of modern human behavior (adapted from McBrearty and Brooks 2000:492, Table 3).

Ecology
Range extension to previously unoccupied regions
(tropical lowland forest, islands, the far north in Europe and Asia)
Increased diet breadth

Technology
New lithic technologies: blades, microblades, backing
Standardization within formal tool categories
Hafting and composite tools
Tools in novel materials, e.g., bone, antler
Special purpose tools, e.g., projectiles, geometrics
Increased numbers of tool categories
Geographic variation in formal categories
Temporal variation in formal categories
Greater control of fire

Economy and social organization
Long-distance procurement and exchange of raw materials
Curation of exotic raw materials
Specialised hunting of large, dangerous animals
Site reoccupation
Intensification of resource extraction, especially aquatic and vegetable resources
Long-distance exchange networks
Group and individual self-identification through artefact style
Structured use of domestic space

Symbolic behavior
Regional artifact styles
Self adornment, e.g., beads and ornaments
Use of pigment
Notched and incised objects (bone, egg shell, ochre, stone)
Image and representation
Burials with grave goods, ochre, ritual objects

Ecological traces reflect the ability to colonise and exploit new environments and resources. Technological traces reveal inventiveness, and like ecological traces, innovation, and planning depth. Economic and social traces demonstrate formalized relationships between individuals and groups, the development and use of systematic plans, and the application of past individual and group experience to new (or foreseen future) situations. Symbolic traces show a capacity for abstract thought and the aptitude to communicate these concepts, the ability to impart meaning to events and objects.

Ecological Signatures

All of the ecological signatures of behavioral modernity are evident in the archaeological record starting in the MSA. With the MSA is an expansion of populations into challenging habitats including deserts and forest by means of improved technology. This use of technology as a means of adaptation represents cognitive sophistication and social complexity (Jones 1992; Klein 1999; McBrearty and Brooks 2000; Torrence 1983). MSA sites are more numerous than earlier sites (Masao 1992). It has been suggested that this may result from either preservational bias or an increase in population size. Nevertheless, the extremely wide distribution across the African continent and adaptation to challenging habitats would suggest to some that population expansion is not sufficient to explain the abundance of MSA sites (McBrearty and Brooks 2000).

Desmond Clark (1964, 1965, 1971, 1982, 1988, and 1992) believes that the expansion into uninhabited regions demonstrates the “improved adaptive abilities” of MSA hominids over their ESA counterparts. Associated with movement into new regions and adaptation to new environments is an increase in diet breadth. The exploitation of new environments, such as coastal areas and their unique resources for example, is facilitated by the development of new technologies. However, technology is emphasised by archaeologists because it is highly visible in the archaeological record whereas other key learning and adaptive behaviors, for example what can be eaten and how it is to be acquired, processed and prepared, are not.

Economic and Social Signatures

I would argue that a considerable economic and social signature is the long distance procurement and exchange of lithic raw materials. Raw material, in terms of availability, abundance, quality and distribution, is the most significant constraint in determining MSA assemblage composition , in fact, is the greatest determinant of lithic production technology period (Andrefsky 1998). The quality, size and form of the raw material was a determining factor in what method – Levallois or discoidal – was used in flake production. Clark (1988:295) argues that most of the regional continuity seen in retouched forms and techniques is likely derived from the raw material used. For example, quartz was more likely to be used to produce flakes, rather than blades, using discoid cores. In contrast, obsidian or fine grained chert would most likely be used to produce blades and/or points using a Levallois technique because of the increased workability of fine-grained materials versus coarse-grained ones. The use of different techniques to obtain separate products from raw material relates to the nature of the raw material itself. As I will argue in a subsequent chapter, raw material availability, abundance, quality, and distribution are significant determinants of assemblage composition.

Procurement strategy and group mobility will also affect raw material utilization. As the mobility of a group decreases, the distance to a new material source will become relevant in the determination of raw material value (Morrow and Jefferies 1989:29, 30). Therefore, the procurement and technological strategies of sedentary groups differ from those of mobile populations. Evidence suggests that residential territories during the MSA were large (McBrearty and Brooks 2000:531). The first evidence for raw material transport beyond the 100-120 km barrier occurs in Africa during the MSA (Marwick 2003:72) including the presence of exotic obsidians in east Africa indicating trade/exchange distances exceeding 300 km (McBrearty and Brooks 2000:531).

Marwick (2003:74) argues that this long distance exchange could only have been achieved by the specific cognitive and linguistic abilities of modern humans. Féblot-Augustins (1993) examined regionally patterned behavior in mobility strategies and the transportation of raw material during the Middle Palaeolithic in Europe. Working on flint assemblages and quarry sites from the Dordogne, France, and Poland, she found differences in the distances travelled are not reflective of differences in planning depth. Rather the distance travelled depended on raw material availability. The same basic level of capacity for planned technoeconomic behavior is evident in all populations. Differences are the result of inter- and intra- regional environmental variability. McBrearty and Brooks (2000:532) suggest that long distance exchange, maintained by the use of symbolic systems, would have acted as a risk-management strategy. This would effectively created an increased population during the MSA. Kin alliances through marriage and the like would have been extremely important as they would have ensured access to resources.

It is also highly probable that ecological, socioeconomic, prestige and ideological constraints could have an impact on raw material availability. Raw material may have been unobtainable owing to an inability to access the source owing to natural processes (change in water level or geologic disruption) or socioeconomic processes (source area may be under control of other group, access may be limited to certain lineages, etc). However, climatic differences do not seem to have any influence on lithic reduction technique or toolkit composition in France during the Middle Pleistocene (Byrne 2004:362). Additionally, aesthetic values and ideological connections to the land have great influence on the selection and use of particular raw material and its sources. Often the preferences have little to do with the working quality of the material.

Binford (1989:35) has stated that until modern behavior developed in the Upper Palaeolithic (LSA) there was a lack of mobility, group size flexibility, and planning depth, and minimal organization of technology. However, selectivity in raw material utilization has been traced back to the earliest stone toolmakers as a significant component of Oldowan technological organization (Stout et al., 2005). Examining selectivity illustrates sophistication, in terms of planning and foresight, and mobility strategies. Martínez (1998:25) concluded that raw material use and tool production during the Middle Pleistocene of Spain is "far removed from purely 'opportunistic behavior', and can be reasonably described as showing forethought and planning." As previously mentioned, MSA peoples were maintaining large territories and long distance exchange networks. Thus, I would completely disagree with Binford. Mobility, and group size flexibility and planning depth are present at least as early as the MSA, and include the complex organization of technology.

Along with complex organization of technology, there are a number of unambiguous examples of complex social organization. These include intricate site structure and modification, and hunting practices. Notably, there is MSA evidence for the extensive quarrying for flint in Egypt (Vermeersch et al., 1990), the deliberate arrangement of large piles of stones, structures at Mumbwa Cave (Barham 1996), and intentionally constructed stone-lined hearths suggesting similar reuse and a formal conception of domestic space (McBrearty and Brooks 2000:518).

The number of projectile points in MSA assemblages throughout Africa indicates deliberate hunting (Bushozi 2011. This is further supported by analysis of cut marks on bone. Not only is hunting evident but there is "good evidence that MSA hunters did not confine themselves to docile prey species or to juvenile targets" (McBrearty and Brooks 2000:508). This indicates a level of sophistication in terms of mobility and planning depth.

Symbolic Signatures

Byers (1994) states that symbolic culture governs behavior. Symbols create meaning by representing something beyond itself. They underlie language, and many aspects of social structure and technology (Chase 1991). The identification of symbolism in lithic artifacts is a very difficult process. It is linked to the issue of stylistic variation – how style contributes to information exchange and carries meaning beyond itself (A.M.B. Clark 1999:104).

According to Wiessner (1983:256), style is the "formal variation in material cultural that transmits information about personal and social identity." However, Sackett (1973, 1982, 1985, and 1986) argues that style does not necessarily reflect a conscious assertion of group identity but rather represents the choices made by the artisan within the limitations imposed by mechanics and raw material. The choices that are made are bound by what is culturally acceptable to the groups at the time of manufacture. For example, points are thought to encode stylistic information because point design is tightly constrained by mechanics (aerodynamic and hafting requirements) therefore successful designs would be replicated, and within groups, sharing or exchange of projectile points imposes design limits as to what is acceptable (McBrearty and Brooks 2000:498). Thus, one can see pronounced stylistic variation within the MSA of Africa just in projectile point design and form.

Choice is the key, as it truly represents style. People use the same styles because they learned to manufacture and use items in specific ways; thus, similar kinds of artifacts reflect common and shared experiences. Style therefore does play a role in the formation and maintenance of social boundaries, and variation in style may serve to integrate or differentiate groups (Cross 1983:100). Lithic artifacts, because they are portable and may be expected to be present in boundary maintaining situations (Cross 1983:101), may also serve to encode messages (Cross 1983; Gero 1989).

How style is inferred from lithic artifacts is contentious. Conkey (1978:61) proposes that before stylistic variability can be examined in material culture, the "potential sources of variability among the products of the particular sociocultural system in question…and in which classes and in what attribute of material culture that stylistic treatment would be most plausible manifest and why" must be understood. This will ensure that stylistic behavior is the plausible source of the stylistic variability. Conkey (1978:61) also stresses that it must not be assumed that stylistic behavior is operative and manifest in the components of the archaeological record that are most often available for analysis.

Inevitably, the issue of style versus function arises. Barton (1988, 1990), Dibble (1987), and Nelson (1991) discuss this issue of style versus function and the suggestion that patterns between morphology and function can be determined. The problem with the style versus function debate is that style is "so nebulous in its usage that it is often discussed without being defined" (Cross 1983:99). Style is often used interchangeably with design. Although the examination of style offers a "complementary approach to the comparative mechanical efficiencies of lithic artifacts" in studying social change, there are a number of different problems that hinder the application of style to material culture (Cross 1983:99). First, style is often a residual category; it is used to "subsume variation for which function cannot be inferred." Second, it is "unmanageably multidimensional." Third, it has little functional value (Cross 1983:99). However, as stylistic behavior plays an important role in symbolising behavior, and is a function of prestige and/or ideological constraints, it is an important consideration when examining behavioral modernity.

Chase (1991) argues three aspects of artifact manufacture – style, imposition or arbitrary form, and standardization – can be used to infer symbolising behavior. The connection of these aspects to symboling is different for each one. For style, it is because, as discussed above, there is a close link between symbolism and style. The imposition of arbitrary form on material is connected because symbols themselves are arbitrary. Language itself is the result of symbols but also involves the imposition of arbitrary form on sound. Some researchers see an intrinsic link between language and symbolic behavior with the origin of modern human behavior (Chase 1991; Chase and Dibble 1987), while others do not (Chazan 1995; Duff et al., 1992). The first appearance of language is a key issue specifically because of the role it plays in transmission of culture.

Evidence for symbolism in the MSA is significant. It includes the wide range of stylistic variation seen in projectile points, body ornamentation, the use of ochre, intentional burials with grave goods, and incised bone, stone, and eggshell (Lindley and Clark 1990; McBrearty and Brooks 2000). Following Sackett (1982, 1985), the presence of distinct regional forms during the MSA suggests the occurrence of choice in the selection of final form thus stylistic behavior. However, functional and technological explanations for this variation cannot be ruled out.

Burials have a symbolic component when the intentional placement of the individual in an enclosure is evident, and when there is unequivocal evidence for the intentional inclusion of artifacts as grave goods (Duff et al., 1992:216). The earliest evidence for intentional burials, dating to ca. 90-120 ka by ESR, are those of *H. sapiens* at Jebel Qafzeh in the Levant (McBrearty and Brooks 2000:519). At least one, Qafzeh 11, may be associated with grave goods. In Africa, deliberate burials of Middle Pleistocene hominids are absent, and evidence for deliberate internment by *H. sapiens* is controversial (McBrearty and Brooks 2000:520). Cannibalism may be present as has been suggested from cut-marks on the temporal bone of the Bodo cranium, and at Klasies River.

Body ornamentation in Africa predates that of Europe by tens of thousands of years (McBrearty and Brooks 2000:521). Bone pendants and ostrich egg shell beads are known from numerous MSA assemblages in both South and Eastern Africa. Evidence of body ornamentation has been dated to at least 130 ky.

Other incised and notched objects, including bone, ochre, and shell, are known from a wide range of sites. Nodules of ochre have been recovered with striations, faceting, and abraded surfaces from Qafzeh and Klasies River Mouth (Lindley and Clark 1990). Numerous sites in South Africa have clear evidence of ochre processing and use (Watts 2002; Wadley et al. 2009, 2010b). The systematic and controlled use and processing of pigment, specifically that of red ochre and hematite, appears to be widespread, and have great antiquity, in Africa (McBrearty and Brooks 2000:526). The particular uses of pigment are contested. Wear facets on some pieces have their use, in some instances, as pencils (Wurz 1999). Palates and grinding slabs for pigment have been recovered from a few MSA assemblages.

In sum, some symbolic characteristics of behavioral modernity, like art, image, and representation, are absent from the MSA. However, there is evidence for symbolic behavior from the presence of regional artifact styles, body ornamentation, use of pigment, incised and notched objects, and burials with grave goods. The presence of these symbolic signatures not only suggests behavioral modernity during the MSA but the continuity of modern behavior across the MSA/LSA as well.

Technology Signatures

Standardization "incorporates the notion that a product has low variability in characteristics that define the product" where products of technology are considered to be standardized when they "exhibit a common set of characteristics which vary little, if at all, from each other" (Marks et al., 2001:20). Marks et al., (2001:20) argue that in order for standardization to be measured three things need to be determined: (1) the significant/relevant characteristics of the product, (2) a metric for measuring the degree of standardization (i.e., variability), and (3) a method for objectively comparing variability between assemblages in a way that can be replicated. The ability to measure the relative presence or absence of standardization in the manufacture of material culture important for interpreting variation in Pleistocene assemblages (Conkey 1978:71).

In lithic tools, standardization is measured in terms of product and process – what is produced and what process (technique) is used to produce it. Examining standardization implies that a conceptualized end product via a conceptualized technique that is characteristic of a group of individuals exists. This cognitive ability to conceptualize or objectify is present in the Levallois technique (Conkey 1978:70-71). Further, a precise means of communication, of information transmission and exchange, is necessary in order to maintain standardization by a population of tool makers.

Standardized production permits highly efficient use of raw material. A smaller weight is needed to produce tools sufficient to meet anticipated needs and more usable cutting edge per unit mass is obtained. Thus, formalized tool production technologies are more portable because a fixed set of needs are fulfilled with fewer tools made from a smaller weight of raw material (Parry and Kelly 1987).

Standardization is supposed to have originated during the Upper Palaeolithic; thus its incidence in an assemblage is used as an indicator of modernity. Further, tool standardization has been used to suggest a material culture manifestation of symbolic behavior and language (Byers 1994; Chase 1991), and the presence of mental templates (Mellars 1989b). Degree of standardization is affected by intensity of tool use and rejuvenation (Dibble 1995), constraints imposed by raw material including proximity, availability, abundance and quality (Andrefsky 1991, Jeske 1989), responses to different environments and resource conditions (Kuhn 1994, 2004), and individual flaking ability (White and Dibble 1986). Not all of these factors can be seen in archaeological contexts (Marks et al., 2001).

Standardized core technology is utilized in the production of blades and microblades. Using the presence of blades, microblades, and backing produced by standardized core technology as a feature of behavioral modernity is widely debated. Bar-Yosef and Kuhn (1999:322) argue that there is “no justification” for linking blade production technologies to “any aspect of hominid anatomy of to any major change in the behavioral capacities of hominids." D'Errico (2003:192) agrees stating "the occurrence of blade production…is better explained as the expression of local tradition than as a reflection of cognitive evolution." Blade industries have tremendous time depth – they appear long before other indicators of behavioral modernity and/or the appearance of anatomically modern humans. In East and South Africa, blades are found in assemblages as early as the Acheulian, as well as, in significant numbers during the MSA; and various members of the genus *Homo* could be responsible for the production of blades. Further, Palaeoindian populations in North American and Australia failed to produce blades at all, living as successful foragers with "only" flakes and bifaces (Bar-Yosef and Kuhn 1999).

Blade production represents both standardized and formalized tool production. Raw material is a major constraint in blade production. Often argued is the idea that blades are a more efficient use of lithic raw material as they represent means of maximizing usable cutting edge and usable end products. However, Eren, Greenspan and Samson (2008) have effectively challenged this argument.

The use of hafting and composite tools requires interchangeable parts of which blades and microblades are ideal. Hafting was "routine" practice during the MSA, as evidenced by patterns of retouch on points (McBrearty and Brooks 2000:497).

The other major technological signature of behavioral modernity present in the MSA is bone tools. McBrearty and Brooks (2000:503) suggest that the presence of bone working in the MSA is easily explained if it bone working is connected to the development of projectile technology. Evidence for a continuous bone working tradition goes well back in the Pleistocene.

Summary

Many characteristics deemed "critical" to modern human culture are often rare in the MSA, serving as fuel for arguments of Africa as a "cultural backwater"

– the “place that gave rise to humanity, but failed to nurture its further development” (McBrearty and Brooks 2000:457). Indeed African Stone Age archaeologists are divided between those who feel the LSA marks the beginning of behavioral modernity, and those who feel some MSA sites have attributes of behavioral modernity (Willoughby 2001b:34). On the basis of the argument and evidence presented above, there is unequivocal evidence for the presence of modern behavior in the MSA. Most of these behavioral innovations have considerable time depth (Figure 3.4). However, if one considers the extreme time depth (up to 280 kya) of some of these ‘modern’ behaviors, there is the possibility that they could be attributed to archaic *H. sapiens*, or even to *H. erectus*/*ergaster*.

It can, therefore, be concluded that modern behavior, like modern anatomy, made its appearance during the MSA in Africa, and that there was continuity from the MSA to the LSA. Arguments otherwise are just to the degree of modernity that is demonstrated. But is the full suite of modern behaviors necessary before a species can be considered modern? I would argue that as most modern foraging societies would fail the test, as no extant or ethnographic population demonstrates the all the necessary diagnostic attributes, that the full suite is not necessary. Rather the full suite argument is a direct result of researchers pushing their model of modern human origins.

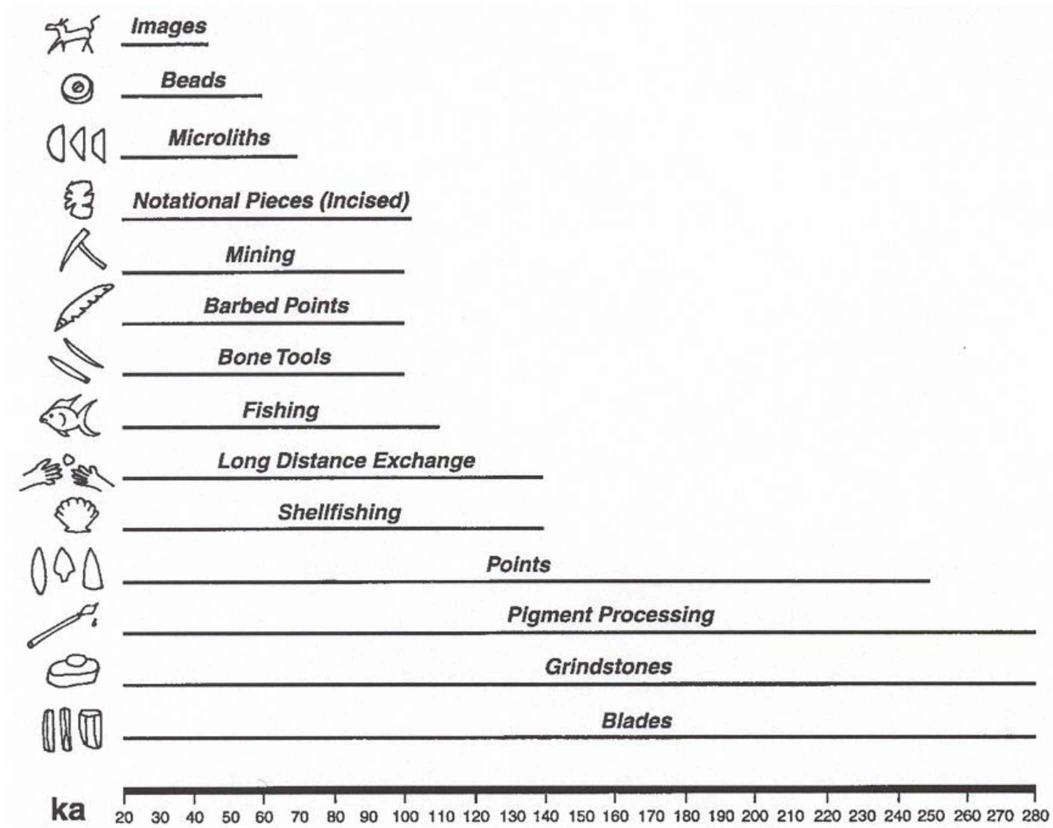


Figure 3.4: Modern behaviors and their time depths in Africa (adapted from McBrearty and Brooks 2000:530, Figure 13).

3.5 Discussion: How Did Anatomically Modern *Homo sapiens* Become Behaviorally Modern? The Relationship Between Behavioral (Cultural) and Biological Change

There are several models that are used to explain and answer the question how did anatomically modern *H. sapiens* become behaviorally modern? The first, long a dominant paradigm, sees behavioral change and innovation as the result of a cultural "revolution" by anatomically modern humans, presumably in Europe, around 40 kya (D'Errico 2003). This is best represented in the Middle to Upper Palaeolithic revolution model as discussed above. It represents an almost certainly genetic-related neurological change, caused by cultural innovation, within the species in a limited area. Humans could be biologically modern but not behaviorally modern until this revolution occurred.

The second model considers behavioral modernity to be the outcome of a gradual process where anatomically modern humans originated in Africa (D'Errico 2003:188). In this model, biological and behavioral modernity are "inextricably linked, advancing together in a long and slow dialectic" (D'Errico 2003:188-189). This model is best represented in the continuity model proposed by McBrearty and Brooks (2000) to explain the MSA-LSA transition.

Ecological models have been developed to explain the appearance of modern behavior in anatomically modern humans. Expansion into new, previously unoccupied regions creates greater opportunities for innovation to occur. Exploiting new resources requires technological, thus behavioral, change. It seems obvious then that the apparent complex of behaviors would reflect adaptive strategies unique to problems with colonising new regions rather than just a progression from archaic to modern behavior (D'Errico 2003:199).

Closely related to ecological models are those derived from evolutionary biology, which focus on genetic diversity and selective advantage. A bottlenecking event could have adversely affected early human populations in Africa. With a drastic decrease in population a loss of genetic variability would occur. The subsequent migration of anatomically modern humans out of Africa, in accordance with the Recent African Origins model, following the bottlenecking event could represent the recovery of these populations. This would explain the relatively minor genetic variation between human populations globally today.

Eswaran (2002:750) suggests that the collective suite of modern human characteristics offered a strong selective advantage. This favoured modern genotype would have overcome archaic populations, aided by natural selection, via a “diffusion wave” process – a slow, wave-like spread of modernity (Eswaran 2002:751). Likely it was not a single revolutionary event but a series of revolutionary waves spreading throughout the globe.

Klein (2000:17-18) takes this a step further and proposes that the shift to fully modern behavior, and the corresponding geographic expansion, were the “co-products of a selectively advantageous genetic mutation.” This mutation, a neurological light switch for behavioral modernity, results in the rupture of the pattern of co-evolution between anatomy and behavior, and more change in the archaeological record during forty thousand years than in the prior million years (Klein 2000:18). What this suggests is that no matter how many of the traits of behavioral modernity are demonstrated in the assemblages of a hominid species, it is not modern until a precise neurological change occurs. The problem with this argument as with others relating to the link between anatomical and behavioral modernity, is that Klein fails to suggest why such a change would have adaptive, evolutionary significance and what would have necessitated this adaptation.

As previously stated, African Stone Age archaeologists are divided between those who feel the LSA marks the beginning of behavioral modernity and those who feel some MSA assemblages have attributes from the Upper Palaeolithic – thus indicators of modern behavior (Willoughby 2001b:34). MSA and LSA sites in the Rukwa Rift Valley of Tanzania show signs of continuity despite noticeable differences between them, and there are no indications of a sudden replacement of one kind of technological system by another (Willoughby 2001b:34). There is substantial inter- and intra-site variation within the MSA

(Clark 1988:297, 1992; Deacon 1992, 2001). An example of this variation is MSA projectile technology as previously discussed. MSA assemblage variability is related to the environment and material constraints (raw material availability, distribution, quality, and abundance). Further study of the role of material constraints is necessary. This temporal and spatial variation, as well as the presence of clear stylistic elements or at least "functionally equivalent choices", are associated with behavioral modernity.

Most modern behavioral markers present in MSA assemblages relate to the presence of mode 4 or 5 (Upper Palaeolithic) industries. Bone harpoons from Katanda in the Congo (Yellen et al., 1995) provide both evidence for the production of tools out of organic materials and the exploitation of aquatic resources as much as 80 kya. Bone tools and pressure flaked stone points from Blombos Cave (Henshilwood and Sealy 1997) clearly demonstrate, again, the use of bone as a raw material for tool production, and the utilization of a new production technique (most likely requiring the use of antler or other organic material as a pressure flaker). Other Upper Palaeolithic industry traits seen in the MSA include hafted and tanged projectile points, and flake blades. In sum, the presence of these Upper Palaeolithic attributes lends support to arguments that the Upper Palaeolithic was not the only time and place where behaviorally modern humans developed (Willoughby 1993:7).

3.6 Conclusions

I would argue that the presence of "Upper Palaeolithic" attributes in MSA is evidence for the presence of behavioral modernity. Perhaps, if one views the transition from the MSA to the LSA (and from the Middle to the Upper Palaeolithic) as a continuum rather than a revolution, a more complete picture of the appearance of behavioral modernity would become obtainable. Simply, I believe that modern anatomy can be explained using the Recent African Origins model; however, behavioral modernity is the result of multiregionalism. I do not believe the transition to modern behavior is analogous to the flipping of a switch à la Klein, but rather is the result of continuous adaptation over time. How genetic events, such as bottlenecking could have affected population dynamics like migration, and the necessity for species to disperse and adapt to new environments must be examined. With an increasing awareness of the significance of raw material on assemblage diversity and technological organization, there is a need to establish raw material characterization data for lithic materials in regions hominids were exploiting.

Finally, there is a serious necessity to re-evaluate what attributes of modern behavior are considered to significant and why we feel this way. Are the attributes selected through the biased perspective of a subscribed to modern humans origin model or are the attributes the result of, thus reflect, modern behavior? As mentioned above, the full suite of behavioral characteristics should not be deemed necessary in order to determine modernity.

Chapter 4: African Stone Tool Technology

4.1 African Stone Age Technocomplexes

The straightforward African Stone Age scheme introduced in the previous Chapter provides a structure in which the numerous regional technocomplexes or industries can be placed. It is important to recognise that there are numerous variations both regionally and across the continent in the names used. Table 4.1 shows many of the generally accepted regional technocomplexes and industries throughout Africa. These regional industries may be differentiated on the basis of a single "type" artifact or using a detailed assemblage-level typology. Some are found at only single sites while others are widely distributed. Table 4.2 provides an overview of just the East African industrial complexes and their associated stone tools and hominids. Only those industries generally agreed upon, and which have not fallen out of common use, are included. Time periods provided are approximate. It is by no means comprehensive in terms of the sites listed. As previously stated emphasis will be placed on the MSA and LSA.

African Stone Age Scheme	West Africa	North Africa & the Sahara	Nile Valley	Western Desert of Egypt	the Levant	Central Africa	South-Central Africa	South Africa	East Africa
Late Stone Age (LSA)	(Mode 5 microlith)	Holocene UP: Typical Capsian Upper Capsian Columnatan - - - - - - Epipalaeolithic after 18ky: Eastern Oranian/ Oranian/ Iberomaurusian Dabban (early UP)	Epipalaeolithic- Fakiturian Mode 4 UP Iberomaurusian	Epipaleolithic - - - <Gap> - - - Aterian	Ahamarian Emiran (transitional)	Tshitolian Ndolian	Nachikufan Tshangula	Wilton Albany/ Oakhurst Robberg Transitional MSA/LSA	Elementeitan Neolithic (Mode 5 microlith) Doian (Kenyan Capsian) Eburran Sakutiek Bambatan-like
Middle Stone Age (MSA)	Levalloiso-Mousterian Lupemban-like	Libyan Pre-Aurignacian Aterian Levalloiso-Mousterian Mousterian	Late MP: Halfan Safahan Idfuan Khormusan Middle MP: Nubian Mousterian (N group) Denticulate Mousterian (K group) Early MP: Nubian 1&2, Aterian-like	Dakhleh Oasis Units Kharga Units	Levantine Aurignacian Levantine Mousterian	Lupemban Djokocian	Lupemban Sangoan	Bambatan (MSA 3) Howieson's Poort (MSA 1or 2): Pietersberg Lupemban	Lupemban-like Sangoan-like
Early Stone Age (ESA)	???	Acheulian (nothing older than 1my)	Early Palaeolithic – Late Acheulian	Late Acheulian	Acheulo-Yabrudian/ Mugharan (Pre-Aurginacian/ Amudian): 3 varieties (Yabrudian, Acheulian and Amudian facies)	Kalinian	Acheulian	Acheulian	Acheulian
									Karari
									Developed Oldowan A&B Oldowan

Table 4.1: Regional Technocomplexes situated within the African Stone Age scheme.

African	Dates (BP)	Industrial Complex	Hominin	Key stone tool type(s)	Key Sites
Holocene LSA	12 ky – 400 yr	**Oldeani**	*H. sapiens*	Backed microliths (crescents)	Mumba, Tanzania Njarasa, Tanzania (Lake Eyasi)
		Olmoti		Backed microliths (intro. of pottery)	Nasera, Tanzania
Pleistocene LSA	40 – 12 ky	**Silale**		Microlithic backed pieces	Mumba, Tanzania Nasera, Tanzania
		Lemuta		Blades	Nasera, Tanzania (Level 4 & 5) Olduvai, Tanzania (Naisiusiu Beds)
Intermediate LSA/MSA	37 – 23 ky	**Naseran**		Small retouched points	Mumba, Tanzania Nasera, Tanzania
	65 – 23 ky	**Mumba**		Backed pieces Knives	Mumba, Tanzania Nasera, Tanzania
Middle Stone Age (MSA)	40 – 17 ky	Lupemban	*H. sapiens* *H. heidelbergensis*	Large heavy-duty picks and core axes	Muguruk, Kenya Nsongezi, Uganda Kalambo Falls, Zambia Kagera River valley sites Twin Rivers, Zambia (200 – 140 ky!?)
	~90 ky	**Kisele**		Typologically diverse scrapers Retouched points	Nasera, Tanzania Mumba, Tanzania (Bed VI-A)
	~131 ky	**Sanzako**		Retouched (bifacial) flakes	Mumba, Tanzania (Bed VI-B)
	Contemporaneous with sangoan?	Charaman or Proto-Stillbay		Light duty flake tools dominated assemblages	Broken Hill, Zimbabwe Bambata , Zimbabwe Pomongwe Caves, Zimbabwe Kalambo Falls, Zambia
	190 – 100ky	Sangoan **(Njarasa)**		Double-ended points	Sango Bay, Uganda Kalambo Falls, Zambia Twin Rivers, Zambia Mumbwa, Zambia Eyasi Lakeshore, Tanzania
Early Stone Age (ESA)	1.6 my – 150 ky	Acheulian	*H. ergaster* *H. erectus*	Hand axes Cleavers	Olduvai Gorge, Tanzania (Beds II & IV) Isimila, Tanzania Olorgesailie, Kenya Peninj, Tanzania
	1.6 – 1.2 my	Karari (Oldowan var.)	*H. habilis* *H. rudolfensis* *Paranthropus ?*	Bifaces Wide range of tool types	Koobi Fora, Kenya
	1.7 – 1.5 my	Developed Oldowan B		Proto bifaces (made on cobbles)	Olduvai Gorge, Tanzania (Upper Bed II) Sterkfontein, South Africa (?)
		A			Olduvai Gorge, Tanzania (Lower, Middle Bed II)
	2.6 – 1.6 my	Oldowan		Manuports Hammerstones Cores & core tools Flakes	Olduvai Gorge, Tanzania (Bed I and Lower Bed II) Koobi Fora, Kenya Omo, Ethiopia Gona Ethiopia

Table 4.2: East African Industrial Complexes. Note: those industries in bold font are from Mehlman’s (1989) typology .

4.2 African MSA lithic assemblage characteristics

The Middle Stone Age lasted approximately 150 kya. Although its boundaries are not accurately defined, evidence supports the MSA beginning by at least 250 kya and ending sometime around 45 kya. There is no support for any significant interval between the end of the ESA and the beginning of the MSA, other than in regions where extreme climatic and environmental conditions would have resulted in abandonment by large game and humans (Clark 1988:239). The appearance of the MSA correlates with Oxygen Isotope Stage 6 (195,000 – 128,000 BP) – the latter part of the Penultimate Glaciation (Clark 1988:251). The earliest East African MSA sites converge on 240 – 280 kya (McBrearty and Brooks 2000:488). In South Africa, interior sites are undated and coastal sites appear to be absent prior to the last interglacial (McBrearty and Brooks 2000:489). MSA sites appear in North Africa as early as 230 kya.

Culturally, the term MSA defines a "group of cultures, differing from region to regions…but all having a great deal in common with regard to lithic technique and typology" (Masao 1992:99). It represents an accelerated shift away from broad cultural uniformity towards increasingly distinct regional traditions, thus it is a more diverse and environmentally more specific industry than the preceding Acheulian (Masao 1992; Phillipson 2005).

Specifically, it encompasses flake and blade tool industries that often include prepared cores and points made by radial disc or prepared core (Levallois) technology (Goodwin and van Riet Lowe 1929:95-145). Levallois reduction (Figure 4.1) involves the extensive shaping of a core in order to determine flake size and shape, so that a finished flake tool can be removed ready for use without further modification (Klein 1999:411, Willoughby 1993:6). Consequently, the size, shape, and character of the flakes, or blanks, produced are standardized and thought to be predetermined (Brantingham and Kuhn 2001). Flakes are removed from around the periphery of the selected nodule using a downward stroke. These peripheral flake scars are then used to remove flakes systematically from one surface of the core as a means of preparing the surface using an inward stroke.

Finally, flakes are struck off "whose size and shape was determined by the arrangement of previous flake scars on the core surface" (Klein 1999:411). The defining characteristics of Levallois flakes are the pattern of dorsal scars created, which reflect deliberate preparation of the core surface, and the frequent presence of a faceted platform (Klein 1999:411).

Levallois cores, therefore, have a very distinct final form. However, different initial core forms can produce products that are seemingly Levallois (Dibble 1989; Brantingham and Kuhn 2001). This variability is the result of the diverse techniques applied in using the Levallois method, as well as, any dynamic adjustments made necessary by variations in raw material or errors encountered during reduction (Brantingham and Kuhn 2001:749). This emphasis on standardization might have developed from or in order to facilitate hafting.

The term flake-blades is used to describe Levallois blades in South Africa where the length is greater than the width, whereas, blade specifically refers to flakes that are at least twice as long as they are wide. Further, flake-blades refer to blades made using prepared core methods. Various techniques are used to produce blades, such as, bipolar and unipolar variations of Levallois production (Figure 4.2; Klein 1999:413). Both involve the preparation of the core, and differ only in how many striking platforms are used. In unipolar reduction, a single striking platform, and in bipolar, two opposed striking platforms, are used. Continuing blade and flake production requires continuing core preparation (Klein 1999:413), and the process of production halts with the exhaustion of the core.

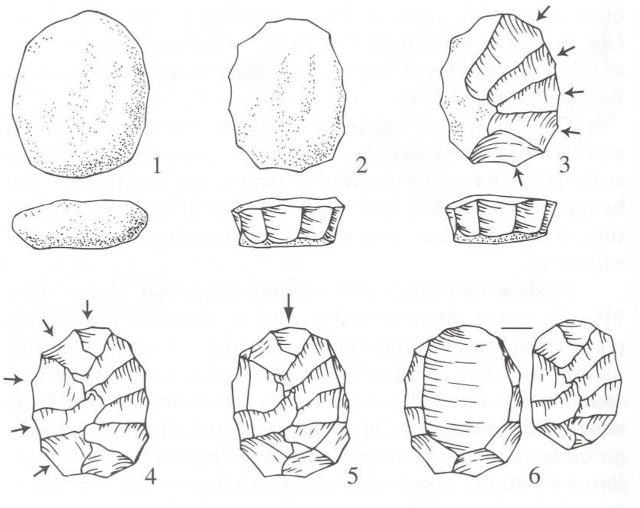


Figure 4.1: Stages in the classic Levallois technique (adapted from Klein 1999:412, Figure 6.24): (1) raw nodule, (2) nodule with flakes struck off around the periphery, (3) nodules with flakes struck radially inward on one surface using the peripheral scars as striking platforms, (4) radial preparation completed, (5) final hammer blow to remove flake, and (6) final Levallois core and flake.

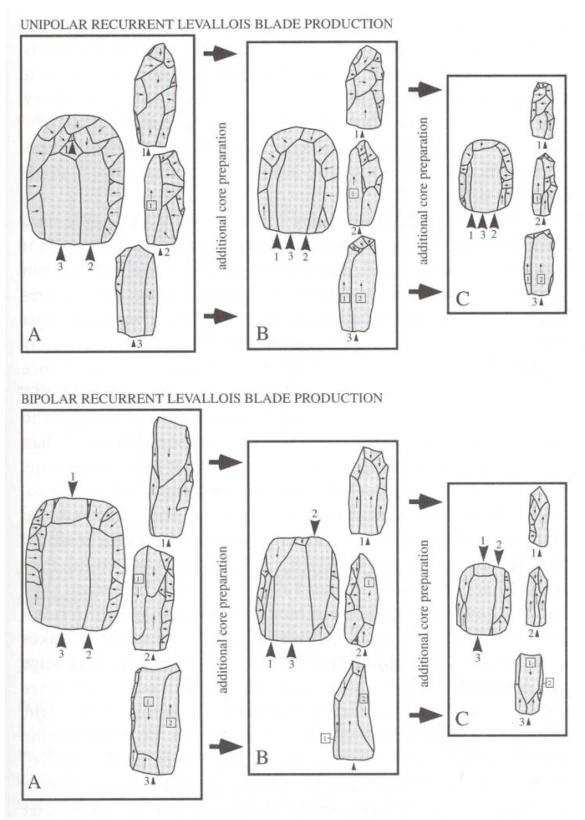


Figure 4.2: Two variants of Levallois core reduction (adapted from Klein 1999:413, Figure 6.25).

Flake tools include end, side and convergent scrapers, notches, denticulates, bifacial pieces and projectile points (Willoughby 2001b:34). MSA types are defined on morphological attributes. European Palaeolithic archaeologists, notably Gabriel de Mortillet (1883) and François Bordes (1961, 1968), used position and quality of retouch to define different Mousterian tools and subsequently formalise a Mousterian/MSA typology. Bordes' (1961) Lower and Middle Palaeolithic typology recognises 63 discrete flake tool types, focused on 21 types of sidescrapers (*racloirs*), two to three types of retouched points, and three to four denticulated (notched) pieces.

Following Bordes, a scraper is a unifacially retouched flake, usually on the dorsal surface; a sidescraper is a "flake on which one or more edges bear smooth, continuous retouch"; a point is a relatively thin flake "on which two continuously retouched edges converged directly opposite the striking platform"; and a denticulate is a "flake that was retouched to produce a ragged or serrate edge, comprising several adjacent indentations" (Klein 1999:418). Considerable debate has centered on the legitimacy of Bordes' typology as many of these retouched tools may just be stages of reduction (see Rolland and Dibble 1990). It is based on style but for all shaped tools.

Although these methods of flake and blade production were developed during the ESA, MSA assemblages do not contain the classic, large, Acheulian bifaces (Willoughby 1993:6). Consequently, the earliest MSA assemblages recognised as such are those where Acheulian bifaces are no longr present (Clark 1988:237). This replacement of hand-held tools by hafted implements represents major technological reorganization (McBrearty and Brooks 2000:485).

Projectile technology during the MSA is significant (Figure 4.3) as it best illustrates regional differences and the presence of regional styles, stylistic information relating to design constraints, and the utilization of new raw materials such as bone (McBrearty and Brooks 2000). Retouched points are possibly the earliest MSA artifacts at 235 kya (Wendorf et al., 1994). In comparison to the Mousterian (Middle Palaeolithic) of France for example, the MSA features large numbers and careful design of points, and a relative lack of scrapers (McBrearty and Brooks 2000:496). As they are carefully made, thin, and symmetrical, these retouched points are a suitable size for use as projectiles (McBrearty and Brooks 2000:497). MSA points were likely used by thrusting spears to dispatch game (Bushozi 2011). Hafting is evident and the small size of some suggests their use with bow and arrow. Whereas the shaping of organic materials (bone, antler, etc.) into tools is a hallmark of the Upper Palaeolithic, bone working is associated with the MSA in Africa. McBrearty and Brooks (2000:500) suggest bone working appears in the MSA because of the intimate link between bone working, or at least the use of organic materials as handles for hafting, and the development of projectile technology.

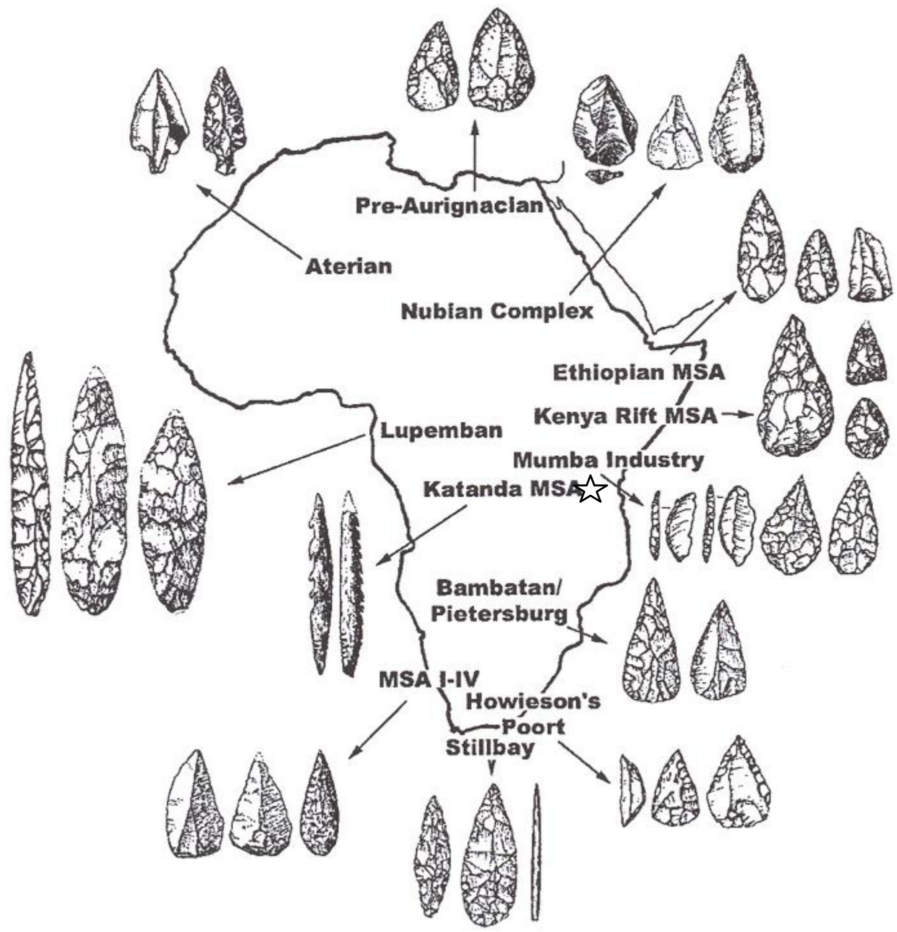


Figure 4.3: Distribution map of point styles in the MSA (adapted from McBrearty and Brooks 2000:498, Figure 5). The star represents the approximate location of Iringa Region.

4.3 African LSA lithic assemblage characteristics

Klein (1992, 1995, and 2000) argues that the LSA is the archaeological sign of the beginning of fully modern behavior. In comparison to the MSA, defining the LSA is a difficult task. When the term was first introduced by Van Riet Lowe in 1926, the LSA was defined as several stone industries and/or cultures containing several non-lithic items, excluding MSA tools (Wadley 1993). LSA people were seen as biologically and behaviorally modern. There are major problems with this as subsequently it has been realised that there is no correlation between the appearance of the modern humans and LSA technological evolution (Wadley 1993:244). Today only the qualifier that LSA assemblages should lack MSA artifacts remains (Wadley 1993:244). It is important to note that LSA tool types are present in MSA assemblages, gradually becoming more frequent over time (Willoughby 2002).

The lack of a unanimous definition of the LSA is a result of the nature of the transition from the MSA to the LSA. As a means of dealing with issues relating to transitional assemblages and problems in defining early LSA assemblages, using data from South Africa, Wadley (1993:260) divides late Pleistocene stone tool industries into four groups: (1) microlithic industries dated between ca. 40 000 and ca. 19 000 B.P., described as early LSA (ELSA), or as late MSA, or as MSA/LSA transitions or interfaces; (2) the non-microlithic, bladelet-poor industries with dates between ca. 40 000 and ca. 19 000 B.P.; (3) the microlithic industries with bladelets dated between ca. 18 000 and ca. 12 000 B.P.; and (4) the non-microlithic, bladelet-poor industries dating between 12 000 and 8 000 B.P.

Through argon-argon (^{39}Ar-^{40}Ar) dating, it has been shown that the transition to the LSA began prior to 45 kya (Stringer 2002a:568). Around that time, geometric microliths, backed pieces, endscrapers, burins, borers, blades and blade technology either appear for the first time or increase in abundance in assemblages in which they were already present (Willoughby 2002:204). Bladelets function as preferred performs, subsequently retouched into backed pieces or shaped further through microburin technique to yield geometric microliths. Geometric microliths are a "significant hallmark" of LSA technology (McBrearty and Brooks 2000:500). Microliths are small bladelets or segments of blades and flakes with retouch along one or more edges, which may or may not be geometric in shape. These would have been used in various combinations in composite tools. They are more abundant in the Holocene of East Africa than in the Pleistocene. Backed pieces are flakes or blades where its edges are steeply trimmed in order to blunt them so they did not split their hafts or cut their user (Phillipson 2005:92). Phillipson (2005:92) suggests this blunting retouch also provided an attachment region for the adhesives (e.g., mastics or gums) used in hafting.

At the same time microlithic assemblages were being made, non-microlithic assemblages have been recovered. These non-microlithic assemblages appear around 12 kya (Wadley 1993). Little is known about these assemblages other than their apparent lack of microlithic artifacts. Often these assemblages are in a mixed context with MSA tools. Bladelets appear around 18 kya in both microlithic and non-microlithic assemblages. These are recovered in a number of assemblages representing regional industries (Wadley 1993).

Importantly the LSA is not defined so much by specific artifact types as it is by more broadly defined behavioral characteristics. In comparison to the MSA, LSA assemblages are seen as much less variable/more standardized (Klein 1999; Mellars 1989a). Klein (1999:420) argues MSA people focused on function (the character of the edge, sharpness of a point) whereas LSA people were concerned with style (overall shape of finished goods). Thus, the LSA represented a shift in the preference of tool form and the expansion of the microlithic technique, not dramatic innovation (A.M.B. Clark 1999:101).

4.4 The MSA-LSA Transition

There is considerable disagreement concerning the MSA-LSA transition. There are three competing interpretations relating to this transition: the first claims that MSA technology disappears by ca. 40 kya and is replaced by the early LSA; the second claims that the MSA survived much later until ca. 25-20 kya; and the final sees the MSA and LSA on a continuum, rejecting the concept of a boundary (Wadley 1993:260).

One problem lies in debates over which criteria defines the early LSA (McBrearty and Brooks 2000:49). It is a sticky issue as transitional assemblages, those containing both MSA and LSA elements, have been found that overlie unequivocally MSA industries and underline assemblages which are unquestionably LSA. A.M.B. Clark (1999:101) explains these mixed assemblages as demonstrating a shift in the production of lithics to LSA techniques while the preference for tool types was for those from the MSA. Another problem arises when one considers that there are a number of sites with a chronological, but not stratigraphic, hiatus between the MSA and LSA assemblages. Examples of this include South African sites where final MSA assemblages predate 60 kya and the earliest LSA dates at or later than 20 kya (McBrearty and Brooks 2000:491). Dealing with this issue is more difficult. The search for sites with unbroken stratigraphic sequences and excellent chronology must continue.

Grahame Clark's Technological Modes

Attempts to compare assemblages in time and space have resulted in the creation of several models. Grahame Clark's (1969) technological modes scheme appears frequently in the literature. He sees a clear, evolutionary progression in technology during the Palaeolithic based on homotaxial assemblages, which he divides into five modes (Table 4.3). It is important to note that Clark (1969:30) recognises that "more often than not particular industries seem to combine techniques from more than one stage of development." The development of stone tools and stone tool technologies involved the addition of new traits, but importantly, the development of a "more derived mode" does not imply the disappearance of ancient modes, as characteristics are cumulative (Foley and Lahr 1997:7). Clark's (1969:30) modes have since been adapted to fit archaeological realities and revised typologies better (Table 4.4). Importantly this revision incorporates the differences concerning Stone Age Africa versus European Palaeolithic models.

Relevant to the topic under discussion, there are Mode 3 technologies representing MSA industries and elements of Upper Palaeolithic industries that are present in the MSA – blades, barbed, stemmed, and tanged points, and fishing implements (Foley and Lahr 1997:7). Mode 3 industries gradually transition into those of mode 4 – the LSA falls into this category (Masao 1992:100).

However, Mode 3 technology alone cannot be equated with the MSA for the following reasons: (1) prepared core technology appears first in association with ESA (Acheulian) assemblages; (2) many MSA assemblages lack prepared cores; (3) many MSA industries are blade-based (Mode 4 technology); and (4) several MSA industries contain backed geometrics (Mode 5 technology) (McBrearty and Brooks 2000:485). These modes are used as a method of correlating archaeological assemblages throughout the Old World based on technological (assemblage characteristics) and chronological associations. For the same reasons, typologies have been established, like the aforementioned Bordes' (1961) typology for the Middle Palaeolithic, allowing archaeologists to use a common descriptive language.

Table 4.3: Grahame Clark's (1969:30) Technological Modes

Dominant lithic technologies	*Conventional divisions of the older Stone Age*
Mode 5: microliths and composite artifacts	Mesolithic/Epipalaeolithic
Mode 4: punch-struck blades with steep retouch	Upper Palaeolithic
Mode 3: flake tools from prepared cores	Middle Palaeolithic
Mode 2: bifacially flaked hand-axes *Mode 1*: chopper-tools and flakes	Lower Palaeolithic

Table 4.4: Technological Modes and Associations (adapted from Clark 1969:30; Stringer 2002:567)

Dominant lithic technologies	*Stratigraphic*	*Western Eurasia*	*Sub-Saharan Africa*
Mode 5: microliths and composite artifacts		Mesolithic/Epipalaeolithic	
Mode 4: punch-struck blades with steep retouch	Upper Pleistocene	Upper Palaeolithic	Later Stone Age
Mode 3: flake tools from prepared cores	Middle Pleistocene	Middle Palaeolithic	Middle Stone Age
Mode 2: bifacially flaked hand-axes *Mode 1*: chopper-tools and flakes	Lower Pleistocene	Lower Palaeolithic	Early Stone Age

There are problems with establishing artifact classifications (material "cultures") and typologies. Often they are overly subjective, represent a mixture of variables (functional and technological), incorporate untested assumptions about cognition and skill of the tool producers, neglect the role of constraints in production, fail to recognise the continuous nature of reduction and production (the cycle of use, reuse, and discard), and have problems with inter-and intra-observational error (Bisson 2000; Dibble 1987). Furthermore, typologies can be subjective because they are based on the morphological attributes deemed significant by the analyst, lack definitional consistency, and produce incomparable categories (Amick and Mauldin 1989:166; Dibble 1987; Handly 1994:74; Sullivan and Rozen 1985:757). Therefore, other attribute information that may aid in interpretation could be disregarded (Handly 1994:74). Nonetheless, typologies and modes provide a useful heuristic tool for discussion and communication if the limitations of their application are recognised. They do provide a means of examining assemblage diversity in a larger comparative context.

Mehlman`s Typology

In this study, all artifacts were classified according to the typology created by Michael Mehlman (1989) with some modifications by Pamela Willoughby to account for variance seen in lithic assemblages in Iringa Region (Appendix A). Although the use of typologies has been criticized (see above, also Cahen and Van Noten 1971), basic lithic artifact typologies remain an efficient way for archaeologists to communicate the various methods and techniques for lithic analysis used in their studies (Andrefsky 2005:722) and to allow for comparison between assemblages (Mehlman 1989:121). Generally lithic typologies can reduce the variability in assemblages by focusing on describing the central tendency of only a small portion of the assemblage or are unique for each particular assemblage; however, Mehlman's typology is quite extensive and attempts to account for the high variability seen in MSA and LSA assemblages. He emphasizes not only retouched pieces but recognises several varieties of cores and numerous types of flakes and debitage. He uses evidence from ethnographic observations, from archaeological collections and from studies of experimental replication in the creation of his types and subtypes. He made clear that he was aware of the limitations of his own typology and provided detailed arguments as to all the choices he made during the development of the typology. How this typology relates to culture history, and the industries defined by Mehlman were discussed in Chapter 2 (pages 20 - 21).

Mehlman`s typology is based on morphology. It includes all stone implements produced as the result of both chipped and ground stone technology. Ground stone artifacts (attribute 6.4), as they represent an entirely separate process of raw material selection and tool use, were not included in this study and as such will not be discussed. To understand, and in part simplify, this classification scheme, I have developed a flowchart (Figure 4.4) based on Andrefsky (1998:74, Figure 19.2). The first dichotomy in the typology is between artifacts that are tools (includes attribute #6.1: trimmed pieces or tools and attribute #6.2: cores) and artifacts that are not tools (attribute #6.3: debitage). All artifacts on the left side of the flowchart are "objective pieces that have been intentionally modified or modified by use" (Andrefsky 2005:723). As cores are intentionally modified pieces, whether they are formally used or reduced with the intention of use or not, I have placed them to the left of the figure under the tool category following Andrefsky (2005:723). Debitage, or materials that were removed from the objective pieces during this shaping process and are not further shaped, used or retouched, are placed on the right side of the chart. Tools are then separated into flake/blade tools and cores, while debitage is separated into flake and non-flake types.

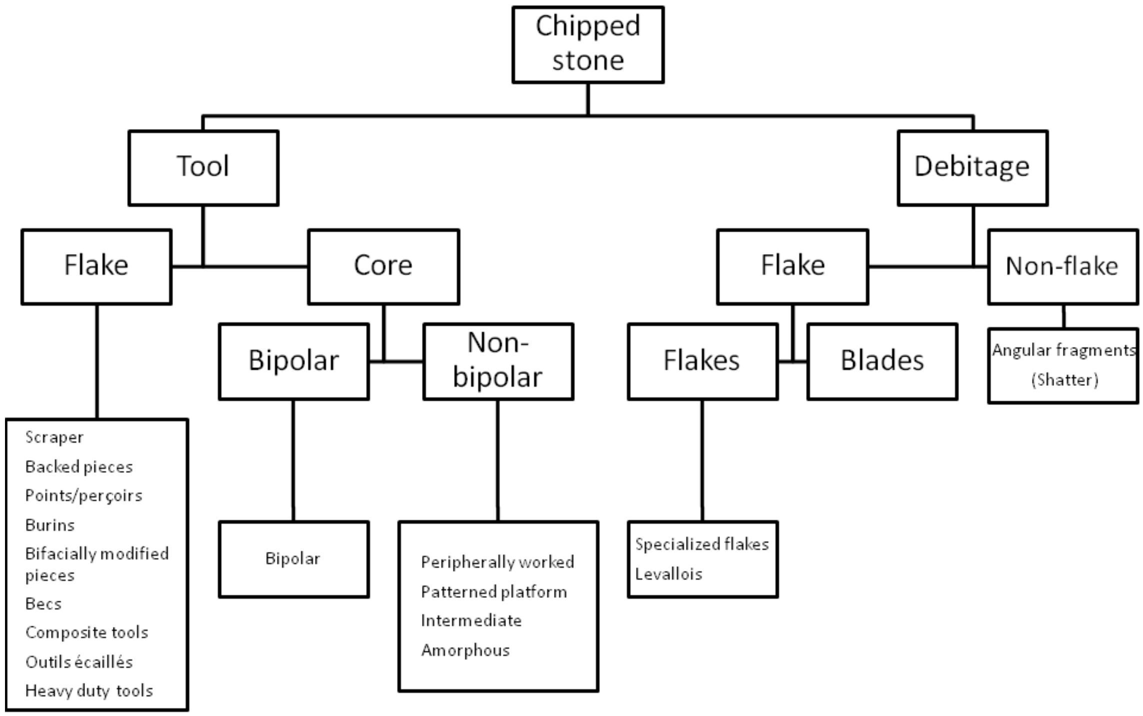


Figure 4.4: Flowchart illustrating Mehlman's (1989) typology for all chipped stone artifacts.

Flake and blade tools include all scrapers (attribute #7.1, subtypes #8.1-23), backed pieces (attribute #7.2, subtypes #8.24-8.34), points/perçoirs (attribute #7.3, subtypes #8.35-8.37 and #8.106), burins (attribute #7.4, subtypes #8.38-8.40), bifacially modified pieces (attribute #7.5, subtype #8.41-8.43), becs (attribute #7.6, subtype #8.49), composite tools (attribute #7.7, subtypes #8.45-8.48), outils écaillés (attribute #7.8, subtype #8.49), and heavy duty tools (attribute #9, subtypes #8.50-8.110). Unfortunately, Mehlman's typology mixes up those tools which are bifacially modified versus those which are not. In some ways it would have been more useful had he recognised this important technological indicator.

With Stone Age assemblages, particularly during the Acheulian, it is common for large flakes to serve directly as cores. Mehlman recognises five types of cores (attributes #7.11-7.15) including 20 subtypes (attributes #8.057-8.076). These types are based on the type and location of platform(s) used, the degree of platform retouch, the patterning of flake removal, and the extent of the surface that is flaked. In Figure 3.5, I divide these cores into bipolar and non-bipolar types.

Debitage (attribute #6.3) includes all the by-products of tool production excluding cores. The decision to recognise cores as potential tools is mine and not Mehlman's. Debitage contains five subtypes: angular fragments (attribute #7.16, subtypes #8.77-8.81), specialised flakes (attribute #7.17, subtypes #8.82-8.83), flakes (attribute #7.18, subtypes #8.84-8.87), blades (attribute #7.19, subtypes #8.88-8.91), and Levallois flakes (attribute #7.20, subtypes #8.92 and 8.93). In Figure 3.5, I group these various debitage subtypes according to whether they are flakes or non-flake. The flake category is then further subdivided into flakes or blades. Again as with the tool types, Mehlman's debitage typology fails to recognise some important technological attributes/distinctions although he does distinguish Levallois flakes from all others. He (1989:148) states that "some typological systems would exclude Levallois and/or trimmed/utilized pieces from debitage classes" but includes them in his arguing that the kind of edge modification that he terms trimmed or utilized ("T/U") is "neither clearly intentional nor clearly the result of usage." Mehlman (1989:149) correctly suggests that edge modification may be the result of artifact movement or "scuffling" underfoot, the outright trampling of artifacts and post-depositional stress within deposits "in the relatively confined and intensely used space of a rock shelter"; therefore, grouping "T/U" pieces with tools "infiltrates tool counts with non-descript, dubious tools" which will cause interpretive issues.

4.5 Technological Indicators Used in Behavioral Inference

In a technological analysis, the classification or categorization of lithic artifacts appears to follow two patterns. First, lithics are classified into 'types' by the stage they are thought to represent in the lithic reduction sequence (i.e., primary, secondary, tertiary). Morphological attributes determined through replication experiments are used for characterization. These classificatory schemes are referred to as stage typologies. With the second pattern, characterization is conducted by examination of these same attributes in terms of fracture mechanics. From these experimentally derived principles of fracture mechanics, the technology thought to have been used in production is inferred. These fracture mechanics-based typologies treat reduction strategies as a continuum.

Although both classification schemes are essentially focused on the technique that was employed in the production of lithic artifacts, and thus are equally valid in lithic artifact classification, there are a number of problems related to the stage typology approach as discussed above. Therefore, I believe that the second way of classifying lithic artifacts, where lithic reduction is viewed as a continuum, is more preferable for behavioral inference. This is because fractures are not only representative of raw material type, but also reflective of the techniques that produce them.

Fracture Mechanics

By classifying lithic artifacts on the basis of fracture mechanics one is accounting for the variability in both the technologies and the variation in the products within and between different technologies. An indirect result of this is that one is also accounting for the behavior of the flintknapper and his/her knowledge about the material being worked (cognition). By understanding fracture mechanics, archaeologists can identify possible manufacturing techniques that produced those morphological attributes subsequently used to create lithic artifact typologies. Based on three modes of fracture in flake initiation, Hertzian initiation (or conchoidal fracture), bending initiation (or billet), and wedging initiation (or bipolar) flakes, Cotterell and Kamminga (1979, 1987, 1990) have created a scheme for flake classification. Each of the initiation types can be directly correlated with a specific technological strategy recognising that there are always some flakes with ambiguous indicators. Hertzian initiation or conchoidal flakes result from hard hammer percussion, bending initiation or billet flakes are the product of soft hammer percussion or pressure flaking, and wedging initiation or bipolar flakes are produced in bipolar reduction. These modes of fracture for flake initiation are discussed in greater detail below as indicators of the lithic reduction strategies/technologies. Prior to this discussion, I first offer a general examination of the principles of fracture mechanics.

Fracture mechanics can be used to elucidate manufacturing techniques and the nature of use-fracturing because of the nature of lithic materials themselves (Cotterell and Kamminga 1987:97). Fracture is dependent on the chemical composition and microstructure of the lithic type because in order for fracture to occur in a material, the bonds between the atoms must be broken. The fracture strength of a material tends to be equal to the amount needed to overcome the strength of its weakest atomic bonds, and can be overcome via the application of stress or force (Cotterell and Kamminga 1979:98). It has been demonstrated that with stone tool production there are two vectors of stress, compressive and bending, which can cause fracture and result from and vary according to the manner of force application (i.e., hard hammer percussion versus soft hammer percussion versus bipolar percussion versus pressure flaking). Other attributes can also affect the nature of the fracture including core surface morphology (Pelcin 1997), hammer mass and velocity (Dibble and Pelcin 1995), original core size and weight (Tomka 1989), and angle of force application (Cotterell and Kamminga 1987).

In summary, the mechanical variables significant in understanding the flaking of stone materials can be classified into three categories: first, those which relate to the properties of the lithic raw material being fractured; second, those variables relating to the properties of the flaking device; and third, those variables of the experimental situation (Moffat 1981:195). As fracture type can be diagnostic of a particular lithic production technique, it is one of the technological attributes (attribute #8) used for this study.

The work of Semaw (2000, Semaw et al., 2003) illustrates that the makers of the earliest stone artifacts at Gona, Ethiopia had a "sophisticated understanding of stone fracture mechanics and control" over these materials (2000:1197). The Gona assemblages date to 2.6-1.5 Mya and group into the Oldowan Industry. These studies demonstrate that the importance of knowing properties of the selected toolstone, as they relate to fracture mechanics and thus raw material quality, has been present in the minds tool makers since the very beginning.

4.6 Lithic Production Technologies: Indicators

There are a number of different technological strategies employed in stone tool production. These production strategies are generally described in terms of the types of fabricators used as part of the technique and are reflected in the nature of the flakes produced: hard hammer percussion, soft hammer percussion, bipolar percussion and pressure flaking. As each of these techniques is explained a number of attributes will also be introduced. Those attributes which were selected for use in this study are accompanied by an attribute number. The complete codebook with a full listing of every technological and raw material attribute used can be found in Appendix A.

Hard Hammer Percussion

Hertzian flakes are characteristic of hard hammer percussion. The percussor strikes the surface of the brittle solid creating compressive radial stress which becomes tensile near the edge of the contact zone forming a partial Hertzian cone (Cotterell and Kamminga 1987:685). With conchoidal fracture, tensile stress is compressive because the initiation of the fracture tends to be near the side face of the nucleus forming a partial cone (Cotterell and Kamminga 1987:686). There is an increase in the outward bending as the fracture propagates causing the crack to curve back towards the nucleus to complete the bulb of force (Cotterell and Kamminga 1987:687). This bulb of force (or bulb of percussion) is characteristic of conchoidal flakes. Other features typical of Hertzian flakes include an initiation angle greater than 90° on the flake and less than 90° on the scar, an inverted systematically V-shaped platform, concentric partial Hertzian cone cracks, and éraillure scars (Cotterell and Kamminga 1987:687). Hayden and Hutchings (1989:245) argue that the frequency of éraillure scars is more likely a product of different styles of knapping rather than the percussor type.

Soft Hammer Percussion

Soft percussors, where contact stresses are small, create bending initiation fractures (Cotterell and Kamminga 1987:689). Bending flakes, often referred to as billet flakes, have diagnostic features that allow for their distinction from those flakes produced by hard hammer and bipolar percussion (Cotterell and Kamminga 1987; Hayden and Hutchings 1989; Tomka 1989). Generally, billet flakes have a waisted appearance in plan view and lack a bulb of force. If a bulb is present, it will be extremely diffuse (Cotterell and Kamminga 1987:690; Hayden and

Hutchings 1989:247). Unfortunately, ambiguous flakes often appear within archaeological assemblages. Lipping and relatively large bulbs of percussion can occur with both soft and hard hammer percussion depending on angle, direction, and amount of force (Cotterell and Kamminga 1987:686; Hayden and Hutchings 1989:247).

Flakes produced by pressure flaking are very similar to those produced by soft hammer percussion. However, there is no clear evidence that flakes produced by pressure flaking are by any means different from those produced by percussion flaking (Cotterell and Kamminga 1979:101). This further supports the suggestion that the nature of the flake is largely dependent on the skill of the knapper and the nature of the raw material as influenced by fracture mechanics.

Bipolar Technology

Bipolar technology is generally described an expedient lithic reduction strategy. The nodule to be worked or reduced is placed on top of an anvil and is struck by a hard hammer, which is usually just dropped from some height above the material (Kobayashi 1975; Shott 1989b). Most bipolar flakes are created by wedging initiation fractures (Cotterell and Kamminga 1987:688), although conchoidal or Hertzian fracture also can occur. Wedging occurs under two mechanisms: debris can be forced into a pre-existing flaw on the surface of the nucleus initiating a crack at the tip of the flaw, or under a very hard, sharp indenter the nucleus can deform plastically creating a wedging action and, thus, crack initiation (Cotterell and Kamminga 1987:688). However, blunt indenters under high loads behave as if they are sharp. Wedging requires high pressures and, as such, typically only occurs with hard hammer percussion (Cotterell and Kamminga 1987:688). The initiation angle is around 90°, but secondary detachments, and crushing of the initiation platform, make measurement difficult (Cotterell and Kamminga 1987:689).

Using experimental data, on the basis of ventral surface characteristics, Kobayashi (1975) identifies four types of bipolar flakes (A, B, C and D). Group A includes all flakes that have one or twin bulbs of percussion on the ventral surface at the *proximal* end (Kobayashi 1975:117). Group B includes all flakes that have one or twin bulbs of percussion at the *distal* end where they were in contact with the anvil (Kobayashi 1975:117). Group C flakes are the "true" bipolar flakes, which have one or twin bulbs on both the proximal and distal ends (Kobayashi 1975:117). Group D contains those flakes that are removed from the core at the same time as were others – "the two flaked scars are seen on the surface of the core as if the core were a bi-directional opposed angular one" (Kobayashi 1975:117).

However, modifications to these categories are necessary on the basis of evidence from further experimentation and interpretations made using data from the archaeological record. Most flakes representing bipolar technology fail to exhibit the attributes of a "true" bipolar flake as described by Kobayashi (1975:117). Often there is crushing of one or both platforms resulting in the obliteration of the bulb of percussion (Crabtree 1972:42). Therefore, although the presence of twin bulbs of percussion is proof positive that the flake was produced by bipolar reduction, the absence of these same bulbs cannot be used to definitely say that the flake was not. Nonetheless, Jeske and Lurie (1993:141) suggest, from a blind test using experimentally reproduced bipolar and free-hand hard hammer percussion flakes, that the ability to distinguish between the two reduction techniques is dependent on the type and quality of the raw material. Further, Jeske and Lurie (1993:145) argue that if a site contains debitage from both bipolar and hard hammer techniques, "it is not possible to distinguish the two techniques by examining individual flakes." The debris must be analyzed and interpreted as an assemblage.

As I argue raw material attributes influence the technological strategy employed, it must also be noted that bipolar technology is also an adaptation to small pebble sized raw materials (Kuhn 1991; Jeske 1992; Low 1997). Bipolar reduction splits a pebble into two cortex covered flakes, which will have a usable edge for cutting or scraping. In this case then, no residual core will exist, just two usable blanks.

Bipolar Technology: Cores and/or Wedges?

Cores are flaked stone artifacts exhibiting only negative percussion features (Rozen and Sullivan 1989b:181; Sullivan 1987:48). Cores are generally described on the basis of the directional state of force application as indicated by the pattern of flake scar removal. There are four main patterns of directional force application: unidirectional, multidirectional, bipolar or bifacial (Sullivan 1987:49). Generalized core technologies are those that lack a standardized set of products, and the flakes produced show no consistent set of formal or technological attributes (Teltser 1991:363). However, unlike Teltser's (1991:363) suggestion that these flakes are used without modification, they can form the basis for further reduction strategies. Generalized cores are amorphous, a result from being reduced in a non-systematized manner (Teltser 1991:363). Generalized core technology represents an expedient reduction strategy. All this considered, there are major morphological, technological, and functional differences then that can be used to distinguish generalized cores from bipolar cores.

Some debate has occurred as to whether the objects produced by bipolar reduction were employed as cores or wedges (Le Blanc 1992). The disagreement arises directly in the context of use, as few would debate that the attributes seen on bipolar objects are caused by being struck with a percussor while placed on an anvil during production (Shott 1989b:4). Because the two opposing views ascribe bipolar objects to either use as cores for the production of flakes (Shott 1989b), or as wedges to shape bone, antler or wood for their application in fashioning tools (Le Blanc 1992), this debate of context of 'use' affects the inference and reconstruction of the past behavior of those who utilized the bipolar technique. Shott's (1989b) evaluation of archaeological and ethnographic data suggests that bipolar objects are expediently produced cores, not wedges. However, Le Blanc's (1992) archaeological and experimental work suggests a definite association of these bipolar objects with wedging functions. Therefore, it is reasonable to suggest that bipolar objects were most likely used as both wedges and cores, and that further analysis, notably those examining use-wear patterns, is necessary before any definitive conclusions can be made.

Debitage Analysis

Debitage provides important information about patterns of human behavior, especially the lithic production strategy employed (Amick and Mauldin 1989; Sullivan and Rozen 1985). It includes all flaked stone artifacts that are not cores or tools which do not have retouch modification, use-related shaping, or evidence of use wear (Jamieson 1999, 2000, and 2002; Rozen and Sullivan 1989b:181). Artifacts classified as debitage display single interior surfaces indicated by positive percussion features (Sullivan and Rozen 1985:758).

Through debitage analysis, Tomka (1989) was able to show statistically significant paired attribute groupings which can be used to differentiate multidirectional core reduction from bifacial core and bifacial nodule reduction. Hayden and Hutchings (1989), using a comparable form of debitage analysis, were able to show similar attribute groupings which distinguish soft from hard hammer from bipolar reduction techniques.

Ultimately, those attributes that differentiate artifact types on the basis of technological indicators are size and weight (Ahler 1989; Baumler and Downum 1989; Dibble and Whittaker 1981; Tomka 1989), modification of initiation face or striking platform, platform lipping and éraillure scar (Hayden and Hutchings 1989), exterior scar count and pattern, presence or absence or saliency of a bulb of percussion (Cotterell and Kamminga 1987; Kobayashi 1975), presence or absence or saliency of compression rings or rippling (Crabtree 1972), and secondary flake detachment (Leaf 1979). These attributes can also used to diagnose expedient versus curated technologies (discussed in Chapter 5). Not all of the attributes discussed below were used in this study. They are included here to provide an overall understanding of how variable and thus useful the careful and detailed analysis of debitage is.

Size and weight distributions can provide information alluding to the nature of the fabricator when used in fracture mechanic-based typologies. Size grading (attribute #9) is based on the assumption that flakes produced using different reduction methods (e.g., hard hammer, soft hammer, pressure, and bipolar) will exhibit notably different size grade distributions (Ahler 1989:205; Baumler and Downum 1989). Still, the effect the original core size will have on the overall size of flakes removed from it must be considered (Tomka 1989:145). Flake weight (attribute #17) should co-vary with the size grade categories representing different modes of reduction and lithic production intensity (Ahler 1989:205; Milne 1999:54). However, these attributes tend to be assemblage specific, and the experimental data acquired through numerous investigations provides only a general, not absolute, outline for lithic reduction.

Modification of the initiation face or striking platform can represent different reduction techniques depending on what state of modification is recognised. Typically, a crushed or shattered initiation face suggests bipolar and/or hard hammer reduction. However, it can also result from the use of excessive force in soft hammer percussion (Hayden and Hutchings 1989:247; Cotterell and Kamminga 1987:686). An abraded or ground initiation face suggests greater investment of time and energy in tool production, which possibly represents either a curated production strategy (Handly 1994; Milne 1999) or indirect versus direct percussion where a roughened surface keeps the flaker from slipping as pressure is applied. Platform dimensions including length, breadth, area, angle and number of platform facets (attributes #22-26) illustrate the decisions made during core reduction in terms of from where and how flakes and subsequent flakes are struck.

Lipping is typical of a classic waisted bending flake produced by soft hammer percussion or pressure flaking. Therefore, its presence is usually indication of these reduction strategies (Cotterell and Kamminga 1987:690; Hayden and Hutchings 1989:240). Lipping can, nevertheless, occasionally occur with hard hammer percussion. Éraillure scars, small flakes removed from the surface of the bulb of percussion, are associated with Hertzian (conchoidal) or bending initiation. It must be emphasised, however, that the frequency of éraillure scars is more likely a product of different styles of knapping rather than percussor type (Hayden and Hutchings 1989:245).

Exterior or dorsal scar count frequencies (attribute #27) combined with the direction of the exterior scars allows for the inference of the overall flake size and the size and number of previous flake removals (Amick and Mauldin 1989:82). The total numbers on each flake should provide a rough indication of intensity of reduction (Tomka 1989:145). Flake size will have an impact this. Direction may be also noted because a greater degree of variation in the direction flakes are removed should occur as reduction proceeds (Milne 1999:56). Following McBrearty (1986:183) dorsal scar pattern (attribute #28), as it relates to platform use, is also recorded. Flake planform or shape (attribute #29) can provide an indication of why a particular flake would be selected for use or modification (McBrearty 1986:198-199).

Salient bulbs of percussion, otherwise described as a partial Hertzian cone, are typically produced in hard hammer percussion, whereas more diffuse bulbar protrusions, when discernible, are generally produced in conjunction with the bending initiations associated with bipolar and soft hammer percussion are present (Cotterell and Kamminga 1987:686,690; Milne 1999:161). As noted above, although salient or diffuse bulbs of percussion do occur with bipolar reduction (Kobayashi 1975), there is often crushing of one or both platforms resulting in the obliteration of the bulb (Crabtree 1972:42).

Compression rings or rippling are attributed to bipolar percussion (Ahler 1989:210; Jeske and Lurie 1993:140). However, if excessive force is used to remove a flake with hard hammer percussion, pronounced compression rings may be present (Hayden and Hutchings 1989:240). Finally, Leaf (1979:39) and

Cotterell and Kamminga (1990:140) illustrate that secondary flake detachment also accompanies bipolar percussion. Generally, these flakes, which are not an intended product but result as a consequence of the redirection of force back up through the nuclei, display a crushed striking platform and hinged terminations (Leaf 1979:39).

Toth flake types (or Toth flake numbers) were created by Nicolas Toth on the "technological patterns" exhibited by whole flakes he examined as part of his PhD research (Toth 1982:56). The technological patterns were determined by the location of cortex (or lack thereof) on the butt (or platform) and dorsal surface of the flake (Toth 1982:73). He recognised six types ranging from flakes with fully cortical platforms and dorsal surfaces to those with non-cortical platforms and dorsal surfaces (attribute #21). These represent the various steps in flake removal beginning with the first flake to come off of a cobble through the later stages of flaking.

As demonstrated the presence or absence of each of these attributes allows one to determine the type of force applied to produce the artifact, thus the reduction technique used by the knapper. But understanding the method or technique of production is only one of the small pieces in the whole spectrum of behaviors present in stone tool production. As has been repeatedly noted by flintknappers and archaeologists, the raw material itself and the knappers knowledge of the properties of the various types of stone play a significant role in determining what the end product will be. I will return to this topic in Chapter 5.

Tool Analysis

Only two attributes are measured for retouched tools: angle of retouch (attribute #30) and the type of retouch (attribute #31). Retouch attributes are important as some researchers argue that the pattern of retouch may relate to the task for which the tool was used (Shott 1993:76). The angle of retouch, though difficult to measure consistently, is an important characteristic in terms of the nature of materials the tool was used to work and the technique used to work it (Andrefsky 2005:172). The type of retouch, as recorded in this study following Clark and Kleindienst (1974:85), could be described more precisely as the degree of invasiveness of retouch. Each worked edge of the tool is evaluated as having either marginal, semi-invasive, invasive or no retouch. Marginal retouch is where the margin itself is the focus of the modification. With semi-invasive and invasive retouch, some to a significant portion of the interior of the piece is removed (Odell 2003:74). This is not as formalized as Clarkson's (2002) index of invasiveness or Kuhn's (1990) geometric reduction index but does provide a basic idea of retouch on that particular tool. Bushozi (2011) analyzed the points from our assemblages for his doctoral research. The results of his research will be considered, in terms of raw material selection and use, in Chapter 8.

4.7 Summary

The characteristics of MSA and LSA lithic assemblages should make it clear that technological change is gradual and adaptive when looking at long time periods. Despite the long time depth represented by these assemblages, it is possible to make behavioral inferences based on technological indicators; i.e.m attributes. Fracture mechanics and debitage analysis will play a significant role in the interpretation and description of the lithic production strategies associated with these assemblages. However, we cannot limit our understanding of these assemblages to information derived from the attributes of the artifacts. We must recognise the role that strategies play in the overall organization of technology, the topic of the next chapter.

Chapter 5: Organization of Technology

5.1 Introduction

For archaeologists specializing in lithic technology, understanding the larger socio-technical structures that influence the production and use of stone tools is of the utmost importance. While still incorporating and drawing from research on fracture mechanics (Cotterell and Kamminga 1979, 1987; Dibble and Pelcin 1995; Moffat 1981; Purdy 1975), experimental replication (Ahler 1989; Callahan 1979; Crabtree 1970, 1972), use-wear analysis, core refitting (Cahen et al., 1979; Frison 1968), and ethnoarchaeology (Gould et al., 1971; Hayden 1984), emphasis is now placed on technological organization. Technological organization is the study of "the selection and integration of strategies for making, using, transporting, and discarding tools and the materials needed for their manufacture and maintenance" (Nelson 1991:57). By understanding the dynamics of technological behavior – the dialectical interrelations of economic, social, functional, environmental and behavioral variables of social structure manifest as, and in material culture – archaeologists are stressing the individual behind the tool and not just the tool itself.

5.2 Design Theory

Design theory focuses on the various task, material, technological, socioeconomic, and prestige and ideological constraints, in order to explain why differences occur in the organization of technology. These constraints include those imposed by raw material availability (in terms of abundance, quality, size and distribution) (Andrefsky 1994a, 1994b; Beck and Jones 1990; Cobb and Webb 1994; Gramly 1980; Jeske 1989), mobility (Andrefsky 1991; Cowan 1999; Kuhn 1994; Lurie 1989; Morrow and Jefferies 1989; Parry and Kelly 1987), settlement occupation (Sullivan 1992), and efficiency and optimisation (Bamforth 1986; Hayden 1989; Jeske 1989, 1992; Jochim 1989; Torrence 1983). These lead to a number of design considerations including reliability and maintainability (Bleed 1986), multifunctionality, and longevity, which ultimately affect the nature of the production/reduction, maintenance and 'recycling', and rejuvenation and modification strategies.

Artifact form and assemblage composition are, therefore, the consequence of different ways of organising technology through the implementation of different strategies (Nelson 1991:62). Strategies are problem-solving processes that are responsive to conditions created by the interplay of agents and their social/physical environment (Binford 1973, 1977, 1979; Bleed 1986; Kelly 1988; Nelson 1991; Parry and Kelly 1987; Shott 1986). These conditions vary spatially and temporally. Generally, two broad technological strategies are recognised – curation and expediency.

Curation

Lewis Binford (1973, 1977, 1979) first introduced the concept of curation to archaeological studies. Binford (1983:143) originally described a curated technology as one in which "a tool, once produced or purchased, is carefully curated and transported to and from locations in direct relationship to the anticipated performance of different activities." Over the past few decades, the application of this term has varied greatly, along with its definition. Critics have gone so far as to demand that its use be discontinued unless a specific definitional statement is made (Bamforth 1986; Kuhn 1989; Lurie 1989). Nelson's (1991:62) expansion of Binford's original definition is used for the purpose of this discussion: "a strategy of caring for tools and toolkits including advanced manufacture, transport, resharpening, rejuvenation, and storage/caching." The critical variable that distinguishes curation from its counter part expediency is the advanced preparation of raw materials in "anticipation of inadequate conditions [materials, time, or facilities] for preparation at the time and place of use" (Nelson 1991:63). Curated tools are generally made from 'exotic', better quality raw materials, when material is not widely available or is short in supply (Andrefsky 1994a:21; Morrow and Jefferies 1989:30). These tools are conserved through more intensive resharpening and rejuvenation as a means of prolonging their use-life (Shott 1989). In general, curated technological strategies imply a greater investment of time and energy in tool production and maintenance. Additionally, curated tools are used more intensively and because of this “will have a greater tendency to range in patterned stylistic expression and formal variability” (Binford 1973:243). Biface and microblade production typify curated technological strategies; however, Rasic and Andrefsky (2001:75) suggest that the utilization of a microblade core technology has less to do with concerns over efficiency than concerns with the size of available lithic raw material.

Expediency

Expediency, in contrast, refers to minimized technological labour (time and energy expenditure) under conditions where time and place of tool use are highly predictable (Bleed 1986; Nelson 1991; Parry and Kelly 1987). Whereas curation anticipates the need for materials and tools, expediency anticipates the presence of sufficient materials, the absence of time stress, and longer occupation or reuse of a location to take advantage of raw material stockpiling or local abundances (Nelson 1991:64; Torrence 1983). Using locally and often abundantly available raw materials, expedient tools are made for immediate use (Binford 1973:267), exhibit minimal specificity in design, and are not readily maintained. They are made, used, and discarded in the same location without regards to waste of material (Andrefsky 1994a; Parry and Kelly 1987). Bipolar and generalized core reduction tool technologies typify expedient technological strategies.

Opportunistic Behavior

Because not all technological behavior is planned, a third technological strategy is recognised – opportunistic behavior. Nelson (1991) contrasts this with, but Binford (1979) subsumes it within, expediency. Technological opportunism is unplanned and unanticipated (Nelson 1991:65). Immediate constraints (including needs and available resources) condition the design and distribution of tools produced using an opportunistic strategy (Binford 1979; Nelson 1991). Expediency and opportunism can be confused since they involve the immediate production and use of tools at the time and place where they are needed (Nelson 1991:65). However, care should be taken to differentiate the two since both have different implications for artifact design and distribution in the archaeological record and represent significantly different adaptive strategies. This occurs because one is planned, while the other is not (Milne 1999; Nelson 1991).

Distinguishing Curation from Expediency

A number of technological and morphological attributes can be used to distinguish artifacts produced by a curated technological strategy from those produced using an expedient strategy. Curated technological strategies are represented by tools displaying increased time and energy expenditure in their production (i.e., symmetrical morphologies, uniform flaking patterns, grinding, abrasion, edge serration), maintenance such as resharpening and rejuvenation (e.g., platform modification and faceting) (Towner and Warburton 1990) and raw material conservation (Andrefsky 1991, 1994a). Use of high quality raw materials is expected (Andrefsky 1991, 1994a). If these sources are non-local or exotic, greater variability in raw material types should occur. Evidence of pressure flaking and soft hammer production is expected as these methods of reduction are more precise in flake removal, conserve raw material, and are used in late stage tool manufacture and repair (Hayden 1989; Hayden and Hutchings 1989). All stages of manufacturing debris should be present as the result of manufacturing, repairing, and rejuvenating tools to be used elsewhere. Because formal tools are often removed from the site for future use, late-stage debitage produced during manufacture or maintenance may be all that is recovered from a site (Jeske 1992:472; Nelson 1991:75; Parry and Kelly 1987:301). This is a pattern which may become more acute when raw materials are scarce (Milne 1999:34). Formal tools will be conserved more intensively and discarded only when exhausted or broken in such a manner that they cannot be rejuvenated or modified into another form (Shott 1989). Biface and microblade production typify curated technological strategies. Attributes associated with debitage/flakes produced by these strategies focus on edge and platform morphology including platform abrasion, greater length than width, one or more dorsal arrises from overlapping negative flake scars, dorsal flake scar counts and scar direction counts (Barton 1988, 1990; Towner and Warburton 1990). Notching flakes are definitive evidence of biface production and can be identified by their lunate shape. V-shaped platforms, indistinct or crushed contact points, and round or expanding plan view (Towner and Warburton 1990).

Expedient technological strategies are represented by tools displaying minimal retouch and investment of time and energy in production. Because expedient tools are made, used, and discarded in the same location, the extent to which they are shaped by intentional retouch is conditioned by the immediate task, not by planned maintenance, use, or reuse (Nelson 1991:80). A regular relationship between the amount of debris produced and the number of tools deposited is expected since expedient tools are made, used, and discarded in the same place (Binford 1983:265). Specific reduction techniques depend on the size and shape of materials available for making tools but should not reflect raw material conservation, curation, or transportation constraints and concerns (Nelson 1991:80). Hard hammer percussion is more common in expedient technology as precision in manufacturing and raw material conservation are not primary concerns Hayden 1989:11; Parry and Kelly 1987). Some core preparation is expected in expedient tool kits since cores serve as stockpiled material to be used when needed (Parry and Kelly 1987). Because cores serve this purpose, cores at different stages of reduction should occur (Milne 1999). However, this is not always the case. Flakes can be struck from unprepared cores with little difficulty, the only preparation being use of a flake scar, which occurs as the result of testing of the quality of the raw material, for the striking platform.

Bipolar and non-standardized (or generalized) core reduction strategies are characteristic expedient strategies (Jeske 1992; Teltser 1991). Attributes associated with flakes produced through these strategies include the presence of ‘pigs’ (also called‘humpbacks’), absent to diffuse bulbs of percussion, multiple edges, crushing, pronounced rings of percussion, step/hinge fractures/terminations, and general irregular shape (Jeske 1992). It should be noted that ‘pigs’ especially occur with the bipolar reduction of poor quality material. Although classification of an assemblage as either curated or expedient is an oversimplification, they are terms useful in describing important aspects of technological behavior (Bamforth 1986:49).

5.3 Design Theory: Strategies and Constraints

Curation and expediency are not mutually exclusive strategies – they can occur simultaneously depending on local constraints and conditions (Nelson 1991:65). This co-occurrence has significant implications for understanding inter- and intra- assemblage variability within a single settlement system (Milne 1999:27, 28). Delineation of multiple strategies is necessary to understand assemblage composition and the behaviors that created it. By using this concept of technological strategies to understand variation in assemblages, one is implicitly recognising that the selection of one strategy over another is the result of adaptation, an active response to environmental (social, political, physical) conditions. Design theory allows us to examine the various constraints that are involved in adaptive, responsive processes (Hayden et al., 1996:10). There are five groups of constraints: material, task, socioeconomic, technological, prestige and ideological (Figure 5.1).

Briefly, material constraints are those that relate to raw material availability including quality, abundance and distribution; task constraints relate to efficiency and optimising labours; socioeconomic constraints relate to procurement and portability of raw materials; technological constraints include production costs, skill, resharpening and replacement; and prestige and ideological constraints are those relating to power, trade and exchange networks, and social organization. Here it is useful to comment that one can easily draw parallels between Hayden et al.'s (1996) design theory constraints and McBrearty and Brooks' (2000) archaeological signatures of behavioral modernity. This subject will be discussed in Chapter 8.

Material Constraints: Raw Material Availability

Raw material availability is the greatest determinant of lithic production technology (Andrefsky 1998). Andrefsky (1994a, 1994b) discusses how the attributes of availability – abundance, quality and distribution of lithic raw materials – condition the technological strategy. Andrefsky's (1991:29) study suggests that the extent to which local lithic raw materials are employed is a function of their abundance. When raw materials are scarce, non-local resources are typically procured and manufactured into formal, standardized tool forms. When raw materials are abundant, it is quality that predictably influences the production of informal (non-standardized, expedient) or formal (standardized, curated) tools. High quality materials, because they are easier to work with and shape, typically are used to make curated, formal tools. Conversely, poor quality materials, because they are more difficult and unpredictable to work/knap owing to inclusions and/or flaws, are more often made into expedient, informal tools. Therefore, when raw material abundance, availability, and quality are considered together in terms of their effect on the nature of the tool production strategy employed, a pattern emerges (Table 5.1).

Task Constraints
(Acceptable Performance)
- Task Mechanics (Precision, Force, Nature of Action)
- Efficiency
- Quantity
- Time Available
- Failure Consequences (Risk)

Material Constraints
- Available Materials and Associated Costs
- Relative Performance
- Relative Wear/Failure Rates

Technological Constraints
- Available Technology
- Production Costs
- Repair/Resharpening/Replacement Costs
- Skill Required

Socioeconomic Constraints
- Mobility
- Transport Capacity
- Available Labour
- Storage

Prestige and Ideological Constraints
- Kin Relations and Structure
- Restrictions/Limitations on Access to Resources
- Exchange/Trade Networks

↔ DESIGN CONSIDERATIONS

- Size and Weight
- Edge Angle and Form
- Prehension and Hafting
- Length of Use (Use life)
- Specialisation
- Reliability (robustness or "overdesign")
- Ease of repair
- Multifunctionality (versatility)

↔ TECHNOLOGICAL STRATEGIES

e.g.
- Expedient Block Core
- Biface
- Bipolar
- Scavenging/Recycling
- Ground stone
- Resharpening:
  - hard hammer
  - billet
  - pressure
  - grinding

Figure 5.1: A schematic representation of the various kinds of constraints impacting lithic tool production and their relationship to other design considerations and production strategies (adapted from Hayden et al., 1996:11; Figure 1).

Table 5.1: Relation of quality and abundance of lithic raw material and kinds of tools produced (adapted from Andrefsky 1994a:30, Figure 4.1).

		Lithic Quality	
		High	Low
Lithic Abundance	High	Formal and Informal Tool Production	Primarily Informal Tool Production
	Low	Primarily Formal Tool Production	Primarily Informal Tool Production

However, Brantingham et al., (2000) argue that raw material quality is an important, but not an absolute, constraint on the development of sophisticated, formal tool production strategies. Instead, biogeographic, adaptational, or behavioral processes exclusive from the effects of raw material quality are proposed as providing explanation for the absence of prepared, formal core technologies in a region. Notably, using thin-sections to examine percent crystallinity, average crystal size, range of crystal size and abundance of impurities, Brantingham et al., (2000) suggest that the scale of occurrence of these mineralogical variables have an impact the workability of stone materials. This method can, therefore, provide an estimation of the value of a particular raw material based on workability.

Distance between source and location of use, which is interconnected with mobility and portability (Newman 1994), is an important material constraint. "Distance is a measure of time and effort costs of acquiring raw material" (Hayden 1989:10). These costs have direct implications for tool production and, hence, technological strategies. Sites are usually placed where the basic conditions of human life (presence of food, water, and shelter) are met, and where raw materials are close at hand (Bryan 1950; Katalin 1998).

The distance from site to source plays an important role in determining the material (variety and amount) that will be found at a site. Generally, the closer to the site is to the source, the greater the amount of material from that source. Most other models suggest an exponential and proportional fall-off in quantity when compared to distance. The relationship between distance and use is directly related to concepts of value and labour – which can be referred to in terms of work, investment, or effort. As the amount of labour involved increases, the likelihood that some other, closer source instead will be used increases. There are regularities in the way in which this decrease in raw material quantity and availability occurs, and this pattern informs us about the mechanism by which a material reaches its destination.

Additionally, natural barriers and seasonal and technological constraints must also be considered. This occurs because the measured distance from site to sources is not the key variable; ease of procurement depends not only on distance but also upon ease of travel and social distance (Feder 1981). This is referred to as "effective distance" (Renfrew 1977:72). Effective distance takes into account natural barriers to trade and exchange (mountains, deserts, large bodies of water) as well as technological factors (e.g., without watercraft, waterways and bodies of water are a barrier, but serve to facilitate movement for those groups who have watercraft technology) and cultural elements (Feder 1981). The presence of well established networks of trade and exchange serve to decrease the effective distance (Feder 1981:195). Renfrew (1977:72) suggests that "effective distance may indeed be regarded as a measure of energy required to move goods between two points" where energy is labour. As labour, in some measure, determines an item's value in a society, effective distance can be used to infer a raw materials value in a society. In temperate areas, seasonal variations in ground conditions impact the accessibility and use of lithic raw material sources (Hayden 1989:10; Kuhn 1989). Heavy snow and ice cover greatly increase the cost of raw material procurement during the winter. Therefore, groups may either stockpile adequate resources during warmer months or they may rely on curated strategies conserving stone tools for a greater part of the year (Milne 1999:32). Additionally groups may instead choose to use osseous technologies (Le Blanc 2010).

Task Constraints: Labour, Efficiency, and Optimisation

Minimally, a tool must be effective, but as Bleed (1986:739) states "a good design will be more than a minimally effective solution" or adaptation to the conditions at hand. Different kinds of efficiency can be expected to be significant in different situations (Ricklis and Cox 1993). Technological efficiency is "the ability of technological organization (the supply of tools) to meet the requirements of the overall adaptive system for a certain gross utility (output) in order to maintain the lifeway" (Ricklis and Cox 1993:445). Simply put, technological efficiency is the ability to adapt to all the constraints and conditions discussed here in order to satisfy the needs and requirements of the group.

Discussions of energetic efficiency and optimisation occur with one main underlying assumption – that "the primary goal of any lithic-technology system is to increase energy yield from the environment" (Jeske 1992:469). Generally, the more energy that is expended in the acquisition and manufacturing of the tool, the more likely the object is to be transported or curated (Odell 1989). Jeske (1989) suggests that as raw material becomes more expensive, economizing strategies or behaviors, such as standardization in artifact from, reduction in tool size, and extension of tool use-life, are employed in lithic procurement and use. When raw material becomes more expensive, because of an increase in energy expenditure, Jeske (1989:36) argues two major consequences are observable. First, greater economy in the consumption of raw material is achieved, and second, artifact form becomes more standardized. High cost materials will be used to create standardized tools that require high energy input to manufacture, and when compared to tools made from low cost materials, expensive tools are smaller and less expediently discarded in the utilitarian context (Jeske 1989:45). This demonstrates that as energy expenditure and efficiency become important issues (constraints), the likelihood that a curated technological strategy will be selected over an expedient strategy increases. "Efficiency of use is a direct function of the value of a raw material" (Feder 1981:196) and value is a direct function of the inherent qualities of the material (workability, flexibility) and of the amount of labour necessary for procurement – a direct function of the effective distance to a source. Of course, this argument can be reversed to state that if a curated tool is desired, it is more likely that more time and energy will be spent on it.

The term 'risk' is used, along with expenditure, to discuss issues of efficiency and optimisation when discussing lithic raw material acquisition and utilization (Bleed 1986; Torrence 1989). Although generally discussed solely in reference to subsistence activities, risk is also relevant to technology as used in these activities. By organizing technology efficiently and optimally, risk is reduced providing greater support for subsistence strategies affected by resources which may or may not be reliable. Additionally, expenditure and efficiency is also treated in terms of time – time stress and availability, scheduling etc. (Torrence 1983). Time is most limited in highly seasonal environments in which mobile resources are used, resulting in diverse and complex tool kits facilitated by curated technological strategies and embedded procurement (Binford 1977, 1979; Torrence 1983). Table 5.2 summarizes some costs and benefits of expedient flake tool versus curated bifacially produced tool production strategies.

However, it should be noted that other aspects of culture and behavior will influence decisions concerning the allocation of time and energy. For example, social activities (trade, exchange, warfare) can yield other bonuses such as political alliances (Jeske 1992:469). As archaeologists know all too well, context is everything; it is not just raw material abundance and quality but social demands and situations that influence selection of a strategy as a means of adaptation.

Table 5.2: Costs and Benefits of Chipped Stone Tool Production Strategies (adapted from Cowan 1999: 594, Table 1).

Costs and Benefits	Flake Tools from Cores (Expedient)	Bifacial Tools (Curated)
Production costs	Low	High
Tool use life	Short	Long
Raw material consumption	High	Low
Multifunctional utility	Low	High
Hafting costs	High	Low
Portability	Low	High

Socioeconomic Constraints: Procurement and Portability

The type of procurement strategy is a major socioeconomic constraint that ties back into both task and material constraints. Procurement is directly influenced by raw material availability and mobility. Generally, sedentary populations are identified with an expedient technological strategy (or informal/non-standardized tool technology) and mobile populations with a curated technological strategy (or formal/standardized tool technology) (Andrefsky 1994a:21). Gramly (1980:831) suggests one can predict little variation in tool and raw material frequencies in assemblages produced by sedentary groups as it can be suggested they were able to anticipate their yearly requirements for raw materials and satisfy all needs in a single visit to a source. However, this fails to account for gift giving practices and other social interactions/behaviors. Nevertheless, inverse to Gramly's (1980:831) argument, one can predict tool and raw material frequencies in assemblages produced by mobile populations. These will demonstrate greater variability as visits to different sources can be incorporated into seasonal movements (Morrow and Jefferies 1989). There are several procurement strategies including: (1) trade and/or exchange networks; (2) special-purpose trips direct to source areas; and (3) trips to a source embedded within seasonal movements through the region (Morrow and Jefferies 1989:27). These strategies are reflected in the nature of raw material usage and a number of different hypotheses can be presented based on the differential usage of local versus non-local lithic types relative to the different procurement strategies.

In general, the frequency of exotic or non-local material types should rise with greater mobility or exchange (Beck and Jones 1990). Trade and exchange can mean much the same thing when referring to material goods. However, exchange has a wider meaning used to describe all interpersonal contacts (exchange of non-material goods, i.e., information). Trade or exchange networks are generally the means of obtaining exotic materials for sedentary populations, and the cost of transaction will then be determined in terms of the agreed value of the goods exchanged (Morrow and Jefferies 1989:30).

In the absence of exchange, populations moving greater distances would come into contact with, and have access to, more sources than less mobile populations (Beck and Jones 1990:284). Direct procurement refers to the situation where the user of the raw material goes directly to its source without the intervention of any exchange mechanism (Morrow and Jefferies 1989). Costs are measured in terms of the time and energy expended on the journey (Morrow and Jefferies 1989:30). With both trade and exchange and direct procurement, non-local raw material utilization should reflect the greater costs of their acquisition; i.e., differential usage compared to that of local materials. In general, non-local raw materials acquired through these means of procurement should reflect curated usage.

Embedded procurement occurs when "part of the groups is conducting other extractive tasks in the vicinity of the source area as part of their normal, seasonal movements" (Morrow and Jefferies 1989:30). Embedded procurement, then, is associated with mobile populations. In this manner lithic raw materials are easily acquired with little additional cost in terms of time and effort invested into travel. These non-local lithics should then be used in an identical manner to the local ones – in an expedient and/or curated manner (Morrow and Jefferies 1989:30). Gould and Saggers (1985:117) state that Binford's (1979) ideas of embeddedness are "overly restrictive and inadequate" and cannot account for the variability observed in their study, and overstated to the point where "parsimony approaches reductionism." Instead, they suggest that embedded procurement cannot be considered solely in relation to subsistence economy – that if our primary task

> is accounting for the variability we observe within and between the materials we actually find in our sites (and) those materials happen to be stone artifacts, then our view of embeddedness must incorporate technological as well as subsistence factors if we are to avoid the charge of scientific reductionism. (1985:118)

However, the rest of their study also demonstrates the necessity of considering sociocultural factors, a point I will return to subsequently in this chapter.

Vermeersch et al., (1990) determined four main categories of raw material procurement extractions based on field observations in Egypt, which are supported by other studies (e.g., Ericson 1984): incidental collecting, intensive collecting, systematic quarrying, and underground mining. These four categories can occur within either direct or embedded procurement strategies. Incidental collecting occurs when raw materials are found and collected without any prior planning. This form of collecting is associated with expedient technological strategies. With intensive collection, abundantly available raw materials are collected without specific organised extraction strategies (Vermeersch et al., 1990:80). Sites where intensive collection has occurred can be identified by the presence of huge amounts of waste materials and cores (Vermeersch et al., 1990:80). Systematic quarrying occurs in areas with abundant raw material located in a primary source. Quarrying results in well delimited open-air features, which were dug to quarry the material; this produces large amounts of waste materials and cores (Vermeersch et al., 1990:80). Underground mining occurs with large, good quality sources resulting in the creation of subterranean structures and large volumes of waste material (Vermeersch et al 1990:80).

However, the actual procurement of the material varies according to the nature of the quarry/source site itself (Gould et al., 1971). Primary sources are *in situ*, bedrock outcrops where raw materials are acquired through direct collecting, quarrying, or mining. Secondary sources are those redeposited materials such as glacial till and water-laid gravels (Lavin and Prothero 1992:97). Whereas quarrying and mining are most likely to be associated with primary sources, intensive and incidental collecting may occur with either primary or secondary sources.

The utilization of a source, as a quarry, and the means of raw material procurement determine the structure of the lithic production system (Table 5.3). Ericson (1984:3) defines a lithic production system as “all activities and locations involved in the utilization and modification of a single source-specific lithic material for stone-tool manufacture and use in a larger social system.” It is the source-specific factor in lithic production systems that require the information produced by provenance studies in order to best understand the other factors and processes involved, and the reverse is also true.

Conversely, with secondary sources or non-quarry primary sources, different procurement strategies are employed resulting in different lithic production systems. The utilization of materials procured through quarrying and mining from primary sources should reflect the additional time and energy expenditure associated with these procurement strategies. Economising behavior manifests as maintenance, rejuvenation and retouch (curation) to help offset these increased costs (Morrow and Jefferies 1989).

Both procurement and technological strategies are influenced by portability. Unretouched flake edges are fragile and easily damaged in transit, and cores are heavy and cumbersome (Cowan 1999; Kuhn 1994; Nelson 1991). Standardized production permits highly efficient use of raw material – smaller weight is needed to produce tools sufficient to meet anticipated needs and more usable cutting edge per unit mass is obtained. Thus, formalized tool production technologies are more portable because a fixed set of needs are fulfilled with fewer tools made from a smaller weight of raw material (Parry and Kelly 1987). Although portability can be attained in several ways, all "seek to maximize the utility of derived from a toolkit in relation to its size and weight" (Rasic and Andrefsky 2001:64). The benefits of portability outweigh the added costs of producing and maintaining tools in a curated strategy. Portability is directly affected by technological constraints (rejuvenation and resharpening) and design constraints such as longevity, multifunctionality (versatility and flexibility), reliability, and maintainability.

Table 5.3: Stages, zones of production, and products (adapted from Ericson 1984:5).

Zone of Production	Stages of Production Terminal	Sequential	Irregular
Quarry	Final product produced here, then conveyed to region	Partially completed products to region	Some production at quarry
Local	Final products produced here, then conveyed to region	Partially completed products to region	Final and incomplete natural materials supplied from quarry and local production zone
Regional	n/a	Production completed at or near site of consumption and use	Natural materials supplied from quarry and local production zone

Note that Table 5.3 only represents some of the possible lithic production systems based on the sites of production, and the products found at a site.

Technological Constraints: Rejuvenation and Resharpening

Technological constraints include available technology, production costs, skill required and costs of repair, resharpening and replacement. Rejuvenation and resharpening are the most significant technological constraints as they have significant impact on technological organization. Towner and Warburton (1990) make a distinction between rejuvenation and resharpening. Whereas rejuvenation is defined as "the refurbishing of a broken tool into a functionally equivalent tool" (Towner and Warburton 1990:311), resharpening is "the retouching of a dulled tool to provide a fresh, sharp cutting edge" (Towner and Warburton 1990:311). Both techniques are associated with curated technological strategies. The importance of understanding and interpreting rejuvenation and resharpening relates to one of the debates around curation, questioning its effects on and visibility in the archaeological record (Bamforth 1986; Gramly 1980). The archaeological record demonstrates that resharpening and rejuvenation of stone tools occurred throughout prehistory (Dibble 1987; Frison 1968). Kelly (1988) has suggested the types of sites that may favour, and technological strategies that may structure, the rejuvenation of projectile points. Evidence for resharpening and rejuvenation is evidence for curation. Therefore, it supports arguments suggesting curation does affect the nature of lithic assemblages and is visible in the archaeological record. Towner and Warburton (1990:319), based on their analysis of experimental replication of a resharpened and rejuvenated assemblage, conclude that "behavioral manifestations of curation and technological organization can be identified in the archaeological record and in lithic assemblages", if proper site sampling, field recovery (notably use of screens with smaller grades), and analytical techniques and methods are employed.

Prestige and Ideological Constraints

Prestige and ideological constraints are arguably difficult to uncover or come to any conclusions about without supporting historical or ethnographic records. Studies by Pokotylo and Hanks (1989) of mountain Dene in the

Northwest Territories, Canada, and Gould et al., (1971), and Gould and Saggers (1985) of Australian desert aborigines, reflect similar attitudes towards raw material acquisition. Aesthetic values and ideological connections to the land have great influence on the selection and use of particular raw material and its sources. Often the preferences have little to do with the working quality of the material. Greater importance, again, is placed on the ideological (spiritual, emotional) connection to a region based in kinship. These materials recovered from ancestral (familial, "sacred") sources are quite often transported over large distances and curated (Gould et al., 1971).

Power can be manifest in terms of differential access to goods and services including raw materials. Power is this ability to act, to accomplish something, and it makes social labour possible (McGuire 1992:132). There are two types of power: "power over" and "power to." "Power over" is the power to "thwart another." It is a form of negative action where power becomes something set apart by society as a whole, something held by some and not by others. "Power to" is "the ability of all people to act, or intervene, in a set of events so as, in some way, to alter them." It is an inherent aspect of human existence which may involve "power over." Because power is the result of human action (agency), it too does not exist apart from society. By reinforcing and reproducing "beliefs that mask power and domination from the people of a society" (McGuire 1992:105), material culture becomes a "medium for domination and the exercise of power over people" (McGuire 1992:104). The strength of this perspective on power is that it allows for the recognition of the many forms and sources of power. This, therefore, allows archaeologists to examine ideology and structure without lapsing into the limitations of a hierarchical scheme.

Power becomes significant when access to raw material sources is influenced and/or determined by lineage and territorial rights. Control over, or rights to, raw material sources may belong to some lineages or groups but not others. If raw material sources are located in boundary or transitory areas then access may not be limited. Or if limited, they may still be available through reciprocal exchange or emissary trading. This concept of differential access to raw material sources is connected to an interrelated socioeconomic constraint – kin organization. There are four main patterns of residence that are the function of kinship structure: matrilocal, patrilocal, neolocal and avunculocal; which are in turn influenced by whether marriage is structured by exogamy or endogamy (Schultz and Lavenda 2001).

Where suitable materials were available in a region but an "important amount" of material was brought to the sites from exogenous sources from up to 100 km away, Baales (2001:127, 139) interprets this as reflecting "regular social contracts with people in neighbouring regions" and mobility is necessitated by the need for maintenance of the social relations. He suggests that knowledge of and intermarriage between different groups provides a form of "insurance" in times of local subsistence scarcity, and also makes it possible to avoid inbreeding of the local groups (Baales 2001:139). These networks enable the exchange and diffusion of knowledge of technological innovations in addition to material goods.

Gould and Saggers' (1985) ethnoarchaeological work with Australian desert Aborigines illustrates a number of prestige and ideological constraints that have an impact on raw material procurement practice. Although the trips summarized by Gould and Saggers (1985:122) refer only to those carried out with the purpose of obtaining lithic materials for stone tool production, they noted a number of significant social and ideological factors which impacted raw material procurement. These included the "willingness" of individuals and groups to make long trips for the primary purpose of visiting sacred sites, meeting with members of the patrilineages controlling those sites, and arranging betrothals thus establishing in-law relationships over long distances. However, the actual choice of the lithic source to be visited was "structured in part by its relative proximity to a habitation base camp where people happened to be at that time" (Gould and Saggers 1985:120). Therefore, these special trips are an example of embedded procurement. Similar procurement trips occurred for mineral pigments, spinifex resin and *Crotalaria* bark (Gould and Saggers 1985:120).

Essentially, long distance trips were essential for establishing social networks and connections, which involve the obligatory sharing of food and access to resources. These social networks are among the "most strictly observed relationships in the society" (Gould and Saggers 1985:122). Furthermore, although stone tool making was not an exclusive male activity, only men made the special purpose trips to obtain lithic materials (Gould and Saggers 1985:120). This strict division of labour by sex can be attributed, in part, to the patriarchal social organization of the groups involved in the long-range social networks. Of thirteen lithic source localities visited in their study, nine had sacred associations which only men with "specific affiliations to those sites could approach" (Gould and Saggers 1985:120).

5.4 Design Considerations

The formal design of tools is directly linked to the various tasks and functions for which the tools are employed (Andrefsky 1998). This suggests that design considerations play an important role, yet one separate from constraints, in determining the technological strategy employed. Design considerations are a class of conditions separate from the basic constraints described above. They include the "purposeful consideration" of reliability, maintainability, versatility, flexibility, and longevity (Hayden et al., 1996:12; Nelson 1991:66).

Reliability and Maintainability

Reliability and maintainability are the two most important design considerations that influence the lithic production technique utilized, as they are the determining features for whether or not a curated versus expedient strategy will be employed. Bleed (1986:739) uses seven criteria to characterize reliable tool strategies (or systems): (1) overdesigned components (parts made stronger than they minimally need to be); (2) understressed (system used at less than full capacity); (3) parallel subsystems and components (redundant and standby); (4)

carefully fitted parts and generally good craftsmanship; (5) generalized repair kit including basic raw materials to affect any repair; (6) maintained and used a different times; and (7) maintained and made by a specialist. Arguably, these criteria can be reduced to the few that are directly inferable from archaeological lithic assemblages, including overdesigned and carefully fitted parts, good craftsmanship, specialist manufacturing and maintenance, and maintenance outside of the context of use (Hayden et al., 1996:12). Although reliability can be an important and necessary design consideration for some production strategies, it has costs that can make it a less than ideal adaptation for some situations (Bleed 1986:740). Reliable strategies are costly in terms of time, energy, raw material, and greatly affect the potential to implicate other design constraints – notably portability.

A maintainable strategy is an optimal design for unpredictable conditions, especially when accompanied by continuous need (Bleed 1986). Bleed (1986:739) uses eight criteria to characterize maintainable tool strategies: (1) generally light and portable; (2) subsystems arranged in a series (each part has one unique function); (3) specialised repair kit that includes ready-to-use extra components; (4) modular design; (5) design for partial function; (6) repair and maintenance occur during use; (7) user maintained; and (8) overall easily repaired, i.e., is "serviceable." Again, these can be reduced into a few archaeologically observable criteria including: lightness and portability, simplicity of design, easy maintenance by people with poor lithic skills, use in a range of functions (versatility), and the occurrence of repair and/or maintenance during use (Hayden et al., 1996:12).

Versatility and Flexibility

While versatility refers to the number of uses for which a tool is designed (Shott 1986:19; Nelson 1991:70), flexibility refers to changes in tool form for different uses (Shott 1986:19; Nelson 1991:70). Hayden et al., (1996) argue that when used in conjunction these terms can be confused. Therefore, Hayden et al., suggest that 'multifunctionality' not only represents the same concepts used by

Nelson (1991) and implied by Shott (1986) but is a more established, clear, and descriptive term. Kelly (1988), in his discussion of the "three sides of a biface", examines the archaeological consequences of the production, use, and maintenance of multifunctional tools. To illustrate the significance of multifunctionality, bifaces can be manufactured to play one or more of three different 'organizational' roles: (1) as cores; (2) as long use-life tools, which is necessary to its role as a resharpenable and usable even if broken tool; and (3) as a by-product of the shaping process (Kelly 1988:719). These features of a biface allow it to be both maintainable and reliable while being versatile enough to serve a number of different functions, and flexible enough to adapt to the task at hand through rejuvenation and retouch if necessary. Multifunctionality does not, however, necessarily indicate a curated technological strategy. Expediently produced flakes can also be multifunctional as they are both versatile and flexible.

Longevity

Longevity, or use-life, is an important consideration, tied closely to curation. "Whether or not a tool is designed to have a long use-life depends on its anticipated context of use (Kelly 1988:720). A tool may be manufactured to have a long use-life if "it is expected to be used under a variety of conditions" (Kelly 1988:721). There is a clear correlation between useful lifetime and the manufacture time of an object (Gero 1989:94). Ultimately, expediently-made tools have a short use-life because first, all methods of tool production are consumptive of lithic materials, and second, unless flake tools are large, they have a limited capacity to be retouched and rejuvenated to perform different tasks (Cowan 1999:594). Bifacially shaped tools, however, have long use life because they can be retouched many times without changing the form of the functional edge. They are resistant to damage and they have sufficient mass to allow for repairs or modified into new forms (Cowan 1999:594). Artifact longevity is an interesting variable because the "longer the use-life expectancy of an artifact, the more appropriate the artifact becomes for carrying social information" (Gero 1989:94).

Style versus Function

Inevitably, a discussion of design constraints leads to an explication of the style versus function issue. Barton (1988, 1990), Dibble (1987), and Nelson (1991) discuss this issue of style versus function and the suggestion that patterns between morphology and function can be determined. Variability in edge attributes provide a measure of the degree to which edges were used and modified. This should then also reflect any associations between edge morphology and function (Barton 1990:58; Dibble 1987; Kelly 1988). However, Barton (1990:67) suggests:

> retouched 'tools' seem more likely the end result of the extent and nature of the use of their various edges than planned tools for which the maker had some form of 'mental template'… [Therefore] the primary factors that contribute to variability in edges seem to be the dimensions of the original flake used, whether edge use was extensive or concentrated, and the intensity of edge use and subsequent rejuvenation.

Whereas Barton (1990:70) concludes "with respect to the interpretive value of lithics, questions of style and function may be moot for most retouched tools", Dibble (1987:116) takes a contrary position. He suggests "it is clear that the isolation of different aspects of lithic variability related to technology, function, style, and even raw material will continue to be basic to our understanding of assemblage variation." Function can be inferred from stone tools using use-wear analysis and experimentation. Inarguably, design is a function of function. Contention arises in whether or not design, in terms of the intent and planning of the tool producer, can be inferred from function. Kelly (1988) illustrates that when other design constraints and considerations are adapted for, style can serve to meet a number of tool-use needs and functions. Ultimately the distinction between style and function is a product of the decontextualization and dehistoricization of artifacts.

The problem with the style versus function debate is that style is "so nebulous in its usage that it is often discussed without being defined" (Cross 1983:99). Style is often used interchangeably with design, as the discussion above of Barton's (1990) and Dibble's (1987) work shows. Although the examination of style offers a "complementary approach to the comparative mechanical efficiencies of lithic artifacts" in studying social change, there are a number of different problems which hinder the application of style to material culture (Cross 1983:99). First, style is often a residual category; it is used to "subsume variation for which function cannot be inferred." Second, it is "unmanageably multidimensional." Third, it has little functional value (Cross 1983:99). However, stylistic behavior can be a function of prestige and/or ideological constraints. Style plays a role in the formation and maintenance of social boundaries and variation in style may serve to integrate or differentiate groups (Cross 1983:100). Lithic artifacts, because they are portable and may be expected to be present in boundary maintaining situations (Cross 1983:101), may also serve to encode messages (Cross 1983; Gero 1989). As such, style will remain a necessary attribute of material culture to be considered by archaeologists in their interpretation of lithic assemblages.

Design Theory Conclusions

As the above discussion illustrates, these design considerations and constraints are heavily interconnected. Arguably, the design, implementation, and utilization of technological strategies cannot be attributed to any one factor. Instead, it can be attributed to the interrelation of task, material, socioeconomic, technological, and prestige and ideological constraints and design considerations. This is wholly consistent with the definition of a strategy as previously stated: problem-solving processes that are responsive to conditions created by the interplay of agents and their social/physical environment.

5.5 *Chaîne Opératoire* and the Anthropology of Technology

Recently the concept of chaîne opératoire, or operational sequence, has been introduced into the study of Old World prehistory. Originating with Andre Leroi-Gourhan, chaîne opératoire is a cognitive approach. Chaîne opératoire is a conceptual model as well as an analytical tool. As an analytic tool, it is successfully applied to two fundamental kinds of research questions: those which identify the sequential technical operations by which natural resources were transformed into culturally meaningful and functional objects, and once these sequences are identified, those which infer something of abstract cognitive processes and underlying normative logic systems structuring those acts (Dobres 2000). As a conceptual model, chaîne opératoire is a technical chain of sequential material operations by which material resources are acquired and physically transformed into cultural commodities. It is a dynamic act of material and social transformation (Dobres 2000). It deals explicitly with people who were engaged in a decision making process, where each decision is made at differing levels of consciousness (Close 2006:8), the people who are behind the artifacts. Sillar and Tite (2000:4) define five areas of analysis within a technology where choices exist:

1) raw material
2) tools used to shape the raw material
3) energy sources used to transform the raw materials and power the tools
4) techniques used to orchestrate the raw materials, tools, and energy to achieve a particular goal
5) the sequence, or chaîne opératoire, in which these acts are united to transform raw materials into consumable products.

These correspond to the five components of technique outlined by Lemonnier (1992:5-6): (1) matter, (2) energy, (3) objects, (4) gestures, and (5) specific knowledge. Each of these can be readily identified or inferred by archaeologists.

The interest of archaeologists in the anthropology of technology is “partially the result of material culture studies (including ethnoarchaeology) that have repeatedly demonstrated that a society's technology includes much that is not necessarily from a purely technical or functional point of view" (Cooper 2006:8). An anthropology of technology approach recognises the impact of material culture on the "creation and reproduction of social relations and cultural values, and focuses on technology as the result of culturally contextualised choices" (Cooper 2006:8). Technology is therefore a system of knowledge, rather than an inventory of objects (Ridington 1982). This shift to a focus on an anthropology of technology and a chaîne opératoire approach is a critical and important shift away from the study of artifact morphology, typology, and function, and toward an interest in the dynamic life histories of artifacts (Dobres 2000).

I would argue it is complementary to a design theory approach as a detailed understanding of raw material procurement selection, and use (i.e., raw material constraints) is central to chaîne opératoire. Chaîne opératoire also incorporates these raw material aspects, including abundance and availability, into understanding stone tool morphology (Bar-Yosef 1991). Sinclair (2000) inflates this into a concept of affordance. This expands the design theory concept of raw material as a constraint, suggesting that raw materials do not simply constrain choice but also offer opportunities for use of particular techniques and expressions of skills and knowledge salient in the creation and maintenance of individual identities (Sinclair 2000).

Dobres (2000) argues that technologies are arenas in which agents construct social identities and forge power relations while also producing and utilising utilitarian objects for practical ends. Agency is the manipulation of structure; it is not individualism but intentional and meaningful action, a dimension of social practice. Technology is particularly amenable to the analysis of past social agency because the material record itself supports an identification of action. The specificity of materials used, and techniques employed to create a particular tool form provide a range of factors that bring the agency of individuals to life, exposing their decisions and their reflections (Sinclair 2000).

Bar-Yosef and Van Peer (2009) offer a critique of chaîne opératoire from the perspective of Middle Palaeolithic archaeology. They do not argue that it is invaluable or invalid, but rather question the direct applicability to Lower and Middle Palaeolithic studies where the essential role of social context cannot readily be explored through ethnoarchaeological or ethnoanthropological studies (Bar-Yosef and Van Peer 2009:117). They agree that less attention should be focused on the descriptive formal classification of debitage products and more on searching for the causes of patterns in the technological record (Bar-Yosef and Van Peer 2009:117). Although replication and use-wear studies are also important aspects of chaîne opératoire studies, they are not discussed here as they are beyond the scope of this research.

5.6 Technological Organization Research Questions

I have developed the following research questions, and test assumptions concerning the relationship between organization of technology, raw material, mobility, and behavioral modernity:

- *What technological (lithic tool production) strategies were utilized at each site as represented in the lithic artifacts recovered?*
- *How was technology organised?*
- *Can technological change be used to explain raw material variability?*
- *Which sources (local, non-local, exotic) were utilized? How were raw materials acquired?*
- *Who were the agents of raw material acquisition, transportation, and utilization? Is their inferred behavior "modern"?*

Assumption I and Test Expectations

If each assemblage (MSA versus LSA) is largely composed of abundant, poor-quality, locally available raw materials, the group likely had low mobility in a restricted range. This may reflect the lack of planning in resource acquisition.

If thisassumption is valid, an assemblage exhibiting minimal energy expenditure in its production is expected. There will be a high relative proportion of debitage to tools. Debitage should exhibit attributes associated with generalized or non-standardized reduction (hard hammer and bipolar percussion). Non-standardized (informal) tools will not be extensively shaped, maintained, or rejuvenated, and should not outnumber standardized (formal) tools. There will not be evidence of conservation of raw material. Tools broken during production and use, as well as exhausted curated objects, are expected. Overall assemblage variability is low.

Assumption II and Test Expectations

If each assemblage (MSA versus LSA) is composed of exotic or non-local, high quality raw materials, then group mobility is high, allowing for the acquisition of materials from a large and varied region. This demonstrates a high degree of planning for obtaining resources.

If this assumption is valid, an assemblage exhibiting greater energy investment and conservation is expected. Tool conservation should be visible in the form of extensive, invasive retouch. Debitage will display soft hammer percussion and pressure flaking attributes since these precision techniques allow for raw material conservation. Greater numbers and varieties of formal tools are expected to be present. However, the full range of reduction debris need not be present as the production of curated implements can occur over the course of a seasonal round (Binford 1979), and the debris present is likely that produced during tool maintenance. Again, overall assemblage variability will be low because the lithic reduction strategies will be narrowly focused on tool conservation and repair.

Assumption III and Test Expectations

If there is pronounced assemblage variability, in terms of the quality of and procurement effort towards obtaining the raw material types utilized, group mobility would still be high. This reflects a need for planning and flexibility, which may be necessary adaptations for dealing with differential access to raw material sources. Access to sources may vary owing to changes in season, landscape, or sociocultural/ sociopolitical interactions with neighbouring groups. This is a strong constraint on group mobility.

If this assumption is valid, assemblage variability will be high. Assemblage composition will vary proportionally depending on the duration of occupation and/or number of reoccupations. Reduction strategies will illustrate diversity with diagnostic attributes. A full range of reduction sequences is expected. Both non-standardized (informal) and standardized (formal) tools will occur.

Finally, some additional assumption may be presented with respect to expectations of differences between MSA and LSA assemblages (see Chapter 4) and in reference to the assumptions presented above.

1. MSA assemblages are characterized by flake and blade tools, largely produced via the Levallois technique. The Levallois technique is utilized to produce standardized pieces that do not require additional reshaping before use. Retouch may occur but is not expected. Thus, MSA assemblages should be largely composed of locally acquired materials, the use of which will be expedient.

2. Conversely, LSA assemblages are characterized by microlithic technology. Microlithic technology is associated with conservation of raw

material and the systematic production and retouch of standardized objective pieces. It is expected that there will be a greater amount of exotic raw materials in the LSA assemblage.

3. Overall, it is expected that there will be greater intra-assemblage variability than inter-assemblage variability; i.e., there should be greater disparity between MSA and LSA assemblages within a single site than there should be for MSA assemblages at both sites or for LSA assemblages at both sites.

5.7 Summary and Conclusions

The assumptions and test expectations presented above attempt to connect the attributes with production technique and technological strategy so that a larger picture of group mobility and raw material acquisition can be inferred. It is important to understand an archaeological lithic assemblage as a whole. This means that the focus must not be just on the attributes of the artifacts themselves (as discussed in Chapter 4) but on what those attributes reveal in terms of the technological strategy employed. In order to make meaningful interpretations relating to the behavior of the individuals who produce lithic assemblages, it is necessary to understand how the assemblage represents the organization of technology.

Chapter 6: Raw Material Provenance

6.1 Lithic Raw Material Provenance: Theory

The provenance of an artifact is the location of its origin. With lithic artifacts, it is the specific geographic and geologic source of the raw material from which the pieces were made. The source can be a quarry, mine, geologic formation (or member within a formation), outcrop or any other "coherent and bounded" geologic feature (Rapp and Hill 1998:134). Following Luedtke (1979:745), 'source' is used here to mean "the area or location from which the (rock) was originally obtained as raw material"; this includes both primary and secondary sources. Primary sources are *in situ* bedrock outcrops where raw materials are acquired through direct collecting (non-quarry outcrops), quarrying or mining. Secondary sources are redeposited materials such as glacial till and water-laid (stream, beach and talus slope) gravels (Lavin and Prothero 1992:97; Luedtke 1979:745). The underlying assumption for all provenance studies is that there is a "demonstrable set of physical, chemical, or mineral characteristics in raw-material source deposits that is retained in the final artifact" (Rapp and Hill 1998:134); moreover this assumption can be tested and justified through empirical analytical research.

Numerous characterization studies have concentrated on specific quarry sites within bedrock outcrops (e.g., Aspinall and Feather 1972, Sieveking et al., 1972); however, this may be a problem if quarries are the only outcrops sampled (Lavin and Prothero 1992:96). There may be extensive outcrops throughout a region of any particular raw material, but few visible quarries. Lavin and Prothero (1992) emphasise the importance of sampling these primary, non-quarry outcrops as well as secondary, redeposited materials such as glacial till and water transported and deposited gravels. Shelley (1993) presents a geoarchaeological approach for the evaluation of lithic raw material characteristics when secondary deposits were exploited for tool production.

The archaeological significance of the information that can be acquired from a provenance study is considerable. As illustrated in Chapter 5, raw material is an important consideration for the understanding of the organization of lithic technology and tool production. Where the raw material is acquired and how it was procured are determinants in how a tool is used. The investigation of lithic material procurement and artifact use is not only illustrative of intrasite economies and activities (see Chapter 5; Katalin 1998), but also of a number of cultural and social processes including trade and exchange, migration and invasion, territory size and location.

Earle and Ericson (1977:3) state that the "interest in prehistoric exchange stems from two factors: (1) a recognition of exchange as central to maintenance and change in cultural systems, and (2) the technological innovations permitting detailed quantitative studies of exchange." The discovery of new resources leads to technological innovation. The use of these newly acquired resources requires the application of old knowledge to materials with unknown/untested properties. This results in the adaptation or even abandonment of old technologies including methods and techniques. New technologies employed by archaeologists in provenance studies, now allow the tracing of the sources of artifactual raw materials with a high degree of accuracy and precision therefore allow the archaeologist to document and infer with some confidence contact between groups of people, and interactions of people with their environment. Provenance investigations, however, are only one aspect of archaeological research on exchange, which also includes descriptive and systemic modeling, and the application of ethnographic and ethnohistorical research (Earle and Ericson 1977:4).

Baales (2001) examines spatial and social organization at the Final Palaeolithic site of Kettig, Germany. He found that in addition to local materials, exogenous (exotic) resources such as flint from up to 100 km away were exploited. Although adequate, good quality raw materials are available locally, there is the regular use of exotics. Baales (2001:127) suggests this reflects the “necessity” of maintaining regular social contacts with neighbouring peoples; necessity because these types of contacts (i.e., opportunity for trade, exchange of goods and knowledge) are of great importance for small hunter-gatherer groups in a sparcely inhabited landscape. Further this allows groups to form “higher level group identity” and constructs a form of “insurance” created by knowledge of and intermarriage between different local groups (Baales 2001:139). He also looked at site formation by plotting the distribution of lithic artifacts within the site: spatial analysis allowed for discernment of two separate occupations. Interestingly in the Baales (2001:139) model, “lithic raw material curation and transportation was simply a by-product of the movements initiated by highly necessary regular social contacts” between groups; this is a direct inversion of design theory argument. However, this study clearly demonstrates that archaeologists must be aware that trade constitutes only one form of exchange.

Ultimately when one discusses trade, exchange, migration, and territory size, one is commenting on the mobility of the individual and of the group. In terms of raw material acquisition, this mobility is further refined as that which is determined or initiated by the need for resources. It is not just movement across the landscape, but that which is deliberate, planned, and intentional. This is not to say that acquisition of resources may not be spontaneous (i.e., opportunistic), but rather I wish to emphasise the importance of defining mobility in this study as that which is resource-driven.

A few important provenance studies have examined the inter-dynamics between raw material utilization and land use during the MSA and LSA including Barut (1994), Kusimba (1999, 2001), Dickson and Young-Gang (2002), Dickson et al., (2004), and Dietl et al., (2005). Féiblot-Augustins (1993), Bernard-Guelle (2005), Wallace and Shea (2006), Burke et al., (2008), Diez-Martín et al., (2008), and Miller and Barton (2008) have also explored Middle and Upper Palaeolithic land use in European contexts. However, the studies by Burke et al., (2008), Diez-Martín et al., (2008), and Miller and Barton (2008) differ from the rest in that they focus more on patterning across a physical landscape rather than on the nature of lithic inventories and raw material economy, changes in site use and site type (i.e., rockshelter versus open air), and mobility.

Barut's (1994) research represents the closest study to that attempted here. He examines changes in the use of lithic raw materials and sites during the later MSA and early LSA in East Africa. Barut analyzed the ithic assemblages from Lukenya Hill, Kenya and Nasera Rockshelter, Tanzania. Two models of hunter-gatherer land use and technological organization for East African savannas are proposed based on changes in the procurement and use of raw materials in the MSA and LSA. The examination of raw material selection at Nasera and Lukenya Hill, which have different availability of raw materials, demonstrates the interaction of raw material properties and availability with the "changing typological makeup of MSA and LSA assemblages" (Barut 1994:59). At Lukenya Hill, raw material was not heavily selected for any particular tool type during the MSA; this selection does increase with the adoption of LSA tool forms (Barut 1994:60-62). Dietl et al., (2005:238) found the same economizing behavior in MSA assemblages at Geelbek and Anyskop, South Africa. At Nasera, there is high selection of chert for MSA tools while the LSA component is largely composed of local raw materials (Barut 1994:65). This suggests that at Nasera, where high quality materials like chert are not locally available as with at Lukenya Hill, there is an attempt to conserve nonlocal materials, likely related to associated procurement costs. Barut (1994:66) argues that the MSA people of Lukenya Hill were likely sedentary as indicated by expedient use of local raw materials, little investment in retouch, and little selection of raw materials for particular tool classes or tool types. The Nasera data supports another picture where the MSA inhabitants were highly mobile peoples transitioning towards sedentism in the LSA. This suggests that at both sites "LSA occupants seem to have had more frequent or planned access to exotic raw materials" and further, "this change in raw material accompanies the adoption of a microlith-based technology" (Barut 1994:67). This study clearly demonstrates the wealth of knowledge that can be acquired from understanding raw material use and availability at a site –

knowledge that is only obtainable from a systematic and detailed characterization and sourcing study.

Attractiveness: Why a source or particular raw material was utilized

Wilson (2007) argues that although provenance studies may tell us which sources are being utilized, they cannot tell us "why." Indeed determining the "why" is often a matter of inference. Based on factors such as quality and abundance we can make best guesses as to why particular rock types and sources were used over others. However, social factors such as trade and exchange networks, social norms and restrictions are speculative at best. Wilson (2007) groups the various reasons why a particular source may be used into two categories: (1) geologic and geographic characteristics of the source (quality, abundance, size, etc.), and (2) human factors (direction of travel, time available, social restrictions etc.). Although the human factors involved are difficult to quantify, Wilson argues that the source geological and geographical characters can be quantified into a single value, attractiveness (A):

$$A_{(source)} = \frac{(\text{quality})(\text{extent of source})(100)}{(\text{difficulty of terrain})(\text{cost of extraction})} \times \frac{(\text{size})}{(\text{scarcity})} \qquad 1.$$

By determining the attractiveness value of each source, one can directly compare each and every one of them.

The attractiveness of a particular raw material generally comes down to its quality. Determining raw material quality, like source attractiveness, is inferential but we can base our "best guesses" on our modern understanding of fracture mechanics and rock microstructures. Generally, rocks that are homogeneous and fine grained tend to exhibit conchoidal fracture, excepting carbonates. As discussed in Chapter 4, this property is preferable for the production of stone tools. The homogeneity and grain size (or texture) of the rock can be determined by a microscopic examination of the rock, and a scale can be produced which illustrates the relative positions of each raw material type in an assemblage. Quality assessments are important as "both quality requirements of the technology used and raw material distributions can significantly alter the relationship between mobility and lithic procurement" (Barut 1994:48). The increase in procurement of exotic, fine-grained raw materials is demonstrated in assemblages for many regions during the Middle to Upper Palaeolithic transition (Gamble 1986:332). This topic will be revisited in Chapter 7.

Defining Exotic versus Local Raw Materials

With provenance studies emphasis is frequently placed on determining which of the raw materials used are local and which are exotic. Local materials are easily defined: those which are found within a short or reasonable distance from the site or location of use, often those that can be acquired within the distance that can be reached by walking in a single day. How one defines what material is exotic varies. Exotic raw materials may be those acquired from a source located a significance distance from the site or location of use (what constitutes a "significant" distance varies too, it can be anywhere from 100 – 500 km depending on the region and time period). Lithic materials that appear infrequently in particular archaeological assemblages or in a particular region may be considered exotic. These are generally high quality raw materials, such as obsidian, and are used in very specific ways, as I have noted earlier in Chapter 5. Hammer (1976:11) states that "even if a material's location is known in only the most general terms, such as being 'exotic'…inferences are possible." Non local raw material proportions in assemblages and the degree of reduction are important as they can indicate territory size and degree of mobility (Barut 1994:48).

Raw material sourcing in practice: East African case studies

In May 2007 I undertook a literature review of three key journals in African archaeology: the *Journal of African Archaeology*, *African Archaeological Review*, and *Nyame Akuma*. The goal of this review was twofold: first, I wanted to determine how many articles mention stone artifacts, and second I wanted to establish how many of those articles mention or describe raw materials. Of the 678 articles examined, 253 mentioned stone artifacts, but only 170 provided some sort of indication of the raw materials used. This review suggests that there is no standardized set of names and no clear typology/taxonomy for lithic raw materials. Often terms such as flint, chert, chalcedony, and jasper are indiscriminately used, as are terms such as volcanic, which not only encompasses a large variety of rock types but also, when incorrectly used, may suggest incorrect information as to the formation environment and potential source areas for the rock types. This indicates that it is important that a standardized method for identifying and describing lithic raw materials be established. Further it does not appear to be common practice for archaeologists in Africa to even mention the raw material types of stone artifacts recovered; an efficient and practical method for identification may encourage more researchers to identify lithic types even if it is not a focal point of their own research.

Conversely, Shackley (2008:194) found that in *Archaeometry* the "number of papers devoted to the analysis of lithic material has increased at least 30 times since 1958 and volume 1." This suggests an "increase in the number of scholars devoting their time to the archaeometry of stone" but also the increasing importance of provenance studies in general in the archaeological sciences. Why this trend is not apparent in the literature of Africanist archaeologists remains to be seen. This could be explained by the types of research questions generally asked by Africanists, but there have been a number of lithic raw material provenance studies conducted on African materials, including a few, but very important, studies conducted in Tanzania. It should not be surprising that this research has mostly occurred as part of large, well funded, multidisciplinary research projects at one of the most important sites in Tanzania, if not the world, Olduvai Gorge.

Lithic Raw Material Use at Olduvai Gorge, Tanzania

Olduvai Gorge is unquestionably one of the most important and famous palaeoanthropological sites in the world. It also has an impressive archaeological record which has been extensively studied. Although the particular researchers, research programs and questions have varied over the years, Olduvai has been almost continuously studied since its discovery in 1911. The extensive labour invested in understanding and interpreting this site has yielded a wealth of information about early hominid lifeways. Significant is the multidisciplinary approach that is still applied to studies there today. Important to the topic at hand is the work done by geologists, in particular that of Richard L. Hay (1963, 1967, 1968, 1976). Hay is responsible for the understanding of the geology of the Olduvai Gorge that we have today.

In his seminal work, *Geology of the Olduvai Gorge*, Hay (1976) provides detailed, comprehensive descriptions (including geographic feature and location, lithologic description and mineral composition) of all rock types in the vicinity of the gorge, and then goes on to contextualise each one in terms of patterns of hominid activities). Inspired by the work of M.D. Leakey (1971), Hay (1976:184-185) emphasizes that chert was extensively utilized and carried into the basin from distant sources when it could not be locally obtained. Chert is available locally at Olduvai as nodules in the lake deposits of Beds I and II. This local chert is typically white and opaque, milky and translucent, or yellowish-brown. Artifacts made from this local chert have only been found in Bed II, and the Ndutu and Naisiusiu beds. Other chert types were likely acquired from distant sources. Other exotic raw materials including an unmetamorphosed gabbro could have come from sources 45 km to the west, and the nearest source for the rhyolitic obsidian excavated from the Naisiusiu Beds is at the south side of Lake Naivasha, 270 km to the north of the site.

Further, Hay (1963, 1968) previously focused on the occurrence of chert in sodium-carbonate lakes in Tanzania and Kenya. This work, along with that of Eugster (1967, 1969), laid the groundwork for understanding chert formation in East African soda lakes, which is critical information for sourcing and characterizing cherts found in archaeological assemblages like those at Olduvai. The connection between chert formation environments and characterization is further discussed below.

Hay was not the only researcher to emphasise the role of raw materials at Olduvai. Stiles (1979, 1991; Stiles et al., 1974) conducted numerous studies of artifact raw material use at Olduvai, particularly in Bed II. This large body of work on raw material use at Olduvai has resulted in two important conclusions regarding early hominid technological behavior. First, the evidence of the manufacture of chert artifacts at a factory site and the subsequent transport of selected whole flakes to another site for use demonstrates that early hominids were capable of planning a sophisticated sequence of activities related to raw material selection, process, and use (Stiles 1991:1). Second, the attributes used to distinguish the Developed Oldowan B from the early Acheulian are the direct result of differential raw material use (Stiles 1991:1).

Obsidian networks in Kenya and northern Tanzania

It is well understood that the political and national boundaries that exist today did not affect the movement of people and goods (i.e., trade and exchange) in the past. Merrick and Brown's (1984) landmark study of the obsidian networks in Kenya and northern Tanzania illustrates this clearly. This study discussed several changing patterns of obsidian use over time. It has served as the foundation of obsidian sourcing for this region that continues to this day (Coleman et al., 2008; Merrick et al., 1990; Negash and Shackley 2006; Negash et al. 2006;

Negash et al., 2007). This includes a major obsidian source survey in Kenya currently being conducted under the direction of Stan Ambrose in collaboration with several international researchers.

Using a combination of x-ray fluorescence (XRF) and electron probe microanalysis (EPMA), over 80 outcrops have been characterized resulting in some 30 distinct petrological groups of obsidian (Merrick et al., 1994). Generally an increase in the use of obsidian is seen from the ESA to MSA to LSA. The overall scarcity of obsidian in ESA sites may be a function of either a preference for other raw materials or the proximity to obsidian sources (Merrick et al., 1994). During the MSA there is evidence of movement of "modest quantities" of obsidian up to 190 km from source to site, and obsidian occurs in very high frequencies in many sites which are within 50 km of major sources (Merrick et al., 1994:39). Obsidian use increases over time to the extent that it forms almost 100% of the raw material found in assemblages within 50 km of major sources during the LSA. The collective body of work demonstrates the importance of the initial establishment of baseline data for lithic raw material sources so that the study of long-term changes in raw material use and socio-territorial organization can begin. It is important to note that obsidian is not present in either of the assemblages studied for this research.

6.2 Raw Material Provenance: Method

Numerous methods of artifact raw material sourcing have been explored by archaeologists. There is a large body of literature devoted to the characterization and provenance of stone artifacts. Shackley's 2008 article provides an excellent history and background of the "archaeometry" of stone emphasizing the role of archaeological petrology. Shotton and Hendry (1979) trace the development of optical petrology in archaeology then discuss the principles behind the use and available techniques of trace-element analysis. Kempe and Harvey's 1983 edited volume entitled *The Petrology of*

Archaeological Artefacts was the first attempt to compile the large growing body of work on the geoarchaeological analysis of stone artifacts. The study of archaeometry of stone has largely comprised the adaptation of techniques and technologies from a multitude of different disciplines in the earth and chemical sciences. Various strengths and limitations have been recognised in association with each of these techniques. The selection of an appropriate archaeometric analytical method is dictated by a number of factors: sensitivity, accuracy, precision, specificity, ease of operation, speed, and cost. The 'compromise' of these factors is "largely determined by the purpose for which the data are to be used and…by the nature of the sample" (Reeves and Brooks 1978:2); the methodology and technique must be selected on the basis of what questions archaeologists are trying to answer. A technique useful in the direct dating of an artifact will not likely prove to be of use in determining the provenance of the raw material it is constructed from. The use of archaeological materials in provenance studies creates some limitations not seen with other materials. Usually these are a small sample size and the requirement for a non-destructive technique (Meschel 1978). With lithic raw material provenance studies emphasis is first and foremost placed on characterizing (i.e., describing) and identifying the various rock types. Characterization and identification is largely dependent on lithology i.e., the degree of distinctiveness of each raw material (Goldman-Neuman and Hovers 2009:73).

For this study standard petrographic analysis has been selected for use. Petrographic analysis is standard practice in geology for the classification and identification of rock and its mineral components. Herz (2001:464) states that "the first step in an analysis of lithic material should be petrographic, preferably with thin sections." Petrographic analysis, the identification of the mineral composition of a rock, can be utilized to determine the composition and texture of the rock, and allows for the identification of microfossils quickly and inexpensively relative to other methods of analysis (Eley and von Bitter 1989:3). It requires both detailed macroscopic and microscopic analyses.

High powered analytical techniques were not used in this research for a number of factors. First, a limited budget restricted the use of more expensive chemical analyses, as did a restrictive time frame. Second, it is important, in terms of my professional development, that I was able to participate directly in the processing and analysis of samples. I did not want to send my samples off to a lab and only be responsible for the interpretation of the results. Third, the use of chemical analyses is only recommended when source samples are available for comparison. In my unpublished B.A. honours thesis (Miles 2002), I was able to differentiate successfully chert artifacts into types using Instrumental Neutron Activational Analysis (INAA); however, as I did not have source samples I was unable to determine if these types represented the geology, that is if they represented cherts from different sources or variation within a single source. When potential sources could not be found during survey in 2008, the decision was made to forgo chemical analyses and to focus instead on constructing a clear, detailed guide for describing the rock types found in the archaeological assemblages (Appendix B). Finally, access to these high powered techniques would be very restricted for my Tanzanian, and other African, colleagues. The University of Dar es Salaam does have basic petrography and microscopy labs equipped with the appropriate facilities for thin section processing and analysis. This makes these techniques the best suited for use on lithic assemblages from Tanzania.

Macroscopic analysis

Lithic sourcing analysis must necessarily begin with lithology or macroscopic analysis – the identification of rock type based on visual physical attributes such as color, lustre, texture, etc. Macroscopic analysis allows for the initial determination, and separation, of the assemblage into types. It is a "low-tech" approach which focuses on visual inspection of variables relating to raw material quality (grain size, texture, homogeneity). It "may in fact be a closer analogue of the practices of the ancient tool-makers that relied only on visual assessment and cobble-testing" (Goldman-Neuman and Hovers 2009:73). Although the formal classification of rock type/lithology is an important first step in a provenance study, it alone is not sufficient to determine ancient selection behavior, just as determining where the raw material was acquired does not indicate why any particular source was used.

Unfortunately, macroscopic analysis is rarely straightforward owing to the subjective nature of most of the attributes examined. Color, in particular, is a very difficult attribute to score consistently even with standardized charts such as those produced by Munsell. Inter- and intra-observer error tends to be quite high, and this is not limited to identification and description at the attribute level either. Often there is disagreement between archaeologists (and geologists) even as to the rock type itself or the proper nomenclature to be used. Generally these problems that are associated with the visual identification of most lithic materials are the result of three issues. First, the expertise of the archaeologist comes from years of experience and frequent handling of the material. Second, this knowledge acquired from years of experience can be arcane, highly personalised, almost a sixth sense, and difficult to communicate to other and newer archaeologists (Luedtke 1979:745). These first two issues are complicated by specialization (like on a particular rock type or a small and specific part of the world), and the diverse backgrounds of various researchers (experiential and educational). A third problem is the frequent disagreement among experts as to the correct classification of any one sample. Any archaeologist who has worked as part of a research team with other archaeologists knows that this is a very real, but unavoidable, issue. I would offer that a fourth issue could be added to the list, that of the nature of the lithic raw materials themselves and the processes that affect and alter them. Toolstones can have very complex life-histories that begin with their selection as a toolstone for use and end with the archaeologist recovering them. In between selection and eventual rediscovery, the artifact, thus the raw material, is subject to many different environmental and anthropogenic processes. This issue will be further explored and discussed in Chapters 8 and 9.

Although categorization is often undertaken with the intention to "sort and characterize the recovered lithics by source and feature so as to produce macroscopic categories that (are) distinguishable with reasonable certitude among the lithic evidence occurring on archaeological sites" (Katalin 1998:3), the problem is in achieving that very task. How does one create macroscopic categories that are both reasonable and mutually exclusive? How does an archaeologist create meaningful descriptions that are acceptable in the eyes of geologists but practical for use by other archaeologists who may lack more than a basic understanding of petrography? Researchers in their attempts to objectify the process of identification through visual characteristics still place greater significance on some attributes than on others, and frequently change the criteria used for definition from one type to another. I must include myself in this group. However, by proposing to conduct two methods of raw material type analysis (independent of each other), I am attempting to reduce the chance of error and the limitations of my expertise, in lithic type discrimination. I will also detail my methods and attempt to base my decisions as clearly stated, on objective and quantifiable data, in order to allow other researchers to evaluate these choices. This, of course, is something easier said than done; however, it is important that this process of describing the lithic raw material types used at Magubike and Mlambalasi is conducted as, as previously stated, this basic form of analysis has not yet been done.

Microscopic analysis has a few important advantages over other means of sourcing analysis. Primarily, it is relatively inexpensive. Many universities have the facilities and equipment for thin sectioning and microscopic analyses, and those that are not equipped can find many private companies who offer thin section preparation and analysis for reasonable cost. It is involves simple comparative identification procedures, while yielding a wealth of information about texture, mineralogy, mode of origin, and rock genesis and diagenesis that is not available from other methodologies (Prothero and Lavin 1990:577). These insights are critical if one is to attempt to identify potential sources of the raw material. Finally thin sectioning is especially relevant when dealing with fine-grained materials as it allows one to determine mineralogy and see inclusions which is not possible not in hand specimen.

Needless to say, detailed macroscopic analysis must occur prior to thin sectioning. Early tool makers would only have been aware of the microscopic properties of the rock as they are reflected or presented macroscopically, so it is unfair to judge why a particular rock would have been selected based on its microscopic qualities alone. Several studies illustrate the successful application of thin section petrography to archaeological materials (e.g., Clough and Woolley 1985, Mason and Aigner 1987).

Mason and Aigner (1987) conducted petrographic analysis on basalt artifacts from three Holocene sites in the Aleutian Islands of Alaska. They compared thin sections with geological samples and were able to infer the location of the artifactual rock sources. All ten samples came from a single flow or related flows 15-30 km from all three sites. They were able to determine this as all samples revealed a "similar mineral composition, indicating that similar conditions of petrogenesis were involved. Thus, quite possibly, the samples come from single or related flows" (Mason and Aigner 1987:600). As with this study they used archaeological criteria to "guide their decisions on which artifacts to thin section" (Mason and Aigner 1987:598). First, samples were selected with reference to technological categories (artifact class); then samples were selected reflecting the relative time spans of the three sites. They provide detailed description of the basalts focusing on type of phenocrysts, texture, and groundmass, and diagenesis (weathering). Diagenesis proved to be important as artifactual basalts lacked evidence of diagenesis, and thus must derive from the younger, fresher deposits (straightforward provenance as other, older deposits show marked weathering). The implications of this led to re-evaluation of previously held beliefs about Aleutian prehistory, primarily concerning their acquisition of lithic resource, namely a willingness to travel to acquire better quality materials – basalt is one of the finer grained, glassy ones available.

Further the temporal continuity between quarry sites suggests direct affinities between the earliest and later periods of Aleutian prehistory (1987:605).

Angelucci's (2010) study is of particular interest because it looks at the recognition and description of lithic artifacts in thin section. It is interesting because Angelucci is not intentionally sectioning the artifacts themselves to identify their rock type but rather is providing a method for identifying and describing the micromorphological characteristics of the knapped lithic artifact when found in thin sections of soils and sediments.

Important to this study is Calogero's (1991) PhD research where the macroscopic and microscopic analysis of artifact rocks, from central Connecticut, revealed "alarming disparities" in identification (Calogero1992:87). In order to test whether "others shared [her] confusion in identifying artifact rocks macroscopically", Calogero (1992) asked five colleagues with many years of archaeological experience in her study area to identify the remaining portions of flakes that had been sectioned. Twenty-five percent of the flakes were not identified or only described. Of those flakes identified, only 24% were correct. However, Calogero (1992:89) states that one of the most "alarming findings of the study was that there was little agreement between the correct or the incorrect answers" any of the archaeologists gave. This means that the results of each participant's analysis of the same assemblage "could support quite different hypotheses about local lithic resource utilization and patterns of prehistoric exchange" (Calogero 1992:89). This study demonstrates the problems not just relying on macroscopic analysis alone in raw material type identification, but also the much greater ramifications of lithic misidentification for our interpretations and understanding of the archaeological record.

As with any analytical technique, petrography has some limitations. First, and foremost, thin-sectioning is a destructive technique. This may be fine for debitage and source samples, but the majority of archaeologists and curators may be reluctant to damage, even minimally, type artifacts or rare artifacts. This can limit insight into the technological processes of lithic reduction as final products and those selected for use are often not sampled. Second, petrography is dependent on variation, and chert, for example, can be extremely homogeneous between sources and/or heterogeneous within a source (Luedtke 1992). The opposite, where in a single source may have too much variation, can also be a problem. Finally, petrographic analysis does not allow for the discernment of the chemical composition. Often chemical analyses are also required as many minerals are notoriously similar in thin section. However, chemical analyses are not sufficient for identification and characterization alone as "rocks with different origins can have identical chemical compositions" (Calogero and Philpotts 1995:4) and further some rocks, like cherts, can demonstrate considerable variation within a single formation.

To summarize, petrographic analyses have been successfully applied to investigations of lithic raw material sources and further application will continue as the benefits of this technique, including their relatively low cost and ease and high speed of sample processing, is increasingly recognised in archaeological literature. As well, data can be re-used and thin-sections can be re-examined for comparative purposes or as new technology becomes available. For example, uncovered petrographic thin-sections can be re-analyzed for chemical composition. However, portable XRF, which has decreased in cost significantly over the past five years, is a highly versatile and fast technique that should be considered for future investigations.

Lithic raw material classification: combining macroscopic and microscopic characteristics

The goal of this research is to develop a standardized system for the classification and description of lithic raw materials found at the Magubike and Mlambalasi sites. This system is derived from petrology and geology but recognises that it will be used by archaeologists working in this area. I include this caveat because it is important to understand that sometimes I have erred on the side of what an archaeologist would find meaningful (in terms of rock type) rather than what is correct according to a geologist/petrologist. Geologists hesitate to identify, especially macroscopically, rock types found within a cultural rather than a geological context, while archaeologists are "generally far less cautious" (Calogero 1992:89). With that begin said it is important to understand that the rock types described herein are by no means meant to be the final word on this subject. The following paragraphs provide a basic understanding of rock classification as generally understood and accepted in geology and petrology. Names such as chert, flint, chalcedony, jasper, and cryptocrystalline silica (CCS) can be used indiscriminately by archaeologists. This may be due to the unfamiliarity of archaeologists with geologic terms and definitions; however, even among geologists there may be little agreement as to what each of these materials are and what these various terms really mean (Hammer 1976:12). In this and in following chapters I will endeavour to make plain the conditions for the application of each name. In a subsequent chapter I will discuss the classification system I have developed and reasons why I may or may not have deviated from these principles.

In this section I will provide a brief overview and description of each of the three general rock type categories as well as the specific macroscopic and microscopic attributes of rocks within those categories. Some excellent sources of information about petrology, petrography, and mineralogy include Williams et al., (1954), Moorhouse (1959), Carozzi (1960 and 1993), Cox et al., (1967), Blatt (1982), Yardley (1989), Philpotts (1990), Shelley (1993), Boggs (2003), and Blatt et al., (2006). The visual atlases of the different rock types and minerals by MacKenzie et al., (1982), Adams et al., (1984), and Yardley et al., (1990), MacKenzie and Adams (1994) were invaluable; they were used to develop the microscopic attribute list used, and the images they contain were used for comparison with the thin section samples, in this study. Kempe and Harvey (1983), Herz and Garrison (1998), Rapp (2002), Garrison (2003), Odell (2003), and Andrefsky (2005) provide good descriptions specific to the petrology of archaeological artifacts. I highly recommend any of the volumes mentioned above should the reader wish to pursue a greater understanding of these topics.

Understanding general petrology is necessary as it will help one understand which macroscopic and microscopic attributes were selected for use in my analyses and will serve as the basis for the characterization undertaken herein. Rocks are classified according to their lithology: the description of rocks on the basis of characteristics including color, composition (specifically the relative proportions of component minerals), and grain size which make up the physical character of the rock (Bates and Jackson 1984:299). These attributes were recorded for every artifact. On the basis of lithology and their formation process, rocks are categorized under three general types: igneous, sedimentary, and metamorphic (Table 6.1).

The relative proportions of component minerals are important as this determines two key macroscopic attributes: color and density. Microscopically, the major, minor, and accessory minerals were also recorded. Rock-forming minerals can be divided into several categories on the basis of abundance in individual rocks: major rock-forming minerals, minor minerals, and accessory minerals (Blatt et al., 2006:20). The proportions of major minerals are typically useful for determining the broadest rock classification (i.e., igneous, sedimentary, or metamorphic), whereas the presence or absence of minor minerals is commonly used as a qualifier in rock classification (for example biotite granite versus hornblende granite) (Blatt et al., 2006:20).

Grain size is significant as it determines what is referred to as the texture, and from the perspective of the knapper and the archaeologist, the quality of the rock. Textures are “inherently small-scale aspects of the rock most easily recognised in a hand specimen or a thin section” (Blatt et al., 2006:29).

Table 6.1: General characteristics of igneous, sedimentary, and metamorphic rocks (adapted from Blatt et al., 2006:xix; Table I-1).

Igneous	Sedimentary	Metamorphic
Outcrop characteristics and structures		
1. Volcanoes and related lava flows 2. Cross-cutting relations to surrounding rocks, as in dikes, veins, stocks, and batholiths 3. Thermal effects on adjacent rocks, such as recrystallization, color changes, reaction zones 4. Chilled (finer-grained) borders against adjacent rocks 5. Lack of fossils and stratification (except for pyroclastic deposits) 6. Generally structureless rocks composed of interlocking grains 7. Typically located in Precambrian or orogenic terranes but also non-orogenic settings such as rifts 8. Characteristic shapes and sizes, as in laccoliths, lopoliths, sills, stocks, batholiths, and lava flows	1. Stratification and sorting 2. Structures such as ripple marks, cross-bedding, or mud cracks 3. Often widespread and interbedded with known sediments 4. The shape of the body may be characteristic of a sedimentary form, such as a delta, bar, river drainage system, and so on 5. The rocks may be unconsolidated or not	1. Distorted pebbles, fossils, or crystals 2. Parallelism of planar or elongate grains common over large areas 3. Located adjacent to known igneous rocks, occasionally as a zoned aureole 4. Typically located in Precambrian or orogenic terranes 5. Rock cleavage related to regional structures 6. Progressive change in mineralogy over a wide area 7. Some are massive hard rocks composed of interlocking grains
Textures		
Porphyritic, glassy, vesicular, amygdaloidal, graphic, pyroclastic, or interlocking aggregate	Fragmental, fossiliferous, oolitic, pisolitic, stratified, interlocking aggregate	Brecciated, granulated, crystalloblastic, or hornfelsic
Characteristic minerals		
Amphibole Feldspar abundant Leucite Micas Nepheline Olivine Pyroxene Quartz Glass	Abundant quartz, carbonates (especially calcite and dolomite), or clays Anhydrite Chert (microcrystalline quartz) Gypsum Halite	Amphibole Andalusite Cordierite Epidote Feldspar Garnet Glaucophane Graphite Kyanite Sillimanite Staurolite Tremolite-actinolite Wollastonite Micas Quartz

Igneous Rocks

Igneous rocks are “those that formed from molten magma” (Rapp 2002:42); magma being “naturally occurring molten rock material, generated within the earth” (Bates and Jackson 1984:307). They are divided into two different categories: those that crystallize within the earth’s crust (intrusive or plutonic), and those that solidify at the surface (extrusives or “volcanic”). Silica (SiO_2) is generally the dominant chemical constituent, and thus, is used in igneous rock classification (Table 6.2). However, carbonatites, a carbonate dominated igneous rock, are well known in the East African rift valley.

The texture of igneous rocks is determined by the degree of crystallinity, grain size and shape, and the geometric arrangement of individual mineral grains. This last characteristic is also commonly referred to as fabric (Blatt et al., 2006:29). Although large-scale igneous structures characteristic to each particular outcrop are often difficult to ascertain from a rock removed from its original context (i.e., an artifact in an archaeological context), observations of texture and fabric at both the macroscopic and microscopic levels may provide some clues for what types of outcrops to look for. In terms of mineralogy, igneous rocks contain a significant variety of minerals that fall into two broad categories: high-temperature primary minerals, which crystallize directly from magma, and secondary minerals, low-temperature minerals that occur as alterations of the primary minerals (Blatt et al., 2006:20).

The color of igneous rocks assists in identifying mineral composition. Dark colored, or mafic, rocks are rich in magnesium, iron, and calcium, and frequently include olivine, pyroxene, amphibole and calcium plagioclase. Rocks rich in silica and aluminum, containing large amounts of quartz, potassium feldspar, and sodium plagioclase, are generally light in color and are called felsic. Intermediate rocks have an approximate proportion of 50% light to dark colored minerals in hand specimens. In thin section, particular emphasis is thus placed on the presence/absence of quartz, olivine, and nepheline, and the types and proportions of feldspars as they relate to the macroscopic property of color.

Table 6.2: Classification of common igneous rocks (adapted from Kempe 1983:54, Table 3.1 and Rapp 2002:43, Table 3.1.).

		SiO_2, Na_zO, K_2O →	CaO, MgO, FeO		
Chemical type	Felsic (Acid)	Intermediate		Mafic (Basic)	Ultramafic (Ultrabasic)
Coarse grained, Plutonic	**Granite**	Granodiorite Syenite	**Diorite** Monzonite Tonalite	Gabbro	Peridotite Pyroxenite
Medium-grained	**Felsite** **Poriphyritic granite**	Microsyenite Poriphyritic syentite	Microdiorite Poriphyritic andesite	**Dolerite**	Lamprophyres
Fine grained, Extrusive	Rhyolite	Dacite Trachyte	Andesite	**Basalt**	Picrite
Vitreous/glassy, Volcanic lavas	**Obsidian**				

Bold indicates common artifact material in East Africa.

There are generally six kinds of textures found in igneous rocks: glassy, vesicular, aphanitic, phaneritic, porphyritic, and fragmental. Glassy textures do not have visible crystal structures even under high magnification. Igneous rocks with glassy or aphanitic textures are the most common types to be used in tool production, including obsidian, rhyolite, andesite, and basalt.

Degree of crystallinity relates to the relative proportions of crystals to glass. Rocks such as granite, which are composed entirely of crystals, are classed as holocrystalline. Rocks, like obsidian, are composed wholly of glass and are referred to as holohyaline. Rocks which contain both crystals and glass can be described more precisely by stating the relative proportions of crystals to glass: hypocrystalline or hypohyaline (Williams et al., 1954:13).

Granularity refers to the grain size as determined by what the unaided eye can or cannot see. When all crystals of the major minerals can be distinguished by the unassisted eye the rock is termed phaneritic. Rocks are called aphanitic if all minerals, other than any phenocrysts, cannot be distinguished by the unaided eye. Two aphanitic sub-types exist: microcrystalline, where minerals can be identified in thin section, and cryptocrystalline, where minerals cannot be detected even with the use of a microscope (MacKenzie et al., 1984:9). Absolute crystal size describes grain size as it ranges from fine to coarse, while relative crystal size describes whether all crystals are approximately the same size (equigranular) or if they differ substantially in size (inequigranular).

The fabric of the rock relates to the shape and the mutual relationships between grains or crystals. Crystal shape is determined by two attributes: the quality of development of the faces on crystals and three dimensional crystal shapes. Other specific terms, such as dendritic or skeletal, may be also be used. Texture (and subtexture), as determined in thin section, is the mutual relationships between the crystals. With equigranular rocks, three subtextures are recognised: euhedral, subhedral, and anhedral. Inequigranular rocks include seven kinds of subtextures: seriate, porphryitic, glomeroporphyritic, poikilitic, ophitic, subophitic, and interstitial. There are also oriented, aligned, and directed, intergrowth, radiate, and overgrowth textures. MacKenzie et al., (1984:18-26) is an excellent visual guide which provides descriptions and images of all of these textures.

Sedimentary Rocks

Sedimentary rocks are "those which form at low temperatures and pressures at the earth's surface by deposition from water, wind, or ice" (Rapp 2002:48). Sedimentary rocks are also predominantly comprised of silica. There are three main types of sedimentary rocks established by the mode of their formation (Table 6.3). Clastic sedimentary rocks are classified primarily by grain size and composition (Table 6.4).

Non-clastic sedimentary rocks including those formed from either chemical or biogenic precipitates are characterized according to texture, allochemical components, and cement types. With sedimentary rocks three grain size textures are recognised: cryptocrystalline, microcrystalline, and macrocrystalline. Cryptocrystalline rocks consist of "crystals that are too small to be recognised and distinguished under the ordinary microscope" or are "indistinctly crystalline" (Bates and Jackson 1984:120). The texture of a rock is said to be microcrystalline when it is composed of crystals that are visible only under the microscope (Bates and Jackson 1984:325). Finally, rocks with a macrocrystalline texture consist "of crystals that are distinctly visible to the unaided eye or with the use of a simple lens" (Bates and Jackson 1984:307).

Grain shape and sorting was recorded in addition to grain size (modified to use Wentworth Scale) for sedimentary rocks. Additionally, for cherts and other siliceous/cryptocrystalline rocks, the absence or presence of mottling, speckling and banding, translucency, degree and color of patination, and absence or presence of visual inclusions was also recorded. As cherts are an important lithic raw material type I discuss these at length below.

In the microscopic analysis of sedimentary rocks, the division into clastic versus non-clastic is maintained. Microscopic attributes examined for clastic rocks include grain size, sorting, roundness, sphericity, orientation, grain types, matrix and cement. Crystallinity, grain types (and sub-types), and texture are key microscopic attributes for non-clastic rocks.

Metamorphic Rocks

Metamorphic rocks are those sedimentary and igneous rocks which have undergone mineralogical and textural changes in response to being subjected to pressure (P), temperature (T) or stress conditions different from those in which they originally formed (Rapp 2002:55). The "bulk composition of the preexisting rocks and the temperature and pressure of the metamorphism control of the mineral composition of metamorphic rocks" (Rapp 2002:56). Variability in the mineralogy or texture of metamorphic rocks accounts for the wide range of names of rocks within the major metamorphic rock types (Table 6.5). There are many ways metamorphic rocks can be classified. Two of these will be used here. For descriptive purposes, the simplest way is to classify them into broad lithologic types as shown in Table 6.5. The facies classification system (Table 6.6) was developed to show the relationship between the three key metamorphic variables: pressure, temperature, and bulk (chemical) composition. Although rocks belonging to a particular metamorphic facie will have been metamorphosed over a specific range of P-T conditions, they can have radically different mineral assemblages and thus rock names.

Table 6.3: Classification of major sedimentary rocks (adapted from Rapp 2002:50, Table 3.3.).

Clastic	Chemical	Biogenic
Conglomerate and Breccia	Limestone	Chalk
Sandstone and Arkose	Dolomite	Some carbonates
Greywackes	Chert	Chert
Siltstone and Argillaceous rocks	Gypsum	Coal
Shale	Anhydrite	Some iron formation
	Salt (halite)	
	Some iron formation	

Table 6.4: Common clastic sedimentary rocks (adapted from Andrefsky 2005:52, Table 3.2).

Rock Name	Texture	Composition
Conglomerate	Coarse (> 2mm)	Rounded fragments of any rock type
Breccia	Coarse (> 2mm)	Angular fragments of any rock type
Quartz sandstone	Medium (2 – 1/16 mm)	Predominantly quartz Other minerals may be present in minor quantities
Arkose	Medium (2 – 1/16 mm)	Quartz with > 25% feldspar
Graywacke	Medium (2 – 1/16 mm)	Quartz with high clay content
Siltstone	Fine (1/16 – 1/256 mm)	Quartz and clay minerals
Shale	Very fine (< 1/256 mm)	Quartz and clay minerals

Table 6.5: Major types of metamorphic rocks (adapted from Kempe 1983:55, Table 3.2, and Rapp 2002:56, Table 3.5).

Through high-temperature (→) and high-pressure (→) transformation of sedimentary rocks								
Limestone	→	**Marble**						
Sandstone	→	**Quartzite**						
Greywacke **Shale** Argillite	→	**Slate**	→	Phyllite Hornfels	→	Schist	→	Gneiss Granulite

Bold indicates common artifactual material in East Africa.

Table 6.6: Metamorphic facies arranged according to inferred relationship to pressure and temperature (adapted from Moorhouse 1959:407, Table 18).

←------- Pressure Increasing	-------------------------------- Decreasing Temperature ---------------------------------------→			
	Sanidinite facies			Zeolite facies
	Pyroxene-Hornfels facies	Amphibolite facies	Epidote-albite-amphibolite facies	Greenschist facies
	Granulite facies			
	Eclogite facies	Glaucophane-schist facies		

Facies classification "recognises certain mineral associations as characteristic of particular pressure-temperature environments" (Moorhouse 1959:406). The facies are defined by "*critical mineral associations,* which distinguish them from other facies" (italics in original, Moorhouse 1959:407) and named after this critical mineral assemblage or equivalent, representative rock type (Williams 1954:172). The criterion by which each may be recognised is as follows (Moorhouse 1959:407-408, Williams 1954:172):

1. Sanidinite facies: very high temperature, minimum pressure; feldspars, tridmite, lime and silicates.

2. Pyroxene-Hornfels facies: high temperature, moderate pressure; hornfelses and pyroxenes (diopside, hypersthenes).

3. Granulite facies: extremely high temperature and pressure; pyroxene and garnet (complete absence of biotite and hornblend is key).

4. Eclogite facies: extremely high temperature and pressure; pyroxene (omphacite) and garnet.

5. Amphibolite facies: moderate temperature and pressure; hornblende and plagioclase (oligoclase or calcic) feldspar. These are the most abundant regionally metamorphosed rocks.

6. Glaucophane-schist facies: moderate temperature and high pressure; amphibole (glaucophane).

7. Epidote-albite-amphibolite facies: moderate temperature and pressure; similar mineralogically to the amphibolites facies but plagioclase is represented by epidote-albite.

8. Zeolite facies: moderate temperature and pressure; serpentine, chlorite, dolomite, and magnesite.

9. Greenschist facies: low temperature moderate pressure; chlorite, albite and carbonate, sometimes with fibrous amphibole and biotite.

The presence or absence of micas and type of foliation, when present, was recorded for metamorphic rocks. Foliation is the result of the preferred orientation of tabular and platy minerals in metamorphic rocks, and thus is pronounced in rocks with well developed and abundant micas and amphiboles (Herz and Garrison 1998:203). Metamorphic rocks that are foliated include phyllite, slate, argillite, schist, amphibolite, and gneiss. Rocks that do not develop foliation are termed massive including hornfels, marble, quartzite, granulite, metaconglomerate, and serpentinite among others.

Textural terms are important for the naming of metamorphic rocks as they indicate both metamorphic processes and the history of metamorphism (Yardley et al., 1990:85). A number of different terms are generally recognised: crystalloblastic, porphyroblastic, poikiloblastic or sieve, lepidoblastic, nematoblastic, granoblastic or mosaic, blastoporphyritic, blastophitic, hypidoblastic, xenoblastic, and decussate. These describe grain size, shape, or orientation, the presence of inclusions, or the parent rock from which the texture was derived.

6.3 Iringa Region Lithic Tool Materials

Before describing the various types of rock types present in Iringa Region which have known use as toolstones, it is important to provide a brief overview of the geology of Tanzania. Simply stated, the geology of Tanzania is old (Figure 6.1). The present geological setting of Tanzania is the result of a series of events beginning with the evolution of the ancient Archean Craton. Tanzania is "cradled on (the) Archean Craton; progressively younger crystalline rocks rim this grantitic nucleus with sediments and volcanic of Paleozoic to Recent age" (Schlüter 2006:226). Over the past 30 years, the geological history of the country has been reconstructed and 12 major geological units have been defined (Government of Tanzania 2005:28):

1. Cenozoic volcanic
2. Cenozoic sedimentary rocks
3. Mesozoic-Cenozoic alkali intrusive
4. Upper Mesozoic sedimentary rocks
5. Mesozoic-Palaeozoic Karoo Supergroup
6. Palaeozoic-Proterozoic Bukoban Supergroup
7. Proterozoic Karagwe-Ankolean Supergroup
8. Proterozoic Usangaran and Ubendian Supergroups
9. Archean Granite-Gneiss terrane
10. Archean Kavirondian
11. Archean Nyanzian Supergroup
12. Archean Dodoman Supergroup

The Iringa Region is located within the Usagaran Belt or System (Figure 6.2). The Usagaran Belt (1.9-2 Ga) occurs to the south and east of the Archean craton and consists of metamorphic rocks. It formed by strike-slip tectonics thus is highly metamorphosed. It is composed of the Usagaran metamorphic and magmatic belt, Eclogite zone, and Konse group (Fritz et al., 2005; Figure 6.4). The dominant rock types in this region are generally classified as "granulites and biotite gneisses of pelitic origin", with quartzites being common (Government of Tanzania 2005:28). More specifically the rock types include granites, granodiorites, granitoid orthogneiss, biotite-garnet-kyanite/sillimanite gneiss, biotite-hornblende-garnet-pyroxene granulite, feldspathic and/or micaceous quartzites, and metamicrodiorites (Hathout 1983; Sommer et al., 2003).

A study of the geological 1:125,000 quarter degree sheets (QDS) for Iringa Region, and areas immediately surrounding Iringa (QDS 196, 197, 214, 215, 232, 233, 234), provided a list of generalized rock types (Table 6.7). I describe each of these below including their visual and microscopic properties, and their suitability and/or desirability as a toolstone. Table 6.8 provides a summary of the basic macroscopic and microscopic characteristics of these lithic raw materials. Chert is not identified on any geological map for Iringa and its surrounding regions;

however, as it is found in archaeological assemblages throughout the region it has been included here. Only major or common mineral components of each rock type are given; many of these rock types are highly variable (Table 6.9). This is especially true of metamorphic rocks as their mineralogy is dependent upon the parent rock. Not all of these are suitable as toolstones but it is important to recognise that the raw materials found in an assemblage do not always represent the entire resource base available. As the discussion above demonstrates, preference or perceived suitability of any particular raw material type can and does change over time as raw material availability and abundance, and technological strategies change.

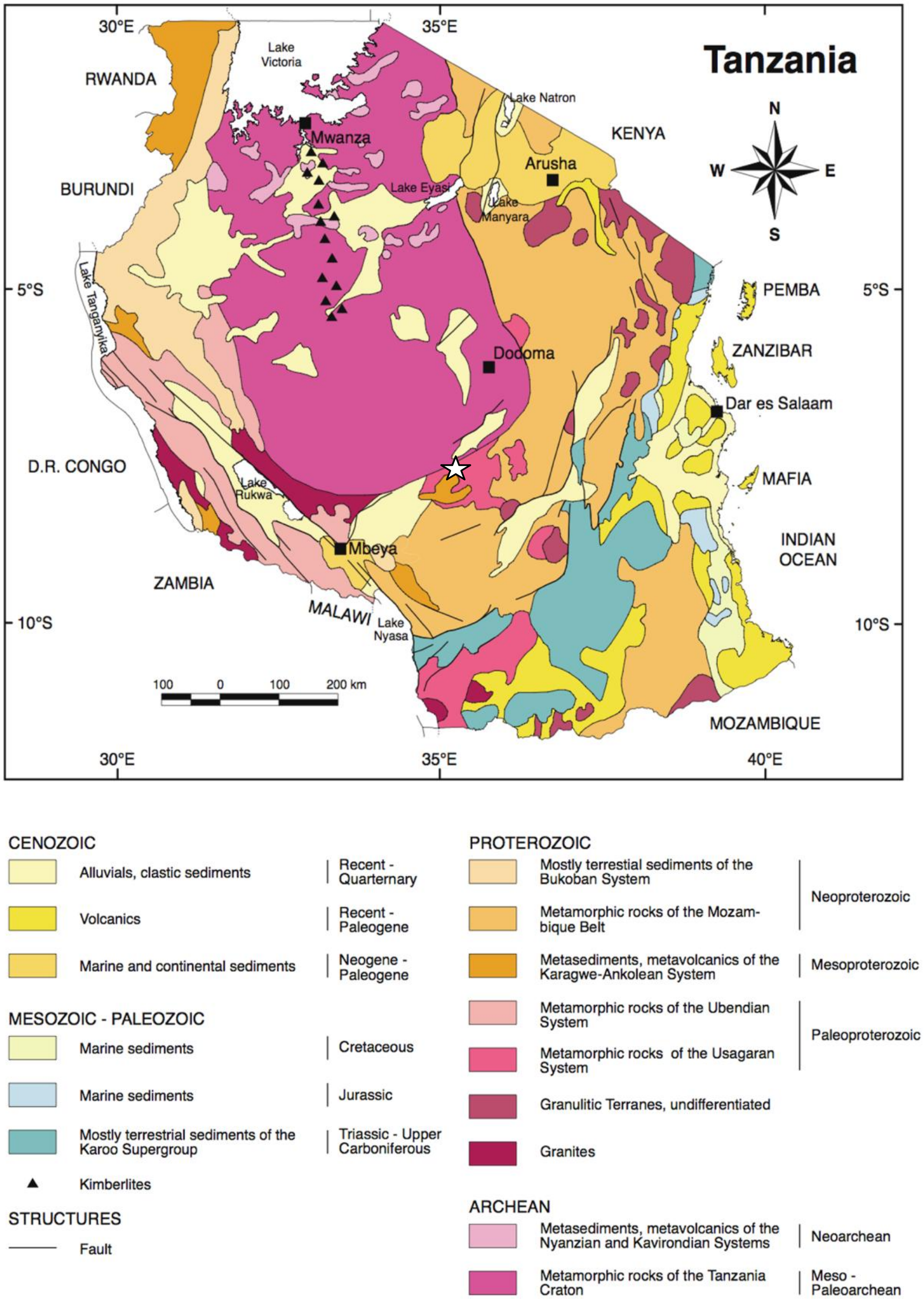


Figure 6.1: Geological overview of Tanzania (adapted from Schlüter 2006:227, Fig.214). The star represents the approximate location of Iringa Region.

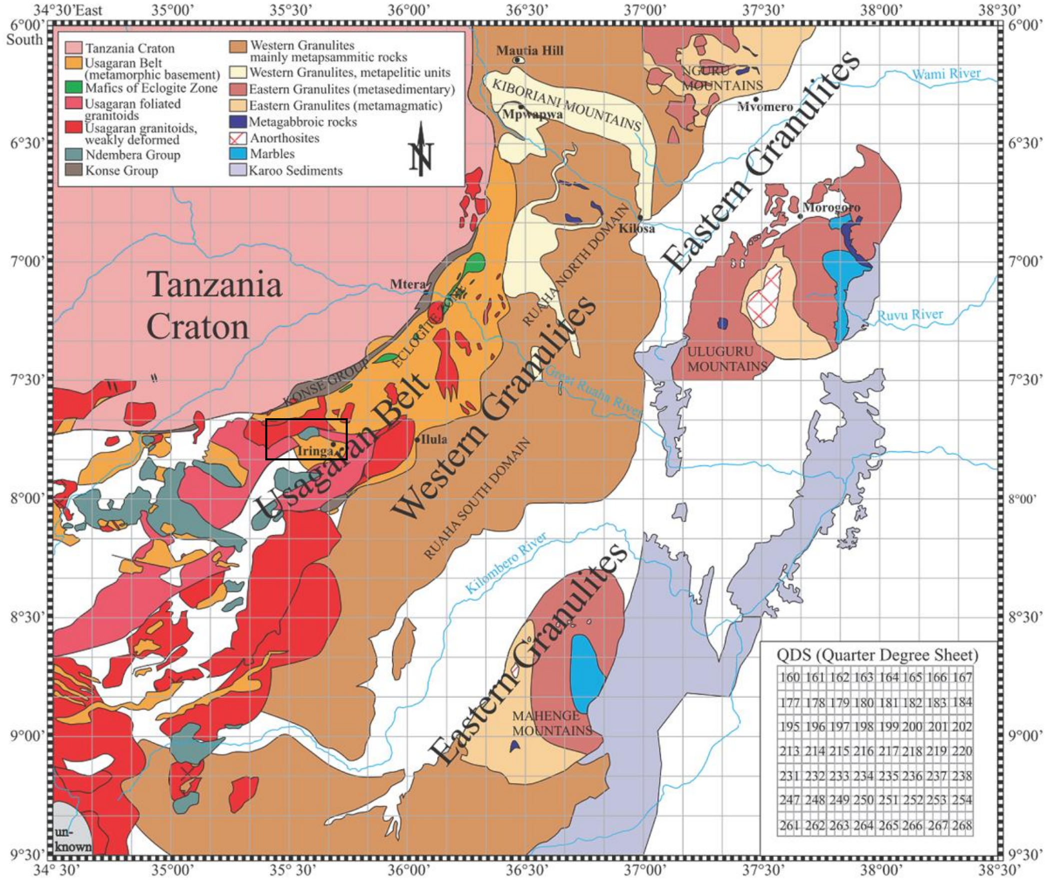


Figure 6.2: Lithological units for central Tanzania (adapted from Fritz et al., 2005:2, Figure 1a). The box represents the approximate location of the study area.

Table 6.7: Lithic raw material types found in Iringa Region.

Sedimentary	Igneous	Metamorphic
Conglomerates	Appinite	Amphibolite
Limestone	Bostonite	Epidosite
	Diorite	Gneiss
Chert*	Dolerite	Granulite
	Gabbro	Hornfels
	Granite	Migmatite
	Granodiorite	Phyllite
	Granophyre	Phyllonite
	Hornblendite	Quartzite
	Lamprophyre	Schist
	Lavas	Serpentinite
	Monzonite	
	Pyroxenite	
	Syenite	
	Tonalite	
	Trondhjemite	
	Tuffs	

Table 6.8: Characteristics of Iringa Region Lithic Raw Material Resources.

	Origin	Color	Texture	Major Mineral Components
Chert	Sedimentary	Highly variable	Cryptocrystalline	Silica: chert, chalcedony, quartz
Conglomerate	Sedimentary	Red, brown, yellow, gray-black	Clastic, coarse grained	Rock fragments
Limestone	Sedimentary	Variable (grey) Weathers to buff	Micro to cryptocrystalline	Silica: quartz, chert Calcium carbonate: dolomite
Quartzite	Sedimentary Metamorphic	White to grey to pink	Micro to macrocrystalline; Granoblastic	Quartz. Feldspars
Amphibolite	Metamorphic	Dark	Medium grained	Amphibole (hornblende), Plagioclase feldspar
Epidosite	Metamorphic	Dark	Medium grained	Epidote, Quartz
Gneiss	Metamorphic	Grey	Medium grained	Micas. Quartz. Feldspars. Garnet
Granulite	Metamorphic	Light (similar to granite)	Coarse grained; Granoblastic	Quartz, Feldspar. Pyroxene
Hornfels	Metamorphic	Grey to dark brown to black Weathers to tan	Fine grained; Granoblastic	Quartz. Feldspar, Pyroxene, Grossularite. Calcite
Migmatite	Metamorphic	Similar to granite	Variable	Quartz, Feldspar
Phyllite	Metamorphic	Variable	Fine grained	Mica, Chlorite. Quartz
Phyllonite	Metamorphic	Variable	Fine grained	Quartz, Calcite, Albite, Epidote. Mica, Chlorite
Schist	Metamorphic	Grey	Medium grained	Highly variable
Serpentinite	Metamorphic	Dark green	Coarse grained	Serpentine, Olivine, Pyroxene
Appinite	Igneous	Dark	Medium to coarse grained	Hornblende, Feldspar
Bostonite	Igneous	Pale (grey to pink)	Fine grained	Alkali feldspar
Diorite	Igneous	Grey to dark grey	Coarse grained	Plagioclase feldspar (>75%). Biotite, Quartz, Pyroxene, Hornblende
Dolerite	Igneous	Dark (black)	Fine grained	Pyroxene, Feldspar, Olivine

Table 6.8: Characteristics of Iringa Region Lithic Raw Material Resources cont.

	Origin	Color	Texture	Major Mineral Components
Gabbro	Igneous	Dark (greenish)	Coarse grained	Pyroxene , Olivine, Plagioclase feldspar, Amphibole
Granite	Igneous	Variable (pink to grey)	Fine to coarse grained; Subhedral granular	Feldspar, Quartz, Muscovite, Biotite, Hornblende
Granodiorite	Igneous	Similar to but darker than granite	Medium grained	Biotite, Hornblende, Amphiboles, Feldspar
Granophyre	Igneous	Similar to granite	Medium grained	Quartz, Alkali feldspar
Hornblendite	Igneous	Dark	Medium grained	Hornblende
Lamprophyre	Igneous	Black Weathers to tan	Variable	Feldspar, Potassic amphiboles, Biotite Highly variable
Lavas	Igneous	Variable	Fine grained	Variable
Monzonite	Igneous	Variable (often confused with granite)	Coarse grained	Feldspar, Quartz
Pyroxenite	Igneous	Dark	Coarse grained; granular	Pyroxenes
Syenite (trachyte)	Igneous	Grey to black Weathers to tan	Medium to coarse grained	Feldspar, Nepheline
Tonalite	Igneous	Light	Coarse grained	Feldspar, Quartz
Trondhjemite	Igneous	Light	Coarse grained	Oligoclase, Quartz
Tuffs	Igneous	Variable	Fine grained; Porphyritic to porous	Volcanic glass, Sedimentary material, Quartz, Feldspar, Pyroxene

Table 6.9: Varieties of Iringa Region Rock Types.

Rock type	Varieties
Amphibolite	Garnet amphibolite (varieties)
	Pyroxene amphibolites
Conglomerates	Quartzitic conglomerate
Diorite	Hornblende-biotite quartz diorite
Dolerite	Altered/Altered olivine dolerite
	Metadolerite
Gabbro	Biotite or hornblende metagabbro
	Hornblende-pyroxene gabbro
Gneiss	Hornblende gneiss (varieties)
	Biotite gneiss (varieties)
	Diorite gneiss
	Epidotic gneiss
	Kyanite gneiss
	Migmatitic varieties
	Phyllonitizied gneiss
	Porphyroblastic varieties
	Quartzitic and quartzofeldspathic-biotite gneiss
Granite	Biotite granite (varieties)
	Hornblende-biotite granite (varieties)
	Microgranite
Granodiorite	Hornblende-biotite granodiorite
	Hybrid granodiorite (varieties) (Nebulite)
Granulite	Biotite granulite
Hornblendite	Biotite Hornblendite
Hornfels	Garnet Hornfels
Lamprophyre	Sericitised or Kersantitic or Spessartitic lamprophyre
Lava and tuff	Contact metamorphic acid lavas and tuffs
	Intermediate lavas and tuffs
Limestone	Crystalline dolomitic (locally silicified)
	Crystalline
Migmatite	Quartzofeldspathic with biotite (med- to coarse- grained)
	Quartzofeldspathic w biotite & garnet (med- to coarse- grained)
Phyllite	Ferruginous quartz phyllite (varieties)
Pyroxenite	Hornblende pyroxenite
	Olivine-hornblende Pyroxenite
Quartzite[1]	Arkosic
	Brecciated
	Calcareous
	Feldspathic
	Ilmenite-sericite quartzite with hematite
	Magnetite-grunerite quartzite
Schist	Actinolite schist (varieties)
	Mica (including biotite) schist (varieties)
	Chlorite schist (varieties)
	Hornblende schist
	Migmatitic varieties
	Quartz- schist varieties
	Sericite schist
	Tremolite schist (varieties)
Serpentinite	Sericitized
Syenite	Syn-kinematic hornblende alkali syenite
	Hornblende-biotite Syenite

[1.] These "quartzite" varieities would better be termed as metasandstone, however, they are included here to be consistent with the geological maps.

Conglomerates

Conglomerates are sedimentary rocks consisting of individual clasts in a fine grained matrix. Conglomerates are named according to dominant clast size (granule, pebble, cobble, boulder), and these clasts are rounded and larger than sand (>2 mm) by definition. They may also be further classified according to the nature of clast lithology: whether clasts are of a single, few, or many lithologies, and if the clasts were derived from the same or a different formation from in which they are found. The texture of conglomerates is determined by the grain size, shape and rounding. Conglomerates are not a preferable raw material for tool production as they generally do not fracture in a controllable manner.

Limestones

Limestones are sedimentary rocks composed of over 50% carbonate, primarily in the form of calcite (calcium carbonate or $CaCO_3$). Although limestones are grain stones like most sedimentary rocks, most grains in limestones are biogenic in origin. These include the skeletal fragments of marine organisms such as corals or foraminifera but also other carbonate grains such as ooids, peloids, intraclasts, and extraclasts. Limestones which do not contain grains are formed completely by the chemical precipitation of calcite or aragonite. Limestone can also contain variable amounts of silica. The silica can be in the mineral form of chalcedony or chert, or as siliceous skeletal fragments from diatoms, sponge spicules, and radiolarians. Limestones, and dolostones (carbonate rocks in which the mineral dolomite is more abundant than calcite), are "perhaps the most difficult group among (sedimentary rocks) to treat, because of the variety of conditions by which they may be formed and the difficulty of relating specific limestones and dolostones to a particular mode of formation" (Moorhouse 1959:370). This is further complicated by the difficulty in distinguishing between calcite and dolomite in thin section particularly in rocks in which both minerals are present (Moorhouse 1959:370).

Folk (1959, 1962) and Dunham (1962) have developed two of the more popular and most widely used carbonate classification systems (Figures 6.3 and 6.4). Both represent the wide range of textures present in limestones as determined by the type of clasts and matrix present. Folk's system is better suited for thin section analysis as it focuses on the most common grains present; while Dunham's system deals with depositional textures which are more often more readily viewed using a hand lens.

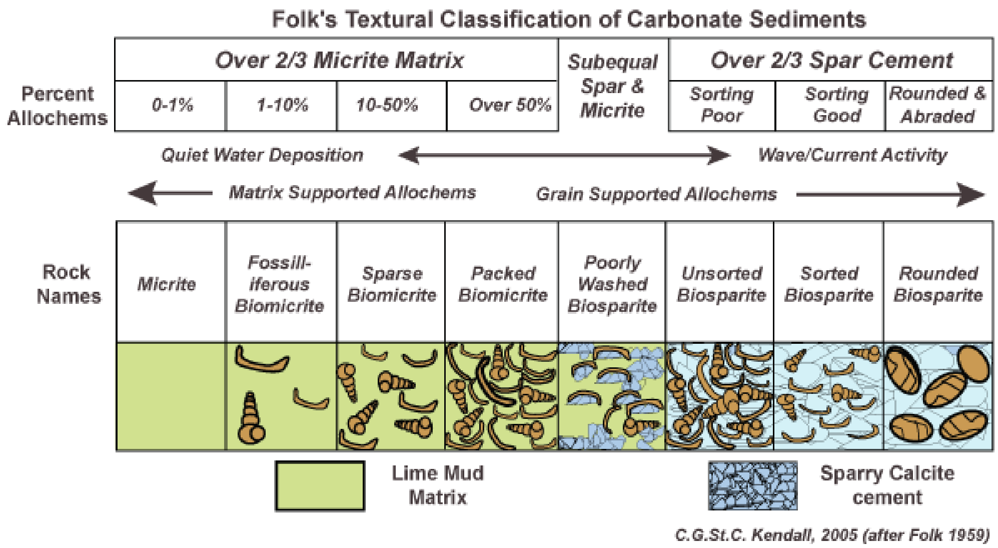


Figure 6.3: Folk's carbonate classification system (used with permission from Kendall 2005).

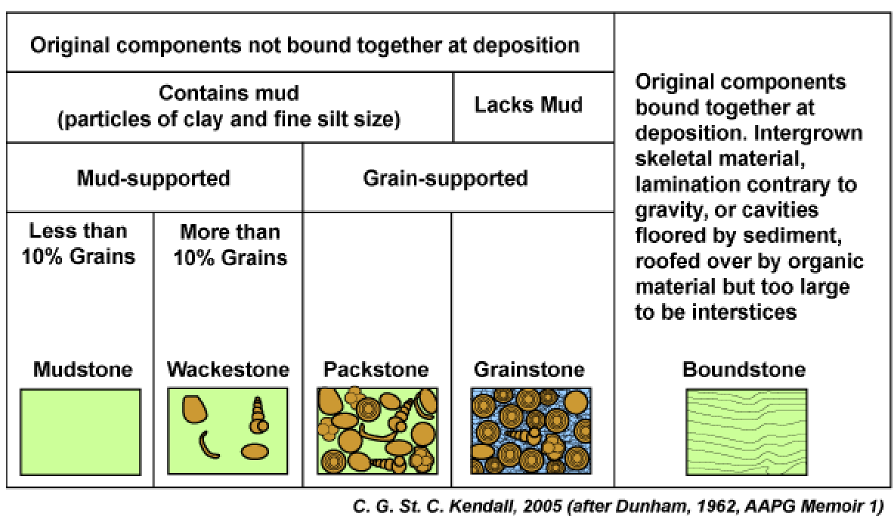


Figure 6.4: Dunham's carbonate rock classification system (used with permission from Kendall 2005).

Quartz and Quartzite

Quartz and quartzite are ubiquitous across the landscape of Iringa. Quartzite artifacts are characteristic to the LSA and are readily found on the surface of most, if not all, sites. It is important to make a distinction here between quartz, a mineral, and quartzite, a rock type. Quartz is not generally used as a toolstone, only occasionally when found in a macrocrystalline form; i.e., rock crystal. Quartzite, however, finds abundant use in tool production, despite being of relatively poor quality for lithic flaking. It should be noted that although modern knappers consider quartzite to be an inferior flaking material, it is used ubiquitously by humans in the past and, therefore, the tools constructed from it satisfied their purpose for use. Quartzite is a hard, durable material that is highly variable (i.e., it can be quite fine grained and homogeneous). It is a composed almost exclusively of the mineral quartz, and some varieties can be composed of almost pure macrocrystalline quartz. Quartzite is preferable to quartz because with flaking quartzite the knapper is trying overcome bonds between minerals (i.e., causing fracture between quartz crystals) whereas with quartz the knapper is trying to overcome atomic bonds within the crystal structure itself. Quartz, therefore, should only be used for the mineral and its rock crystal form and not for rocks largely composed of macroscopic quartz crystals.

Based on genesis, there are two major types of quartzite. Orthoquartzite is a sedimentary rock where quartz sand is cemented together with silica in the form of opal, chalcedony, or quartzose material (Carozzi 1960; Ebright 1987). Within orthoquartzite, a continuum exists in respect to the type of cementation involved and the degree of alteration of the original sand grains (including overgrowth) (Carozzi 1960). Metaquartzites represent metamorphosed sandstones characterized by the recrystallization of quartz (shape and size) and complete reconstruction of the original rock (Ebright 1987:32). Deformation features may include elongation or distortion of grain morphology, appearance of strain marks, and presence of grains with intense undulose extinction, are visible. Metaquartzite grains tend to be clear while orthoquartzite grains may be cloudy owing to inclusions or secondary overgrowth (Ebright 1987:32). These are important distinctions as not only they allow for determination of the potential formation environments of the quartzite(s) found in assemblages but also may account for variations in the quality of quartzite(s), and thus in how they were used.

Quartzites are often neglected in characterization, provenance, replicative, and even basic lithic analysis studies as they are difficult to characterize in environments where they are abundant. Ebright (1987) argues that given its relative importance in prehistoric lithic industries greater attention must be paid to this neglected material. As noted above, sedimentary and metamorphic varieties can be defined from a petrological and morphological perspective, and this information can allow for assessment of its qualities and desirability as a toolstone (Ebright 1987:29). Further quartzites may be traced back to a particular source when a particular variety demonstrates considerable macroscopic contrast to other lithic raw materials, including other quartzites, in the region.

Naibor Soit quartzite found in assemblages at Olduvai Gorge is a good example of one such quartzite (Hay 1976:9, 184). It is green to brown and coarse-grained as opposed to the white, medium grained quartzite found to the south of the gorge (Hay 1976:9). It is not only visually distinctive but was utilized differently than the white quartzite. Hay (1976:184) states: "clearly the medium-grained quartzite was a less desirable raw material than the quartzite" as few artifacts in medium-grained quartzite were found. Further the Naibor Soit quartzite was selected in not just in preference to white quartzite but also over lava, in particular for light duty tools and utilized flakes and bifaces (M.D. Leakey 1971).

Quartz and quartzite are commonly used raw materials for stone tools but can be difficult for archaeologists to analyse. This occurs because quartz and quartzite naturally flake in a way that is difficult to distinguish from intentional knapping. Many quartz assemblages appear to comprise amorphous pieces that are not easily recognised as humanly modified. Callahan (1987) refers to this as the "gravel effect." A number of researchers have experimentally knapped quartz and quartzite in order to understand the fracture mechanics of the material and to establish frameworks for analyzing archaeological quartz and quartzite assemblages (Dickson 1977; Flenniken 1981; Knutsson 1988; Tallavaara et al., 2010; and Driscoll 2011). Driscoll (2011:734) found that while it is generally easy to differentiate bipolar knapping from direct percussion in vein quartz, it is hard to differentiate between soft and hard hammer percussion.

Therefore, because quartz and quartzite are difficult to characterize and because it is difficult to determine first, if the fracture has been intentionally produced and second, what type of percussion was used in the reduction, quartz and quartzite are not included in my technological and raw material analyses. They will be considered in terms of the entire composition of the assemblage (i.e., relative to other raw material types).

Chert

Chert is the most common lithic raw material used in tool production. Although the presence of chert is not indicated on any geological map for Iringa or surrounding regions, it is commonly found at archaeological sites throughout Iringa and Tanzania. There are formations, primarily limestone, in which chert or chert-like rock could be present. As it is an important tool stone I have included it in this discussion of raw material types.

In an earlier work (Miles 2005), I provided a detailed description of chert as a raw material type which I will attempt to summarize here. There is much confusion in archaeological literature concerning the use of the terms chert, flint, and chalcedony. In this dissertation, I follow Luedtke's (1992) convention of using chert as general term for all rocks composed of primarily crypto- to microcrystalline quartz. B.E. Luedtke's (1992) monograph on chert and flint is comprehensive and highly recommended. The use of the term flint will be restricted to gray to black chert found in chalk and marly limestone. It generally has a dull to waxy lustre. Microscopically it is characterized by the presence of organic matter from which the dark color is derived. Chalcedony is used only in relation to microcrystalline quartz that appears as bundles of radiating fibres in thin section; I do not use it as a name for a particular rock type. Chalcedony is often found as void infilling textures in chert. Jasper is another name frequently adopted for chert varieties which are red or green in color.

All of the different names for chert simply reflect variations in color and/or the structure of the silica. Silica (SiO_4) is structured as a tetrahedron. In this tetrahedron there is a combination of both covalent bonds (outer electrons are shared between atoms) and ionic bonds (electrostatic attraction between oppositely charged ions). These bonds produce, overall, a very strong microstructure. This microstructure is significant as it is the cause of the property of conchoidal fracture and means chert is homogeneous and isotropic. These properties, which are not direction-dependent and are characteristic of brittle materials, allow for predictable flake form and make chert an ideal material from which to make stone tools (Cotterell and Kamminga 1987:677, Crabtree 1971a). Chert thus fractures owing to inherent lines of weakness built into its microstructure between the quartz grains and inhomogeneities (impurities).

This microstructure is the direct result of chert formation or diagenesis. Diagenesis can be defined as low temperature/low pressure changes that occur during the lithification of sediments (Luedtke 1992:25) or processes that lithify loose sediment (Prothero and Schwab 1999:12). Essentially diagenesis represents the processes that turn sediment into sedimentary rock. Genesis, as defined by Prothero and Schwab (1999:12), is the “physical disintegration and chemical decomposition (weathering) of pre-existing rocks.” This generates fragments of rocks and minerals (clasts) which are entrained (picked up and transported) by water, wind, and ice, then deposited as the transporting agents slow, stop or melt. It is the diagenetic processes that are then responsible for lithification of the sediments produced by the processes of genesis – the formation of chert. Compaction, cementation, chemical alteration, replacement, and recrystalization are the main processes through which chert forms and is deposited.

Although theories of chert formation are controversial, it is generally accepted that chert is formed through an Opal-A to Opal-CT to quartz sequence (Figure 6.5). This sequence occurs in the oceans, the main formation environment, where silicate, in the form of Opal-A, is deposited by silicate-secreting organisms, including radiolarians, sponges, diatoms and silicoflagellates (Luedtke 1992:26). The ocean floor sediments become saturated with silica (in the form of dissolved Opal-A) in this manner resulting in the precipitation of Opal-CT, an "inherently unstable form of silica" that must eventually change to the more stable form of quartz (Luedtke 1992:27). Silica solubility and precipitation, and temperature are the driving forces in the chert diagenesis sequence. Overall, it is a long, slow developmental process, which may involve more than one episode of silicification and recrystallization depending on the formation environment; this must be considered when looking at the characterization of chert.

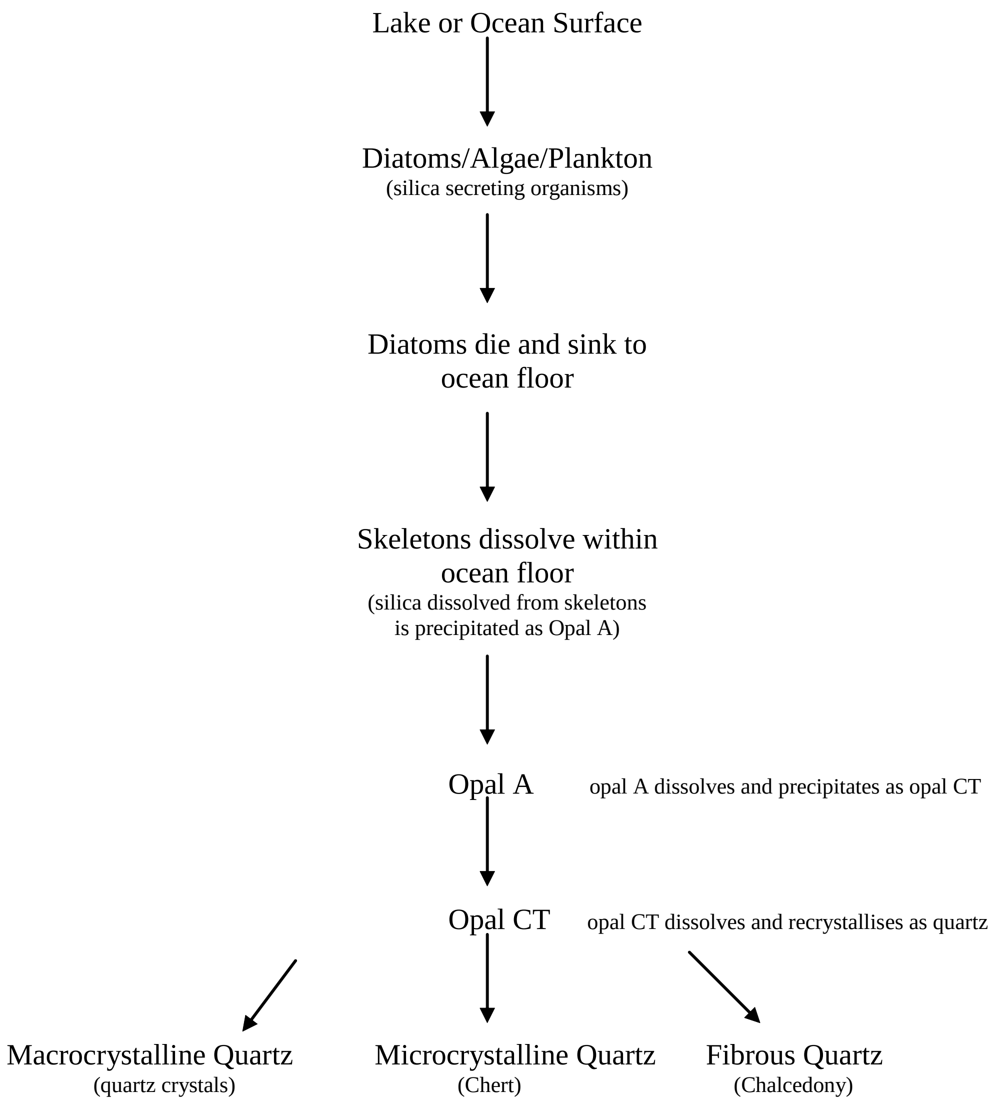


Figure 6.5: Representation of the process of silica transformation which results in chert formation (adapted from Andrefsky 2005:55, Figure 5.2).

There are three basic formations in which chert is found: (1) nodular cherts formed as nodules or lenses by replacement of carbonate rocks; (2) bedded cherts occurring in deep-water shales and greywackes, as the result of the alteration of siliceous ooze, originally composed of radiolarians and diatoms; and (3) residual cherts produced by the secondary silicification of a parent rock, other than a carbonate, during weathering, forming silicretes and small nodules (Prothero and Lavin 1990:562). Different cherts from diverse origins can reflect quite discrete concentration ranges of certain elements and similar ranges with other elements (de Bruin et al., 1972:59). Thus, an understanding of the origin of the chert involved in the provenance study will aid in the selection of an appropriate analytical technique. Petrographers divide cherts into groups based on these genetic associations (Prothero and Lavin 1990:561). However, the different formations of chert origins only partially account for the variation we see in cherts.

The main cause of variation within chert is the presence of impurities (Luedtke 1992:35). In general, the impurities are present in the surrounding matrix and are incorporated into the chert during formation. The impurities present (iron minerals, carbonates, organic matter, clay minerals, rare earth elements) are a reflection of the surrounding conditions including weathering, other rock types present, sedimentation processes, and many other environmental influences. The majority of impurities found in cherts are those incorporated into the chert during formation from materials present in the area of deposition – including acritarchs and other microfossils (Luedtke 1992:36).

Igneous rocks

Bostonite is a fine grained, pale (grey or pink) colored, intrusive igneous rock. It is composed almost entirely of alkali (orthoclase, anorthoclase, perthite, and albite) feldspars, creating a characteristic texture of feldspar laths in a fine grained matrix. Dolerite is also fine grained but contains a visible texture of euhedral plagioclase laths in a finer grained matrix of clinopyroxene. It is a fine grained version of a gabbro.

Appinite and hornblendite are both medium grained plutonic rocks that are rich in the amphibole hornblende. Appinite is richer in feldspars (both plagioclase and alkali) and may or may not contain quartz. Amphibolite is the metamorphic equivalent of hornblendite, and contain significant quantities of both hornblende and plagioclase. Diorite, granodiorite, monzonite, and granophyres are all intermediate intrusive igneous rocks. Diorite is a grey to dark grey rock composed of plagioclase, feldspar, biotite, hornblende, and/or pyroxene. Granodiorite is close in composition to granite, a coarse-grained igneous rock discussed below, but contains more plagioclase than potassium feldspar. Granophyres also have a composition similar to granite, however, has characteristic angular intergrowths of quartz and alkali feldspar. Monzonite contains almost equal proportions of plagioclase and orthoclase feldspars with minor amounts of hornblende and biotite. Quartz is generally absent in monzonite so when present and greater than 10% of the rock, the rock is named quartz monzonite or adamellite. Because of its coloring adamellite is often confused with granite however, in granite quartz represents greater than 20% of the minerals and is coarser grained.

Lamprophyres are a catch-all category of igneous rocks. In brief, they are a group of rocks containing phenocrysts, usually of biotite, amphibole, and pyroxene, in a feldspar groundmass. These ultramafic rocks are usually dark in color owing to an abundance of ferromagnesian silicates. The presence or absence of plagioclase, orthoclase, biotite and hornblende allow for separation into a few specific rock types including spessartite and vogesite. These rocks also contain iron oxides, apatite, sphene, augite, and olivine.

Tonalite, syenite, granite, trondhjemite, and gabbro are all coarse grained intrusive igneous rocks. Gabbro is easily separated from these other intrusives as it is mafic. It has greenish to dark coloring, and contains pyroxene (clinopyroxene), plagioclase, amphibole, and olivine (which means it is chemically equivalent to basalt). Its texture is equigranular to porphyritic.

Granite, syenite, and tonalite are all felsic intrusives. All have a color index of less than 25% dark minerals. Granite is the most common. It may have granular or porphyritic texture, is generally massive, hard, and tough. Granites can be pink to grey in color depending on chemistry and mineralogy. Syenite has the same composition as granite (quartz, feldspars, and ferromagnesian minerals) but with quartz either absent or present in relatively small amounts. It is not a common rock. Tonalite, conversely, contains greater than 20% quartz with plagioclase as the main feldspar, and biotite, amphiboles and pyroxenes as accessory minerals. Trondhjemite is similar to tonalite but is poorer in mafic minerals and also generally contains a more Na-rich plagioclagse than tonalie. Pyroxenites are closely related to hornblendites. It is an ultramafic rock composed mainly of pyroxene minerals including augite, diopside, hypersthenes, bronzite, or enstatite. They are also closely related to gabbros but differ by the absence of feldspar.

Generally coarse grained igneous rocks are not desirable materials for the production of stone tools. However, granite and diorite are mechanically tough and often free of inclusions and cracks. They are also aesthetically pleasing and are capable of being highly polished (Rapp and Hill 1998:122). These properties have made them desirable for use in monument construction, bowls, vases, axes and mace heads (Rapp and Hill 1998:22).

Lavas and tuffs

Lavas are molten rock expelled by a volcano during an eruption. They are generally classified as felsic, intermediate, and mafic as with other igneous rocks. Felsic lavas include rhyolite and dacite. Rhyolite is the fine-grained mineralogical equivalent to granite; they are rich in silica and feldspars. Intermediate lavas, also called andesitic, are lower in silica. These are richer in magnesium and iron which tends to present itself in the form of a darker groundmass with phenocrysts of amphibole or pyroxene. Mafic or basaltic lavas are characterized by their high ferromagnesian content.

Tuffs, on the other hand, are a type of rock consisting of consolidated volcanic ash which is also ejected during an eruption. Any rock that contains greater than 50% tuff is called tuffaceous. Tuffs are generally classified according to the nature of the volcanic rock of which they consist; e.g. rhyolite tuffs, trachyte tuffs, basaltic tuffs. Frequently tuffs or lavas may undergo metamorphism producing metavolcanic rocks. These types of metavolcanic rock are commonly found in greenstone belts. They can contain the minerals quartz, feldspar, amphibole, pyroxene, and less common minerals can include biotite, garnet, actinolite, epidote, chalcedony, and prehnite.

Metamorphic rocks

Amphibolite is composed largely of amphibole (primarily hornblende) and plagioclase feldspar. Generally it is dark colored, weakly foliated rock with schistose texture. Amphibolites are mainly derived from metamorphosed mafic rocks. Amphibolites may be divided into two sub-groups based on mineralogy: orthoamphibolites and para-amphibolites. Orthoamphibolites are those that contain amphibole and albite with minor epidote, chlorite, quartz and sphene. Para-amphibolites have the same basic mineral assemblage as orthoamphibolites but contain more biotite, quartz, albite, calcite, and wollastonite.

Schists and gneisses are both large groupings of metamorphic rocks. Schists are highly foliated and characterized by the flaky appearance resulting from having at least 50% lamellar, platy or elongated minerals such as micas, chlorite, talc, hornblende, and graphite among others. Gneisses are also highly foliated but do not contain large amounts of platy minerals like schists. Gneisses develop compositional banding under high temperature and pressure conditions where minerals are arranged into bands of more mafic and more felsic minerals.

Granulites are medium to coarse grained metamorphic rocks. Although the minerals found in granulites are dependent on the chemical composition of the parent rock, they are generally composed mainly of feldspar and associated quartz and ferromagnesian minerals. Often they have a granoblastic texture and gneissose to massive structure. Granulites are closely related to gneisses as they contain the same minerals but are finer grained with weaker foliation.

Hornfels are fine grained metamorphic rocks produced from sandstone, shale, limestone, slate, and dolerite. Slates, shales, and clay-based rocks yield biotite hornfels where biotite is the most abundant mineral followed by quartz and feldspar. Other minerals such as graphite and iron oxides are found in trace amounts. Faint banding or striping may result from the original banding of the parent rock. Common is spotting, visible in hand specimen, which develops from the presence of graphite or carbonaceous (organic) inclusions. Calcite-silicate hornfels form from the thermal alteration of impure limestones. They are fine grained, often banded, and much harder than the original limestones. Mineralogically they are highly variable. A third type of hornfels rise from diabases, basalts, and andesites. They consist primarily of feldspar with hornblende and pale pyroxene. The original textures and structures (porphyritic, vesicular or fragmental) of the parent igneous rock are clearly visible in those hornfels where alteration is less advanced.

Less common rocks in Iringa Region include epidosite, phyllite, serpentinite, phyllonite, and migmatites. Epidosite is a highly altered rock containing epidote and quartz. Phyllite, produced from the metamorphism of slate or pelite, is a highly foliated rock composed of quartz, sericite, mica, and chlorite. Serpentinite is a rock composed of one or more serpentine group minerals. Phyllonites are phyllosilicate-rich mylonites. Mylonites are fine-grained, compact rocks produced by dynamic recrystallization of the component minerals. This process results in the reduction of the grain size of the rock. As mylonite can have many different mineralogical compositions, classification is based on the textural appearance of the rock. Migmatites represent rocks at the divide between igneous and metamorphic rocks. They are rocks in which partial melting has occurred, thus are composed of new materials crystallized during melting and old material which resisted melting.

6.4 Summary

The characterization of the lithic material involved and the determination of the material's source can illustrate the different factors and processes that influence and the components that collectively form the lithic production system. Without the ability to trace a material back to its source, it is difficult to place the material within the larger system of raw material use. In terms of prehistoric economic interpretation, this is the question of "how much the provenance of certain objects can be traced back to different sources" that are unevenly and arbitrarily distributed (Katalin 1998:2)? An appropriate response to this is the question of "how unique and identifiable the given product or raw materials found in an archaeological context can be" (Katalin 1998:2)? The answers to these questions lie in the information which provenance and characterization studies can provide.

Chapter 7: Sample, Analysis and Raw Material Results

7.1 Sampling Method

Sampling for thin sections was done in several ways in order to accommodate various objectives. Following Calogero and Philpotts (1995), for the determination of lithic diversity in both assemblages, I analyzed a range of macroscopically different materials. For assessment of lithic use relative to time, samples from every macroscopically determined type were selected from each excavation level. For tentative identification of regional use of particular material, samples were taken from two sites with different cultures and activities represented for comparison. Finally, a "curious rock" approach (Calogero and Philpotts 1995) was also undertaken where artifacts classified simply as "unknown" or "odd rock" were sampled. "Odd rocks" (i.e., those where only a single example of this rock type was present) were sampled in total as were any "unknown" rocks whose type could not be determined. Table 7.1 presents an overview of the population and sample sizes for macroscopic and microscopic analyses but does not include artifacts recovered from the surface or artifacts with no definitive context (e.g., area of rock removal).

Tables 7.2 and 7.3 provide a breakdown for Mlambalasi and Magubike respectively including all artifacts from all contexts. Many artifacts from Magubike were also classified as "unknown" owing to the heavy coating of sediment/calcium carbonate on them; these were sampled by excavation level. This sampling method has built in redundancy because the determination of type by macroscopic properties is subjective and does not guarantee "coverage" of all materials in an assemblage (Calogero and Philpotts 1995:4).

Table 7.1: Population and sample size by maximal artifact category.

Maximal artifact category	Mlambalasi			Magubike		
	Population	Sample Size		Population	Sample Size	
		Macro	Micro		Macro	Micro
Debitage	2686	734	157	10881	5086	361
Core	1124	123	40	2225	452	44
Tool	593	14	14	5815	171	13
Total	4403	911	211	18921	5709	418

Table 7.2: Summary of artifacts sampled for macroscopic and microscopic analyses from Mlambalasi by context.

	Macroscopic	Microscopic
Unknown	23	1
Room 1 Surface	48	8
Room 2 Surface	6	1
Room 1/Slope Surface	5	0
Slope Surface	86	10
Outside shelter Surface	1	0
Surface subtotal	146	0
Test Pit #1 (TP#1)	131	50
Test Pit #2 (TP#2)	793	146
Assoc. with TP#1	12	0
Total (sample)	1088	215
Total (all artifacts)	11537	
% of all artifacts	9.43	% of macro sample: 19.85

Table 7.3: Summary o artifacts sampled for macroscopic and microscopic analyses from Magubike by context.

	Macroscopic	Microscopic
Unknown	0	0
Surface	247	28
Test Pit #1 (TP#1)	1188	99
Test Pit #2 (TP#2)	166	21
Test Pit #3 (TP#3)	4538	271
Total (sample)	6139	419
Total (all artifacts)	20060	
% of all artifacts	30.6	% of macro sample: 6.8

7.2 Raw Material Analysis

7.2.1 Methods

A 10x magnification hand lens was used for macroscopic analysis. For the macroscopic analyses, the Mlambalasi and Magubike assemblages were initially sorted into preliminary macroscopic type groups. Quartzite, quartz, and rock crystal (quartz variant) were not selected for analysis in this study. This is owing to the overall homogeneity and macroscopic similarity of these varieties, as well as the difficulty in distinguishing between natural and knapped fractures in these materials, as discussed in Chapter 6. Identification of all the assemblage raw material types macroscopically proved to be problematic especially for rocks with abundant calcium carbonate coating or "cement". The macroscopic analysis did allow for the definition of an initial 74 types at Mlambalasi and 92 types at Magubike. All artifacts were then individually scored using the attributes discussed in Chapter 6 and listed in Appendix A.

Samples for thin sectioning were taken from these tentative macroscopic types following the procedure outlined above. From Mlambalasi, 215 artifacts designed XCM and 419 from Magubike, designated XOF, were selected for thin sectioning. All of the 634 thin sections were prepared at Spectrum Petrographics Inc. using a standard thin section methodology and equipment. A Leitz Labourlux 11 polarizing microscope with 3.2x, 4.0x, 10x, and 40x objectives was used for the analysis of the thin sections. Microphotographs were taken using this same scope affixed with a Nikon 995 coolpix camera with 3.34 mega pixel resolution. The attributes of each sample were scored according to the standardized system discussed in Chapter 6 and outlined in Appendix A. Next the samples were grouped into petrographically similarities categories, which were then subdivided on refined mineralogical and textural criteria. These groups represented microscopic rock types.

A petrographic comparison using international and local literature was executed in order to identify each rock type by name. Drs. Charles Schweger

(Professor Emeritus, Department of Anthropology, University of Alberta), Dorian Smith (Professor Emeritus, Department of Earth and Atmospheric Sciences, University of Alberta), Ronald Burwash (Professor Emeritus, Department of Earth and Atmospheric Sciences, University of Alberta), and Tom Chacko (Professor, Department of Earth and Atmospheric Sciences, University of Alberta) were consulted as recognised experts in petrology and petrography. Fourteen types were identified: three igneous (types A, B, and C), five metamorphic (types D-G, K), and six sedimentary (types H - M) (Figure 7.1; Table 7.4). Quartzite is subdivided into its sedimentary and metamorphic varieties (Ka and Kb). The cherts (type M) were further subdivided into seven subtypes (Table 7.5). Eight samples were unique (types a-g): three are cherts which are not like any of the seven chert sub-types, five could not be identified.

These microscopic types were then compared with the initial macroscopically determined types. The macroscopic types were lumped based on best fit with the microscopic types. This resulted in 10 final macroscopic types and 10 sub-types (Tables 7.6 – 7.7). Detailed descriptions and photographs of each of the types appear in Appendix B. There is some overlap between microscopic types macroscopically. This is the result of misidentification at the macroscopic level. Lithic type misidentification at the macroscopic level is to be expected (see comments concerning methodology in Chapter 6) and will be discussed at length in the following chapter (Chapter 8).

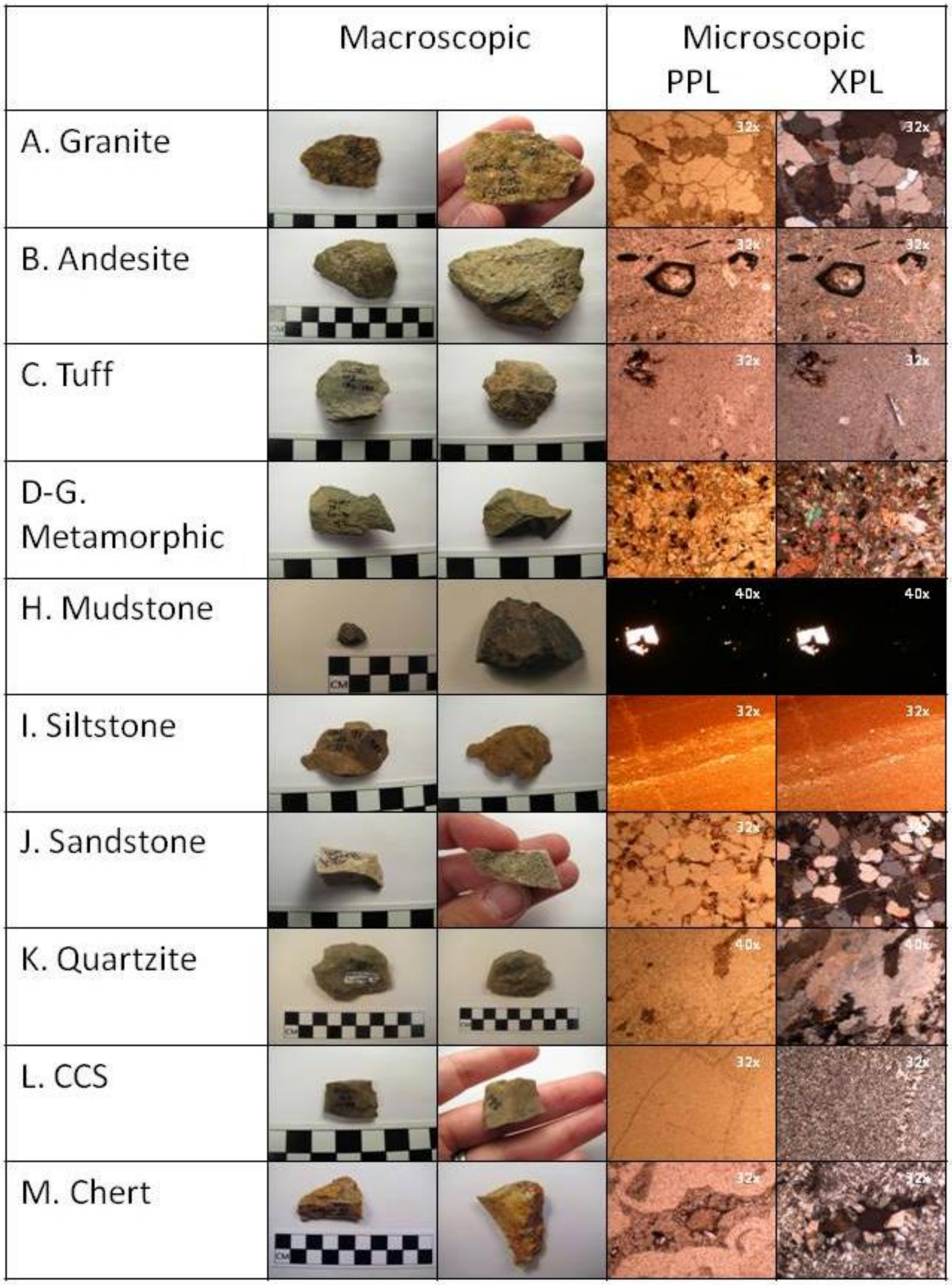


Figure 7.1: Raw material types from Mlambalasi and Magubike.

Table 7.4: Microscopic characteristics of all lithic raw material types.

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**a**	**b**	**c**	**d**	**e**	**f**	**g**
Amphibole	±	±			±	X														
Pyroxene		X		±	±	±														X
Feldspar			X	X	X	X	X				±					X				X
Plagioclase	±	X																		
Sanidine																				
Microcline	±																			
Quartz	X		X	X	X		X		X	X	X	X	X	X	X	X				X
Chert/CH										X	X	X	X	X			X	X		
Nepheline	X																			
Olivine/chlorite					X	X														
Andesine		X																		
Micas																				
Biotite	±		±				±													
Muscovite			±				±			±										
Opaques	±	±		X	X	X	X			X		±	±			X	X		X	
Carbonate			±				±						±					X		
Clay minerals			±			±	±	X	X	±		±								
Organic inclusions					±					±										
Phaneritic	X										X									
Aphanitic																				
macro	±			X		X					X					X	X			X
micro		X	X		X		X										X			
Cryptocrystalline		X	X	X	X	X	±	X	X			X	X	X	X			X	X	
Turbid			±																	
Micrographic											X									
Granular	X										X	X								
Porphyritic		X	X																	
Ophitic to subophitic				X	X	X										X				
Trachytic							X													
Clastic								X	X	X										
Non-clastic													X	X	X			X		
Macrocrystalline											X	X								
Microcrystalline									X	X		X								
Homogeneous								X	X						X		X	X		

X = present – = absent ± = may or may not be present

a-g = unique/unidentifiable varieities

Table 7.5: Microscopic characteristics of chert raw material types.

	I	**II**	**IIIi**	**IIIii**	**IIIiii**	**IIIiv**	**IV**	**a**	**b**	**e**
Cryptocrystalline quartz	X	X		X	X	X	X	X	X	
Microcrystalline quartz										
Macrocrystalline quartz										
DQM						±				X
PseudoDQM						±				X
Replacement quartz	X	X								
Quartz vein inclusions										
Quartz crystal inclusions										
Chalcedony			X	±	X	X		X		X
Spherulitic chalcedony						±				X
Carbonate										
Low (grey) δ			X	X	±					X
High δ			±		X		±			X
Pyrite			±			±				
Clay minerals	±				±					
Feldspar inclusions	±									
Hematite/FeO staining	X	X	±	±	±	±	±	X		X
Hematite/FeO inclusions		X	±	±		±	X			X
Relict texture			X	±		±				X
Serpentinite-like					X					
Fossil inclusions										
radiolarian								X		

X = present – = absent ± = may or may not be present

a-g = unique/unidentifiable varieities

Table 7.6: Macroscopic characteristics of all lithic raw material types.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**a**	**b**	**c**	**d**	**e**	**f**	**g**
Phaneritic	X			X				X									
Aphantic			X	X		X	X	X	X	X	X	X	X	X	X	X	X
Porphyritic			X														
Homogeneous					X	X			X								
Vesicular			X														
Poorly sorted																	
Well sorted							X										
Dark to very dark: black to dark grey		X	X	X						X	X	X				X	
Intermediate I: White to black ratio ~50%				X													
Intermediate II: grey to blue-grey to greenish		X	X	X				X	X	X							
Intermediate III: yellow, orange, red, brown, purple						X	X		X	X	X	X	X	X	X		X
Light (white, buff)	X						X	X	X	X							
Patina white to buff							X			X							
Patina white to grey																	
Patina buff to yellow to red, orange, brown (“rusty”)		X	X	X				X	X	X					X	X	X
Banded										±							
Speckled										±		X					
Mottled									±	±	X				X		
Waxy			X	X					X	X	X				±		
Vitreous	X	X		X			X			X	X	X					
Dull	X	X	X	X		X	X		X	X			X	X	±	X	X
Resinous											±						
Semi-translucent to Translucent								X	X								
Quartz vein										±					X		
Quartz crystal										±					X		
Micas																	
Other inclusions										±							

X = present – = absent ± = may or may not be present

a-g = unique/unidentifiable varieities

Table 7.7: Macroscopic characteristics of chert raw material types.

	I	**II**	**III**	**IIIi**	**IIIii**	**IIIiii**	**IIIiv**	**IV**	**a**	**b**	**e**
Dark to very dark: black, dark grey						X	X	X	X	X	
Intermediate I: pink, red, purple	X	X		X	X	X	X			X	
Intermediate II: dark brown to light brown, orange				X		X	X		X		
Intermediate III: grey to blue-grey				X			X	X			
Light (white, buff, yellow, light greenish)				X		X	X				X
Patina white to buff							±				
Patina white to yellow							±	±			
Patina white to pink					±						
Patina red, orange, brown (“rusty”)											X
Mottled		±		±	±	±	±		X		X
Speckled				±		±	±			X	
Banded						±	±				
Waxy				X	X	X	X	X	X		X
Vitreous									X	X	
Dull	X	X		X	X	X	X	X			X
Chalky	X										
Resinous									X		
Quartz inclusions				±			±				X
Quartz vein				±							X
Quartz crystal											
Other inclusions				±		±	±				

X = present – = absent ± = may or may not be present

a-g = unique/unidentifiable varieities

7.2.2 Description of Lithic Raw Material Types

Although descriptions and photographs of each of the types appear in Appendix B, it is important to provide some additional information about each type at this juncture. It should be noted that while the properties described correspond to expected descriptions for each lithic type, those provided here are specific to the toolstones found in the assemblages at Mlambalasi and Magubike.

These descriptions serve to illustrate the relationship of the macroscopic and microscopic properties of each raw material with their potential formation environments and thus source locations. That being said it is likely all of the rocks are from the same volcanic formation environment (personal communication, T. Chacko, 21 May 2010). The chert subtypes represent stages in a continuum of replacement of igneous crystals or clasts. The metamorphic rocks also represent a continuum. As will subsequently be made clear, it is not always easy to place a particular sample within a particular subtype.

Figure 7.2 illustrates a generalized scheme for differentiating the three igneous varieties macroscopically. Figures 7.3 and 7.4 illustrate the schemes for differentiating the various metamorphic and sedimentary types, respectively, macroscopically.

Granite: macroscopic type 1, microscopic type A

Granites from Mlambalasi and Magubike are light (white, grey to pink) rocks (Figure 7.5). They have a coarse, granular texture which is apparent in both hand specimen and thin section. This texture plus its quartzofeldspathic composition (including quartz and abundant microcline, plagioclase, and albite plagioclase) distinguishes granite from the other toolstones in the assemblages. The quartz shows undulating extinction in plain polarized light (PPL) and has higher interference color in cross polarized light (XPL) than the feldspar (Figure 7.4). Microcline feldspar is clearly identified by typical cross-hatched or “tartan” twinning, while plagioclase/albite shows polysynthetic twinning. Plagioclase may also be zoned. All minerals, with the exception of accessory biotite when present, are colorless in PPL. Biotite is usually brown colored in PPL and pleiochroic in XPL. Pleiochroism is the term applied to the phenomenon of variation in color which may be seen "depending on the orientation of the crystal with respect to the plane of polarization" (MacKenzie and Adams 1994:14). Few opaques, likely representing iron oxides, may be present.

Andesite: macroscopic type 2, microscopic type B

Whereas granite is coarse grained, andesite is fine grained to porphyritic. Like granite it may be light but it can also be quite dark and is always greyish in color. Andesite may also be patinated with buff to orange-brown patina (Figure 7.7). Andesite has a fine-grained groundmass which is likely feldspar (Figure 7.8). Pyroxenes and amphiboles phenocrysts are present with accessory plagioclase feldspar and augite inclusions. Generally the pyroxenes are brownish in plain view and show bright interference colors under crossed polars. Amphiboles are also brownish and pleiocroic thus it can be difficult to distinguish them from pyroxenes. Oxidation rims may also be present on some of the phenocrysts (see Figure 7.8). The oxidation (black) rims are due to the formation of iron oxide as a result of oxidation (MacKenzie and Adams 1994:40).

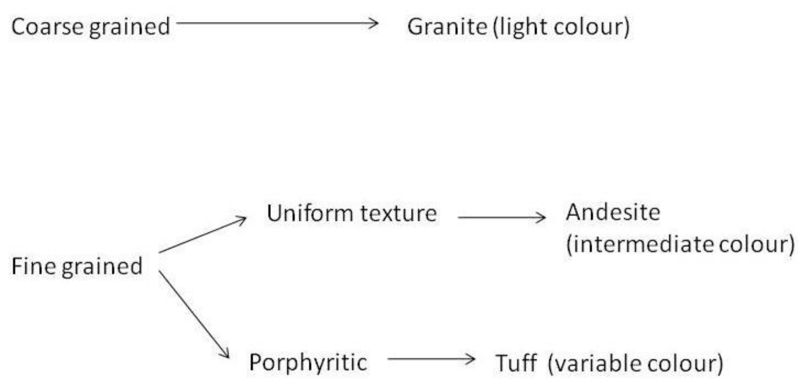


Figure 7.2: Scheme for separating igneous rock types macroscopically.

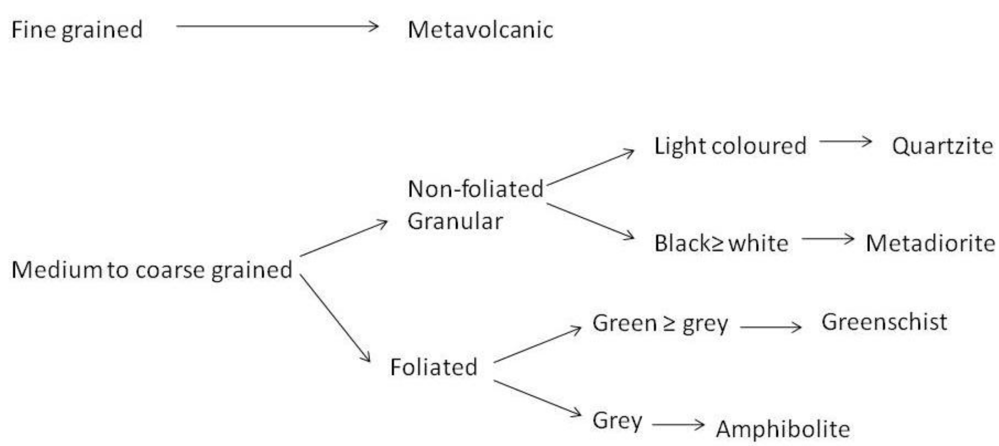


Figure 7.3: Scheme for separating metamorphic varieties macroscopically.

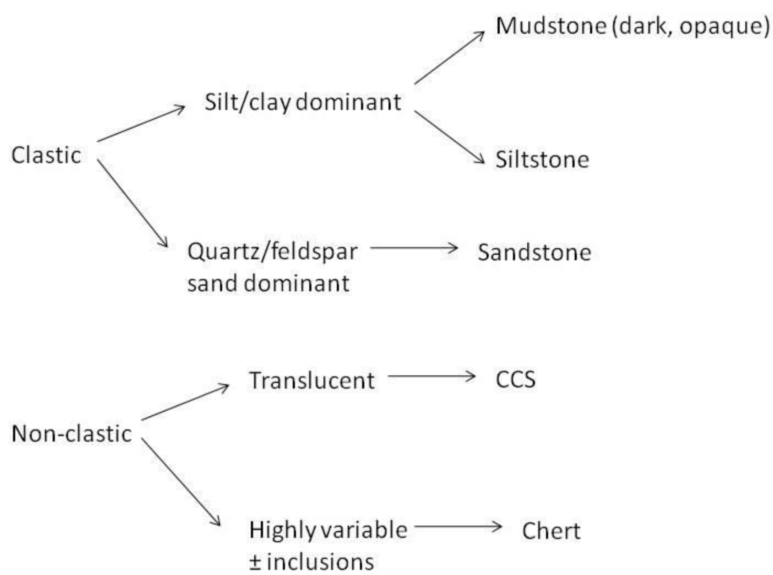


Figure 7.4: Scheme for separating sedimentary varieties macroscopically.

Figure 7.5: Granite (type 1/A); XCM026.

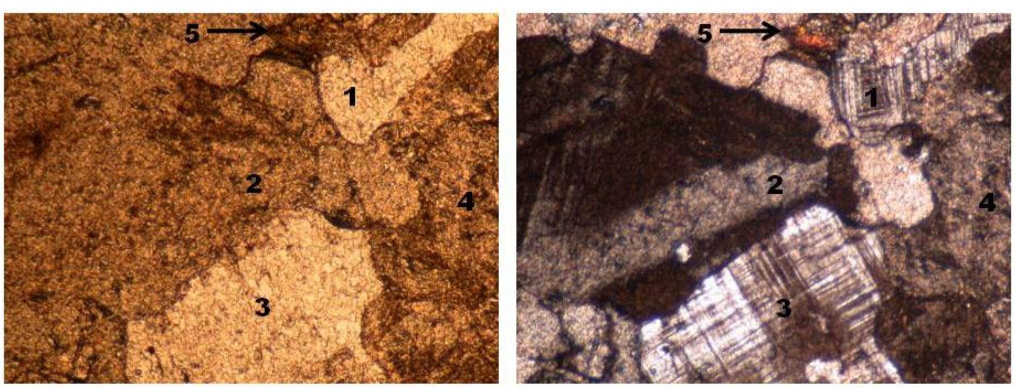


Figure 7.6: Microphotograph of XCM026. 40x, PPL (left), XPL (right). 1: Zoned plagioclase feldspar. 2: Twinned plagioclase (albite). 3: Microcline with tartan twinning. 4: Quartz. 5: Biotite.

Figure 7.7: Andesite (type 2/B); XOF178.

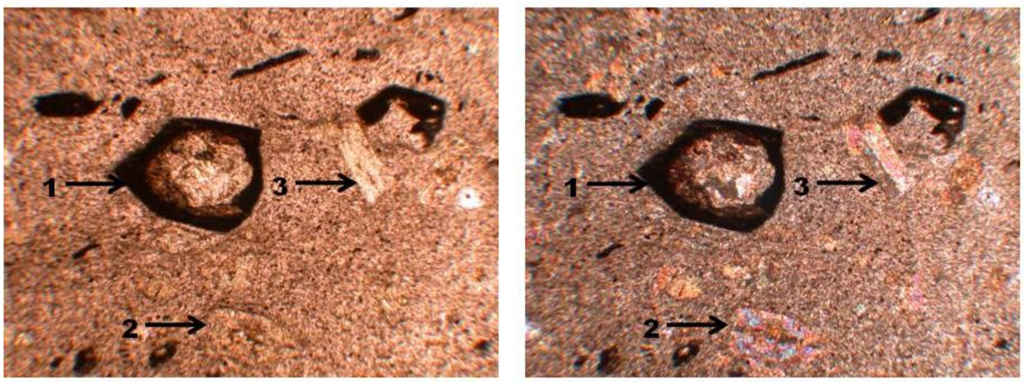


Figure 7.8: Microphotograph of XOF178. 32x, PPL (left), XPL (right). 1: Phenocryst with oxidation rim. 2: Pyroxene phenocryst. 3:Plagioclase feldspar phenocryst with twinning.

Figure 7.9: Volcanic tuff (type 3/C); XOF248.

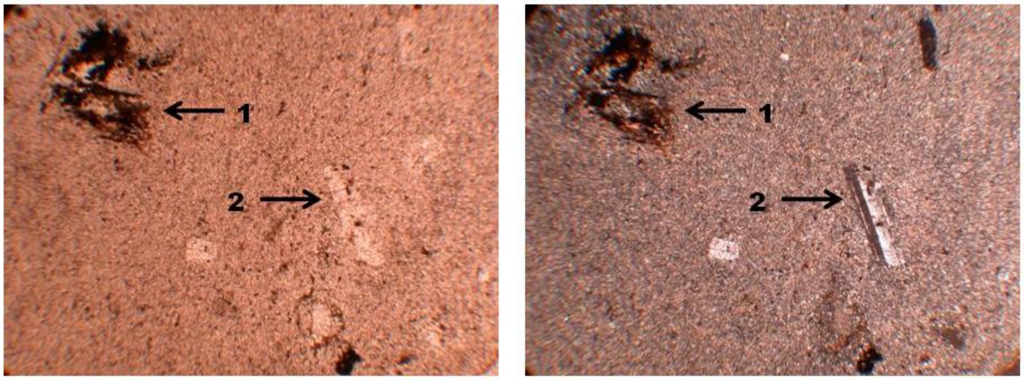


Figure 7.10: Photomicrograph of XOF248. 32x, PPL (left), XPL (right). 1: Mica (biotite). 2: Plagioclase feldspar phenocryst.

Metamorphic Subtypes	Macroscopic / Microscopic (PPL, XPL)
D. Metadiorite	
E. Greenschist	
F. Amphibolite	
G. Metavolcanic	

Figure 7.11: Metamorphic raw material subtypes.

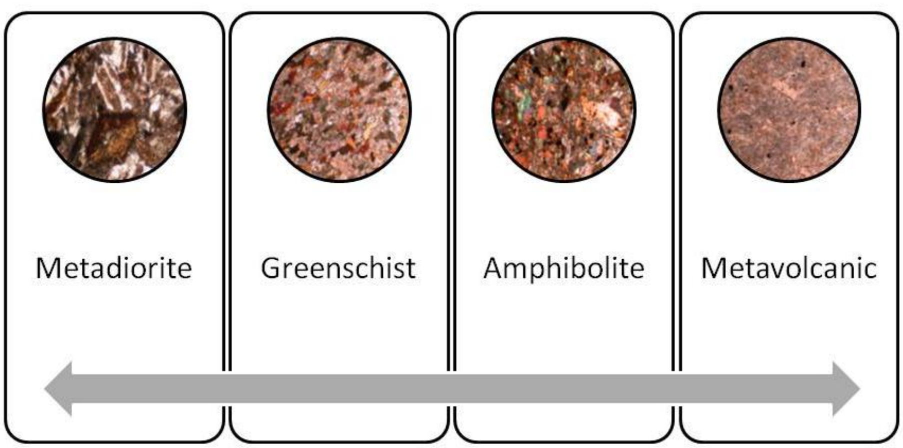


Figure 7.12: Continuum of metamorphic rock types. Relates to quality with lower quality (larger grain size) types on the left and higher quality (smaller grain size, greater homogeneity) towards the right.

Tuff: macroscopic type 3, microscopic type C

The tuffs are highly variable; they can be light grey to blue-grey to greenish grey to dark grey to black in color (Figure 7.9). They are porphyritic: heavily altered quartz and feldspar phenocrysts are present in a frequently turbid groundmass (Figure 7.10). Carbonates, micas (biotite, muscovite), and clays are common accessory minerals as are opaques. Macroscopically it can be difficult to distinguish tuffs from cherts; microscopically tuffs can be separated from cherts owing to the presence of plagioclase phenocrysts.

Metamorphic varieties: macroscopic type 4, microscopic types D-G

All metamorphic varieties are intermediate to dark in color ranging from light grey to greenish to dark grey to black. They may have a buff to orange brown patina. Recognition of the four metamorphic subtypes is extremely difficult at the macroscopic level – these can best be identified on the basis of grain size that is only visible microscopically. I have devised a scheme that allows for preliminary separation of metamorphic varieties (Figure 7.11). Although such differentiation is especially difficult at the macroscopic level some general comments can be made. Problems in distinguishing the various metamorphic varieties were further complicated by the high degree of cementation present on these artifacts. I suggest that the relative coarseness of the amphibolite and greenschist facies rocks attributed to the large amount of cement/concretion present on the surface of the artifacts of those varieties. Cherts and other fine-grained types had relatively coating in comparison.

I was unable to identify the metamorphic toolstones to any particular type but rather can generally classify their features as relating to particular metamorphic facies such as amphibolites and greenschist grade rocks. Recall that both amphibolite and greenschist facies represent low to moderate temperature and moderate pressure environments. Greenschists are low grade while amphibolites are medium grade rocks. Therefore, it is likely that the subtypes of metamorphic rocks represent a continuum of degree of metamorphism (Figure 7.12).

Metadiorites (macroscopic type 4, microscopic type D) are granular, non-foliated rocks which typically have “salt and pepper” coloring – that is to say the proportion to dark to light minerals is approximately equal where black minerals only slightly more abundant than white ones (Figure 7.13). They are aphanitic, macrocrystalline, and hypocrystalline with ophitic to subophitic texture (Figure 7.14). They are composed predominantly of heavily altered feldspars and quartz. Accessory minerals are green to brownish in PPL with varied birefringence, likely pyroxenes.

Greenschist metamorphic rocks (macroscopic type 4, microscopic type E) have a greenish color in hand specimen (Figure 7.15), and microscopically, have an abundance of green minerals including hornblende, chlorite, actinolite, and epidote (Figure 7.16). Although metadiorites and greenschists are both aphanitic with ophitic to subophitic texture, greenschists are microcrystalline and hypocrystalline with some foliation/schistocity. Opaque inclusions are present.

Figure 7.13: Metadiorite (type 4/D). Top: XOF204. Bottom: XOF419.

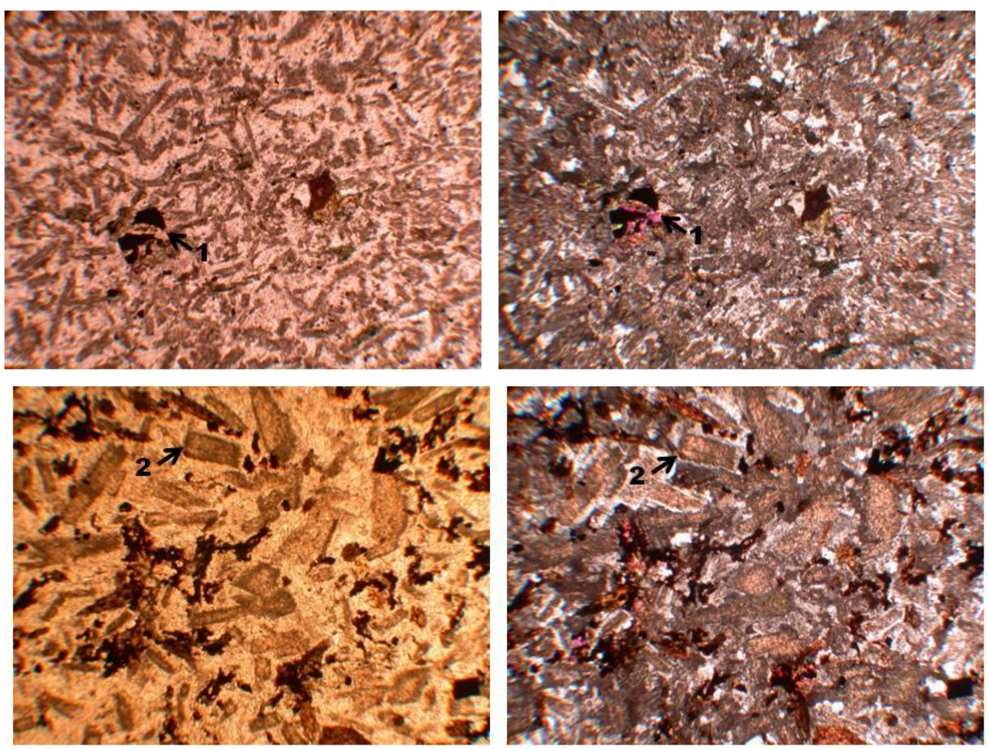


Figure 7.14: Photomicrograph of metadiorite (type 4/D). Top: XOF204. Bottom: XOF419. 32x, PPL (left), XPL (right). 1: Highly altered pyroxene. 2: Heavily altered feldspar.

Figure 7.15: Greenschist (type 4/E). Top: XOF284. Bottom: XOF223.

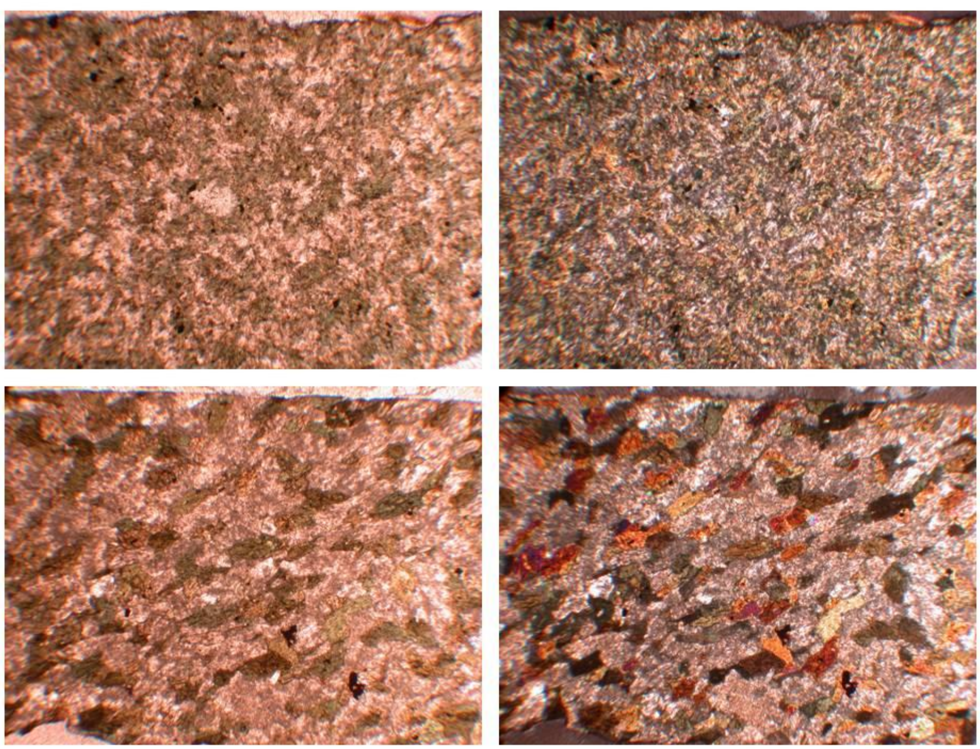


Figure 7.16: Photomicrograph of greenschist (type 4/E). Top: XOF284. Bottom: XOF223. 32x, PPL (left), XPL (right). Green minerals in PPL are hornblende, epidote, and/or chlorite.

In contrast to both metadiorites and greenschists, amphibolite metamorphic rocks (macroscopic type 4, microscopic type F) are composed primarily of hornblende (amphiboles). These amphiboles, in association with highly altered plagioclase, produce a greenish to greyish coloration macroscopically under plain polarized light (Figures 7.17 and 7.18). Similar to metadiorites, greenschists are macro- and holocrystalline.

I have decided to lump macroscopic type 4/microscopic type G rocks under the generalized term of metavolcanics. Metavolcanic rocks are igneous rocks that show evidence of having been subjected to metamorphism (Figure 7.19). Although ghost or relict igneous textures are visible that provide some clue as to their original formation environment, many of the minerals have been highly altered by metamorphism. As this was the state they were acquired for use as a toolstone, it is important to note that it is the attributes visible today that would have been selected for, not the original, premetamorphic ones. Metavolcanics can be distinguished from tuffs and cherts microscopically as metavolcanics have a trachyitic texture (glassy groundmass) with aligned, and frequently altered, plagioclase feldspar laths (Figure 7.20).

Figure 7.17: Amphibolite (type 4/F). Top: XOF211. Bottom: XOF212.

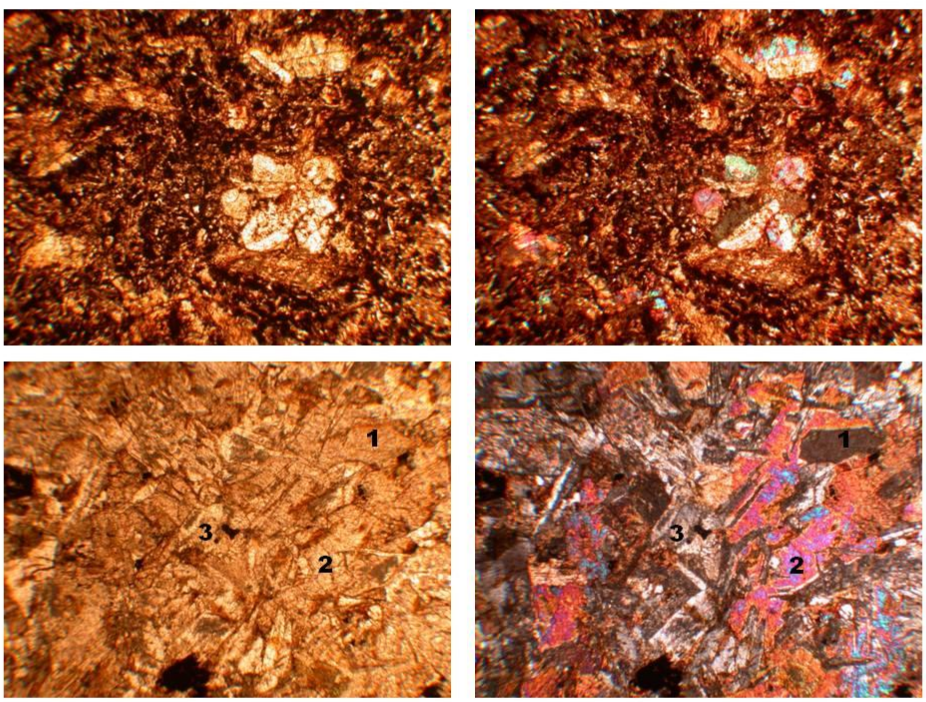


Figure 7.18: Photomicrograph of amphibolite (type 4/F). Top: XOF211, showing dark staining (clay minerals or iron oxides. Bottom: XOF212. 32x, PPL (left), XPL (right). 1: Quartz. 2: Hornblende (amphibole). 3: Altered plagioclase feldspar.

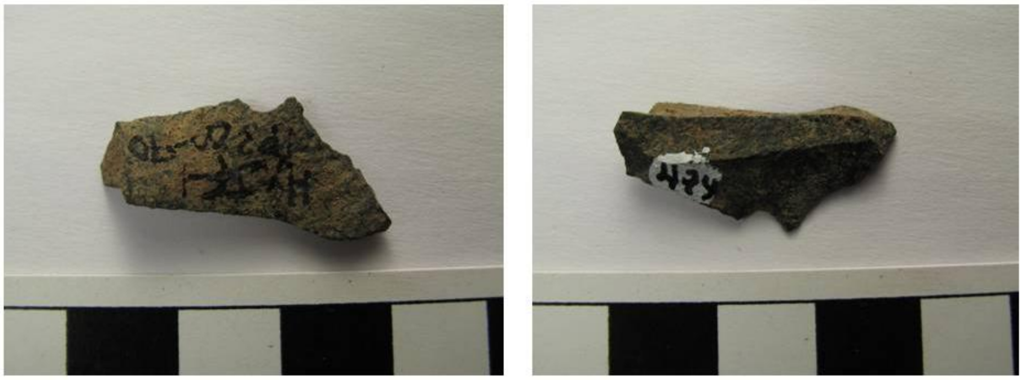


Figure 7.19: Metavolcanic (type 4/G); XOF307.

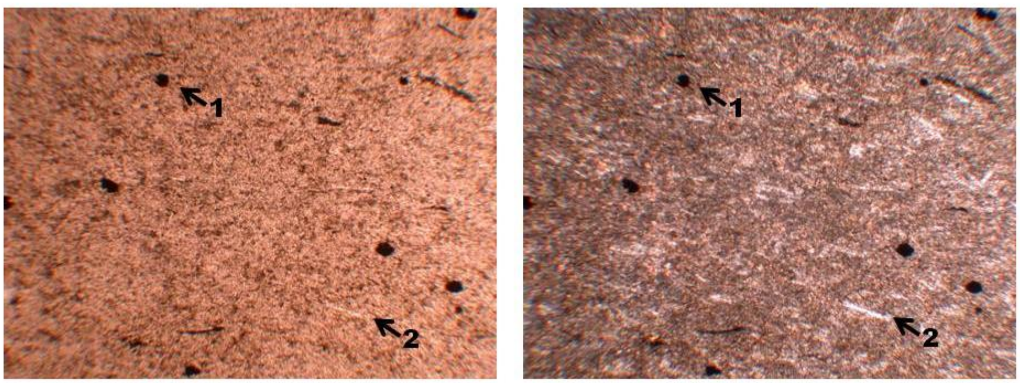


Figure 7.20: Photomicrograph of a metavolcanic rock (type 4/G); XOF307. 32x, PPL (left), XPL (right). 1: Rounded iron oxide inclusion. 2: Feldspar lath. Note alignment of feldspar laths.

Mudstones: macroscopic type 5, microscopic type H

There is only a single instance of a mudstone, found in the Iron Age component of test pit #2 at Mlambalasi. The mudstone is black with a dull to greasy/resinous lustre (Figure 7.21). Macroscopically no inclusions are visible though quartz crystal inclusions were identified in thin section. It is homogeneous and opaque in both plain and cross polarized light (Figure 7.22).

Siltstones: macroscopic type 6, microscopic type I

As with the mudstones, there is only a single siltstone represented in the MSA assemblage of test pit #1 at Magubike. The siltstone is a dull, mottled, brown with no visible inclusions (Figure 7.23). It is clearly clastic microscopically composed predominantly of quartz (Figure 7.24). Interestingly it shows some foliation; there is directionality/alignment of the quartz clasts.

Sandstones: macroscopic type 7, microscopic type J

Sandstones are relatively rare in both assemblages. The sandstones are white to pink in color (Figure 7.25). They are matrix supported, characterized microscopically by a fine grained matrix and plagioclase feldspar ± composite clasts. The composite clasts are possibly volcanic derived (personal communication, T. Chacko, 21 May 2010). All of the clasts are well rounded, and the matrix is either cryptocrystalline quartz (chert) or chalcedony (Figure 7.26). Sandstones are only found in IA assemblages at Mlambalasi. At Magubike, they were recovered throughout the site in all assemblages.

Figure 7.21: Mudstone (type 5/H); XCM 32.

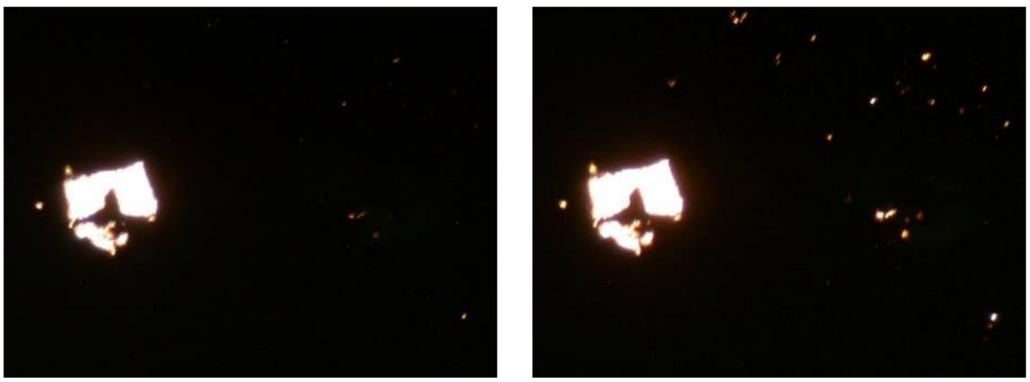


Figure 7.22: Photomicrograph of mudstone (type 5/H); XCM32. 40x, PPL (left), XPL (right). Note large altered quartz crystal to left of image.

Figure 7.23: Siltstone (type 6/I); XOF060.

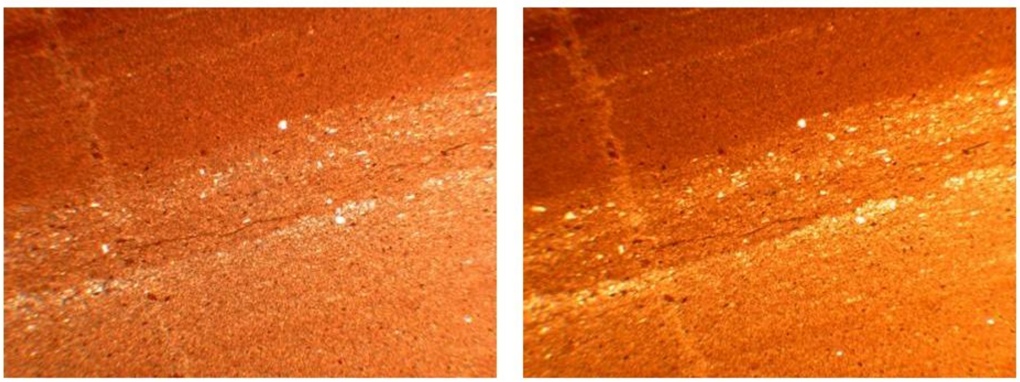


Figure 7.24: Photomicrograph of siltstone (type 6/I); XOF060). 32x, PPL (left), XPL (right).

Figure 7.25: Sandstone (type 7/J). Top: XOF035. Bottom: XOF194.

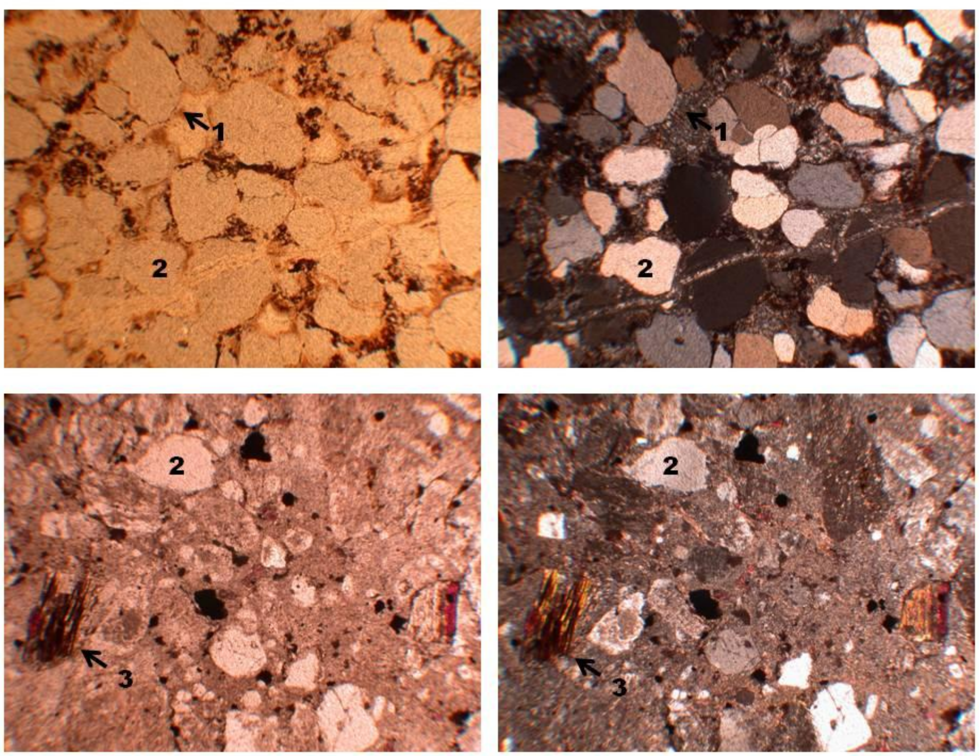


Figure 7.26: Photomicrograph of sandstone (type 7/J). Top: XOF35. Bottom: XOF194. 32x, PPL (left), XPL (right). 1: Chalcedony/chert groundmass. 2: Quartz. 3. Mica (biotite).

Quartzites: macroscopic type 8, microscopic type K

Before I discuss quartzite, it is important that one recalls that quartz and quartzite artifacts were not selected for macroscopic and microscopic analyses, owing to their relative homogeneity and to the difficulty in differentiating fractures produced naturally versus intentionally. The only reason quartzite is present in the samples I analyzed, and only in the Magubike assemblage, occurs because of the heavy cementation on the surface of artifacts, which made macroscopic identification of rock type difficult if not impossible. However, the microscopic analysis does demonstrate that it may be of value in future investigations to look at quartzites microscopically as this may be able to determine more about what sources are being used in terms of distinguishing ortho- versus metaquartzites. It would also be of value in future research to look at quartz versus quartzites as mentioned previously (Chapter 6), there seems to be some confusion as to application of the two terms; they are often used interchangeably/indiscriminately which is incorrect (geologically speaking) and may be misleading (source, i.e., archaeologically speaking).

Macroscopically, the quartzites are white to greyish (Figure 7.27). Patination can be present and is rusty in color. They are medium to coarse grained and are semi-translucent. They have a quartzofeldspathic composition. As mentioned in Chapter 6, quartzites can microscopically be further subdivided into two subtypes on the basis of texture: orthoquartzite (Ka) and metaquartzite (Kb) (Figure 7.28). The orthoquartzites have quartz grains of varying degrees of roundness and angularity that have been cemented together with chalcedony. The metaquartzites have highly deformed quartz crystals. Deformation features include elongation and distortion of grain morphology, and grains with intense undulose extinction.

Figure 7.27: Quartzite (type 8/K). Top: Orthoquartzite (type 8/Ka); XOF023. Bottom: Metaquartzite (type 8/Kb); XCM001.

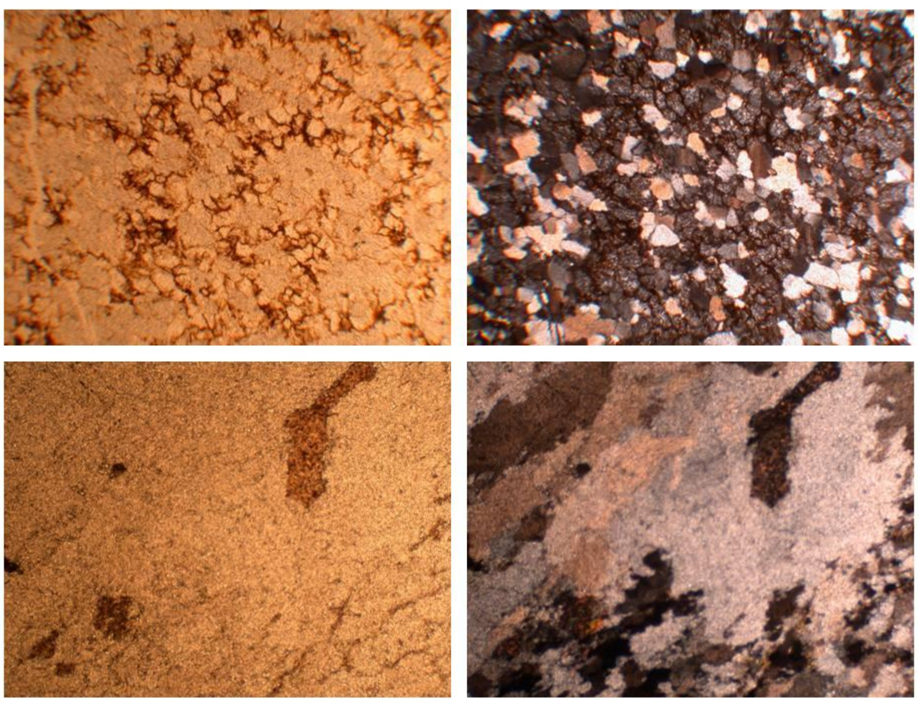


Figure 7.28: Photomicrograph of quartzite (type 8/K). Top: orthoquartzite (type 8/Ka); XOF023. Note chalcedony cement. Bottom: metaquartzite (type 8/Kb); XCM001. Notice deformation features including undulating extinction associated with the quartz grains.

Cryptocrystalline silicates or CCS: macroscopic type 9, microscopic type L

Initially a fair proportion of the CCS was classified as chert (macroscopically) because of its similar texture; however, I chose to separate it from the chert owing to the correlation between microtexture and translucence. CCS is distinguishable from chert in that it is translucent to semi-translucent. It varies from quartzite in that it is cryptocrystalline and homogeneous. Microscopic analysis allows for ease in differentiating quartzites, CCS, and chert varieties (Figure 7.29). Cryptocrystalline silica obviously is the characteristic feature of CCS, as discussed above. Drusy quartz mosaic (DQM) is often found in association with cryptocrystalline silica in cherts. Chalcedony is diagnostic of chert. Microcrystalline and macrocrystalline silica are found in cherts as well. Megaquartz is found in quartzite.

CCS may be mottled and color varies from clear/white through grey to green and pink to red (Figure 7.30). It is generally dull or dull to waxy. Microscopically CCS may have the classic cryptocrystalline silica texture from which its name is derived but it may also be composed, at least in part, of macroquartz and megaquartz (Figure 7.31). Because of the frequent presence of macro- and megaquartz microscopically CCS may be very similar to quartzite, however I have classified it as a separate lithic type owing to its distinct, highly visible macroscopic properties (i.e., homogeneity, translucence/semi-translucence). Ferruginous inclusions (including iron oxide staining) are frequently present.

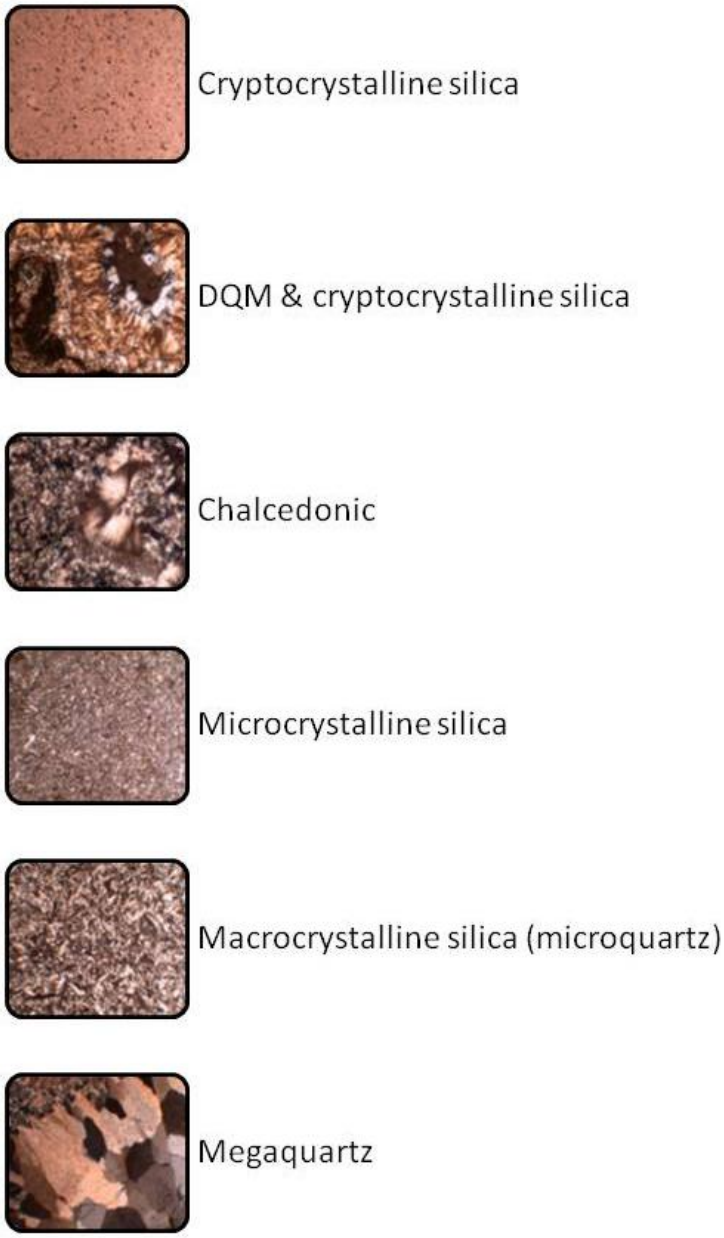


Figure 7.29: Silica fabrics which can be used to distinguish quartzite from CCS from chert.

Figure 7.30: Variation in CCS (type 9/L). Top: XOF104. Bottom: XOF135.

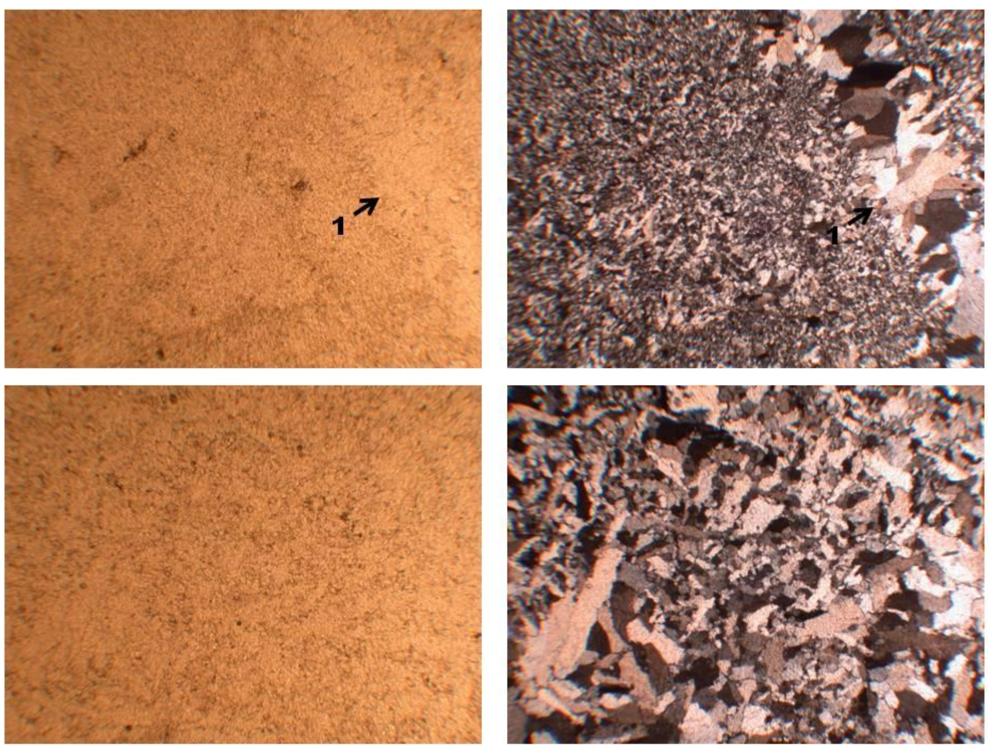


Figure 7.31: Photomicrograph of CCS (type 9/L). Top: XOF104. Bottom: XOF135; borderline quartzite owing to large quartz grain size. 32x, PPL (left), XPL (right). 1: Quartz vein inclusion.

Chert: macroscopic type 10, microscopic types (M.I – M.IV)

Chert is highly variable both macro- and microscopically. Almost every color is possible with many variations present because of frequent mottling, banding, and speckling. Lustre is also highly variable ranging from dull to chalky to waxy to vitreous. Quartz vein and quartz crystal inclusions are visible in hand specimen. The cherts can be divided into four main subtypes: macroscopic 10.I, 10.II, 10.III, and 10.IV, microscopic types M.I, M.II, M.III. and M.IV (Figure 7.32).

Chert M.I is red or pink with a dull to chalky texture (Figure 7.33). This texture is quite distinct compared to that of other cherts: it appears heavily weathered but is definitely not patinated. Few voids are visible both macroscopically and microscopically. Microscopically it is composed of cryptocrystalline groundmass with plagioclase feldspar inclusions (Figure 7.34). It is heavily stained by iron oxides.

Similar in color to M.I, chert M.II is typically pink to dark red/purple but may be greenish to dark grey, and have a dull lustre (Figure 7.35). These darker colors appear to have resulted from weathering; they may be patinas. Microscopically M.II is very opaque with replacement quartz silica fabric and metallic inclusions (Figure 7.36).

Macroscopically M.III represents the most highly variable raw material type. It can only be grouped and subdivided according to variations in microscopic properties; thus M.III is a "catch-all" category for cherts with similar microscopic properties which likely represent a continuum of replacement (Figure 7.37). The microscopic subtypes likely represent intrasource variation, possibly different members with the same formation. However, general statements about the macroscopic properties of each of the subtypes can be made. Chert M.III can be divided into four further subtypes: M.III.i, M.III.ii, M.III.iii, and M.III.iv.

Chert III.i is found throughout both sites in all contexts. Generally M.III.i represents cherts of lighter colors including white, buff, yellow, caramel brown, pinkish brown and grey (Figure 7.38). They may be speckled and mottled with quartz vein inclusions. Few appear to have a peloidal texture. Microscopically, M.III.i has a carbonate groundmass, which looks like a grey film that may be micritic sediment. A relict clast replacement texture with chalcedony void replacement is diagnostic. Variances in microscopic texture are likely owing to variance in the limestone structures being replaced (Figure 7.39a-c). In many ways M.III.i could be classified as a calcareous chert, a designation "limited to the most impure varieties of chert...in which large calcareous residues are clearly displayed in a siliceous cement of dull appearance" (Carozzi 1960:313-314). Differences in microscopic texture are often visible macroscopically (Figure 7.40).

Chert subtype III.ii was recovered in all contexts at Mlambalasi, but only in the MSA of TP#1 at Magubike. It is similar to M.I and M.II as it is dark red to purple in color but differs in that it has a white to pink patina (Figure 7.41). It also is very different microscopically. As with M.III.i , the matrix is a grey, opaque carbonate/micritic sediment (Figure 7.42). Chalcedony void filling silica fabric is more abundant and the relict texture is highly visible. Hematite/iron oxide staining is present in many of the specimens. I argue that it represents the next stage in replacement as there is an increase in the amount of chalcedony present.

Chert subtype III.iii is highly variable macroscopically ranging in color from white to yellow to brown to red to pink to black and may be mottled, speckled and/or banded (Figure 7.43a, b). It is unique in that it frequently has black vein inclusions which are visible but not identifiable in hand specimen. In thin section, carbonates are present but are altered and have high birefringence (Figure 7.44). The groundmass is no longer carbonate/micritic sediment but has been replaced with chalcedony and cryptocrystalline silica. Microscopically M.III.iii has a very distinct serpentinite-like texture, some of which is highly suggestive of plant material. This serpentinite-like texture can be visible macroscopically; many of the specimens almost look like petrified wood.

Chert subtype III.iv is the most macroscopically diverse subtype of all the cherts (Figure 7.45a,b). It appears in every color with a buff to light yellow or buff to white patina, and is dull to waxy. It may be mottled, banded or speckled, and frequently contains quartz vein and black vein inclusions. It represents the chert subtype with the most replacement; it is the subtype which can be most appropriately termed chert microscopically. Only ghost relict textures remain and these are often only visible when stained by iron oxides (Figure 7.46a). It contains typical chert silica fabrics including chalcedony, drusy quartz mosaic (DQM), and pseudo-DQM (Figure 7.46b). Chert III.iv represents the "pure" cherts as they are composed of amorphous silica, chalcedony, and quartz (Carozzi 1960:315).

Macroscopically, chert IV resembles classic flint: it is blue-grey to grey to dark grey to black with a dull to waxy lustre (Figure 7.47). Patination is frequent and buff to yellow in color. Microscopically, M.IV has a cryptocrystalline silica groundmass with abundant, small rounded iron oxide inclusions (Figure 7.48). Additional silica fabrics are absent. Chert IV is a carbonaceous chert as it is grey, has a waxy lustre corresponding to the absence of any visible grain, appears almost colorless in thin section in plain light but faintly greyish blue under crossed polars (Carozzi 1960:321). Chert or flint of this variety is usually found in chalk deposits.

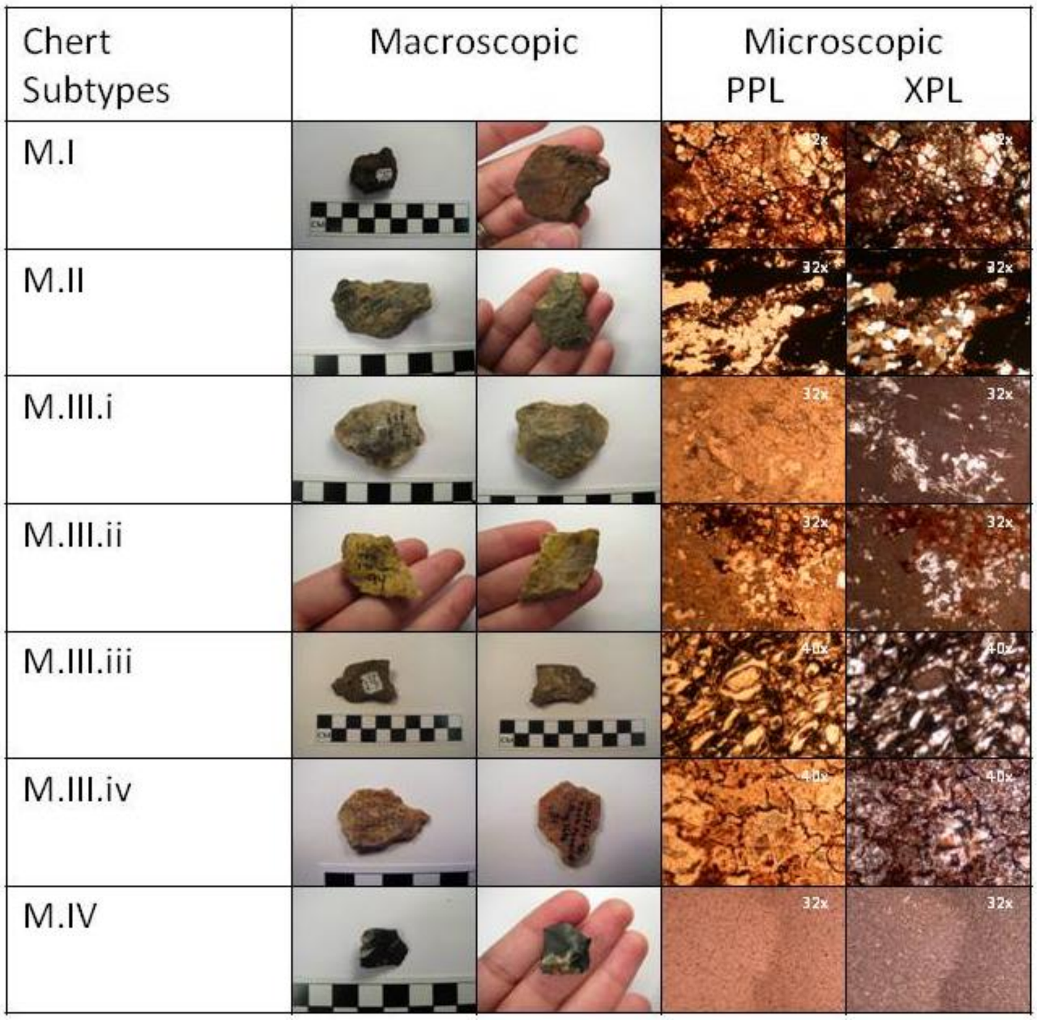


Figure 7.32: Chert raw material subtypes.

Figure 7.33: Chert I (type 10/M.I). Top: XOF099. Bottom: XOF011.

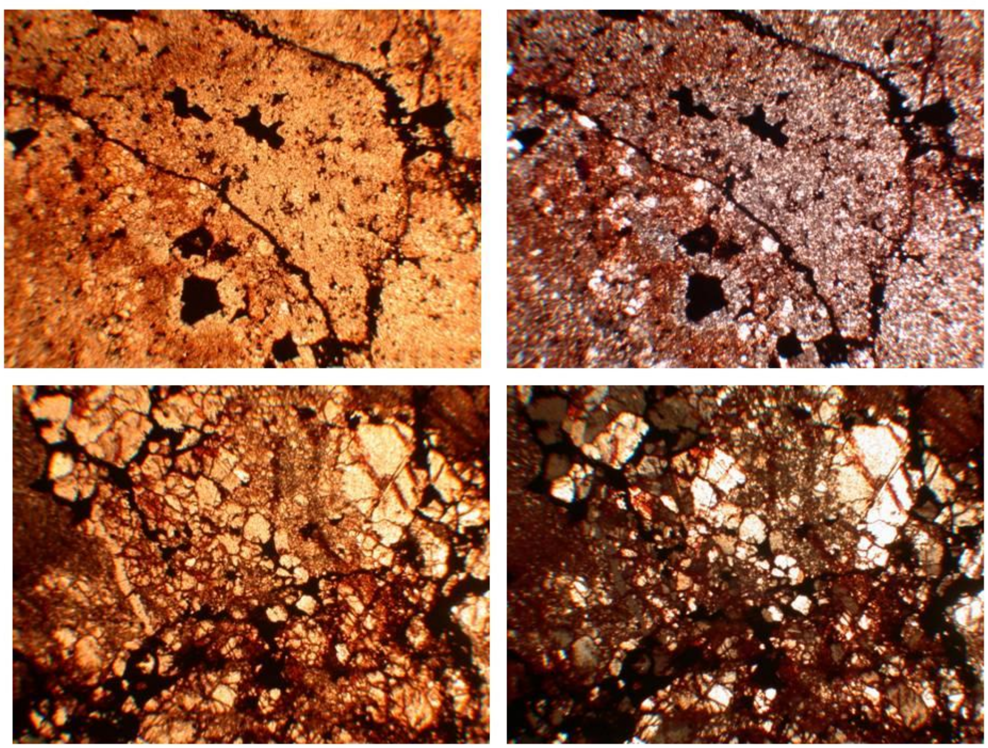


Figure 7.34: Photomicrograph of chert I (type 10/M.I). Top: XOF099. Bottom: XOF011. 32x, PPL (left), XPL (right). Note abundant iron oxide/hematite staining.

Figure 7.35: Chert II (type 10/M.II); XOF188.

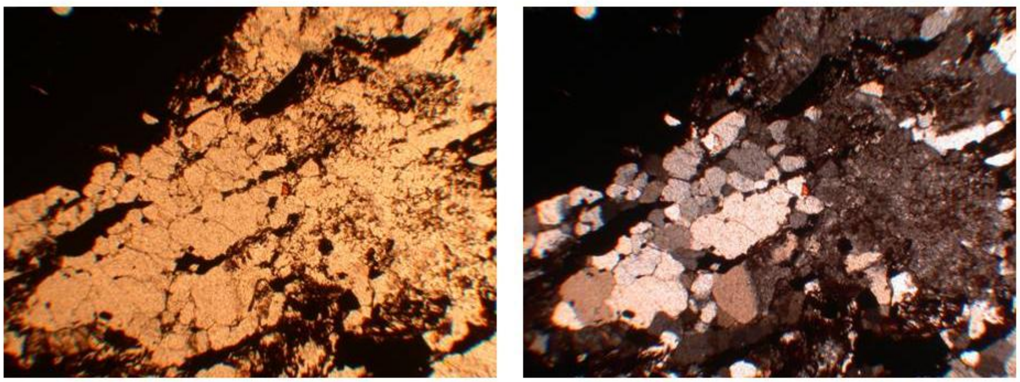


Figure 7.36: Photomicrograph of chert II (type 10/M.II); XOF188. 32x, PPL (left), XPL (right).

Figure 7.37: Continuum of replacement in chert variety III (subtypes III.i – III.iv).

Figure 7.38: Chert subtype i (type 10/M.III). Top: XCM111. Bottom: XOF013.

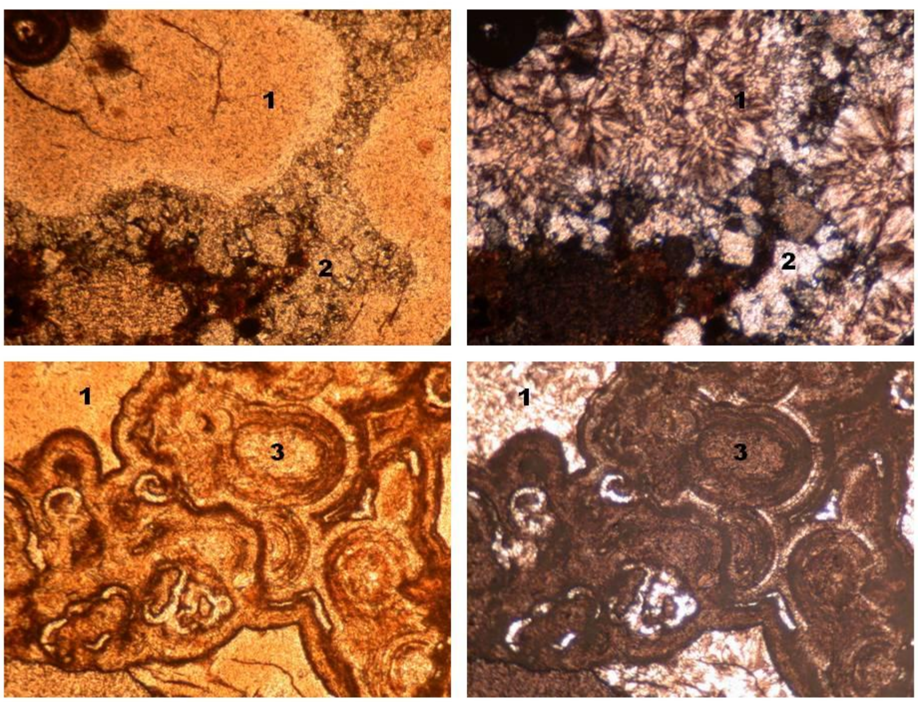


Figure 7.39a: Photomicrograph of chert subtype i (type 10/M.III) demonstrating variability in silica fabrics/texture within a single artifact (XCM111). 40x, PPL (left), XPL (right). 1: Chalcedony. 2: DQM. 3: Possible ooid or peloid.

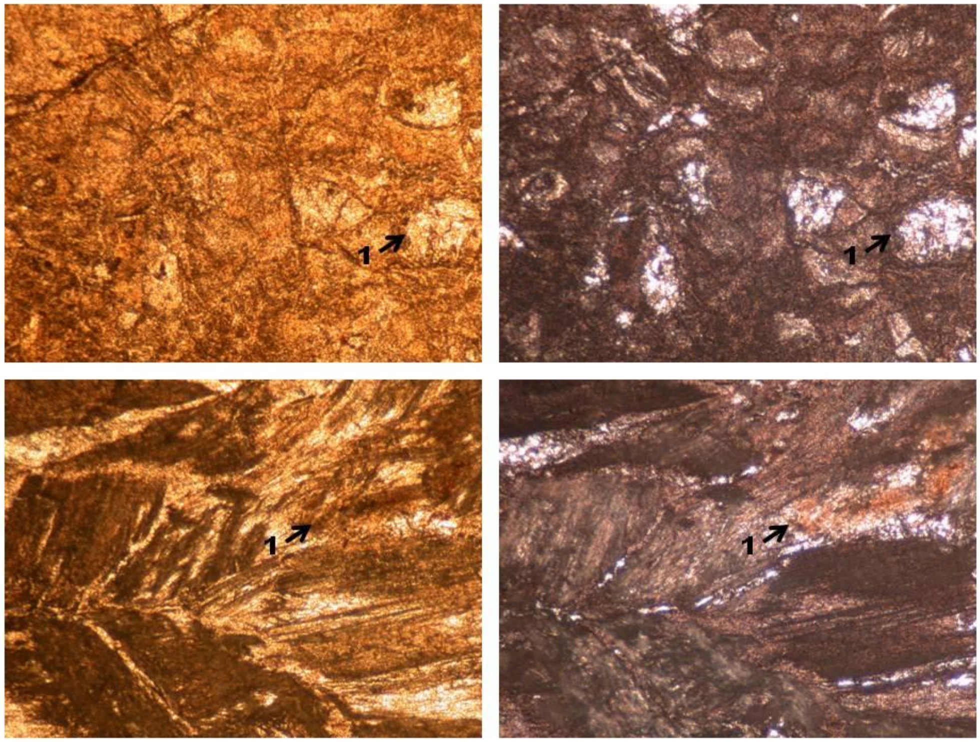


Figure 7.39b: Photomicrograph illustrating differences in relict textures present in chert subtype i (type 10/M.III). Top: XCM068. Bottom: XCM200. 40x, PPL (left), XPL (right). 1: Void-infilling chalcedony.

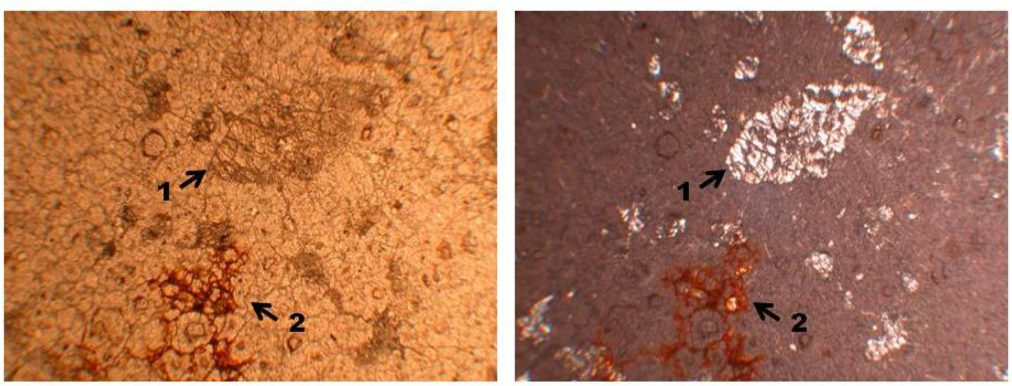


Figure 7.39c: Photomicrograph of carbonate groundmass/micritic sediment found in chert subtype i (type 10/M.III). XOF013. 32x, PPL (left), XPL (right). 1: Chalcedony in void left by microfossil. 2. Iron oxide staining highlighting the relict texture.

Figure 7.40: Variations in microscopic texture are often visible in hand specimen for subtype i, and variability within a single artifact can be significant. Left and center: XCM068. Right: XCM200.

Figure 7.41: Chert subtype ii (type 10/M.III). Top: XCM105. Bottom: XOF164.

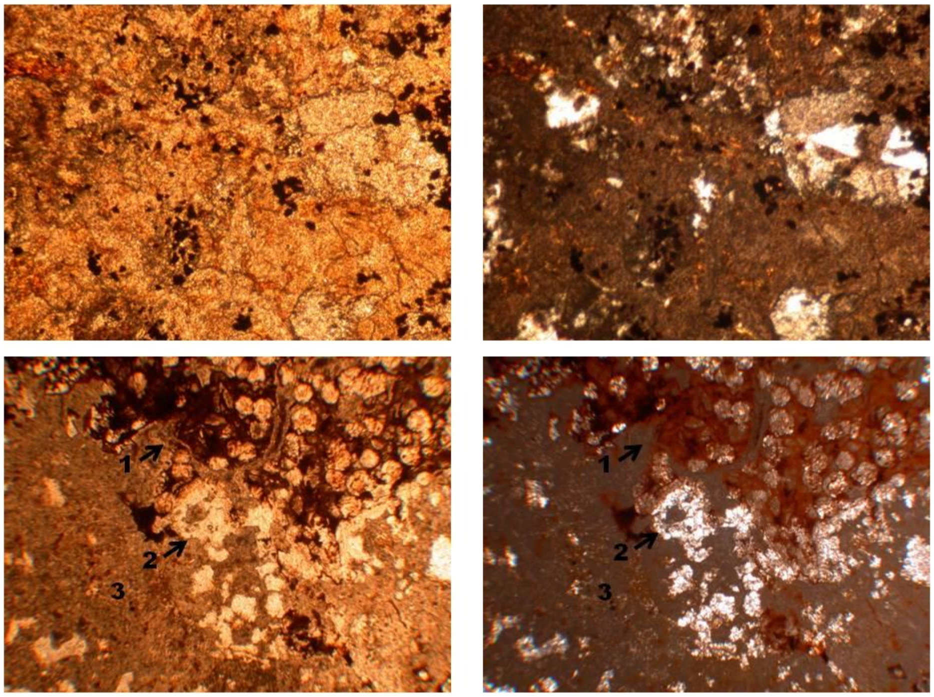


Figure 7.42: Photomicrograph of chert subtype ii (type 10/M.III). Top: XCM105, 40x. Bottom: XOF164, 32x. PPL (right), XPL (left). 1: Iron oxide/hematite staining highlighting relict texture. 2: Void-infilling chalcedony. 3. Carbonate/micritic sediment.

Figure 7.43a: Chert subtype iii (type 10/M.III); XCM127.

Figure 7.43b: Chert subtype iii (type 10/M.III); XOF058.

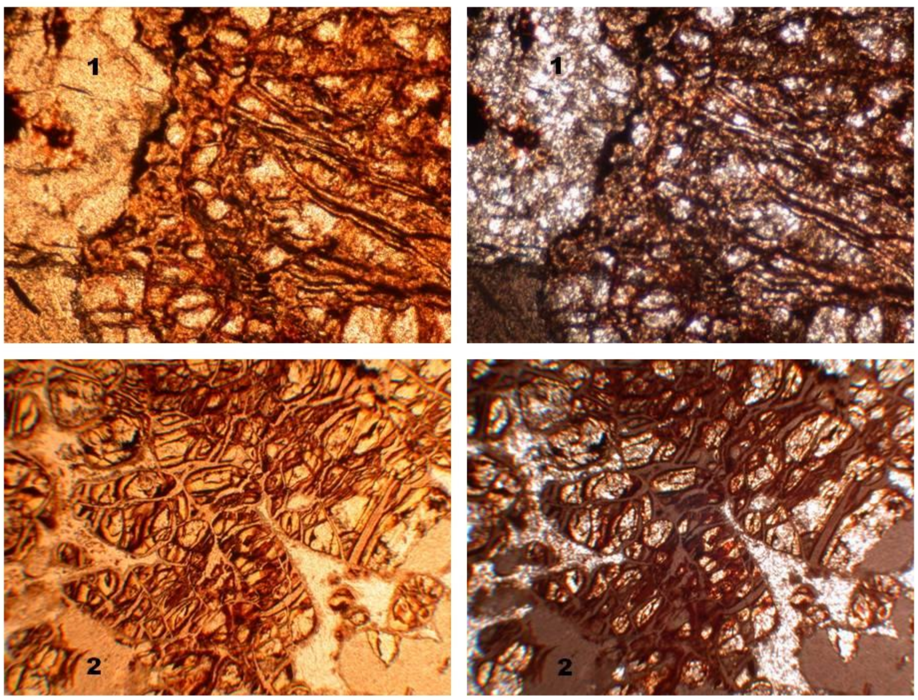


Figure 7.44: Photomicrograph of chert subtype iii (type 10/M.III). Top: XCM127, 32x. Bottom: XOF058, 40x. PPL (left), XPL (right). 1. Chalcedony. 2. Void.

Figure 7.45a: Chert subtype iv (type 10/M.III). Top: XOF001. Bottom: XOF108.

Figure 7.45b: Chert subtype iv (type 10/M.III); XOF004.

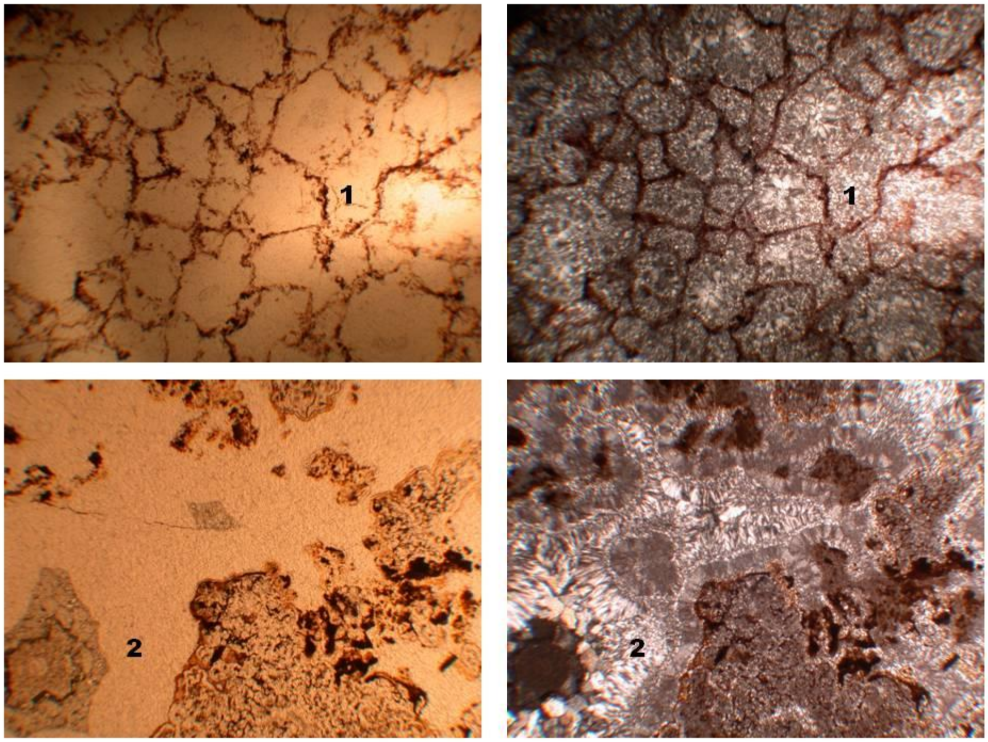


Figure 7.46a: Photomicrograph of chert subtype iv (type 10/M.III). Top: XOF001. Bottom: XOF108. 32x, PPL (left), XPL (right). 1: Chalcedony. 2: DQM.

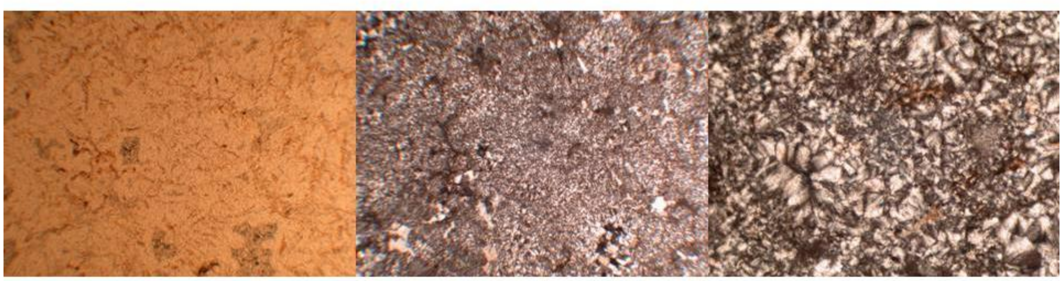


Figure 7.46b: Illustration of chalcedonic groundmass in chert subtype iv (type 10/M.III); XOFOO4. Left: 32x PPL. Centre: 32x XPL. Right: 100x XPL.

Figure 7.47: Characteristic blue-grey to grey to black coloration of flint (type 10/M.IV). Top: XOF029. Bottom: XOF041.

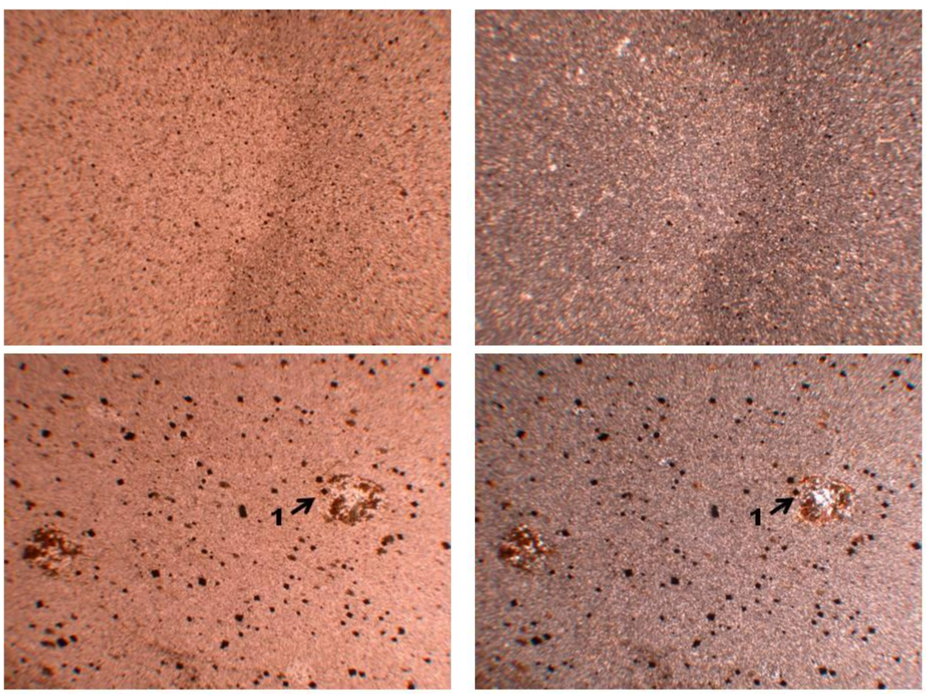


Figure 7.48: Photomicrograph of chert IV (type 10/M.IV). Top: XOF029. Bottom: XOF041. 32x, PPL (left), XPL (right). 1. Pseudo-DQM with hematite/iron oxide staining. Note large number of rounded iron oxide inclusions.

Uniques: a-g

The term "unique" is used here to describe lithic raw material types of which there was only one example in the thin section samples. Three of the seven unique types are definitely cherts but they do not fit into any of the four types I have established. The other four are ones I was not able to assign to any rock type.

Unique "a" is a classic example of a radiolarian chert. It is a mottled dark black to dark brown to yellow in color with a waxy to resinous to vitreous lustre (Figure 7.49). It has a cherty texture with a cryptocrystalline groundmass composed of authigenic silica (Figure 7.50). Void-infilling chalcedony silica fabric is present along with reddish brown iron oxide inclusions, and fossil radiolarian structures are present. It is likely that other artifacts with similar macroscopic characteristics could be radiolarian cherts however thin section analysis would be required to confidently assign such a designation.

Unique "b" is another chert type. Macroscopically it is reddish black, vitreous, with visible but not identifiable white speckles (Figure 7.51). Microscopically it is readily apparent that the white speckles are quartz crystals and chert/chalcedony rock fragments (Figure 7.52). These clasts are present in a red groundmass which may represent heavily stained chert or carbonate. Microscopic voids are also present.

Unique "c" represents an unknown rock type. It has a fine to medium grained texture, is reddish-orange and dull which is suggestive of ochre (Figure 7.53). In thin section, it has an aphanitic, macrocrystalline, holocrystalline texture (Figure 7.54). Heavily altered feldspars are present along with quartz and hematite staining and few voids.

Another possible ochre is unique "d." It too is reddish-orange and dull with a fine to medium texture (Figure 7.55); however it differs from "c" microscopically. Its groundmass is cryptocrystalline silica containing carbonates and chalcedony. It is similar to "c" in that it has extensive hematite/iron oxide staining and contains microscopic voids (Figure 7.56).

Unique "e" is a chert. It is a mottled yellow with a reddish-brown patina (Figure 7.57). It has a dull to waxy lustre with visible quartz vein and quartz crystal inclusions. It has a carbonate groundmass similar to M.III varieties but with visible sparry dolomite present (Figure 7.58). It has both DQM and chalcedony silica fabrics. Iron oxide inclusions and staining are present, the staining highlighting a relict texture.

Unique "f" is truly unique. Texturally suggestive of an igneous origin, it is a fine grained, dull black rock with a rusty patina (Figure 7.59). It has a glassy or cryptocrystalline groundmass with iron oxide inclusions and staining, and microscopic voids (Figure 7.60).

Unique "g" represents a metamorphic rock type which varies from those discussed above. It is dull, pale yellow, with an orangish-brown patina in hand specimen (Figure 7.61). Microscopically, it has an aphanitic (macrocrystalline) texture and is composed of quartz, feldspar, and pyroxenes (Figure 7.62). It is slightly foliated and contains microscopic voids.

Figure 7.49: Unique “a” (XCM140).

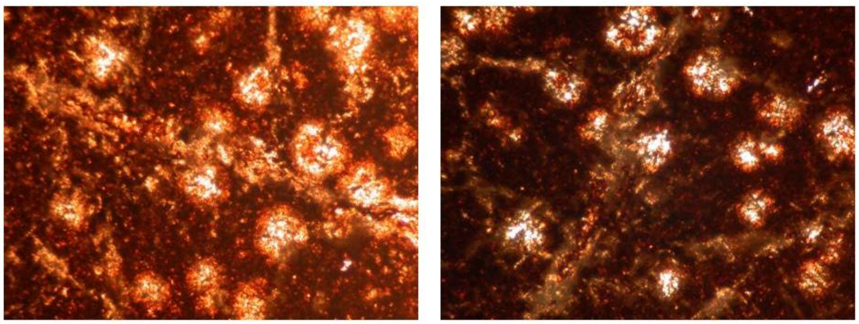


Figure 7.50: Photomicrograph of unique “a” (XCM140). 40x, PPL (left), XPL (right). Note replacement of radiolarian structures with chalcedony.

Figure 7.51: Unique “b” (XCM165).

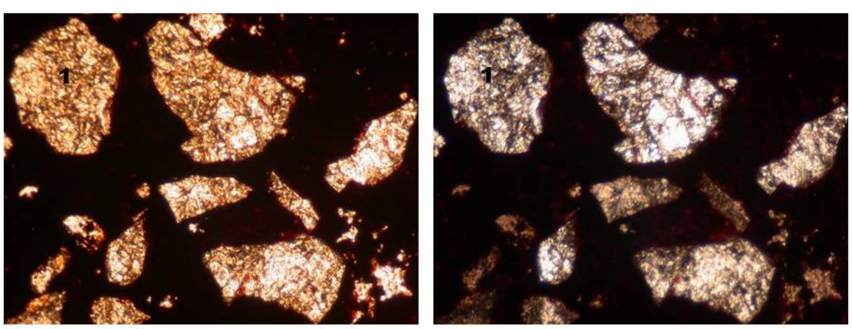


Figure 7.52: Photomicrograph of unique “b” (XCM165). 32x, PPL (left), XPL (right). 1: Void-infilling chalcedony.

Figure 7.53: Unique “c” (XCM048).

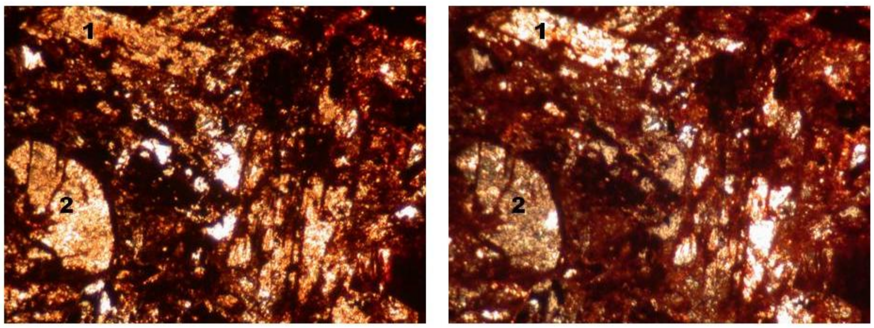


Figure 7.54: Photomicrography of unique “c” (XCM048). 40x, PPL (left), XPL (right). 1: Chalcedony replacement of feldspar lath. 2: Void-infilling chalcedony.

Figure 7.55: Unique “d” (XCM015).

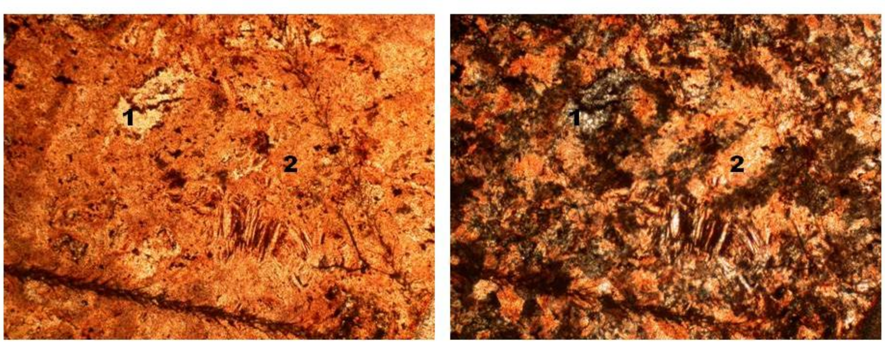


Figure 7.56: Photomicrograph of unique “d” (XCM015). 40x, PPL (left), XPL (right). 1. Void-infilling chalcedony. 2: Carbonate.

Figure 7.57: Unique “e” (XOF077).

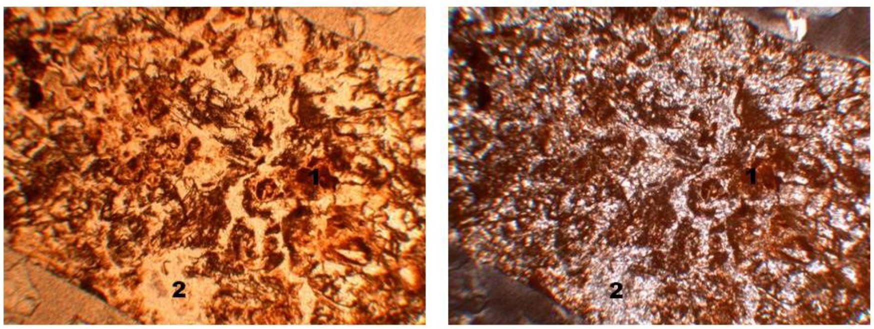


Figure 7.58: Photomicrograph of unique “e” (XOF077). 32x, PPL (left), XPL (right). 1: Hematite/iron oxide staining indicating relict texture. 2: Chalcedonic groundmass.

Figure 7.59: Unique “f” (XOF093).

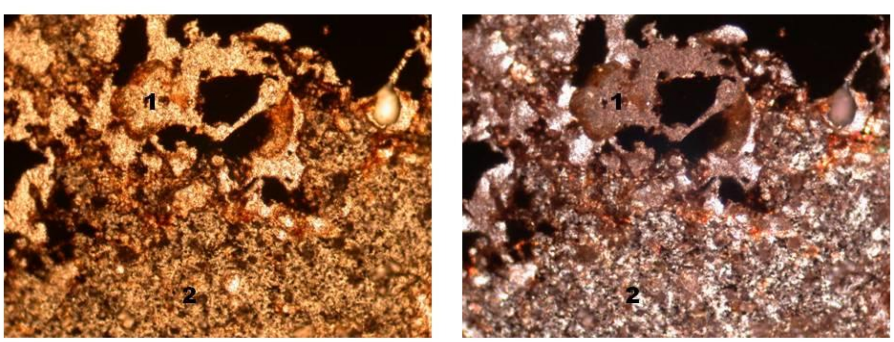


Figure 7.60: Photomicrograph of unique “f” (XOF093). 32x, PPL (left), XPL (right). 1: Void. 2: Chalcedonic groundmass.

Figure 7.61: Unique “g” (XOF398).

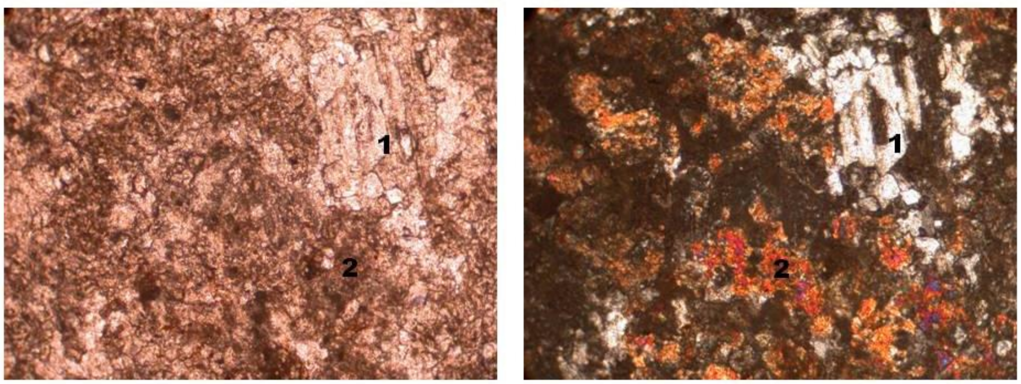


Figure 7.62: Photomicrograph of unique “g” (XOF398). 32x, PPL (left), XPL (right). 1: Pseudo-DQM. 2: Carbonate.

7.3 Results of Raw Material Analyses

Out of the original 634 thin section samples submitted for preparation, 629 are discussed as five were lost by Spectrum Petrographics and thus were not available for analysis. Spectrum's records indicate they received these samples, however, they lost the specimens during the process of preparing thin sections from them. No further explanation was provided as to how this occurred. As described above, analysis of the 629 thin sections resulted in the identification of 10 raw material types. Table 7.8 illustrates the representation of each of the ten types in the thin section sample at each site, while Table 7.9 shows the proportion relative to each cultural period. The correlation of raw material type to cultural designation for each site is shown in Tables 7.10 and 7.11, while Table 7.12 shows this for both sites.

For the tables in which I have combined the data from both Mlambalasi and Magubike, I have done this to provide an overview of raw material resources for Iringa Region. Intraregional variation (i.e., intersite variation) is dealt with to facilitate discussion of intrasite variation. As such the frequency of each raw material type per site is also presented.

Overall chert is the most abundant rock type (42.1%) followed by the metamorphic varieties (26.7%). The eight other raw material types comprise approximately 32% combined. This result is comparable to the results of the macroscopic analysis if one combines metamorphic and igneous rocks (Table 7.13). This must be done as the differentiation between metamorphic and igneous rocks at the macroscopic level proved extremely difficult. This also takes into consideration that 12% of the artifacts could not be positively identified to any type macroscopically and were thus termed unknown. Note that for the macroscopic analysis, rock type definition was limited to identifying the artifact as sedimentary, igneous or metamorphic.

Table 7.8: Representation of rock types in thin section sample.

Rock Type	HwJf-02	HxJf-01	Total	%
Granite	14	4	18	2.9
Andesite	1	5	6	1
Tuff	0	37	37	5.9
Metamorphic	22	147	169	26.7
Mudstone	1	0	1	<1
Siltstone	0	1	1	<1
Sandstone	5	70	75	11.9
Quartzite	1	3	4	<1
CCS	2	51	53	8.4
Chert	161	97	258	41.1
Unique	4	3	7	1.1
Total	211	418	629	100

Table 7.9: Representation of cultural periods in thin section sample.

Cultural Designation	HwJf-02	HxJf-01	Total	%
IA	112	47	157	24.9
IA/LSA	35	28	62	9.9
LSA	31	8	40	6.4
LSA/MSA	25	7	32	5.1
MSA	0	328	328	52.1
IA/LSA/MSA	8	0	10	1.6
Total	211	418	629	100

Table 7.10: Rock type distribution by cultural designation for Mlambalasi.

Rock Type	Cultural Designation						Total
	IA	IA/LSA	LSA	LSA/MSA	MSA	IA/LSA /MSA	
Granite	4	5	1	4	0	0	14
Andesite	1	0	0	0	0	0	1
Tuff	0	0	0	0	0	0	0
Metamorphic	6	10	1	4	0	1	22
Mudstone	1	0	0	0	0	0	1
Siltstone	0	0	0	0	0	0	0
Sandstone	1	0	3	0	0	1	5
Quartzite	0	0	1	0	0	0	1
CCS	0	2	0	0	0	0	2
Chert	97	18	24	16	0	6	161
Unique	a,b	0	d	c	0	0	4
Total	112	35	31	25	0	8	211

Table 7.11: Rock type distribution by cultural designation for Magubike.

Rock Type	Cultural Designation						Total
	IA	IA/LSA	LSA	LSA/MSA	MSA	IA/LSA /MSA	
Granite	0	1	0	0	3	0	4
Andesite	0	0	0	0	5	0	5
Tuff	0	1	0	1	35	0	37
Metamorphic	18	8	1	1	119	0	147
Mudstone	0	0	0	0	0	0	0
Siltstone	0	0	0	0	1	0	1
Sandstone	1	2	2	2	63	0	70
Quartzite	0	0	0	0	3	0	3
CCS	8	3	2	0	38	0	51
Chert	19	13	3	3	59	0	97
Unique	f	0	0	0	e, g	0	3
Total	47	28	8	7	328	0	418

Table 7.12: Rock type distribution by cultural designation for both sites.

Rock Type	Cultural Designation						Total
	IA	IA/LSA	LSA	LSA/MSA	MSA	IA/LSA /MSA	
Granite	4	3	1	4	3	3	18
Andesite	1	0	0	0	5	0	6
Tuff	0	1	0	1	35	0	37
Metamorphic	24	19	2	5	119	0	168
Mudstone	1	0	0	0	0	0	1
Siltstone	0	0	0	0	1	0	1
Sandstone	2	2	5	2	63	1	75
Quartzite	0	0	1	0	3	0	4
CCS	8	5	2	0	38	0	53
Chert	113	32	29	19	6	59	258
Unique	4	0	0	1	2	0	7
Total	157	62	40	32	328	10	629

Table 7.13: Results of macroscopic analysis.

Rock type	HwJf-02	HxJf-01	Total	%
Unknown/unidentifiable	13	840	853	11.87
Igneous	30	2901	2931	40.78
Metamorphic	3	16	19	0.26
Sedimentary	1042	2343	3385	47.09
Total	1088	6100	7188	100

Igneous rocks are not abundant in assemblages from either site. Granite is relatively rare in both assemblages representing around 2% at Mlambalasi and less than 1% at Magubike. Like granite, andesite is relatively rare in the assemblages at Mlambalasi (less than 1%) and Magubike (around 1%). The single piece of andesite from Mlambalasi was recovered from an Iron Age context in Test Pit #1. Five andesite artifacts were found in the MSA assemblages of Test Pits #1 and #3. Tuffs are only found at Magubike but are relatively sparse representing only 8.85% of the entire assemblage. They were recovered on the surface and from all three test pits in MSA levels.

The amount of each type of metamorphic rock varies between sites and within assemblages. Metadiorites are found only in Test Pit #2 at Mlambalasi but in all three test pits and on the surface at Magubike. At Magubike, they are predominantly recovered as part of MSA assemblages (48 out of a total 56 pieces) but are also found in IA and possible LSA assemblages as well (8 out of 56). At Mlambalasi greenschists are found in various contexts ranging from the IA to the MSA on the surface and in both test pits. Greenschists were only recovered from MSA deposits at Magubike with the exception of one backed piece recovered from an IA context in Test Pit #1. Amphibolites are only found in Test Pit #2 at Mlambalasi (IA and LSA), but in all contexts at Magubike (surface, TP#1-#3, IA-MSA). Only a single metavolcanic artifact was recovered from Mlambalasi Test Pit #2. Metavolancanic artifacts were found on the surface and in all three test pits associated with other MSA artifacts.

Sedimentary rocks, in particular siliceous rocks, are the most abundant genera of rock found at both sites. It is also the most diverse group of rocks. There is only a single instance of a mudstone, found in the Iron Age assemblage in Test Pit #2 at Mlambalasi. As with the mudstones, there is only a single siltstone represented in the microscopic assemblage of the MSA in Test Pit #1 at Magubike. Sandstones are relatively abundant in both assemblages. They are found in the greatest proportion in MSA assemblages. At Mlambalasi CCS was only recovered from the surface, whereas at Magubike CCS is distributed throughout all assemblages.

Chert distribution is as variable as the qualities and properties of the subtypes themselves. The two chert I artifacts are both from test pit #1 at Mlambalasi. All three chert II artifacts are from the Magubike test pit #3 MSA assemblage. Chert III.i is found throughout both sites in all contexts. M.III.ii was recovered in all contexts at Mlambalasi, but only in the MSA of TP#1 at Magubike. M.III.iii is found in all cultural periods at both sites, as is M.III.iv. Chert VI was found only in TP#2 at Mlambalasi in a mixed IA/LSA/MSA context and only in the Iron Age assemblages of Magubike (but in all three test pits).

7.4 Summary

This chapter outlined the sampling strategy, methodology, and results of the macroscopic and microscopic analyses of stone artifacts from Magubike and Mlambalasi. Of the 31,597 artifacts excavated from the two rockshelters, 7227 were analyzed for technological and macroscopic attributes (22.87%), and 634 of these were selected for microscopic analysis (2% of total, 8.77% of the macroscopic sample). The combined macroscopic and microscopic analyses allowed for the determination and characterization of 10 lithic raw material types (Appendix B).

The focus of this chapter has largely been on the classification system developed for the lithic raw materials from these two sites. This classification system should allow for the effective description of toolstones found in archaeological assemblages for Iringa Region. The types described here, and in Appendix B, should in no way be considered definitive. They are not, to make a bad pun, written in stone. Indeed without samples acquired directly from potential source outcrops it would be inadvisable to take a hard stance on any of these classifications. Instead I would suggest that this classification system be employed as a baseline upon which many improvements can and should be made.

A discussion of these issues, including implications and interpretation of these results, the application of this classification/descriptive system, and suggestions for future research are discussed in the following chapter.

Chapter 8: Results of Technological Analysis, Interpretation, and Discussion

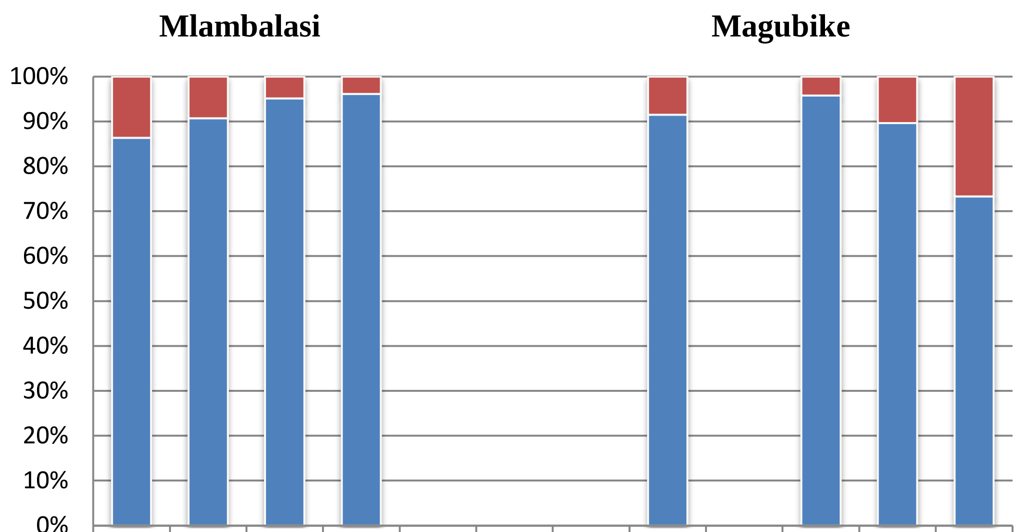
8.1 Results of Technological Analysis

Before presenting any results, I feel obliged to begin by stating that three datasets will be discussed in this chapter. These include the technological-typological data compiled by Willoughby (unpublished), my macroscopic data (mainly focusing on raw material characterization but which includes some technological attributes), and my microscopic data. I will attempt to be explicit when presenting results and state from which data set the information is derived. For additional clarity, for the following tables unless otherwise stated, I have combined the results of all test pits and surface materials per site.

Recall from Chapter 7 that Willoughby conducted a technological-typological analysis of the entire lithic assemblages for both Mlambalasi and Magubike. Figure 8.1 and 8.2 illustrate the proportion of artifacts sampled from each assemblage for macroscopic and microscopic analyses respectively.

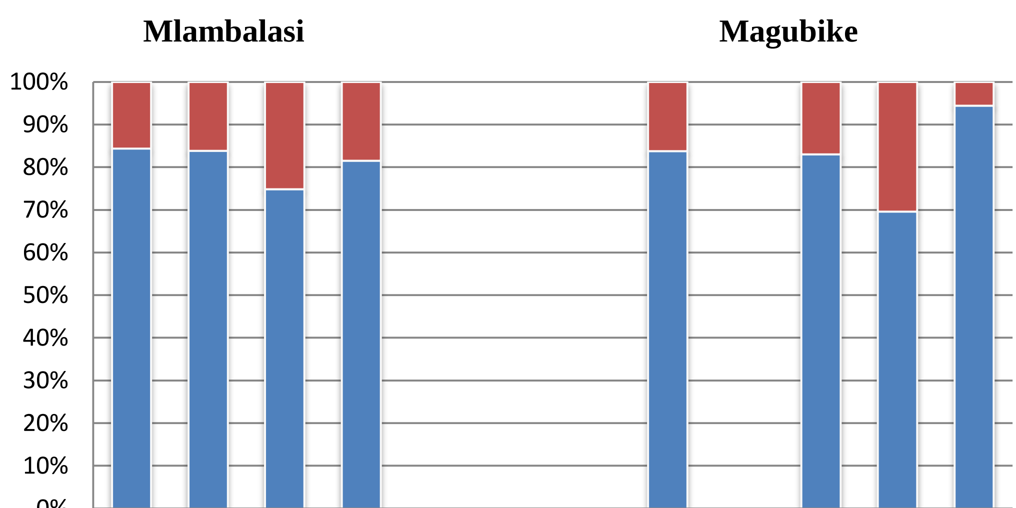
Out of the 7227 artifacts analyzed, valid macroscopic data for 7188 are available. For a few of the artifacts the level from which the artifact was recovered and/or the artifact case number were confused so these were excluded. These 7188 artifacts selected for macroscopic analysis were also scored for several technological attributes in addition to those recorded by Willoughby. The technological variables (Table 8.1) used by myself and Willoughby were presented in Chapter 4 and Appendix A. In some cases data for an attribute was missing. If there was some debate as to the level or case number of the artifact then it was excluded from discussion.

Owing to the scope of this research, only those technological attributes which are meaningful in terms of raw material selection and use are discussed.



	Iron Age	Iron Age & LSA	LSA	LSA & MSA	MSA			Iron Age	Iron Age & LSA	LSA	LSA & MSA	MSA
Macro	576	140	104	110	0			248	0	39	16	5563
Total	3646	1365	2015	2735	0			2662	0	878	138	15252

Figure 8.1: Proportion of artifacts sampled for macroscopic analysis (i.e. non-quartz/quartzite) to total population. Includes artifacts from Test Pits only.



	Iron Age	Iron Age & LSA	LSA	LSA & MSA	MSA			Iron Age	Iron Age & LSA	LSA	LSA & MSA	MSA
Micro	107	27	35	25	0			48	0	8	7	327
Macro	576	140	104	110	0			248	0	39	16	5563

Figure 8.2: Proportion of artifacts sampled for microscopic analysis from those selected for macroscopic analysis. Includes artifacts from Test Pits only.

Table 8.1: Technological variables (adapted from Alexander 2010).

All artifacts	Fracture Size grade Completeness Length (mm) Breath (mm) Thickness (mm) Weight (mm) Abrasion
Whole and utilized/trimmed flakes	Toth types (I-IV) Dorsal scar pattern Number of dorsal scar flakes Number of dorsal scars Number of platform facets Platform length Platform breadth Platform area Platform angle
Cores	Cortex coverage (%) Number of flake scars
Trimmed pieces	Planform Retouch angle Retouch intensity

Although the emphasis throughout this dissertation has been on the Stone Age (MSA and LSA) components of the two sites, the Iron Age materials have also been included in the analysis for the following reasons: (1) poor vertical control during excavation therefore poor resolution of occupations/components/cultural periods, (2) lack of provenienced dates, and (3) poor understanding of post-depositional processes which likely caused the horizontal and lateral movement of artifacts in both sites. Excavations in 2010 at Mlambalasi allowed for some resolution of these issues, however, much of the information collected was not yet available for use in this dissertation. Planned excavations for Magubike in 2012 should allow the same resolution for this important site with hominid remains.

Mlambalasi

As indicated in Chapter 2, two 1 m x 1 m test pits were excavated at Mlambalasi. Test pit #1 (TP #1), positioned centrally in room 1, was excavated to a depth of 120 cm. It contained a well defined Iron Age to LSA stratigraphic sequence. The Iron Age materials were recovered from 0 – 45 cm below surface, and the LSA assemblage was recovered from 45 – 120 cm below surface. It is possible that there are two LSA levels representing Holocene and Pleistocene occupations, and that these overlay a MSA component. This MSA component was inferred from test pit #2 (TP #2). It was excavated to a depth of 160 cm at the top of a slope just outside of the modern shelter overhang. While TP# 2 contained Iron Age, LSA and MSA materials, they had been disturbed by erosion and bioturbation so no clear stratigraphic sequence could be established. The 2010 excavations revealed that the MSA component is not located within the modern rockshelter proper but is located along its margins and underneath a large section of the overhang that collapsed at some point in the past.

Tools represent 64.6% of the total lithic assemblage at Mlambalasi. Other lithic artifact types present include cores (15.9%), debitage (19.2%), and other non-flaked artifacts (0.3%) (Table 8.2). Non-flaked artifacts (other) were not included in the raw material analyses and thus are excluded from discussion. Backed pieces, which represent 81.6% of the total 1,722 modified tools, dominate the assemblage. They are followed in frequency by scrapers (10.9%), bifacial modified pieces (3.2%), burins (1.8%), points (1.1%), as well as other tool types which forms less than one percent (Table 8.2). Tool size grade distribution is consistent for the production of backed pieces as part of a microlithic tool tradition (Table 8.3).

The most common core type in all excavated levels of Mlambalasi was bipolar cores, which accounts for 77.8% of the cores (Tables 8.2 and 8.4). The bipolar technique requires minimal preparation on stone cobbles and does not allow for the conservation of raw material. Platform cores (single, double and multiple platform cores) represent 12.7% of the total cores, while peripherally modified cores (radial, disc and Levallois) represent 8.3% of the core types. The presence of patterned platform and peripherally flaked cores, which involve a systematic edge modification on stone cobble to form a striking platform, indicates a transition towards a curated technological strategy. Of the cores, 85.7% are complete and all are larger than 25 mm^2 (Table 8.5). Table 8.6 (percentage of cortex) illustrates that extensive and exhaustive core reduction was occurring at the site. Few cores contain greater than 50% cortex on their surface and most cores have less than 25% cortex.

Five types of debitage were identified (Table 8.2). Most of the debitage produced was either complete flakes/blades or angular fragments (Table 8.7 and Table 8.8). Overall, the abundant representation of angular fragments and cores in the Mlambalasi assemblage indicates that tool manufacturing was carried out within the shelter. Tools were produced, used, maintained and discarded within the shelter. Debitage size grade is evenly distributed with one exception (Table 8.9). There may have been some bias against in the collection of microdebitage as no artifacts smaller than 5 mm^2 were recovered. Microdebitage was likely missed in the hand sorting process; it may have been recovered had screens been used.

Figure 8.3 shows the relative proportion of cores, debitage, and tools for each level in TP#1. This distribution when placed alongside the stratigraphic profile for the test pit does not show any striking changes in assemblage composition from the Iron Age through the LSA to the MSA. The distribution of specific artifact types, rather than maximal categories, does not delineate any clear boundaries between the Iron Age and LSA components of the site either (Table 8.10).

Figure 8.4 demonstrates that based on size grade distribution for tools by cultural designation. When considered with the distribution of tool types by cultural designation this allows for the division of the Iron Age and the LSA as well as the division of LSA into microlithic and macrolithic components. Tools from the Iron Age are generally smaller than those of the LSA. The microlithic LSA is likely Holocene and thus should be very similar to what is seen in the Iron Age. The macrolithic LSA has tools similar in size, if not larger, than those of the MSA but the tool types are those diagnostic of the LSA. Indeed the clearest division between the LSA and the Iron Age is constructed not from the lithic assemblage but from the radiocarbon dates obtained and the nature of associated non-lithic artifacts (i.e., faunal remains and pottery), a subject I will return to later in this chapter. Owing to the poor context of the MSA materials, it is difficult to distinguish the MSA from the LSA based on technological characteristics alone including the size grade; instead raw material use provides greater insight.

Table 8.2: Distribution of stone artifacts by type in Test Pit #1 at Mlambalasi (Willoughby's dataset; adapted from Bushozi 2011).

Type	**Subtypes**	**Frequency**	**Percentage**
Tools	Backed pieces	1405	81.6
	Scrapers	188	10.9
	Bifacially modified pieces	56	3.2
	Burins	31	1.8
	Points	19	1.1
	Becs	10	0.6
	Ôutils ecailles	7	0.4
	Composite tools	3	0.2
	Core scrapers	3	0.2
Total		1722	100
Cores	Bipolar	330	77.8
	Patterned platform	54	12.7
	Peripheral	35	8.3
	Amorphous	3	0.7
	Intermediate	2	0.5
Total		424	100
Debitage	Flakes	208	40.5
	Blades	28	5.5
	Utilized flakes	17	3.3
	Levallois flakes	3	0.6
	Angular fragments	257	50.1
Total		513	100
Other	Pestle rubber	2	28.6
	Ground stone	2	28.6
	Stone disc	1	14.3
	Anvil stone	1	14.3
	Hammerstone	1	14.3
Total		7	100
Grand total		**2666**	

Table 8.3: Size grade (mm) distribution for tools selected for microscopic analysis from Mlambalasi.

Type of Tool	<5	6-10	11-15	16-20	21-25	26-35	36-50	>50
Scraper	0	0	0	1	0	4	2	0
Backed pieces	0	2	19	22	13	5	0	1
Points/perçoirs	0	0	0	0	0	0	0	0
Burins	0	0	0	0	0	1	0	0
Bifacially modified pieces	0	0	0	0	0	0	0	0
Becs	0	0	0	0	0	0	0	0
Outils écaillés	0	0	0	0	0	0	0	0
Others	0	0	0	0	0	1	0	0
Total	0	2	19	23	13	11	2	1

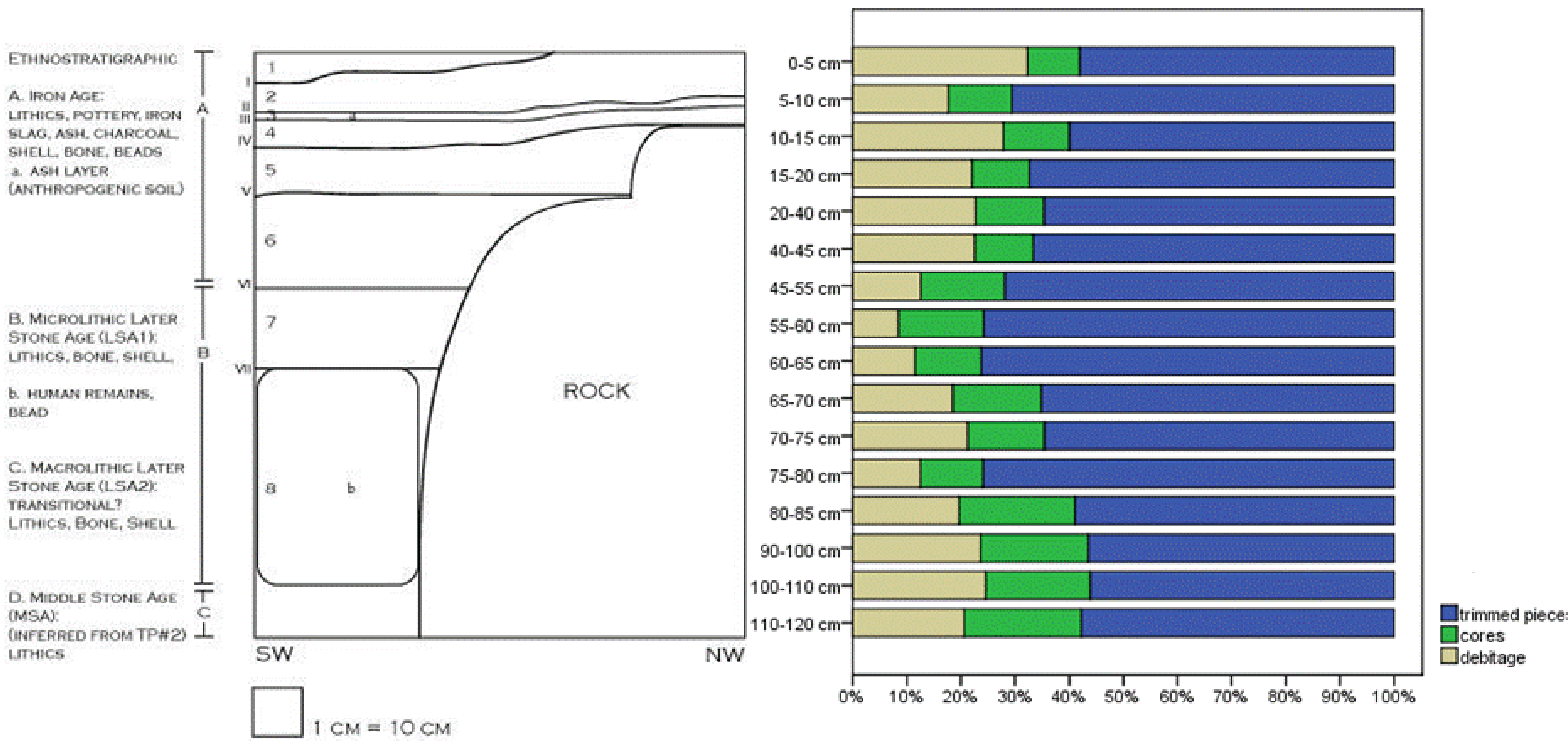


Figure 8.3: Correlation of the stratigraphy from Mlambalasi TP#1 with the distribution of all artifacts by level (Willoughby's dataset).

Table 8.4: Distribution of cores selected for macroscopic analysis at Mlambalasi by cultural designation.

		Type of Core					
		Peripherally worked	Patterned platform	Intermediate	Bipolar	Amorphous	Total
Iron Age	N	7	19	1	30	0	57
	%	12.3	33.3	1.8	52.6	0	100
IA+LSA	N	3	2	0	3	2	10
	%	30.0	20.0	0	30.0	20.0	100
LSA	N	0	1	0	7	0	8
	%	0	12.5	0	87.5	0	100
LSA+ MSA	N	2	0	0	9	0	11
	%	18.2	0	0	81.8	0	100
Total	N	12	22	1	49	2	86
	%	14.0	25.6	1.2	57.0	2.2	100

Table 8.5: Size grade (mm) distribution for cores sampled for microscopic analysis from Mlambalasi.

Type of Core	<5-25	26-35	36-50	>50
Peripherally worked	0	2	1	2
Patterned platform	0	5	2	1
Intermediate	0	0	0	0
Bipolar	0	11	3	2
Amorphous	0	0	0	0
Total	0	18	6	5

Table 8.6: Percentage of cortex on cores sampled for microscopic analysis from Mlambalasi.

Type of Core	0	<10	10-25	25-50	50-75	75-90	>90
Peripherally worked	1	1	3	1	0	0	0
Patterned platform	1	2	3	0	0	1	0
Intermediate	0	0	0	0	0	0	0
Bipolar	3	3	4	4	4	0	0
Amorphous	0	0	0	0	0	0	0
Total	5	6	10	5	4	1	0

Table 8.7: Distribution of debitage sampled for macroscopic analysis at Mlambalasi.

		Type of Debitage					
		Angular fragments	Specialised flakes	Flakes	Blades	Levallois flakes	Total
Iron Age	N	107	2	159	16	1	285
	%	37.5	0.7	55.8	5.6	0.4	100
IA+LSA	N	29	0	49	4	1	83
	%	34.9	0	59.0	4.8	1.3	100
LSA	N	9	0	28	5	0	42
	%	21.4	0	66.7	11.9	0	100
LSA+MSA	N	22	0	36	2	0	60
	%	36.7	0	60.0	3.3	0	100
Total	N	167	2	272	27	2	470
	%	35.5	0.45	57.9	5.7	0.45	100

Table 8.8: Completeness of debitage sampled for microscopic analysis.

Type of Debitage	Debris	Complete	Proximal	Distal/ Medial	Split
Angular fragments	14	10	1	0	0
Specialised flakes	0	1	0	0	0
Flakes	11	60	1	0	0
Blades	1	4	0	0	0
Levallois flakes	0	11	0	0	0
Total	26	86	2	0	0

Table 8.9: Size Grade (mm) distribution for debitage selected for microscopic analysis from Mlambalasi.

Type of Debitage	<5	6-10	11-15	16-20	21-25	26-35	36-50	>50	Total
Angular fragments	0	3	5	10	7	1	3	0	29
Specialised flakes	0	0	0	0	0	0	1	0	1
Flakes	0	0	6	11	18	23	17	1	76
Blades	0	0	0	0	2	0	2	1	5
Levallois flakes	0	0	0	0	0	0	0	0	0
Total	0	3	11	21	27	24	23	2	111

Table 8.10: Distribution of tools sampled for macroscopic analysis from Mlambalasi by cultural designation.

		Type of Tool							
		Scraper	Backed pieces	Points/ perçoirs	Burins	Bifacially modified pieces	Becs	Outils écaillés	Total
Iron Age	N	14	209	0	3	0	1	0	227
	%	6.2	92.1	0	1.3	0	.4	0	100
IA+LSA	N	2	41	1	0	0	0	0	44
	%	4.5	93.2	2.3	0	0	0	0	100
LSA	N	3	34	0	3	0	1	0	41
	%	7.4	82.9	0	7.3	0	2.4	0	100
LSA+MSA	N	0	38	0	1	0	0	0	39
	%	0	97.4	0	2.6	0	0	0	100
Total	N	19	322	1	7	0	2	0	351
	%	5.4	91.7	0.3	2.0	0	.6		100

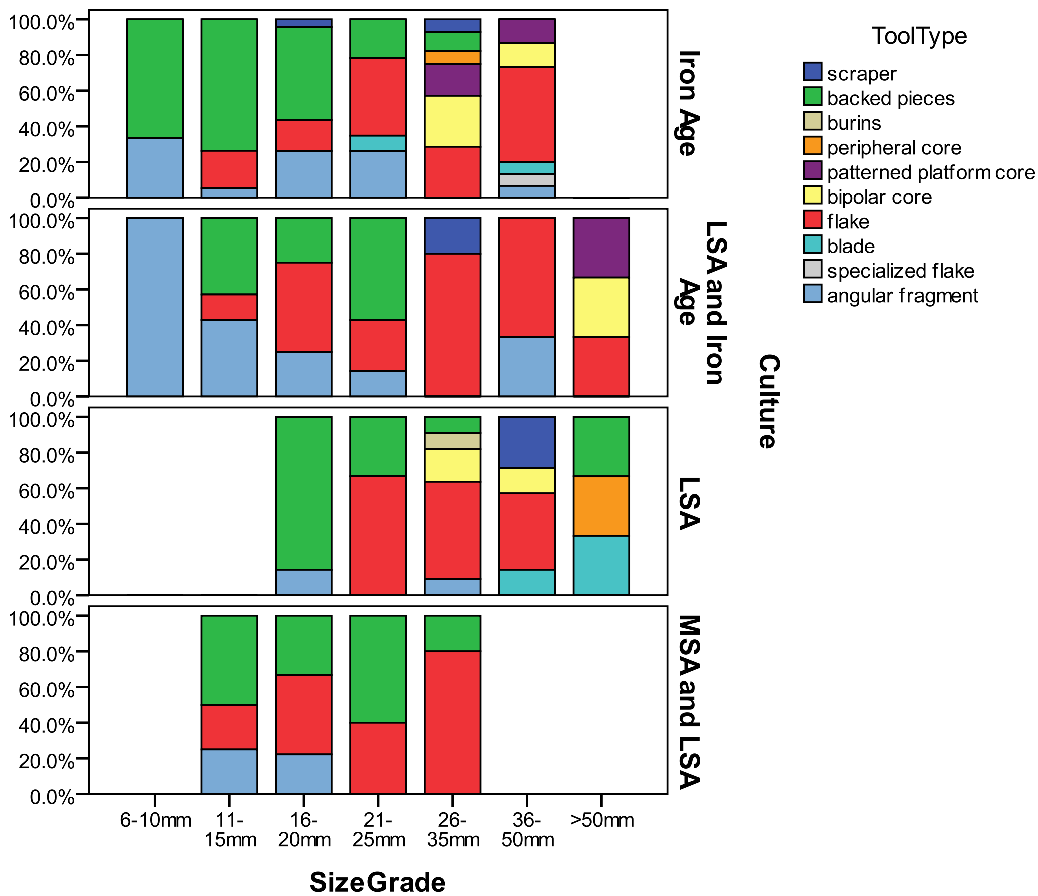


Figure 8.4: Distribution of tools according to size grade for each cultural period.

Magubike

Magubike test pit #1 (TP#1) was excavated within a crevice in the rockshelter. It was extended to a depth of 180 cm. Few artifacts were recovered from the first meter; however, a dense, approximately 50 cm thick layer of large MSA lithics started at approximately 110 cm below surface. Test pit #2 (TP#2) and test pit #3 (TP#3) were excavated under the modern shelter overhang. When large rocks, possibly roof fall, were reached at a depth of 60 cm in TP #2, TP #3 was placed adjacent to the east wall of TP#2. This was excavated to a depth of 210 cm below surface. Both TP #2 and #3 contain Iron Age materials in the top 40 cm and rest of the deposits appear to belong solely to the MSA. This large accumulation of MSA artifacts is likely caused by the disintegration of bedrock and the movement of subsurface water at the site. If there were multiple, repeated MSA occupations at Magubike they cannot be distinguished as deflation has occurred.

Alexander (2010) provides a comprehensive discussion of the properties of the lithic assemblage from Magubike. I will be focusing on the overall picture of raw material use and technological organization at Magubike rockshelter. To allow for a broad and comprehensive picture of technological organization, lithic artifacts from TP #1, #2, and #3 will be examined individually as well as through combined together based on their cultural designation and tool types. During the 2006 test excavations, 20,060 stone artifacts were collected from Magubike of which 17,993 are from an excavated context (i.e., TP#1, #2, and #3). Representing 10.6%, 1903 artifacts are from the Iron Age levels, 883 (4.9%) LSA levels, and 137 (0.8%) from a mixed LSA and MSA context (Table 8.11). The MSA artifacts dominate the total assemblage. Of the excavated artifacts, 15,070 (83.7%) are from a MSA context.

Regardless of cultural period, backed pieces are the most abundant lithic artifact at Magubike. They account for 66.9% of the 4069 shaped tools from the MSA assemblage at Magubike. The high frequencies of backed pieces suggest they are easily made from small flakes or blades produced using a bipolar technique. Backed pieces are used to create standardized geometric and microlithic tools including triangles, trapezes, crescent and burins. They are followed in frequency by scrapers (18.4%), points (4.3%), outils écaillés (3.3%), bifacially modified pieces (1.7%), as well as burins (1.4%) and becs (1.2) (Table 8.11). Table 8.12 shows the distribution of those tools selected for macroscopic analysis from Magubike by cultural designation. This demonstrates that the majority of other (i.e., not backed pieces) tools were largely recovered from the MSA components of the site, although a few becs and outils écaillés are present in the Iron Age assemblage as well. The tools size grade distribution illustrates that the backed pieces are largely microlithic while the points and other tools trend towards larger pieces admitting that there is overlap with the backed pieces (Table 8.13).

Throughout the site, the percentage of debitage relative to the other categories increases with depth, whereas the percentage of tools or trimmed pieces decreases (Figures 8.5 and 8.6). Whole flake categories including flakes, blade, Levallois, and utilized flakes are also abundant throughout the assemblage (Table 8.14). Flakes are largely complete (Table 8.15). The debitage size grade distribution illustrates a lack of microdebitage likely related to collection bias as with Mlambalasi (Table 8.16). Less than 10% of these flakes/blades have faceted platforms indicating the use of Levallois knapping techniques (Figure 8.7).

Bipolar cores predominate, accounting for 1321 out of 1494 (88.4%) cores recorded in the MSA assemblage (Table 8.11). Peripheral, platform prepared, and amorphous cores are also present but in lesser frequencies (Table 8.17). Only 41.7% of cores are complete at Magubike (Table 8.18). The high percentage of incomplete (i.e., broken) cores at Magubike (58.3%) indicates an exhaustive reduction technique where cores were reduced as small as possible, further prioritization of raw material conservation. Raw material conservation is also indicated by the average size grade of the cores. There is a greater range of core sizes at Magubike, likely owing to the larger percentage of fragmentary cores. As with Mlambalasi, the majority of cores at Magubike fall within the 25-35 mm size range (41%; Table 8.19).

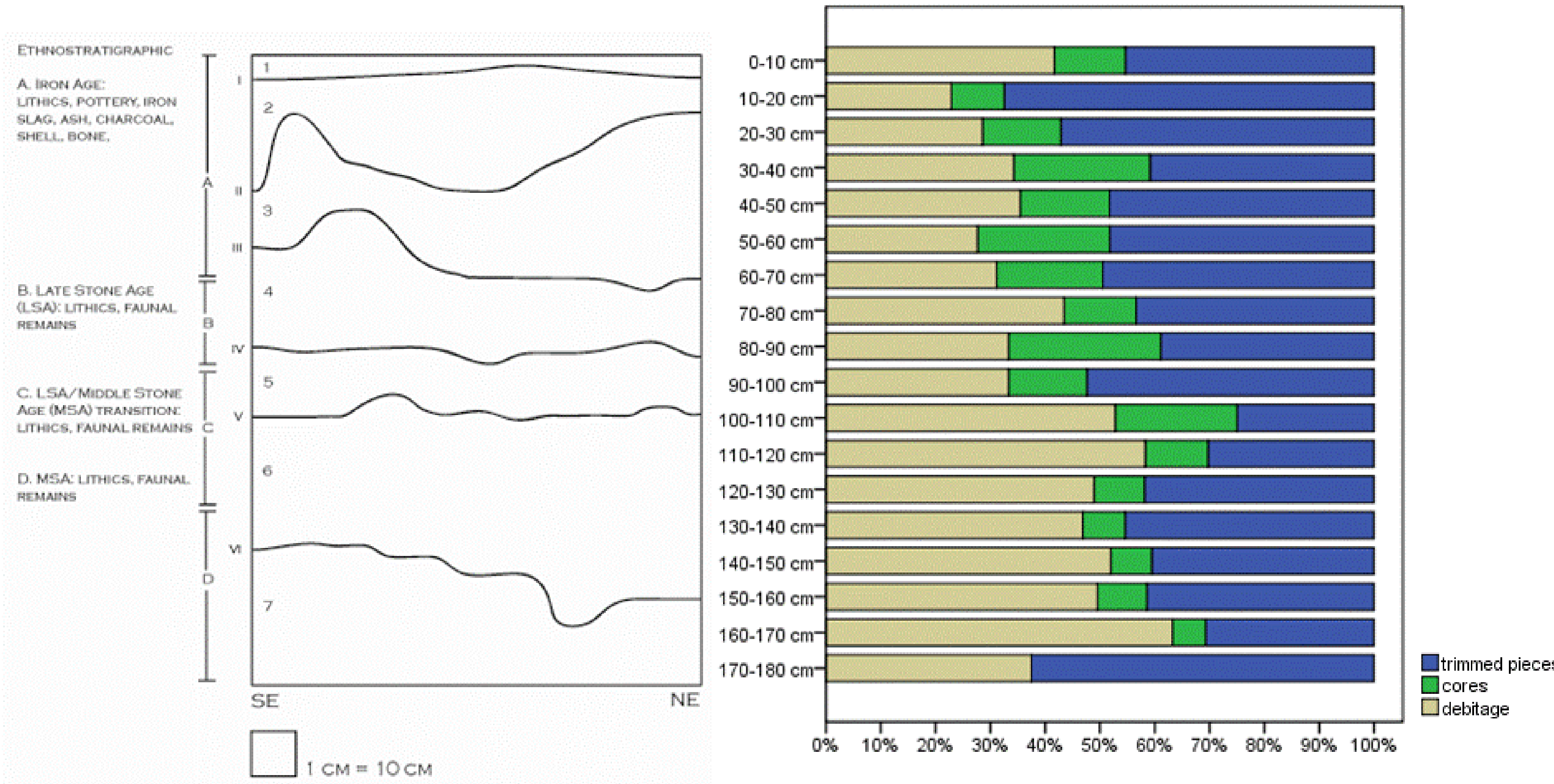


Figure 8.5: Correlation of the stratigraphy from Magubike TP#1 with the distribution of all artifacts by level (Willoughby's dataset).

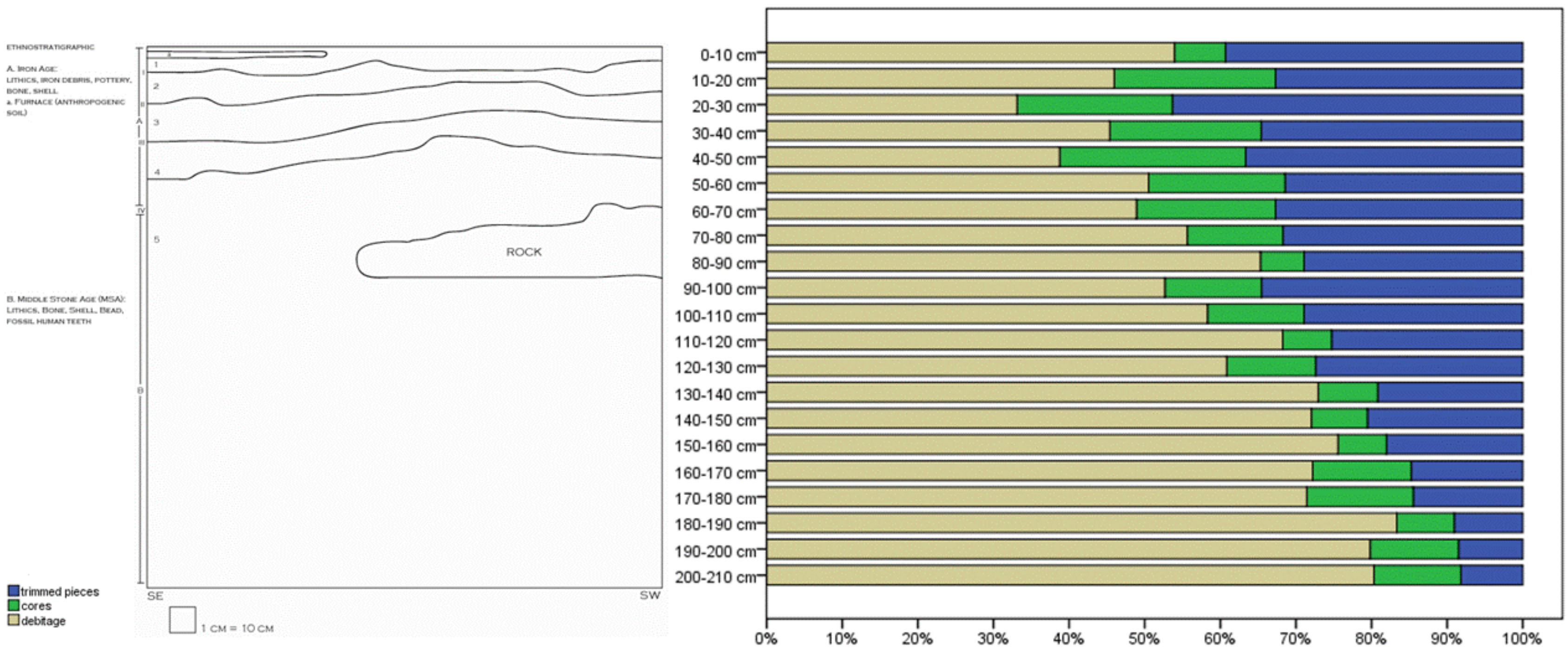


Figure 8.6: Correlation of the stratigraphy from Magubike TP#2 and #3 with the distribution of all artifacts from TP#3 by level (Willoughby's dataset).

Table 8.11: Distribution of lithic artifacts at Magubike Rockshelter by cultural designation (adapted from Bushozi 2011).

Subtypes	**MSA**	**MSA/LSA**	**LSA**	**Iron Age**	**Total**	**%**
Backed pieces	2722	37	349	641	3749	69.9
Scrapers	818	18	58	91	985	18.4
Points	224	0	0	8	232	4.3
Ôutils écaillés	128	4	16	30	178	3.3
Bifacially modified pieces	82	2	2	10	96	1.7
Burins	71	0	2	9	82	1.4
Bec	24	1	2	10	37	1.2
Total Tools	4069	62	429	799	5359	100
Bipolar cores	1321	16	176	314	1827	89
Peripheral cores	121	4	16	11	152	7.5
Platform cores	43	0	2	17	62	3.0
Amorphous cores	7	1	1	0	9	0.4
Intermediate	2	0	0	0	2	0.1
Total Cores	1494	21	195	342	2052	100
Flakes	4293	24	90	273	4680	44.3
Blade	335	2	3	34	374	3.5
Levallois flakes	156	0	0	0	156	1.5
Utilized flakes	82	0	8	14	104	1
Angular fragments	4640	27	158	436	5261	49.7
Total Debitage	9506	53	259	757	10575	100
Sundry ground stone	0	0	0	2	2	28.6
Pestle rubber	1	1	0	3	5	71.4
Total Other	1	1	0	5	7	100
Total All	15070	137	883	1903	17993	

* Totals exclude surface finds

Table 8.12: Distribution of tools selected for macroscopic analysis from Magubike by cultural designation.

		Type of Tool								
		Scraper	Backed pieces	Points/ perçoirs	Burins	Bifacially modified pieces	Becs	Outils écaillés	Other	Total
Iron Age	N	8	44	0	0	0	1	2	0	55
	%	14.6	80	0	0	0	1.8	3.6	0	100
LSA	N	2	8	0	0	0	0	0	0	10
	%	20.0	80.0	0	0	0	0	0	0	100
LSA+ MSA	N	3	0	0	0	0	0	0	0	3
	%	100	0	0	0	0	0	0	0	100
MSA	N	177	442	68	19	2	4	14	1	727
	%	24.3	60.8	9.4	2.6	0.3	0.6	1.9	0.1	100
Total	N	190	494	68	19	2	5	16	1	795
	%	23.9	62.1	8.6	2.4	0.3	0.6	2.0	0.1	100

Table 8.13: Magubike tool type distribution of artifacts selected for microscopic analysis by size Grade (mm).

Type of Tool	<5	6-10	11-15	16-20	21-25	26-35	36-50	>50
Scraper	0	0	0	0	1	14	10	0
Backed pieces	0	0	10	17	14	6	1	0
Points/perçoirs	0	0	0	0	2	3	3	1
Burins	0	0	0	0	0	2	0	0
Bifacially modified pieces	0	0	0	0	1	0	0	0
Becs	0	0	0	0	0	0	0	0
Ôutils écaillés	0	0	0	1	1	0	0	0
Others	0	0	0	0	0	0	0	0
Total	0	0	10	18	20	25	14	1

Table 8.14: Distribution of debitage sampled for macroscopic analysis from Magubike by cultural designation.

		Type of Debitage					
		Angular fragments	Specialised flakes	Flakes	Blades	Levallois flakes	Total
Iron Age	N	26	0	93	9	0	128
	%	20.3	0	72.7	7.0	0	100
LSA	N	7	0	8	1	0	16
	%	43.8	0	50.0	6.2	0	100
LSA+MSA	N	3	0	8	1	0	12
	%	25.0	0	66.7	8.3	0	100
MSA	N	1584	4	2321	196	94	4199
	%	37.7	0.1	55.3	4.7	2.2	100
Total	N	1620	4	2430	207	94	4355
	%	37.2	0.1	55.7	4.8	2.2	100

Table 8.15: Completeness of debitage sampled for microscopic analysis from Magubike.

Type of Debitage	Debris	Complete	Proximal	Distal/ Medial	Split
Angular fragments	9	40	0	3	1
Specialised flakes	0	0	0	0	0
Flakes	28	155	4	0	1
Blades	1	19	0	0	1
Levallois flakes	0	0	0	0	0
Total	38	214	4	3	3

Table 8.16: Debitage size grade distribution for Magubike artifacts sampled for microscopic analysis.

Type of Debitage	<5	6-10	11-15	16-20	21-25	26-35	36-50	>50	Total
Angular fragments	0	0	10	19	16	8	5	0	58
Specialised flakes	0	0	0	0	0	0	0	0	0
Flakes	0	1	4	33	54	75	30	2	199
Blades	0	0	0	2	9	4	5	0	20
Levallois flakes	0	0	0	1	0	4	5	1	11
Total	0	1	14	55	79	91	45	3	288

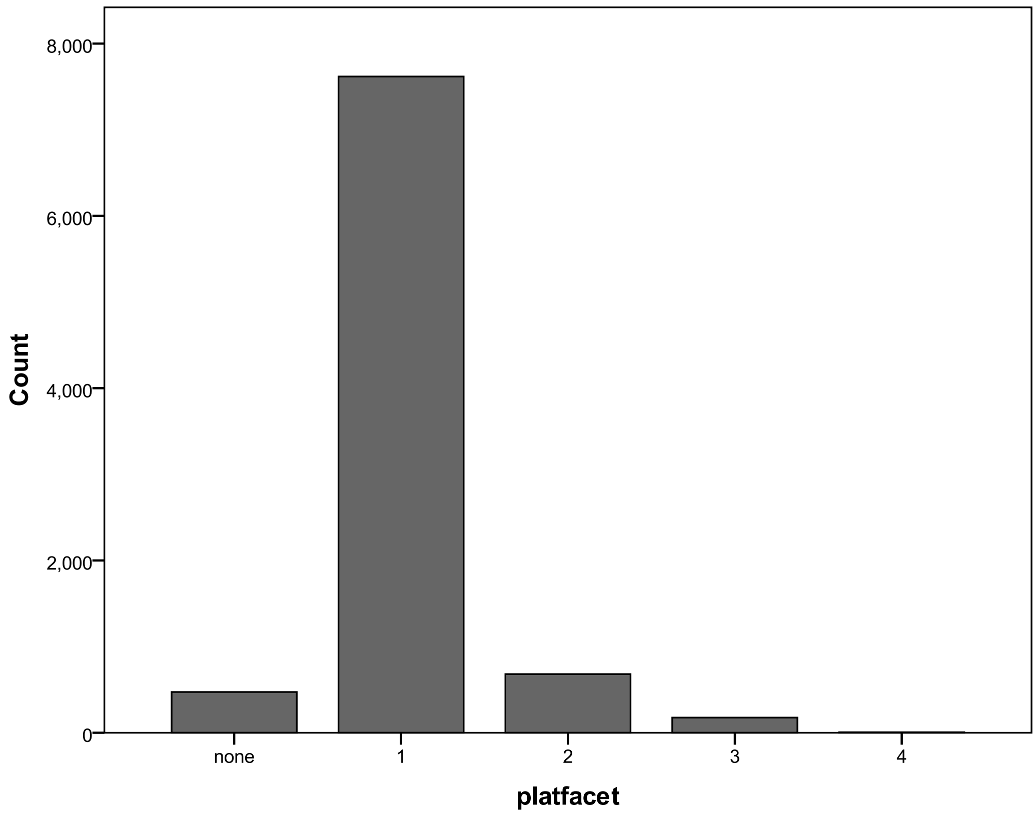


Figure 8.7: Debitage platform facet (platfacet) type distribution for Magubike.

Table 8.17: Core type distribution at Magubike by cultural designation for artifacts sampled for macroscopic analysis.

		Type of Core					
		Peripherally worked	Patterned platform	Intermediate	Bipolar	Amorphous	Total
Iron Age	N	0	5	0	16	0	21
	%	0	23.8	0	76.2	0	100
LSA	N	0	1	0	10	0	11
	%	0	9.0	0	91.0	0	100
LSA+MSA	N	1	0	0	0	0	1
	%	100	0	0	0	0	100
MSA	N	41	17	1	261	4	324
	%	12.7	5.2	0.3	80.6	1.2	100
Total	N	42	23	1	287	4	357
	%	11.8	6.4	0.3	80.4	1.1	100

Table 8.18: Core size grade distribution for artifacts selected for microscopic analysis from Magubike.

Type of Core	<5	6-10	11-15	16-20	21-25	26-35	36-50	>50
Peripherally worked	0	0	0	0	0	1	2	0
Patterned platform	0	0	0	0	1	2	0	0
Intermediate	0	0	0	0	0	0	0	0
Bipolar	0	0	0	3	7	11	6	1
Amorphous	0	0	0	0	0	0	0	0
Total	0	0	0	3	8	14	8	1

Table 8.19: Distribution of cores selected for microscopic analysis from Magubike based on percentage of cortex.

Type of Core	0	<10	10-25	25-50	50-75	75-90	>90
Peripherally worked	1	0	1	1	0	0	0
Patterned platform	0	0	2	0	1	0	0
Intermediate	0	0	0	0	0	0	0
Bipolar	5	3	9	11	3	0	0
Amorphous	0	0	0	0	0	0	0
Total	6	3	12	12	4	0	0

Comparison of Assemblages at Mlambalasi with Magubike

The distribution of debitage at Mlambalasi is remarkably similar to that found at Magubike (Table 8.20). Flakes represent the majority of the debitage followed by angular fragments. Levallois and specialised flakes are rare.

Core type distribution varies significantly between the two sites (Table 8.21). Although bipolar cores predominate at both sites, Mlambalasi has greater quantities of peripherally worked and patterned platform cores. This is interesting as peripherally worked and patterned platform cores are generally associated with MSA/Levallois technology. One would expect to see more of these cores in the large, clearly defined MSA component at Magubike. Amorphous and intermediate cores are rare at both sites.

Backed pieces represent the greatest proportion of tools for Mlambalasi and Magubike alike (Table 8.22). Magubike demonstrates a greater variety and volume of other tool types which can be equated with the large MSA presence at the site. Overall the tools at both sites are largely microlithic with the exception of larger tools seen in the lower levels of the LSA at Mlambalasi and the MSA of Magubike.

When one examines the distribution of fracture patterns for each tool type by cultural designation there does not seem to be any significant pattern produced for Mlambalasi whereas there does for Magubike (Figures 8.8 and 8.9). At Mlambalasi most of the artifacts demonstrated conchoidal to subconchoidal fracture regardless of cultural period. At Magubike, there is a greater proportion of artifacts demonstrating wedging or bending initiated fracture in the MSA versus later assemblages. I would argue that this is likely the result of the high percentage of relatively low quality (medium to coarse grained, non-homogeneous), very hard metamorphic rock types during the MSA. Bipolar reduction, which uses wedging initiation, would be best suited for the primary reduction of cobbles of these metamorphic rock varieties, and is evidenced in the assemblage by the large number of bipolar cores.

Table 8.20: Distribution of debitage sampled for macroscopic analysis by site.

Type of Debitage	#		% of Total	
	HwJf-02	HxJf-01	HwJf-02	HxJf-01
Angular fragments	167	1620	35.5	37.2
Specialised flakes	2	4	<1	<1
Flakes	272	2430	57.9	55.8
Blades	27	207	5.7	4.8
Levallois flakes	2	94	<1	2.2
Total	470	4355	100	100

Table 8.21: Distribution of cores sampled for macroscopic analysis by site.

Type of Core	# of Cores		% of Total Cores	
	HwJf-02	HxJf-01	HwJf-02	HwJf-01
Peripherally worked	12	42	14.0	11.8
Patterned platform	22	23	25.5	6.4
Intermediate	1	1	1.2	<1
Bipolar	49	287	57.0	80.4
Amorphous	2	4	2.3	1.1
Total	86	357	100	100

Table 8.22: Distribution of tools sampled for macroscopic analysis by site.

Type of Tool	# of Tools		% of Total Tools	
	HwJf-02	HxJf-01	HwJf-02	HwJf-01
Scraper	19	190	5.4	24.0
Backed pieces	322	494	91.7	62.3
Points/perçoirs	1	68	<1	8.6
Burins	7	19	2.0	2.4
Bifacially modified pieces	0	2	0	<1
Becs	2	5	<1	<1
Composite tools	0	0	0	0
Ôutils écaillés	0	14	0	1.8
Heavy duty tools	0	0	0	0
Others	0	1	0	<1
Total	351	793	100	100

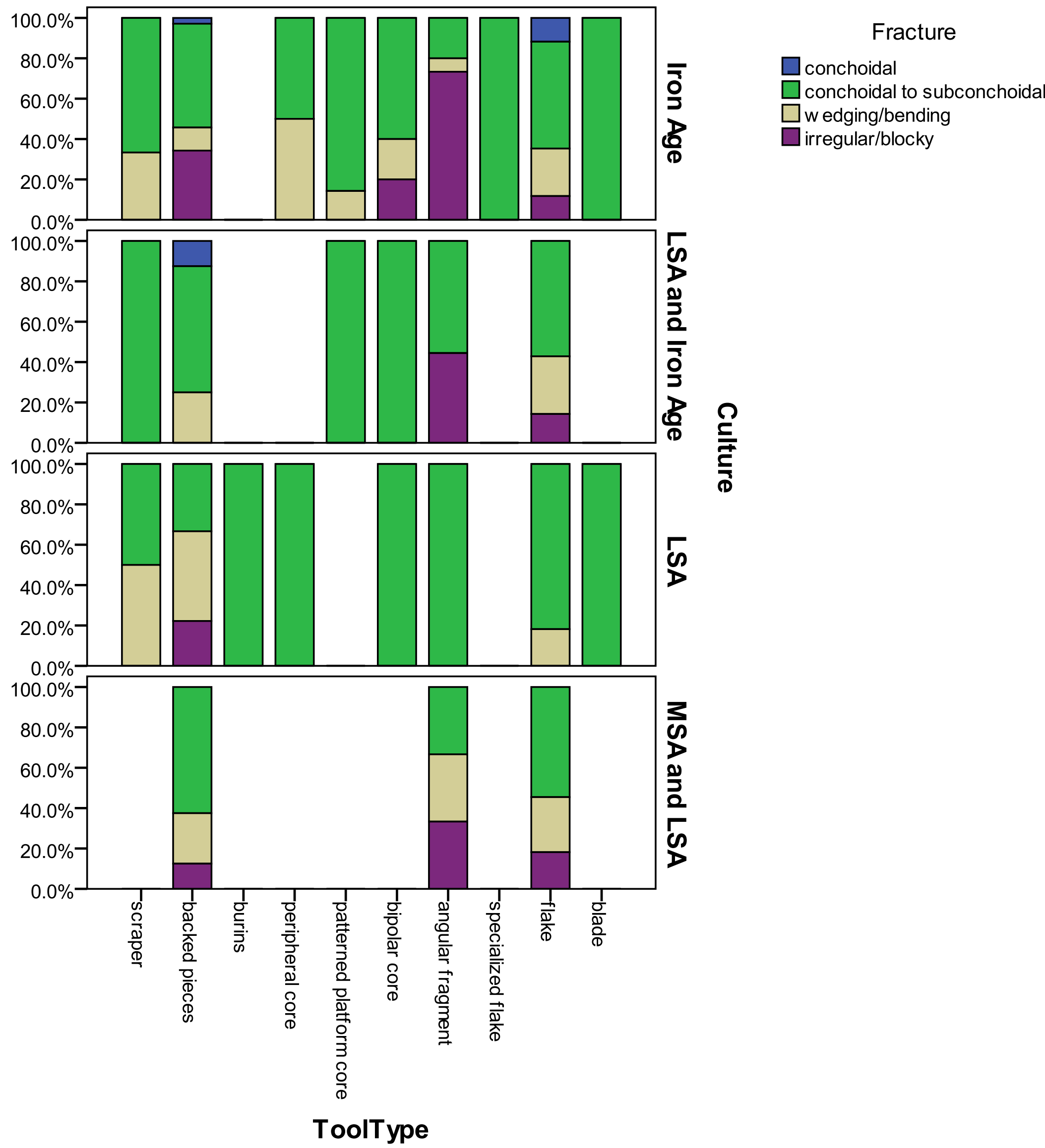


Figure 8.8: Distribution of tool type by fracture pattern for each site by cultural period for Mlambalasi.

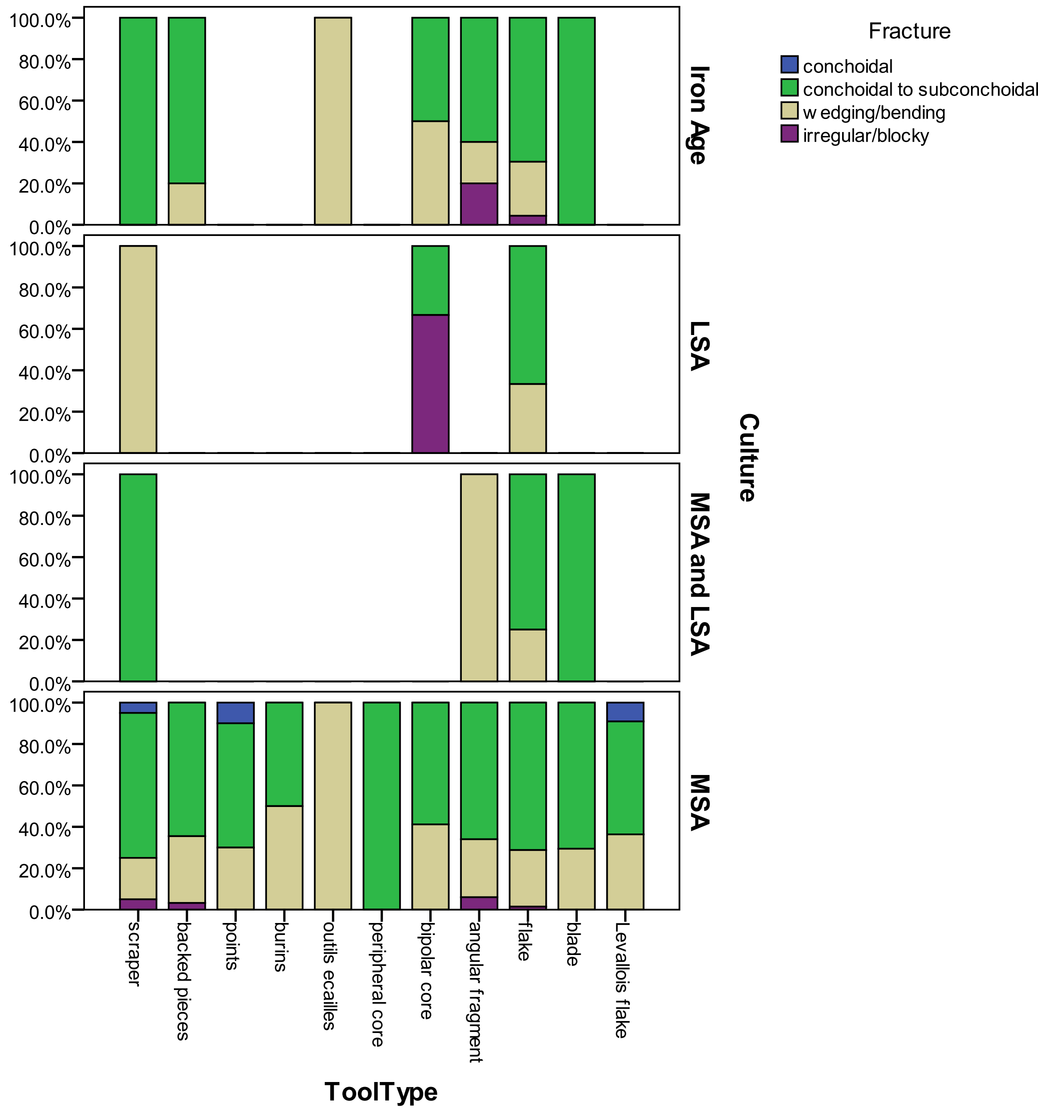


Figure 8.9: Distribution of tool type by fracture pattern for each site by cultural period for Magubike.

8.2 Results of Combined Technological and Raw Material Analysis

Chapter 7 presented the results of the raw material analysis. Here I consider those results alongside those of the technological analysis. Figure 8.10 illustrates the distribution of all artifacts by raw material type for each test pit. Willoughby's analysis recognised five different raw material types: quartz, quartzite, rock crystal, chert/flint, and volcanic. My macroscopic analysis excluded the quartz, quartzite and rock crystal artifacts and initially grouped the artifacts into the general categories of sedimentary (including cherts), metamorphic and igneous. The microscopic analysis allowed for further division into 10 different raw material types. Importantly this revealed that the majority of the lithic raw materials had been classified in error as volcanic or igneous when they are actually metamorphic.

Figures 8.11 and 8.12 show the distribution of tool and core types (respectively) by raw material type. Table 8.23 provides the distribution of raw material type by maximal artifact category as determined by the microscopic analysis; while tables 8.24 and 8.25 breakdown the distribution of the metamorphic and chert varieties respectively. These illustrate that debitage represents the largest portion of artifacts in the assemblages and thus the largest proportion of artifacts sampled for microscopic analysis. Of the debitage from Mlambalasi, 72.7% is chert with all other types poorly represented. Of that chert, subtype III.iv is the most abundant (65.8%). Chert is also the most abundant type of raw material for the cores (90%) and the tools (78.6%). Scrapers and backed pieces are the most abundant tools and were made from a variety of different raw material types. Burins, however, were only produced from chert III.iv (Figure 8.11). Because of the small proportion of burins and other tools in the assemblage at Mlambalasi it is difficult to determine if this does reflect actual selection of particular raw material types for specific tools or if it is just a product of sampling bias. All bipolar cores from Mlambalasi are chert III.iii whereas patterned platform and peripheral cores are chert III.iii but also chert III.i and III.iv (Figure 8.12).

At Magubike, only 21% of the debitage is chert; the largest proportion is the metamorphic varieties (37.1%) with subtype I most abundant (39.6%). Although metamorphic rocks make up most of the tools (46.2%) they only represent 15.9% of the cores. The majority of the cores are chert (40.9%). This discrepancy in the large number of tools versus cores for chert does not appear to be a function of selection of different raw materials during different cultural periods thus suggests that chert tools when produced at Magubike were transported elsewhere for use and abandonment. Unfortunately there may be a sampling bias in the tool types selected for microscopic analysis. In addition to the abundant scrapers, backed pieces and points, only becs and burins were selected for thin sectioning; however, this could be because the other tool types were exclusively produced using quartz and quartzite. If this is the case this confirms the results of the microscopic analysis that suggests that coarser grained raw materials such as sandstone and metamorphic subtype I were selected for production of these tool types, and finer grained materials like cherts and tuffs were reserved for backed pieces (Figure 8.11). This may be a function of raw material preference or availability during different cultural periods. Metamorphic varieties were used most abundantly in the MSA while chert, quartz and quartzite are more abundant in the assemblages from later periods.

The raw materials represented in the cores at Magubike correspond with the types of raw materials of the tools in the assemblage (Figure 8.12). The bipolar cores were produced using most of the available raw material types. Interestingly the peripherally worked cores were only produced using CCS. These cores come from TP#1 and suggest that the occupations represented in TP#1 are separate (i.e., do not correlate) with those in TP#2 and #3. This hypothesis is supported by the overall trend in raw materials seen in TP#1 versus TP#2 and #3.

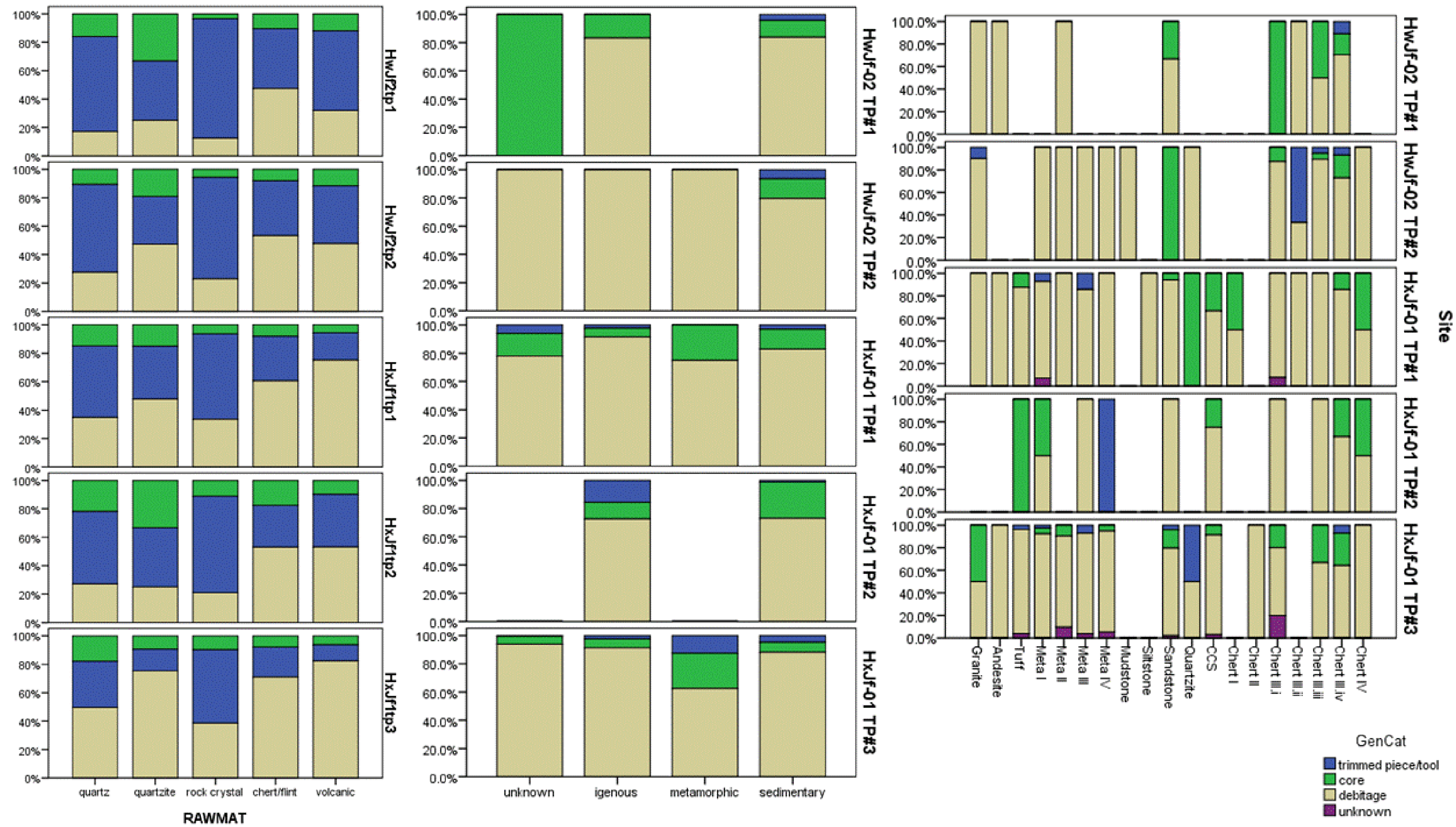


Figure 8.10: Distribution of artifacts for all test pits by raw material type.
Left: Willoughby's data. Center: Biittner's macroscopic data. Right: Biittner's microscopic data.

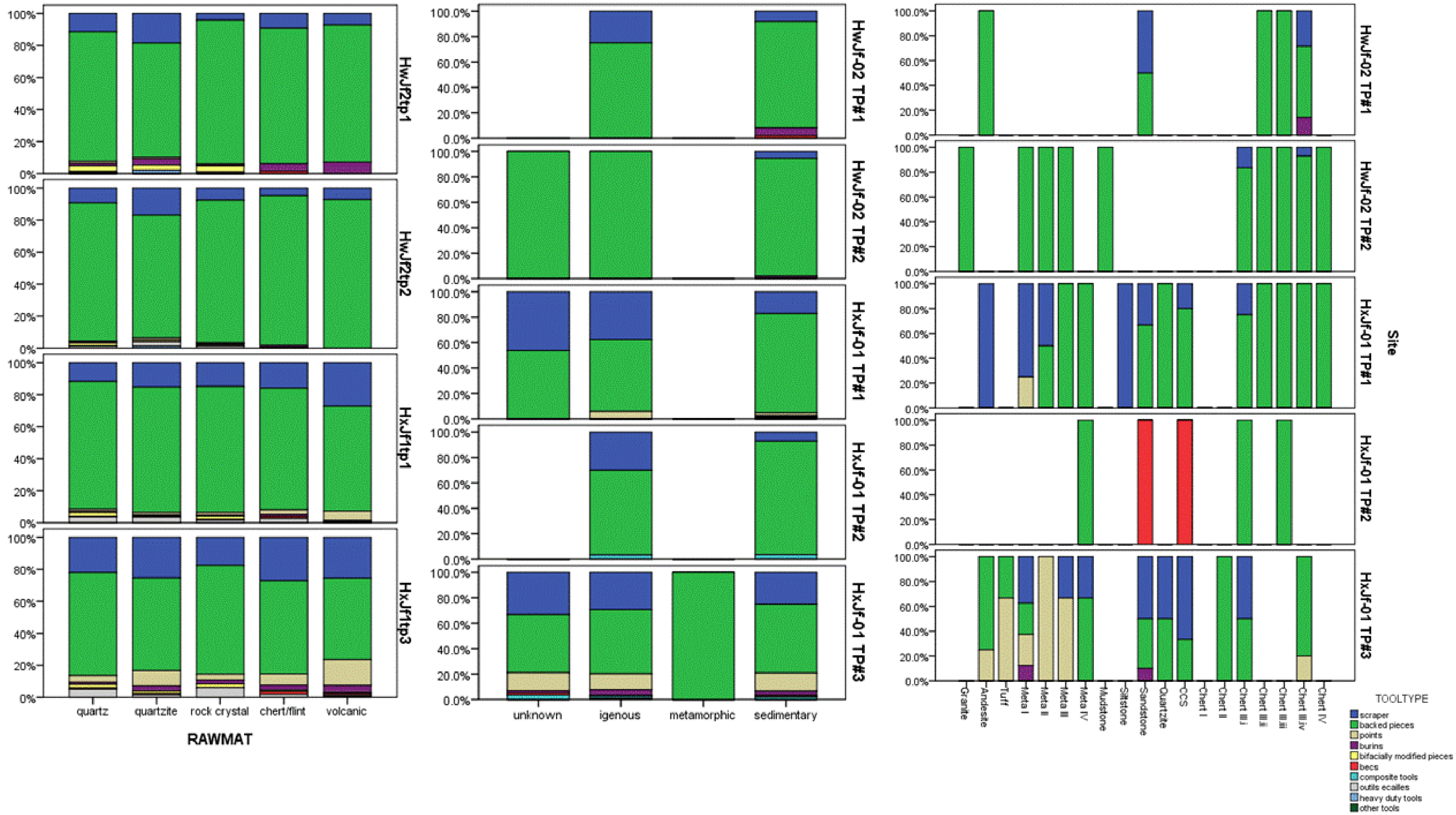


Figure 8.11: Distribution of tool types for all test pits by raw material type.
Left: Willoughby's data. Center: Biittner's macroscopic data. Right: Biittner's microscopic data.

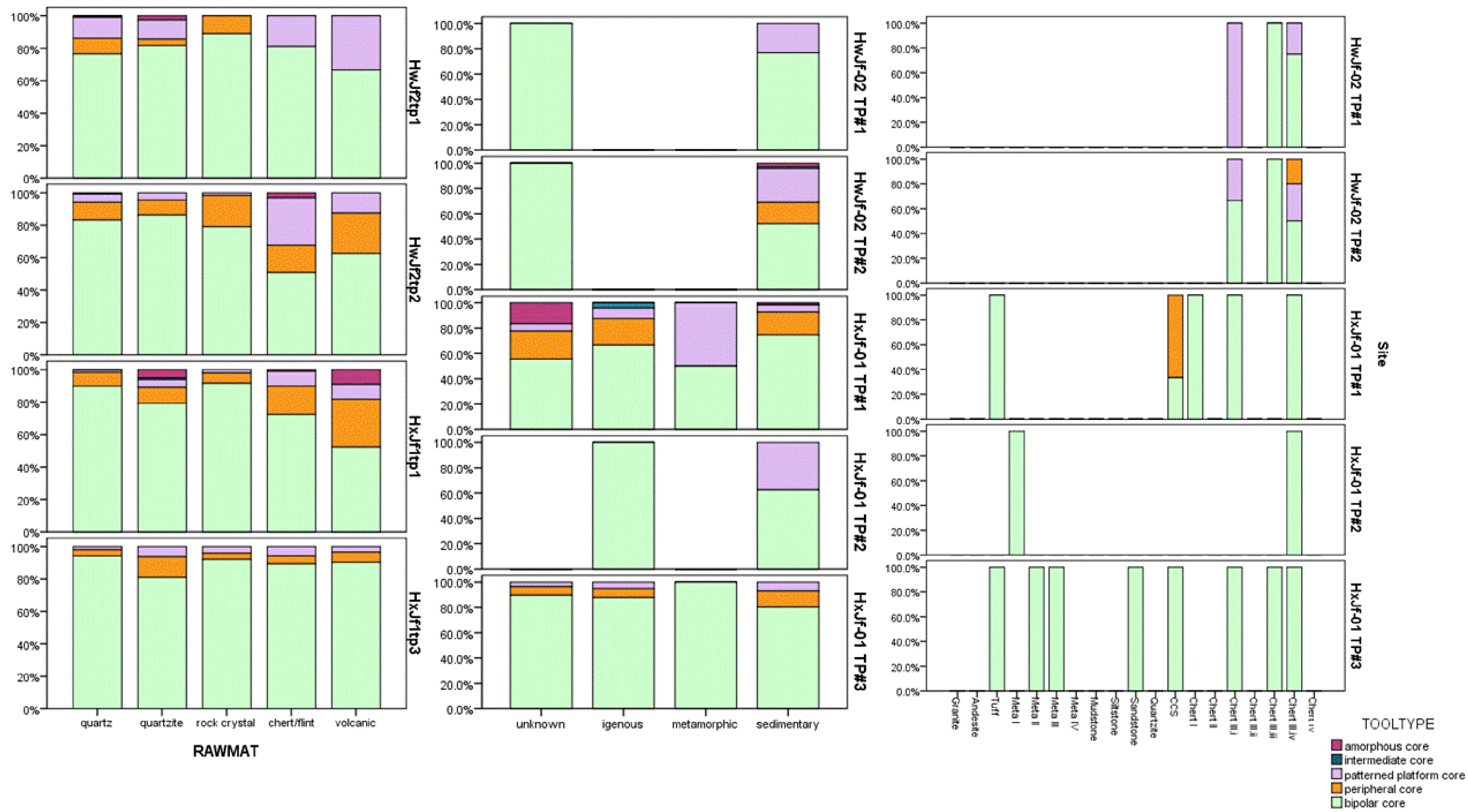


Figure 8.12: Distribution of core types for all test pits by raw material.
Left: Willoughby's data. Center: Biittner's macroscopic data. Right: Biittner's microscopic data.

Table 8.23: Raw material type by maximal artifact category as determined by microscopic analysis.

	Mlambalasi			Magubike		
	Debitage	Core	Tool	Debitage	Core	Tool
Granite	12	0	2	3	1	0
Andesite	1	0	0	5	0	0
Tuff	0	0	0	35	1	1
Metamorphic	20	1	0	134	7	6
Mudstone	1	0	0	0	0	0
Siltstone	0	0	0	1	0	0
Sandstone	3	2	0	59	9	2
Quartzite	1	1	0	2	0	1
CCS	1	0	1	44	7	0
Chert	114	36	11	76	18	3
Unique	4 (a,b,c,d)	0	0	2 (f, g)	1 (e)	0
Total	157	40	14	361	44	13

Table 8.24: Metamorphic raw material types by maximal artifact category as determined by microscopic analysis.

Metamorphic varieties	Mlambalasi			Magubike		
	Debitage	Core	Tool	Debitage	Core	Tool
Meta I	2	0	0	53	4	2
Meta II	14	1	0	23	2	0
Meta III	3	0	0	37	0	3
Meta IV	1	0	0	21	1	1
Total	20	1	0	134	7	6

Table 8.25: Chert raw material types by maximal artifact category as determined by microscopic analysis.

Chert varieties	Mlambalasi			Magubike		
	Debitage	Core	Tool	Debitage	Core	Tool
I	0	0	0	1	1	0
II	0	0	0	3	0	0
III.i	14	4	0	20	1	0
III.ii	4	0	2	1	0	0
III.iii	19	4	1	5	1	0
III.iv	75	28	8	40	13	3
IV	2	0	0	6	2	0
Total	114	36	11	76	18	3

8.2.1 Assessment of Raw Material and Technological Attributes

Numerous technological and raw material attributes were used in this study. Here I briefly present a discussion of the attributes I found were necessary for distinguishing and characterizing the lithic raw materials as well as for inferring organization of technology. Table 8.1 provides a listing of all of the technological attributes used while Table 8.26 lists the raw material attributes employed.

Macroscopic Attributes

Texture is overall the most useful raw material attribute. A basic separation into cryptocrystalline, microcrystalline and macrocrystalline is useful at the macroscopic level, and, as will be discussed below, textural differences at the microscopic level were what ultimately led to the definition of specific rock types. However, I found distinguishing igneous and metamorphic textures difficult. This is likely because of the relatively small size of the artifacts. The larger the artifact the easier it was to see grain size and structures such as foliation. Sedimentary texture was generally more straightforward as the raw materials were either cryptocrystalline or macrocrystalline or clastic. Mineral identification was also hampered by artifact size.

Artifact size is a key constraint. Although Willoughby recorded length, breath and width measurements for each artifact, I found that the use of size grades provides a clearer picture of trends. Size grades can be used almost as proxies for each stage of reduction with the largest size grades representing primary core reduction and the smallest ones indicating tool shaping, retouch or modification. As previously mentioned, the visibility of some attributes is affected by small artifact size. Larger artifacts are easier to characterize using macroscopic attributes.

Color is another useful attribute, particularly when combined with lustre, textural considerations, patination, mottling, speckling and banding; yet it is also highly problematic. Translucence was useful in this regard, in particular for separating CCS from chert varieties. In my M.A. thesis (Miles 2005) I demonstrated the usefulness of mottling, speckling, and banding in distinguishing Ontario cherts from different formations but also members within a single chert formation. These attributes proved useful for Iringa Region cherts as well.

Patina is a useful measure of chemical weathering but is not always a reliable attribute as it can be affected by (1) the features of the rock type (chemical composition, mineralogy, texture), (2) the features of the depositional or weathering environment (soil pH, rainfall, temperature, bacterial activity, drainage), and (3) the position of the rock within the matrix (Sheppard and Pavlish 1992:41). Rather than looking at the degree of patination, I found that the color of the patina when present was useful in distinguishing raw material types. However, many of the rock types have a rusty (orange-reddish to brownish) colored patina which likely has little to do with the properties of the rock and more to do with the high content of iron in the soil throughout all of Iringa.

Lustre is related to both the texture of the rock and the presence/absence of chemical and mechanical weathering, which may or may not produce a patina. So although it proved useful in distinguishing between various rock types and subtypes, it cannot be exclusively used because it can be difficult to establish if the lustre is the natural property of the rock or the result of post-depositional processes.

Microscopic Attributes

Texture is the most useful microscopic attribute. As discussed in Chapter 6, texture is determined mainly by grain size. Micro variations in texture (or subtextures) proved absolutely essential for the differentiation of all of the rock types. All of the metamorphic rock subtypes were constructed on the basis of differences in both texture and mineral component; and the same is true for the igneous varieties. All of the sedimentary artifacts were initially divided based on clastic versus non-clastic (crystalline). The crystalline varieties were then subsequently subdivided depending on crystal visibility. In cherts, the silica fabric is the most important diagnostic attribute. All of the chert subtypes are based on presence/absence of each type of silica fabric such as the relative proportions of chalcedony, DQM, and cryptocrystalline silica.

Texture is also important because it can serve as a proxy of quality (Brantingham et al., 2000). Figure 8.13 illustrates the quality of Iringa Region lithic raw materials which were used in tool production, based on their microscopic properties. At Mlambalasi there does not seem to be preferential selection of higher quality raw materials whereas at Magubike there does albeit to a relatively small degree. In particular the MSA assemblages at Magubike contain a greater number of higher quality raw materials than what is seen in any other assemblage at Magubike or Mlambalasi. This presents a number of possibilities: first, that access to high quality raw materials decreased over time or second, that the technological strategy of LSA peoples did not require high quality toolstone.

Table 8.26: Raw material attributes.

Raw Material Type	Macroscopic Attributes	Microscopic Attributes	
Igneous	Color	Degree of crystallinity	
	Grain size (texture)	Granularity	
	Lustre	Absolute grain size	
		Relative grain size	
		Crystal shape	
		Texture	
		Subtexture	
		Characterizing minerals	
		Accessory minerals	
		Volcanic fragments	
Metamorphic	Color	Crystal shape	
	Grain size (texture)	Foliation	
	Lustre	Protoliths	
	Micas (presence/absence)	Relict textures	
	Foliation (presence/absence)	Characterizing minerals	
		Replacement minerals	
		Accessory minerals	
Sedimentary	Color	Clastic:	Non-clastic:
	Grain size (texture)	Grain size	Grain types
	Grain shape (sphericity)	Sorting	Grain subtypes
	Grain shape (roundness)	Roundness	Texture
	Sorting	Sphericity	
	Mottling	Packing	
	Speckling	Orientation	
	Banding/striping	Maturity	
	Lustre	Grain type	
	Translucence	Matrix	
	Patination	Cement	
	Patina color		
	Inclusions	Characterizing minerals	
		Accessory Minerals	

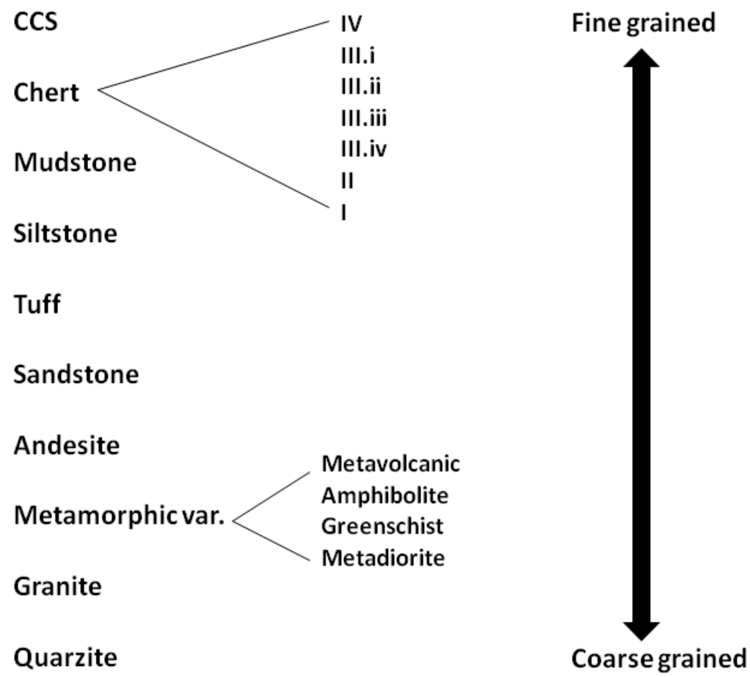


Figure 8.13: Iringa Region raw materials ordered by knapping quality.

Technological Attributes

Many of the technological attributes examined are directly related to the properties of the raw materials themselves. Ultimately the type of fracture that can be induced in a material is determined by the crystal structure of the rock.

As previously mentioned, microdebitage, artifacts less than 5 mm^2 are not represented in the assemblages as they were likely missed by the use of hand sorting over screening. Microdebitage may also have been lost during the processing of the artifacts prior to shipment. Finer mesh (1 mm x 1 mm) screens were used in the 2010 excavations and microdebitage was collected. However, this issue of microdebitage at both sites must be investigated in the future as it is a valuable source of information about lithic reduction, maintenance and rejuvenation.

8.3 Interpretation of the Mlambalasi Assemblage

Ninety-three percent of the lithic assemblage is composed of quartz, quartzite or rock crystal. Overall there are few non-silicate raw materials and those which are present are from a mixed context (Test pit #2). Test pit #2 represents an MSA deposit on top of which later deposits slumped, owing to the slope, which was further disturbed by bioturbation - a large termite mound was found in the unit as were a large number of roots. The majority of cherts present are from one sub-type (III.iv), which is relatively high quality. It is not as homogeneous as the classic grey/blue-grey/black flint and can have quartz vein inclusions. The non-cherts included granite and greenschist facies metamorphic frocks.

The assemblage is dominated by debitage but includes a large number of whole flakes and blades. Bipolar reduction is indicated by the few cores and core fragments present, variable fracture patterns (sub-conchoidal as well as bending/wedging fractures and angular fragments), and overall small size grade

(< 25 mm). Note that in addition to the lack of microdebitage, there are few retouched flakes/blades or tools. The majority of the assemblage reflects core reduction. The Iron Age and LSA assemblages at Mlambalasi are very similar in composition. All MSA artifacts, determined typologically following Mehlman's classification (1989), were recovered from Test pit #2 which, as previously mentioned, is highly decontextualized by bioturbation (termites) and erosion (slumping down the slope).

8.4 Interpretation of the Magubike Assemblage

The cultural sequence of all three test pits suggests that Magubike was often occupied, abandoned, and reoccupied. MSA artifacts from Magubike demonstrate a considerable range of variability in the number of raw material types used. They include quartz, quartzite, metamorphic/metavolcanic, and numerous chert varieties. The LSA artifacts are produced using quartz and quartzite. This is significant as quartz and quartzite are poorer quality raw materials but ubiquitous, whereas other varieties are of higher quality but less abundant.

Magubike rockshelter provides an interesting picture of intra-site variability as represented by differential use of raw materials in different components or occupations of the site. Magubike Test pit#1, as discussed above, has an Iron Age to LSA to MSA sequence while Test pit #2 and Test pit #3 only contain the Iron Age then the MSA. In all components, quartz and quartzite remain the dominant raw material; however, there is differential use of the other toolstone varieties (Table 3). In Test pit #1, metamorphic varieties and sandstone are found in the IA and LSA assemblages along with two sub-types of chert (III.i and III.iv); while all varieties of raw materials are found in the MSA assemblage. In Test pit #2 and #3, metamorphic varieties and cherts III.iv and IV are found in the IA context. As with Test Pit #1, all types are utilized in the MSA. Chert IV (classic "flint") is only found in the Iron Age of Test pits #2 and #3. This is worthy of note as IV is the highest quality raw material likely because of its cryptocrystalline, homogeneous composition.

Unlike Mlambalasi, Magubike has a high number of retouched tools including scrapers, backed pieces, and points. Although the majority of the cores are bipolar, we do see the introduction of some patterned platform cores including Levallois. The MSA assemblage contains a large number of Levallois flakes. Levallois flakes were produced from several different raw materials: tuff, metadiorite, amphibolite facies rocks, sandstones, and CCS. In addition a single variety of chert (subtype III.iv) was used. This subtype is the most macroscopically diverse of the cherts and but has relative microscopic homogeneity.

8.5 Interpretation of Iringa Region Archaeology

8.5.1 Raw Material Procurement and Use

With provenance studies emphasis is frequently placed on determining which of the raw materials used are local and which are exotic. Local materials are easily defined: those that are found within a small or reasonable distance from the site or location of use, often those that can be acquired within the distance that can be reached by walking in a single day. How one defines what material is exotic varies. Here exotic raw materials are those acquired from a source located a significance distance, greater than 350 km, from the site or location of use. Sources found within 50-350 km are defined as non-local. Although lithic materials that appear infrequently in particular archaeological assemblages or in a particular region may be considered exotic, this analysis illustrates that this is not the case for Iringa Region.

Figures 8.14 and 8.15 illustrate the distribution of raw material types at both sites. In Chapters 5 and 6 I presented the lithic raw materials available in Iringa Region which are suitable for use in tool production. Table 8.27 is a modified version of Table 5.8 that highlights those toolstones which have been identified in assemblages at Magubike and Mlambalasi. It is therefore possible to state that all of the lithic raw materials identified in these assemblages were available locally.

However, it is important to understand that they were not necessarily found as an unmodified rock type, nor would these materials have been acquired without some time and labour costs. Study of geological maps from the region in consultation with geologists from the University of Alberta suggests that these non-quartz/quartzite raw materials should be available within relatively close proximity to the rockshelters (again within 50 km). However, they are located along high mountain ridges, which may explain the small volume of these materials in the assemblages. It is likely that they were acquired from secondary sources such as river cobbles and nodular cherts. The presence of large primary reduction flakes including cortical flakes rules out the use of preformed cores and supports a secondary-source acquisition hypothesis.

During the LSA, raw materials were not selected for any particular tool type with quartz and quartzite the predominant toolstones used. This is a drastic shift from the MSA where metamorphic rock varieties are more abundant than quartz and quartzite combined. Chert use is also greater during the MSA and preference is for higher quality (i.e., finer grained, homogeneous) varieties.

Most of the archaeological lithic assemblages in southern Tanzania are composed predominantly of quartz and quartzite. Other raw materials utilized include silicates (chert/flint/cryptocrystalline silicate) and dark, fine grained metamorphic and igneous rocks. Willoughby's research in Mbeya suggests that first, that volcanic raw material use in the MSA is highest in southern sites which are closer to them and second, that that while MSA people in southern Tanzania utilized local materials, the presence of distinctive lithic types shows they also transported raw materials or finished tools over significant distances (Willoughby 2001:14). These lithic raw materials would have been relatively abundant and easily obtainable. Analysis of the MSA assemblages at Magubike follows a similar pattern to that in Mbeya: metamorphic and chert varieties are locally available and thus abundant in lithic assemblages.

As previously mentioned, to southern LSA peoples, cryptocrystalline silica (CCS) was either so highly prized, or so difficult to obtain, small pebble sized inclusions of CCS were extracted from vesicles in the volcanic rocks in the walls of the rockshelter (Willoughby 2001a:14). Generally, during the LSA the tendency is towards the utilization of more exotic raw materials suggesting a significant change in mobility strategies including the possibility of the development of long distance trade and exchange networks for raw material procurement. In both Iringa and Mbeya, LSA sites show a high reliance on quartz/quartzite, in pebble form, which was reduced using the bipolar technique then subsequently flaked and retouched (Willoughby 1996a, 1996b). This is a similar pattern to that seen in the Middle Pleistocene of France, where local quartz and sedimentary pebbles were transported whole and reduced by a variety of techniques including discoid, unipolar, and bipolar flaking (Byrne 2004).

Although LSA assemblages at Mlambalasi and Magubike also correlate with the Mbeya LSA assemblages to a certain degree in that there is a high reliance on quartz/quartzite that was reduced using the bipolar technique; it deviates in that the cryptocrystalline materials, including cherts, were not difficult to obtain thus were utilized in the same expedient manner as quartz and quartzite.

It is of no surprise that quartz and quartzite are the most abundant raw materials used in Iringa as they are ubiquitous across the modern Iringa landscape. Outcrops are frequently encountered and would likely have been highly visible to foraging humans owing to the color and lustre (white and vitreous) of quartzite in contrast to the surrounding sediment (dull and orange-red). Despite quartz and quartzite being seen as a relatively poor quality raw materials by modern knappers, they readily fracture producing sharp, usable edges requiring little to no retouch to serve as functional edges. The other varieties are of higher quality but are less abundant on the landscape, and therefore perhaps not as useful.

Brantingham et al., (2000) argue that raw material quality is an important, but not an absolute, constraint on the development of sophisticated, formal tool production strategies. Instead, biogeographic, adaptational, or behavioral processes exclusive from the effects of raw material quality are proposed as providing explanation for the absence of prepared, formal core technologies in a region. Using thin-sections to examine percent crystallinity, average crystal size, range of crystal size and abundance of impurities, Brantingham et al., (2000) suggest that the scale of occurrence of these mineralogical variables had an impact on the workability of stone materials.

Figure 8.13 illustrates the quality of Iringa Region toolstones, or lithic raw materials that were used in tool production, based on their microscopic properties. At Mlambalasi there does not seem to be preferential selection of higher quality raw materials whereas at Magubike there does, albeit to a relatively small degree. In particular the MSA assemblages at Magubike contain a greater number of higher quality raw materials than what is seen in any other assemblage at Magubike or Mlambalasi. This presents a number of possibilities: first, that access to high quality raw materials decreased over time or second, that the technological strategy of LSA peoples did not require high quality toolstone.

This first point, that access to high quality lithic sources changed over time, can be attributed to a number of causes. Distance between source and location of use, which is interconnected with mobility and portability (Newman 1994), is an important material constraint. "Distance is a measure of time and effort costs of acquiring raw material" (Hayden 1989:10). These costs have direct implications for tool production and, hence, technological strategies. The distance from site to source plays an important role in determining the material (variety and amount) that will be found at a site. Generally, the closer to the site is to the source, the greater the amount of material from that source (Torrence 1986:105-106). Most other models suggest an exponential and proportional fall-off in quantity when compared to distance. The relationship between distance and use is directly related to concepts of value and labour, which can be referred to in terms of work, investment, or effort. As the amount of labour involved increases, the likelihood that some other, closer source instead will be used increases (Torrence 1986:119). Additionally, natural barriers and seasonal and technological constraints must also be considered. This occurs because the measured distance from site to sources is not the key variable – ease of procurement depends not only on distance but also upon ease of travel and social distance (Feder 1981). This is referred to as "effective distance" (Renfrew 1977:72). Effective distance takes into account natural barriers to trade and exchange (mountains, deserts, large bodies of water) as well as technological factors (e.g., without watercraft, waterways and bodies of water are a barrier, but serve to facilitate movement for those groups who have watercraft technology) and cultural elements (Feder 1981). The presence of well established networks of trade and exchange serve to lessen the effective distance (Feder 1981:195). Thus natural and socio-political barriers could have served to increase the effective distance between the sites and high quality raw material sources for LSA populations in Iringa.

Procurement is directly influenced by raw material availability and mobility. Because moderate to high quality raw materials were readily available locally, MSA and LSA populations in Iringa did not need to have a highly mobile lifeway at least from the perspective of raw material procurement. In the case of the Iringa Region, the high variability found in MSA assemblages does not suggest the incorporation of several sources into seasonal movements but rather the richness of local resources.

In general, the frequency of exotic or non-local material types should rise with greater mobility or exchange (Beck and Jones 1990). Trade and exchange can mean much the same thing when referring to material goods. However, exchange has a wider meaning used to describe all interpersonal contacts (exchange of non-material goods, i.e., information). In the absence of exchange, populations moving greater distances would come into contact with, and have access to, more sources than less mobile populations (Beck and Jones 1990:284). Direct procurement refers to the situation where the user of the raw material goes directly to its source without the intervention of any exchange mechanism and costs are measured in terms of the time and energy expended on the journey (Morrow and Jefferies 1989:30). With both trade and exchange and direct procurement, non-local raw material utilization should reflect the greater costs of their acquisition – differential usage compared to that of local raw materials. In general, non-local lithics acquired through these means of procurement should reflect curated usage. As all materials recovered from assemblages at Magubike and Mlambalasi appear to be local sources, it would be difficult to suggest that the trade and exchange of lithic raw materials occurred. Other than the presence of Levallois technique in the MSA, there is no attempt to conserve raw material. Bipolar technology predominates in all of the MSA, LSA, and IA assemblages. Again this is likely the result of quality toolstones being abundant locally.

Size grade distribution of raw materials for each site illustrates that the properties of the toolstones greatly impacts the type of reduction strategy that can be employed (Figure 8.16). Finer grained raw materials were reduced much smaller than coarser grained materials as viable microlithic tools could be produced from greatly reduced cores to the point of exhaustion.

Table 8.27: Lithic raw material types found in Iringa Region.

Sedimentary	Igneous	Metamorphic
Conglomerates	Appinite	**Amphibolite**
Limestone	Bostonite	Epidosite
	Diorite	Gneiss
	Dolerite	Granulite
	Gabbro	Hornfels
	Granite	Migmatite
	Granodiorite	Phyllite
	Granophyre	Phyllonite
	Hornblendite	**Quartzite**
	Lamprophyre	Schist
	Lavas	Serpentinite
	Monzonite	
	Pyroxenite	
	Syenite	
	Tonalite	
	Trondhjemite	
	Tuffs	

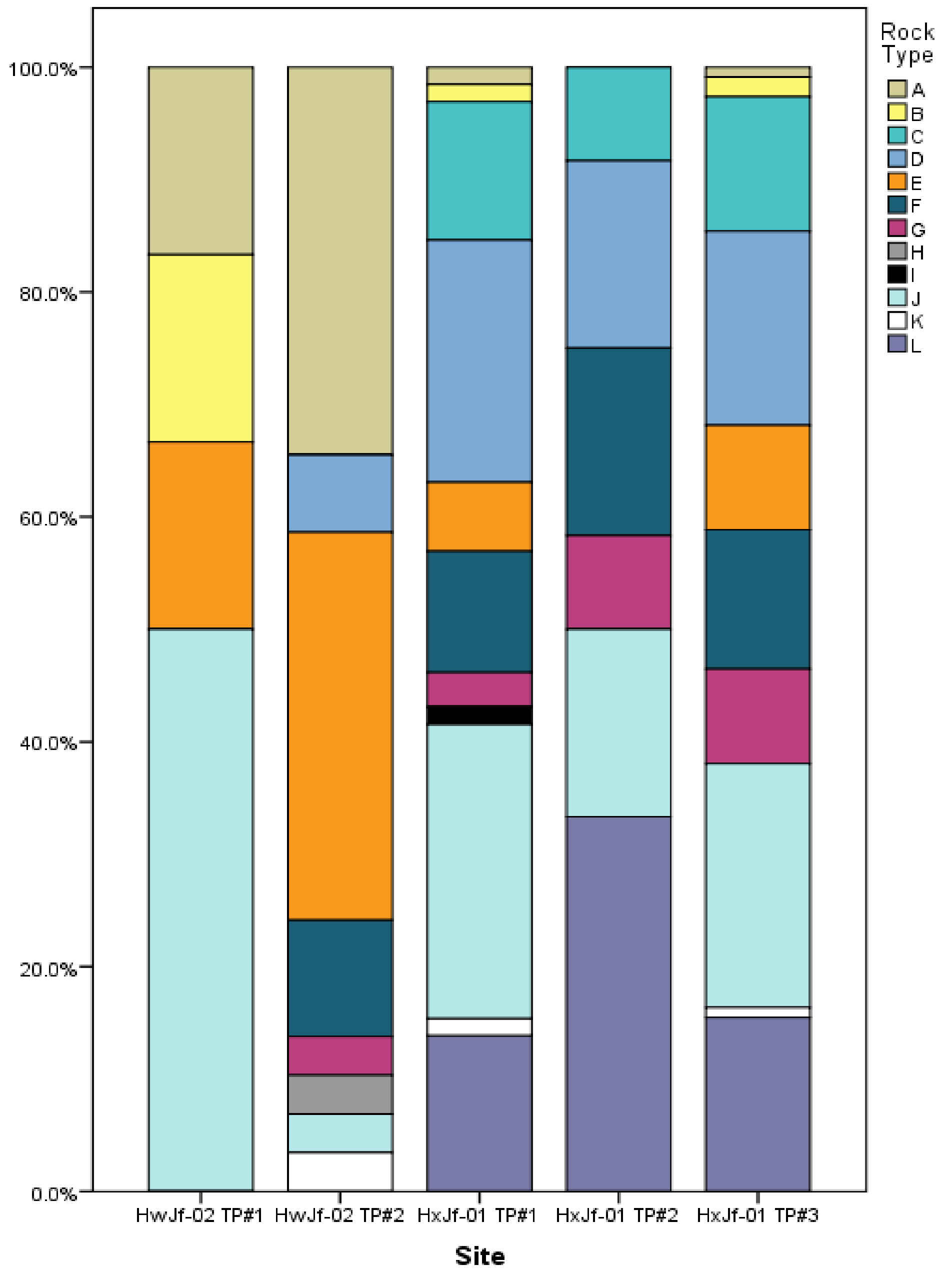


Figure 8.14; Distribution of Iringa Region non-chert raw material types by site as determined by microscopic analysis. Refer to Appendix B for the descriptions of these raw material types.

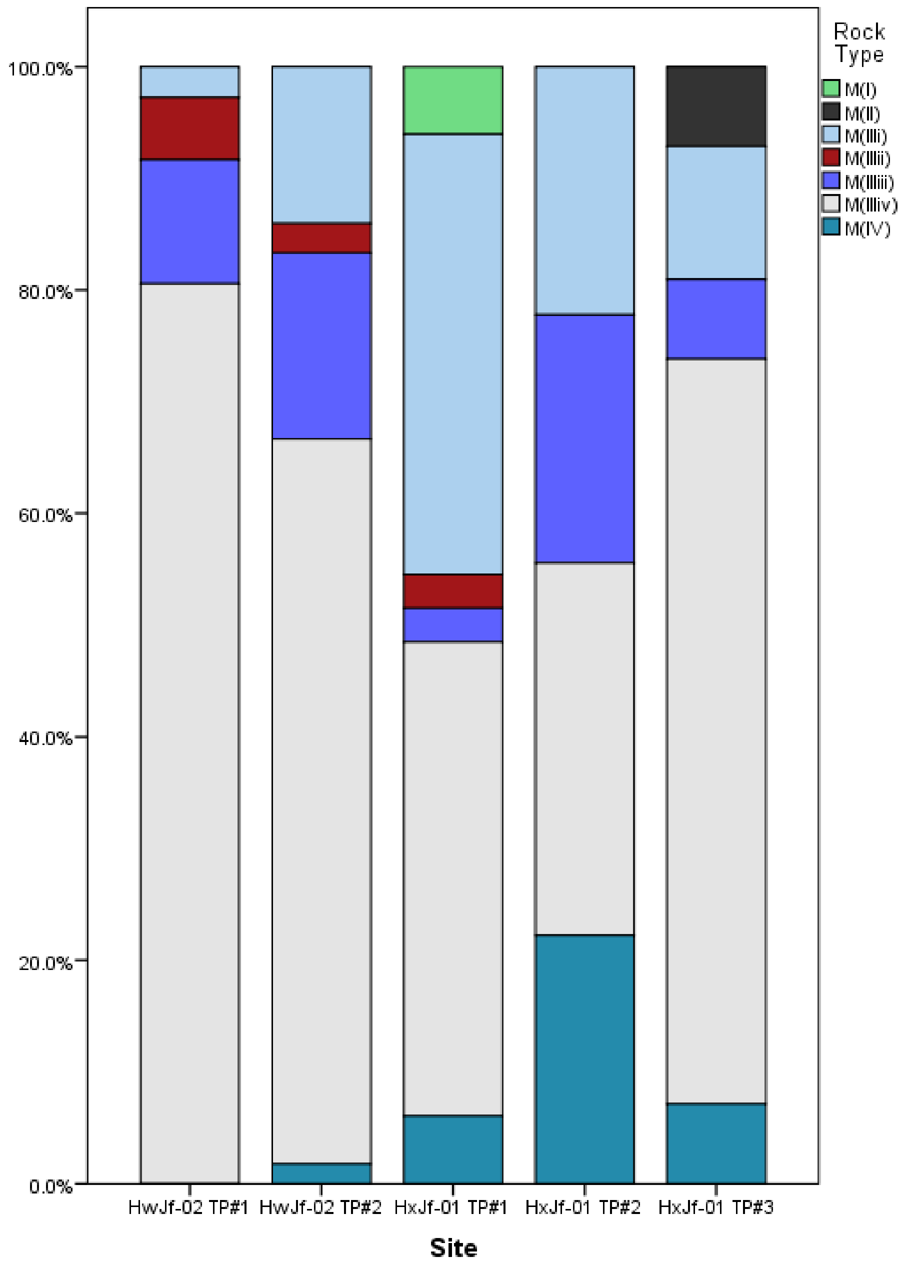


Figure 8.15: Distribution of Iringa Region chert types by site as determined by microscopic analysis. Refer to Appendix B for the descriptions of these chert types.

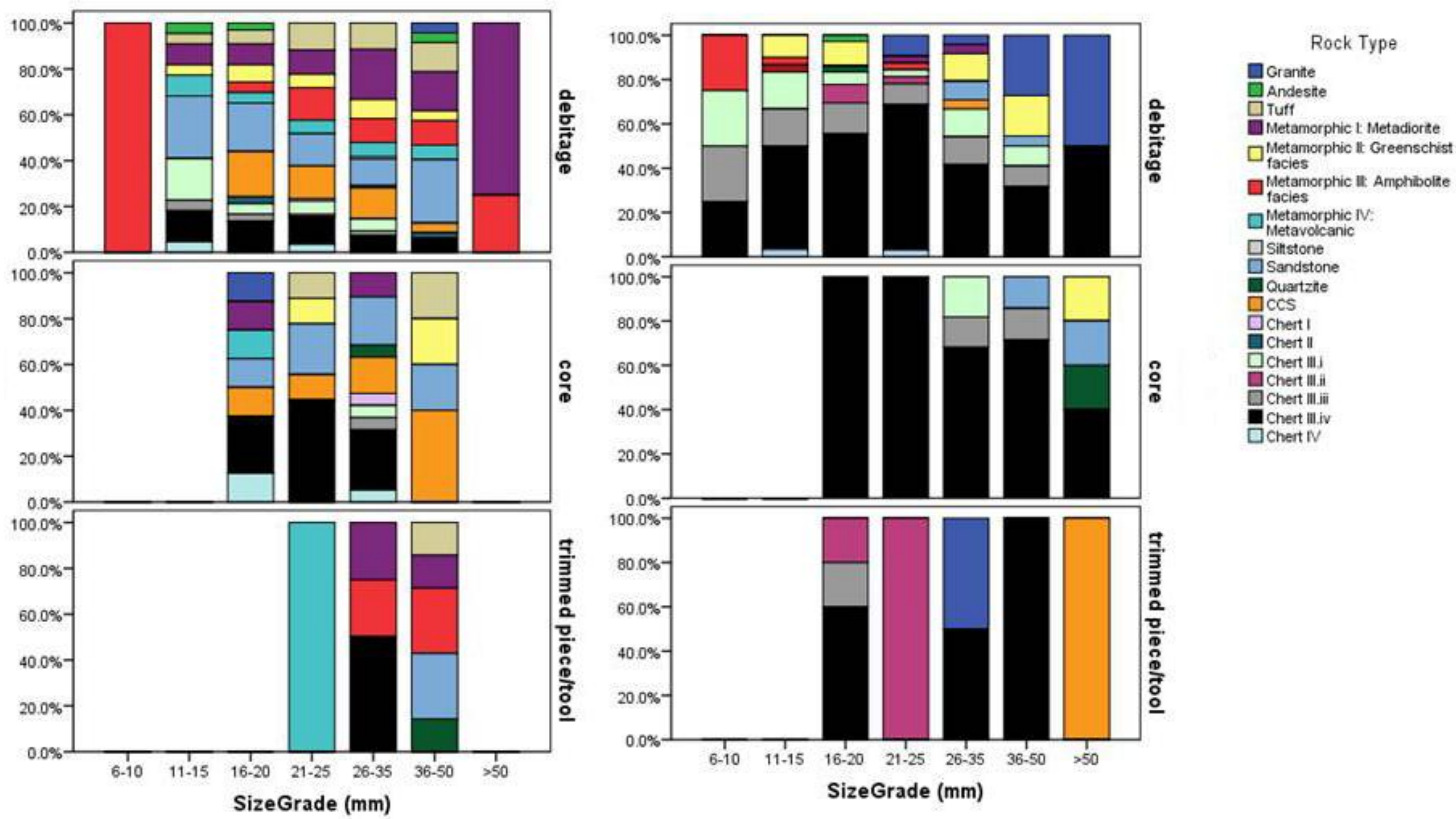


Figure 8.16: Size grade distribution for artifacts from both sites. Left: Mlambalasi. Right: Magubike.

8.5.2 Organization of Technology and Chaîne Opératoire

As indicated previously, the chaîne opératoire represents the different stages of tool production beginning with the acquisition of raw materials through to the discard or abandonment of the end product. Figure 8.17 presents a generalized chaîne opératoire for Iringa region. The dotted lines indicate the kinds of interpretations that can be made from the various parts of the operational sequence. Figures 8.18 - 8.20 indicate and compare the interpretations from Mlambalasi and Magubike for the Iron Age, LSA and MSA respectively. The differences seen in the operational sequences reflect the different social structures and subsistence strategies employed during the different cultural periods.

The spread of iron production to southern Tanzania appears after the entry of Bantu or Iron Age communities involved in iron smelting, ceramic manufacturing, farming and animal keeping (Msemwa 2004). The direct association of Iron Age materials and microlithic tools suggests that iron smelters and gatherer communities would have coexisted in Iringa, the alternative being trade between iron smelters and hunting communities (Bushozi 2011). The Iron Age lithic assemblages at both Mlambalasi and Magubike are not diagnostic technologically but instead are characterized by this association with iron smithing and smelting materials and pottery.

The association of stone tools with faunal remains at Mlambalasi suggests that lithic tools would have been made and used to perform a wide variety of activities during both the LSA and MSA. The faunal assemblage is poorly preserved and was difficult to interpret because of the mixed/combined cultural units (Collins 2009). However, the lithic assemblage does provide some information in terms of human behavior. A wide variety of tools were made, maintained, used, and discarded at the shelter. Although difficult to ascertain from our test excavations, it is likely these activities occurred over multiple occupations with considerable time separating each period of occupation. This is suggested by the wide range of dates obtained from both sites. As previously mentioned, understanding the post-depositional, taphonomic processes at the sites will be focused upon during future excavations at the sites.

Points are poorly represented in LSA assemblage which Bushozi (2011) suggests is an indication that they were not favoured by LSA foragers. Instead backed pieces were preferred, which would have been used as insert for spears and/or arrows (Ambrose 2002; Lombard 2007; Phillipson 1980; Wadley et al., 2009). The presence of patterned platform and peripherally cores at Mlambalasi indicates inherited and shared technological traits with LSA and MSA foragers (Bushozi 2011).

The Iron Age faunal assemblage at Magubike clearly indicates that the site was a campsite where small sized animals were brought whole to be consumed (Collins 2009). However, the LSA faunal assemblage at Magubike was too small and the MSA are too poorly preserved to produce any significant interpretations. Collins (2009:220) does tentatively suggest that there was diversification of meat resources during the LSA and the MSA assemblage suggests an unbiased procurement strategy.

Poor preservation of faunal remains is typical of MSA assemblage in Sub-Saharan Africa (McBrearty and Brooks 2000; Mehlman 1989). Bushozi (2011) argues that this trend of poor preservation in MSA assemblage has obscured our understanding of prehistoric hunting behavior. We do know despite the poor preservation that the Magubike MSA faunal assemblage included not just mammals but molluscs (mainly *Achatina*), birds, reptiles, and turtles. This suggests that MSA foragers used a wide range of wild food resources (Collins 2009). Today *Achatina* snails provide a substantial food resource to hunter and gatherers of northern Tanzania (Bushozi 2011).

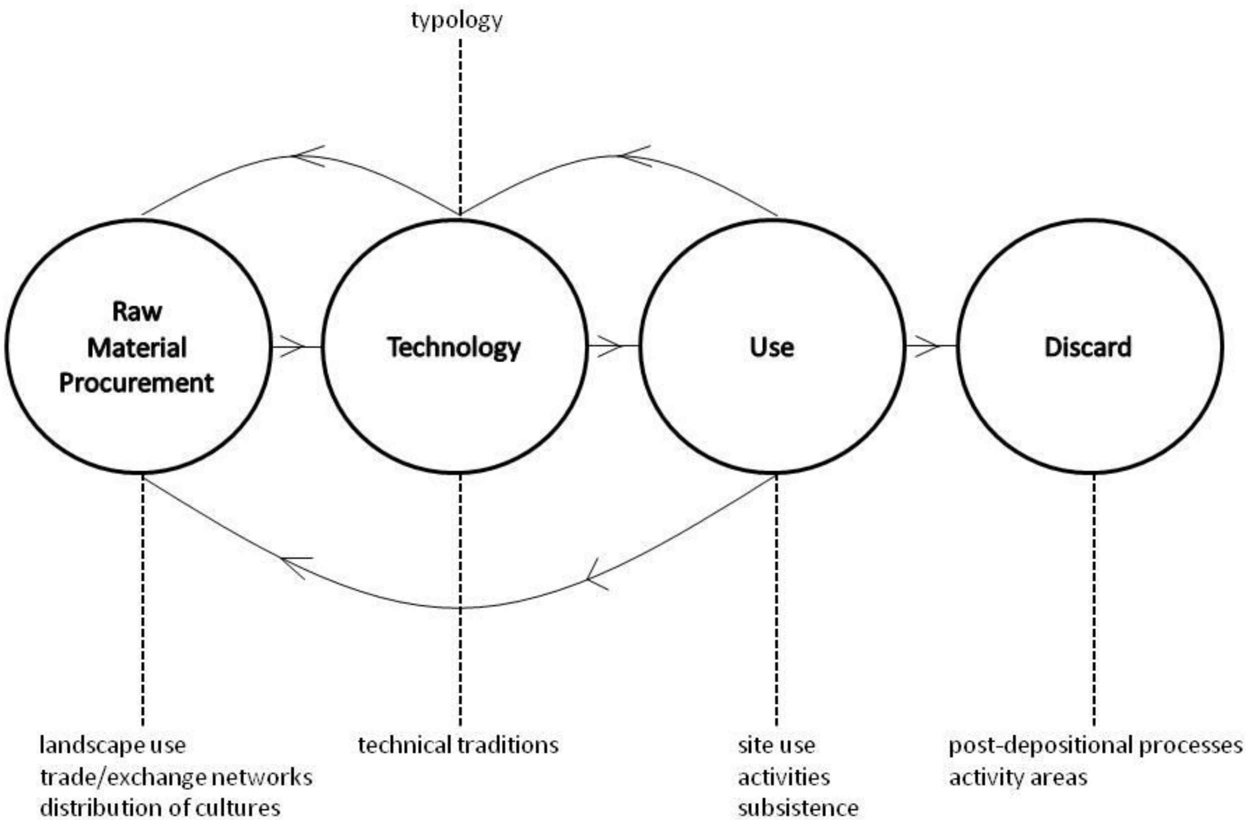


Figure 8.17: Generalized chaîne opératoire (adapted from Grace 2011).

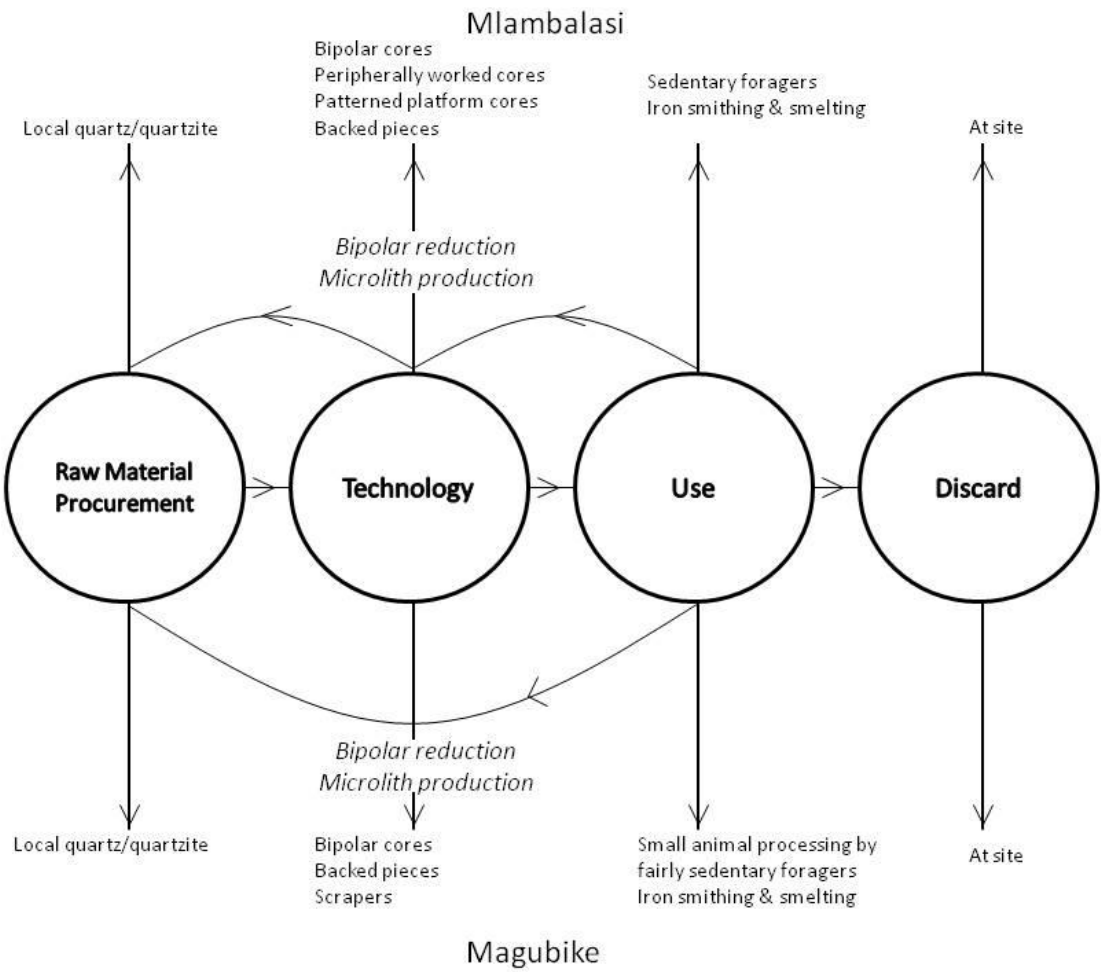


Figure 8.18: Chaîne opératoire for the Iron Age at Mlambalasi and Magubike.

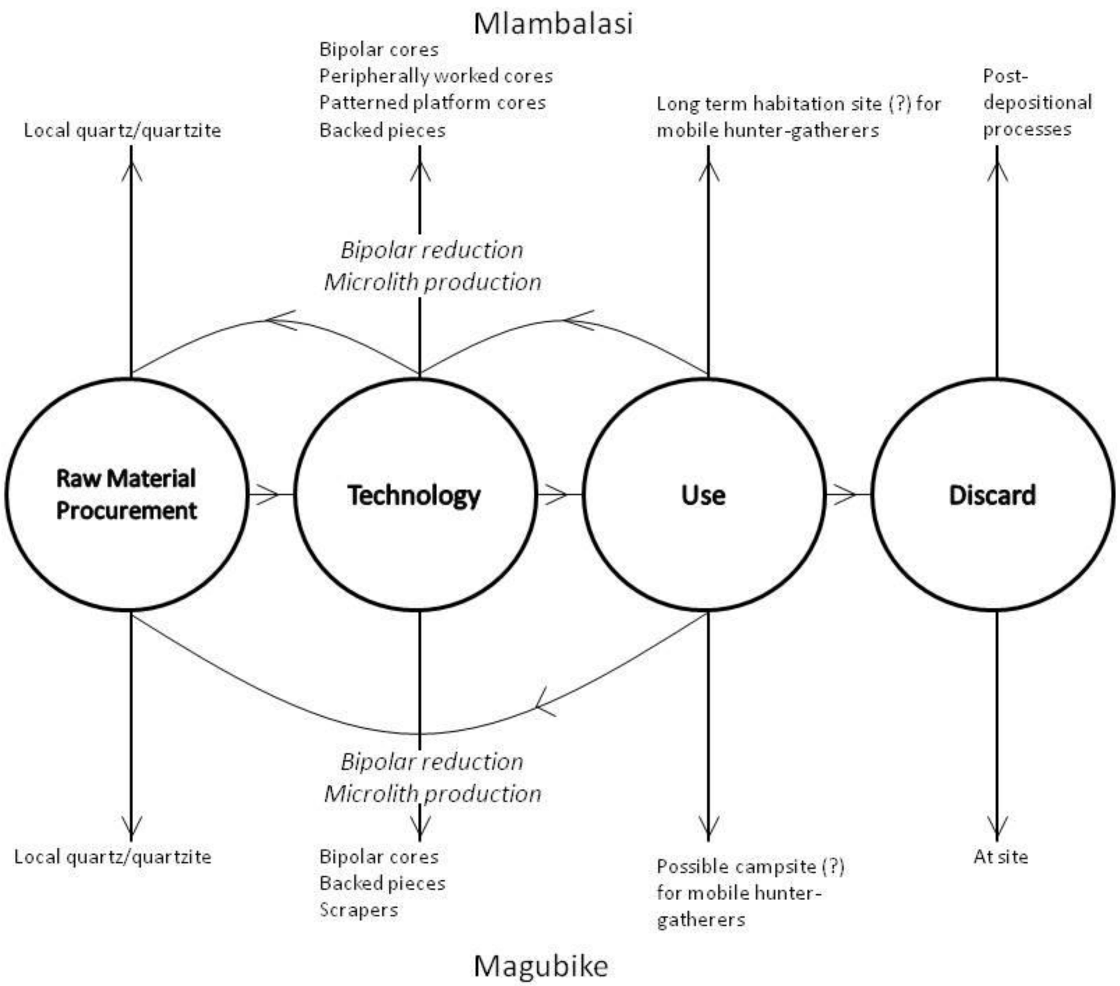


Figure 8.19: Chaîne opératoire for the LSA at Mlambalasi and Magubike.

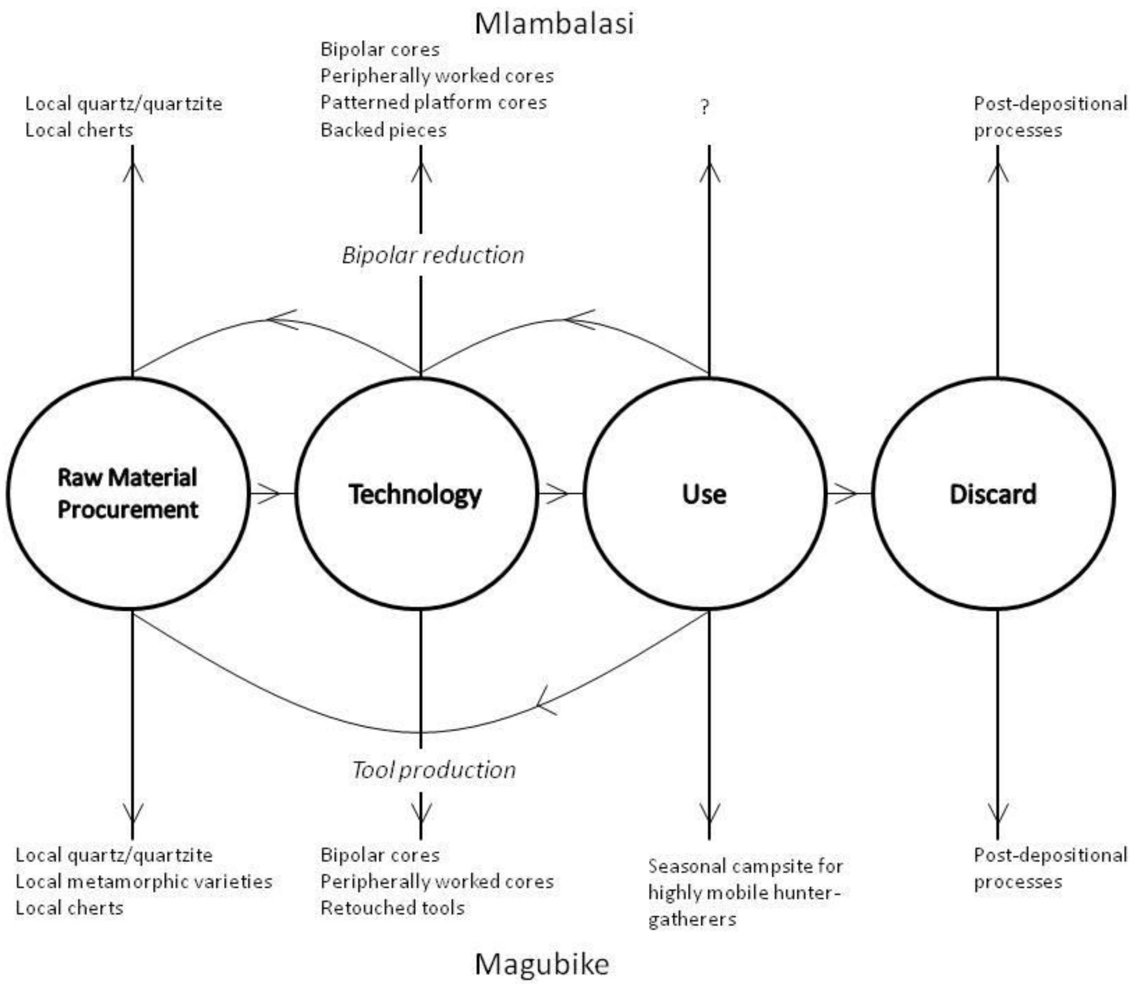


Figure 8.20: Chaîne opératoire for the MSA at Mlambalasi and Magubike.

8.6 Comparison of Iringa Data with Other Sites in Tanzania

Peripherally flaked cores are generally associated with the MSA as they are the product of a radial flaking method that was a widely used characteristic of that period, but bipolar and platform cores are also found in MSA assemblages. Generally, platform cores are indicative of LSA technology as they are usually associated with the classic blade and bladelet technology of the LSA. Bipolar technology is not characteristic of any period; instead it reflects raw material constraints such as size, availability, abundance, and quality. At Mumba and Nasera, the MSA assemblage is dominated by peripheral and prepared platform cores (Mehlman 1989). In contrast, the MSA assemblage at Magubike has fewer peripheral, amorphous, and prepared core platform cores represented compared to the bipolar ones. A similar trend for the dominance of bipolar cores in surface MSA and LSA assemblages was recorded in the Songwe River Valley.

As for tool types, the production of backed microliths is associated with the LSA and later technocomplexes, and scrapers are the dominant tool type in MSA assemblages. The proportion of backed pieces to scrapers can therefore indicate whether an assemblage belongs to the MSA or a later period such as the LSA. According to Mehlman (1989), backed pieces outnumber scrapers in Holocene LSA assemblages, and in earlier industries, scrapers are the dominant tool type. Points, bifacially modified pieces, and heavy duty tools are also more common in the MSA. Alexander (2010:86) argues that “the high number of backed pieces at Magubike presents an interesting question given other possible indicators of cultural change that suggest these oldest layers belong to the MSA, that is, the presence of Levallois technology.” This is likely explained by the flow of water through the deposit resulting in the downward displacement of these small sized artifacts. There is other evidence for significant water activity throughout the site notably in the heavy cementation of calcium carbonate on the surface of artifacts. This cementation frequently coated the entire surface of the artifacts, which had serious implications when it came to identifying raw material type as well as it prevented the examination of the attributes of the rock. Attempts to remove this cement with vinegar and dilute acid solutions were unsuccessful.

Furthermore, the downward movement of small artifacts may have been additionally promoted by the disintegration of the underlying bedrock caused by the movement of subsurface water. As the bedrock breaks down, there would be mixing of overlying deposits. Bioturbation by small rodents and roots would have caused the displacements of artifacts and may have assisted in the physical weathering of the bedrock and overlying strata.

In terms of raw material selection and use, the Iron Age at both Magubike and Mlambalasi is very similar. The use of raw materials during the LSA at Mlambalasi and Magubike are very similar. However, LSA raw material use at Magubike is more similar to that for the MSA within the same site than it is to other LSA assemblages in Iringa and northern Tanzania. Raw material use at Mlambalasi during the LSA is very similar to that found in the MSA assemblages at Mumba. In terms of raw material use, the MSA at Magubike is similar to what was documented in the Songwe MSA assemblages.

The similarities and differences with other sites in Tanzania is likely the result of the distribution of lithic raw material sources and the availability, accessibility and quality of the materials. All of the chert from Nasera is of lacustrine varieties, the nearest sources of which are nodules either 30 km away in Bed I and II at Olduvai Gorge or 60 km away to the east/northeast on the slopes of Lake Natron (Mehlman 1989:28). These ranges are similar to what is expected for Iringa Region; therefore; the use of chert should be similar between them as well.

Table 8.28: Comparison of maximal artifact distribution with other sites. Adapted from Alexander (2010:94).

	Tool	Core	Debitage
HwJf-02 Iron Age	63.8	10.1	26.1
HwJf-02 IA + LSA	59.8	7.8	32.4
HwJf-02 LSA	64.6	17.4	18.0
HwJf-02 LSA+MSA	55.0	10.9	34.1
HxJf-01 Iron Age	43.7	18.5	37.8
HxJf-01 LSA	48.9	21.6	29.5
HxJf-01 LSA+MSA	45.6	15.4	39.0
HxJf-01 MSA	27.3	10.0	62.7
Songwe[1] LSA	15.6	3.6	80.8
Songwe[2] MSA	22.5	16.7	57.8
Mumba[3] LSA	4.4	6.7	88.9
Mumba LSA/MSA	4.1	14.6	81.3
Mumba MSA	13.2	24.6	62.2
Nasera[3] LSA	3.9	7.1	89.0
Nasera LSA/MSA	3.8	6.5	89.7
Nasera MSA	5.6	3.1	91.3

[1]Garcin (2006) and Sipe (2000)
[2]Miller (1993)
[3]All Mumba and Nasera data is from Mehlman (1989)

Table 8.29: Comparison of Iringa Region raw material distribution with other sites (%). Adapted from Alexander (2010:93).

	Quartz	Quartzite	Rock Crystal	Volcanic	Obsidian	Lava	Metamorphic/ Igneous	Chert	Other
HwJf-02 Iron Age	69.6	6.2	9.3	0	0	0	1.3	13.6	0
HwJf-02 IA + LSA	70.9	2.8	14.3	0	0	0	1.3	10.7	0
HwJf-02 LSA	70.8	4.1	17.7	0	0	0	0.4	6.8	0.1
HwJf-02 LSA+MSA	71.6	3.4	20.8	0	0	0	0.4	3.7	<0.1
HxJf-01 Iron Age	71.5	4.3	9.1	0	0	0	6.5	8.6	0
HxJf-01 LSA	44.0	11.3	41.2	0	0	0	1.1	2.4	0
HxJf-01 LSA+MSA	54.3	15.2	14.5	0	0	0	8.7	7.3	0
HxJf-01 MSA	39.2	7.4	1.7	0	0	0	34.1	17.5	<0.1
Songwe[1] LSA	60.8	24.4	0	1.5	0	0	0	13.3	<0.1
Songwe[2] MSA	46.2	15.4	0	8.5	0	0	0	25.3	4.4
Mumba[3] LSA	92.7	2.9	0	0	0.1	0.6	0	3.5	0.2
Mumba LSA/MSA	88.5	5.9	0	0	<0.1	1.4	0	4.1	0.1
Mumba MSA	77.9	10.0	0	0	0	4.5	0	4.8	2.7
Nasera[3] LSA	89.3	0.4	0	0	1.4	<0.1	0	8.2	0.7
Nasera LSA/MSA	94.2	<0.1	0	0	0.6	<0.1	0	3.9	1.3
Nasera MSA	82.0	.01	0	0	0.8	0.2	0	14.8	2.1

[1]Garcin (2006) and Sipe (2000)
[2]Miller (1993)
[3]All Mumba and Nasera data is from Mehlman (1989)

8.7 Summary

The results of the technological analysis when combined with those from the raw material analyses provide a clear picture of raw material selection and use in Iringa Region. Even without having source information the technological analysis supports the conclusion that the lithic raw materials used in tool production at Magubike and Mlambalasi were available locally. Although a preference for a particular raw material (i.e., high quality ones) can be suggested for some tool types (i.e., specialised tools such as becs or burins), in general expedient reduction using the bipolar technique was used regardless of raw material characteristics or desired end product.

Combining the technological data with that of the raw material analyses allows for a clear distinction between the MSA and LSA and the MSA and Iron Age components of Magubike and Mlambalasi. The ability to do this is especially important at Mlambalasi where most of the MSA type artifacts were recovered from a disturbed context as previously mentioned. Unfortunately, separating the Iron Age from the LSA at both sites is not as clear. At Mlambalasi the Iron Age/LSA division is mainly constructed using the radiocarbon dates obtained for samples from both contexts, and the other artifact types associated with the lithics including pottery and faunal remains. Above I argue that the size grade distribution does allow for some separation between the Iron Age and LSA but more importantly, it demonstrates the presence of a microlithic and a macrolithic LSA. Future analysis of recently (2010) excavated materials from Mlambalasi should help clarify these issues.

Chapter 9: Discussion and Conclusion

9.1 Introduction

Originally the intent of this research was to delineate trade and exchange patterns of lithic raw materials in Iringa Region. Unfortunately this was not possible becaue of two issues encountered over the course of this research. First, detailed descriptions of rock types found throughout the region were not available. I had difficulty obtaining information about the geology of Iringa beyond a couple of publications and some geological maps. This demonstrated that the characterization of the lithic raw material types found in assemblages at sites in Iringa could be an extremely valuable exercise to archaeologists and geologists alike. Raw material analyses included the examination of both macroscopic and microscopic attributes. This allowed for the accurate determination of the raw material type. Although, the source(s) for the artifacts could not be determined, some clues as to potential formation environments were revealed. Additionally, this served to illustrate some of the limitations and strengths of the use of macroscopic and microscopic techniques in MSA/LSA raw material sourcing. As one of the first comprehensive lithic raw material studies conducted on Tanzanian MSA and LSA assemblages, this research provides an important contribution towards understanding the prehistory of Tanzania, East Africa, and modern humans.

The second issue was our inability to find any potential source locations, in particular for the cherts. A month was spent surveying. Limited resources and the complex local geology prevented the discovery of potential sources. As mentioned in previous chapters, the examination of the geological maps suggest that cherts, and all of the raw materials identified, should be available within 50 km of each rockshelter. Despite these issues, this research allows for a basic picture of raw material use and technological organization for Iringa Region to be described. This is the major contribution of this research. A guide, Appendix B, has been created for the description and identification of lithic raw material types found in archaeological assemblages in Iringa Region. This guide will be of use to archaeologists, antiquities officers, secondary school and university students, and geologists in Iringa Region. It will serve to ensure a standardized system is used so that a better picture of raw material use in the region can be established.

9.2 Major Findings of the Research

The major theoretical questions examined in this dissertation were (1) what are the characteristics of modern behavior, and (2) whether or not the MSA tools, and the artifacts found in the associated assemblages at Mlambalasi and Magubike rockshelter, demonstrate these characters. The characteristics of modern behavior were established in Chapter 3 to include, but not be limited to, the gradual development of new lithic technologies, high rate of innovation, diversification in materials used to produce tools, portable and parietal art, long distance trade and exchange including range extension, and symbolic behavior as expressed through ceremony and ritual. I would argue that based on the results of the typological, technological, and raw material analyses in this work, the lithic assemblages from Mlambalasi and Magubike do demonstrate some of the hallmarks of modern behavior. These include the use of new technologies (including blades, microblades, microliths, backed pieces), hafting and composite tools, standardization of formal tool categories, and temporal variation in formal categories. Beads, an indication of symbolic behavior, are found at both sites. If wood or bone tools were produced, poor preservation has restricted their visibility in the archaeological record. Although long distance trade and exchange networks are not evidenced by raw material use in the lithic assemblages, the presence of high quality lithics, which are locally available, would negate the need for long distance trade and exchange.

This dissertation also addressed several questions pertaining to raw material use and organization of technology.

- *What technological (lithic tool production) strategies were utilized at each site as represented in the lithic artifacts recovered?*
- *How was technology organised?*
- *Can technological change be used to explain raw material variability?*
- *Which sources (local, non-local, exotic) were utilized? How were raw materials acquired?*
- *Who were the agents of raw material acquisition, transportation, and utilization? Is their inferred behavior "modern"?*
- *How many types of raw material were utilized at each site?*
- *How were the raw material types utilized?*
- *Were the different raw material types utilized differently?*

Bipolar technology predominates at both sites throughout time. Local raw materials were expediently reduced in this way so raw material was not a major consideration shaping the organization of technology at the sites. The majority of artifacts are scrapers and backed pieces that are easily produced from flakes and blades knocked off of bipolar cores. As technological variability between the Iron Age, LSA, and MSA at both sites is low, this variability cannot be explained in terms of technological change occurring over time.

The Iron Age lithic assemblages at both Mlambalasi and Magubike are not diagnostic technologically but instead are characterized by this association with iron smithing and smelting materials and pottery, a topic which is beyond the scope of this dissertation. At Mlambalasi the distribution of artifact types does not show any striking changes from the MSA to the LSA to the Iron Age. But size grade distribution does suggest a transition towards microliths over time. The association of stone tools with faunal remains at Mlambalasi suggests that lithic tools would have been made and used to perform a wide variety of activities during both the LSA and MSA. The presence of patterned platform and peripherally-worked cores at Mlambalasi indicates inherited and shared technological traits with LSA and MSA foragers.

The Iron Age faunal assemblage at Magubike clearly indicates that the site was a campsite where small sized animals were brought whole to be consumed. Although poorly preserved, the faunal assemblage at Magubike suggests that MSA foragers used a wide range of food resources. At Magubike, backed pieces are still predominant but their presence in the MSA assemblage is likely the result of post-depositional processes as discussed in Chapter 8. Throughout the site, the percentage of debitage relative to the other categories increases with depth, whereas the percentage of tools or trimmed pieces decreases. The Levallois technique was used during the MSA; however, it was not a major component of technological organization, the bipolar technique was more important. This is directly related to raw material considerations: first that good to high quality raw material must have been available locally, and second, that the metamorphic rock varieties used are very hard and would have been difficult to reduce using anything other than the bipolar technique. However, raw material use does seem to be more conservative at Magubike than at Mlambalasi. Finer grained materials were reserved for use in the production of backed pieces while coarser grained materials were used for producing other tools.

There does not seem to be preferential selection of higher quality raw materials at Mlambalasi whereas at Magubike there does albeit to a relatively small degree. In particular the MSA assemblages at Magubike contain a greater number of higher quality raw materials than what is seen in any other assemblage at Magubike or Mlambalasi. This presents a number of possibilities: first, that access to high quality raw materials decreased over time or second, that the technological strategy of LSA peoples did not require the use of high quality toolstones.

Because moderate to high quality raw materials were readily available locally, MSA and LSA populations in Iringa did not need to have a highly mobile lifeway if we just look at it from the perspective of raw material procurement. In the case of the Iringa Region, the high variability found in MSA assemblages does not suggest the incorporation of several sources into seasonal movements but rather the richness of local resources.

Assumptions and Test Expectations Revisited

The following assumptions and test expectations were presented in Chapter 5. The results of this research suggest assumption III is correct. Assumption III states that if there is pronounced assemblage variability, in terms of the quality of and procurement effort towards obtaining the raw material types utilized, group mobility would still be high. This reflects a need for planning and flexibility, which may be necessary adaptations for dealing with differential access to raw material sources. Access to sources may vary because of changes in season, landscape, or sociocultural/ sociopolitical interactions with neighbouring groups. Access to resources is a strong constraint on group mobility. If assumption III is valid, assemblage variability will be high. Assemblage composition will vary proportionally depending on the duration of occupation and/or number of reoccupations. Reduction strategies will illustrate diversity with diagnostic attributes. A full range of reduction sequences is expected. Both non-standardized (informal) and standardized (formal) tools will occur.

Some additional assumptions were presented with respect to expectations of differences between MSA and LSA assemblages and in reference to the assumptions presented above. Most of these assumptions were proven to be correct, or at least were not rejected; what this means is another matter entirely. The MSA assemblages are characterized by flake and blade tools; however, they were not produced using the Levallois technique. MSA assemblages are largely composed of locally acquired materials used expediently. Conversely, LSA assemblages are characterized by microlithic technology. Microlithic technology is associated with conservation of raw material and the systematic production and retouch of standardized objective pieces. Although it is expected that there will be a greater amount of exotic raw materials in the LSA assemblage, this is not true for Magubike and Mlambalasi likely owing to the presence of high quality locally available materials.

Overall, it was expected that there is greater intra-assemblage variability than inter-assemblage variability; i.e., there should be greater disparity between MSA and LSA assemblages within a single site than there should be for MSA assemblages at both sites or for LSA assemblages at both sites. This assumption was true for Magubike but cannot be definitively stated for Mlambalasi. This is because of the disturbed/mixed context of MSA artifacts recovered from test pit #2.

9.3 Implications of Research

Ultimately provenance studies can only answer two simple but very crucial questions: is the material local, and what is the true source of the material? This research allowed for the conclusion that the lithic raw materials are local; however, the actual source(s) of the material could not be found. Although this information is useful, one of the larger goals of this research is to answer the question why? Why are particular sources selected over others? Is it location, convenience, quality, ease of access or access restrictions? I have argued that the selection of raw materials in Iringa occurred because moderate to high quality lithics were abundantly available within 50 km of the rockshelters. They were easily accessed either through direct procurement at the source or indirect procurement via secondary sources like river cobbles. Trade rights and prestige goods do not appear to be a contributing factor to organization of technology or lithic raw material selection, use, and procurement in Iringa.

It was important to discover that the lithic raw materials used in tool production were locally available because this has two major ramifications. First, the exclusive use of local materials during the MSA would suggest the absence of long distance trade and exchange patterns but as this pattern continues throughout the LSA this more likely means that long distance trade and exchange networks were not necessary for the acquisition of suitable and/or high quality raw materials. Or this could mean that long distance trade and exchange networks were not utilized for the acquisition of *lithic* raw materials. They may have served another, equally important purpose such as solidification of kin networks.

As Goldman-Neuman and Hovers (2009:73) point out, "unless the raw materials exploited at a given locality are conspicuously exotic to a site's immediate surroundings…it is assumed in most studies that cobbles were collected from the closest river bed." This follows assumptions that early humans adopted "least effort solutions" to the problem of obtaining lithic raw material (Goldman-Neuman and Hovers 2009:73). This assumption proves to be correct for MSA and LSA humans in Iringa Region.

The pattern of raw material use seen in Iringa is not dissimilar to that seen for sites like Mumba and Nasera in Northern Tanzania, and sites in Mbeya Region further south. However, these similarities and differences with other sites in Tanzania are likely the result of the distribution of lithic raw material sources and the availability, accessibility and quality of the materials. This work therefore illustrates the necessity of ongoing material-centered research in Tanzania and East Africa owing to its role in understanding modern human behavior. Despite the exclusive use of local raw materials, the technological choices made by the producers of the lithic assemblages at Magubike and Mlambalasi reflect a level of sophistication one would only expect with behaviorally modern humans.

Minichillo (2006:363), applying a time-dependant foraging model, argues that there although there is a general pattern of long distance and exchange, there is also local intensification and of a mosaic of approaches during the MSA that as a whole is fully modern. Based on the results of this research, I would agree with this argument and further suggest that Iringa presents the ideal region in which to understand the significance of local intensification versus long distance trade and exchange during the MSA.

9.4 Problems with/Limitations of Research

The interpretation of the assemblages from both Magubike and Mlambalasi are complicated by a number of issues. Two major issues which must be addressed at both sites include overprinting and post-depositional processes. Overprinting is the repeated use of different locations in a landscape (Doelman 2008). Overprinting combined with post-depositional disturbance can make it difficult to isolate each use of a site or source location. There is significant evidence from both sites, in terms of the concretions on artifacts, mixed typological contexts, and other stratigraphic indicators such as erosion down slope, which suggest there is subsurface water movement at Magubike and Mlambalasi. These post depositional processes also have implications in terms of identifying the raw material types. According to Rapp and Hill (1998:135), attempts to

> assign artifactual materials to a particular geologic deposit have two inherent problems: 1) it must be established that the artifact has not undergone any chemical or physical alteration that would invalidate direct comparison of it with the same component material from known deposits, and 2) all potential source deposits must be adequately represented in the database for a confident assignment of provenance on the basis of chemical or physical patterning.

Physical alteration of the artifacts through chemical weathering is evident. Patination is quite advanced on some of the artifacts and many have a large amount of cement on their surface obscuring their macroscopic properties. Hammer (1976:11) argues "it would be better not to know which particular material is involved than to misclassify it."

The analysis of the cherts and metavolcanics in this study act as a good illustration of the importance of accurate material definition. Artifacts are readily identified as chert by archaeologists yet the implications of this determination are often not recognised. The metamorphic, mainly metavolcanic, varieties were initially identified as volcanic. This incorrect assumption led to problems when trying to identify potential sources; we were looking in all the wrong places. Additionally, there was a disconnect between macroscopic and microscopic properties. This was further obfuscated by my own lack of expertise concerning rock types/morphologies and geologic processes in our study region.

Luedtke (1979:750-752) identifies three types of errors that are possible with identification procedures. As these relate to misidentifying members within and between sources, inadequate characterization of the sources themselves, and incorrectly assigning artifacts to particular sources, these are not directly relevant to this study. Nevertheless they do provide some insight into some potential problems with my research. First, because some of the rock types do have overlapping qualities, it is possible that I have incorrectly assigned individual artifacts to a rock type. Second, as there is no source data available, it is likely that some, if not all, of the subtypes actually represent variations within a single formation. Finally, as the sources are unknown, the types I have constructed could be misleading. It is likely that they may not represent true geological formations. Until potential source samples are acquired, application of these types should be exercised with caution.

9.5 Ongoing and Future Research

As repeatedly mentioned, extensive survey in 2008 was unable to identify any potential outcrops of these materials. Although surface samples were taken from other sites in the region (Table 6.1), time and budgetary constraints did not allow for their analysis. Exotic raw materials may therefore be in other assemblages in Iringa which must be investigated. Further it is not possible at this time to determine if raw materials from other, older sites like Isimila were recycled for use by later peoples. The recycling of MSA lithics has been seen at other sites in East Africa.

The characterization and description of lithic raw material sources in region (including examination of thin sections used to create original geological maps) including analysis of samples collected from other sites in the region (Table 6.1) and those from Mbeya sites (Table 6.2) will lead to a clearer picture of raw material utilization in the region and southern Tanzania in general. Appendix D contains sample forms which can be used in site and source surveys. Field sampling issues must be accounted for in the research design to help ensure samples taken are representative and adequate for precise and efficient results. Beardsley and Goles (2001:594) found that a "thorough sampling of geological deposits and quarrying debris, along with a relatively large number of laboratory or analytical specimens drawn from the sample, is necessary to achieve a baseline of information" on variability of and between source rocks. Only after this baseline data is compiled can "attributions of artifact-to-source can be made relative to social, political and economic issues of importance within the archaeological record" (Beardsley and Goles 2001:594). Therefore, once this baseline data are constructed, we can then return to artifact-centered or material-centered source analysis.

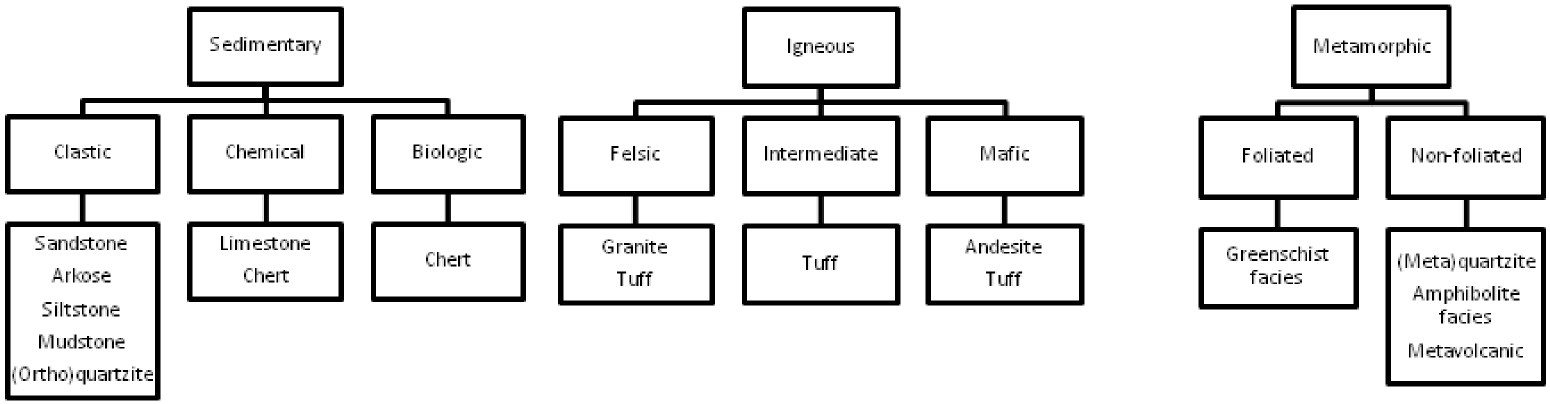
In order to identify the most probable provenance of the toolstones found in assemblages at Magubike and Mlambalasi, all the outcrops in the region which contain similar rock types (QDS maps 196, 197, 214, 215, 232, 233, and 234) should be considered to compare their macroscopic and petrographic features with those of the artifacts. Chemical analyses (EMPA analysis of minerals in polished thin sections and of potential outcrop samples) should also be conducted once potential source outcrops are obtained. A source sampling strategy will be developed which will account for intra and intersource variability. The use of high powered, non-destructive, chemical analytical techniques such as portable XRF would greatly benefit the future study of Iringa Region toolstones, but also for existing museum collections for other regions. Portable XRF would also aid in the analysis of potential source outcrops as in field measurements can occur which would cut down on the number of samples that would physically have to be taken and then transported to laboratory facilities elsewhere. The initial cost of a portable XRF unit may be cheaper in the long term than the transport, processing, and analysis of samples. Although portable XRF has distinct advantages, there are significant limitations with the technique for true quantitative analysis.

Another possible direction following the location of potential sources would be the experimental replication of artifact-types using outcrop samples. This would demonstrate whether or not the potential toolstones can be reduced, modified, and used in a comparable way as those found in the assemblages. Refit analysis of the artifacts from the sites would provide a valuable means of comparison with the replication experimental data.

This study, as with many others concerning raw material characterization, was initiated out of a need to determine precisely what lithic materials were used in tool production (and how this varies in space and time), and from where these materials were collected. True to form, the first objective was more easily realized than the second. A simplified classification scheme for lithic raw materials in Iringa Region was produced (Figure 9.1) which provides a summary of the more detailed descriptions provided. Chemical analyses, once source samples are acquired, may be necessary however I hesitate to comment too much on their application as this is specific to the rock type itself.

The potential heat treatment of a selected chert subtype at Mlambalasi must be further explored. I was able to identify and refit a number of flakes with potlid fractures with the potlids themselves. They all appear to be of the same variety of chert and have other macroscopic attributes (lustre and color change) suggestive of heat treatment. I elected to not examine these artifacts in thin section but this and chemical analyses of these suspect artifacts should occur in the future. McCutcheon (1997) would be a good model to follow.

Analysis of the materials recovered in the 2008 test excavations at Magubike and the 2010 excavation of Mlambalasi is currently ongoing. A full scale excavation of Magubike rockshelter is being planned for 2012 which will focus on the recovery of additional MSA human remains, a comprehensive dating strategy, and understanding the post-depositional processes impacting the MSA component of the site. Further I am beginning to lay the groundwork for the Cultural Heritage in Iringa Research Program (CHIRP) which will engage local communities in the interpretation and development of archaeological knowledge.



	Colour	Texture	Minerals
Sandstone	variable	fine to medium	quartz
Arkose	variable	medium	quartz
Siltstone	brown	fine	+quartz -clay
Mudstone	black	fine	-clay
Orthoquartzite	white to greyish to pink	fine to coarse	+quartz -feldspar
Limestone	variable (grey)	cryptocrys talline	+calcite -silica
Chert	variable	cryptocrys talline	silica

	Colour	Texture	Minerals
Granite	variable; white to pink to grey	coarse	+quartz -feldspar
Andesite	light to dark grey	fine to porphyritic	+quartz -pyroxenes or amphiboles
Tuff	variable; light grey to black	porphyritic to vesicular	+quartz -feldspar (altered)

	Colour	Texture	Minerals
Metadolerite	greyish to greenish	medium	+feldspar +quartz -pyroxenes
Metavolcanic	dark; greenish to greyish to black	fine to medium	+feldspar +quartz -pyroxenes
Greenschist	dark; greenish	fine to coarse	+feldspar +quartz -pyroxenes -amphiboles
Amphibolite	dark; greyish to greenish	fine to coarse	+amphiboles +feldspars -pyroxenes
Metaquarzite	white to greyish to pink	fine to coarse	+quartz -feldspar

Figure 9.1: A classification scheme for Iringa Region raw materials.

9.6 Summary of Research and Conclusions

Originally this study was meant to source raw materials allowing for the inference of mobility patterns and resource use in Iringa Region. Because of a number of problems recounted above, the focus of my research changed to the description and characterization of raw material types found in lithic assemblages at Mlambalasi and Magubike. In 2006, 11,537 lithic artifacts were excavated from Mlambalasi. Of those 11,537, 1088 were analyzed for technological and macroscopic attributes. Of these 1,088, 215 thin sections were prepared for microscopic analysis. In 2006, 20,060 lithic artifacts were excavated from Magubike. Of those 20,060, 6139 of these were analyzed for technological and macroscopic attributes. Of these 6139, 618 thin sections were prepared for microscopic analysis. This allowed for the accurate description of a total of 7227 artifacts using macroscopic analysis and 634 of these 7227 using microscopic analysis. This resulted in the definition of ten lithic raw material types.

This dissertation illustrates the successful application of macroscopic and microscopic analyses in lithic raw material characterization. Macroscopic attributes useful in this regard for all raw material types include color, patina, lustre, and texture; while speckling, mottling, banding, and translucence proved most effective for separating the various chert subtypes, as well as cherts in general from cryptocrystalline silica (CCS). Texture is the most useful microscopic attribute. The limitations and advantages of this two part petrographic approach has been discussed, and evaluated in regard to their successful utilization through the provision of insight into the understanding of the utilization of raw materials. Unfortunately the biggest limitation of future applications of this methodology is that few archaeologists and curators are willing to use destructive techniques when non-destructive ones are available.

This study has contributed to the understanding of Stone Age archaeology in Tanzania specifically the previously understudied southern region of Iringa. A contribution has been made in terms of theoretical approach as well as methodology. By approaching the lithic assemblages from an organization of technology and chaîne opératoire perspective, a more precise picture of human behavior was obtained. Issues of choice of a specific technological strategy in terms largely emphasised the role of raw material availability. Although it proved difficult to explore technological decisions beyond raw material, the theoretical groundwork for examining material culture as representation of social structure and ideology has been laid.

Finally, this research should be considered as a pilot study. It is the first to provide a comprehensive and detailed characterization of lithic raw materials in Tanzania and the first where a comprehensive picture of raw material use is provided. A detailed and accessible guide to lithic raw material description has been constructed, in the form of Appendix B, which will be of value to archaeologists, antiquities officers, students, and government officials in Iringa Region, Tanzania. I view Appendix B as the major contribution of this work. Although there is much more work required on lithic raw materials and their sources in Iringa Region, this study has proven that it is absolutely necessary if we are ever to obtain a clear understanding of the development of modern human behavior in East Africa.

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APPENDIX A: CODEBOOK

1. Site

    Mlambalasi

    (100) HwJf-2 room 1
    (101) HwJf-2 room 2
    (102) HwJf-2 slope
    (103) HwJf-2 slope and room 1
    (104) HwJf-2 outside shelter
    (105) HwJf-2 tp1
    (106) HwJf-2 tp1 - remove rock at 85 cm
    (107) HwJf-2 tp1 south wall cleaning
    (108) HwJf-2 tp1 wall
    (109) HwJf-2 east of tp1
    (110) HwJf-2 tp1 rock removal
    (111) HwJf-2 tp2

    Magubike

    (112) HxJf-1
    (113) HxJf-1 tp1
    (114) HxJf-1 tp2
    (115) HxJf-1 tp3
    (116) Walk to HxJf-2
    (117) HxJf-2
    (118) HxJf-4 (above HxJf-2)
    (119) Walk back from HxJf-2
    (120) HxJf-3

    Kitelewasi

    (121) HxJh-1

2. Case # (for each site)

    0001 to n

3. Level

    (00) surface
    (01) 0-5 cm
    (02) 5-10 cm
    (03) 0-10 cm
    (04) 10-15 cm
    (05) 15-20 cm

(06) 10-20 cm
(07) 0-20 cm
(08) 20-25 cm
(09) 25-30 cm
(10) 20-30 cm
(11) 30-35 cm
(12) 35-40 cm
(13) 30-40 cm
(14) 20-40 cm
(15) 40-45 cm
(16) 45-50 cm
(17) 40-50 cm
(18) 45-55 cm
(19) 50-55 cm
(20) 55-60 cm
(21) 50-60 cm
(22) 60-65 cm
(23) 65-70 cm
(24) 60-70 cm
(25) 70-75 cm
(26) 75-80 cm
(27) 70-80 cm
(28) 80-85 cm
(29) 85-90 cm
(30) 80-90 cm
(31) 90-95 cm
(32) 95-100 cm
(33) 90-100 cm
(34) 100-105 cm
(35) 105-110 cm
(36) 100-110 cm
(37) 90-110 cm
(38) 110-115 cm
(39) 115-120 cm
(40) 110-120 cm
(41) 120-125 cm
(42) 125-130 cm
(43) 120-130 cm
(44) 130-135 cm
(45) 135-140 cm
(46) 130-140 cm
(47) 140-145 cm
(48) 145-150 cm
(49) 140-150 cm
(50) 150-155 cm
(51) 155-160 cm

(52) 150-160 cm
(53) 160-165 cm
(54) 165-170 cm
(55) 160-170 cm
(56) 170-175 cm
(57) 175-180 cm
(58) 170-180 cm
(59) 180-185 cm
(60) 185-190 cm
(61) 180-190 cm
(62) 190-195 cm
(63) 195-200 cm
(64) 190-200 cm
(65) 200-205 cm
(66) 205-210 cm
(67) 200-210 cm

4. Cultural Designation

(00) not known
(01) ESA
(02) MSA
(03) LSA
(04) Neolithic
(05) Iron Age
(06) ESA + MSA
(07) MSA + LSA
(08) LSA + Neolithic
(09) LSA + Iron Age
(10) Neolithic + Iron Age
(11) LSA, Neolithic + Iron Age
(12) MSA, LSA, Neolithic + Iron Age
(13) MSA and Iron Age
(14) MSA, LSA and Iron Age

TYPOLOGY

5. Stone artefact general category

(01) trimmed pieces (tools)
(02) core
(03) debitage
(04) non-flaked stone (includes ground stone)

6. Tool type (subset of 5)

TOOLS
(01) scraper
(02) backed pieces
(03) points/perçoirs
(04) burins
(05) bifacially modified pieces
(06) becs
(07) composite tools
(08) outils écaillés
(09) heavy duty tools
(10) others

CORES
(11) peripherally worked core
(12) patterned platform
(13) intermediate
(14) bipolar
(15) amorphous

DEBITAGE
(16) angular fragments
(17) specialised flakes
(18) flakes
(19) blades
(20) Levallois flakes

NON-FLAKED
(21) hammerstones
(22) anvil stones
(23) pestle rubbers
(24) polished axes
(25) stone discs
(26) sundry ground/polished
(27) manuports

7. Tool subtype (subset of 6)

SCRAPERS (01)

(000) not applicable
(001) small convex scraper
(002) convex end scraper
(003) convex double end scraper
(004) convex end and side scraper
(005) circular scraper
(006) nosed end scraper
(007) convex side scraper
(008) convex double side scraper
(009) nosed side scraper
(010) sundry end scraper
(011) sundry double end scraper
(012) sundry end and side scraper
(013) sundry side scraper
(014) sundry double side scraper
(015) concave scraper
(016) concavity
(017) notch
(018) sundry combination scraper
(019) convex end + concave combination scraper
(020) convex side + concave combination scraper
(021) divers scraper
(022) convergent scraper
(023) scraper fragment

BACKED PIECES (02)

(024) crescent
(025) triangle
(026) trapeze
(027) curved backed piece
(028) straight backed piece
(029) orthagonal truncation
(030) oblique truncation
(031) angle-backed piece
(032) divers backed
(033) backed awl/drill/perçoir
(034) backed fragment

POINTS (03)

(035) unifacial point/perçoir
(036) alternate face/edge pt/perçoir
(037) bifacial point

BURINS (04)
- (038) dihedral burin
- (039) angle burin
- (040) mixed/other burin

BIFACIALLY MODIFIED PIECES (05)
- (041) discoid
- (042) point blank
- (043) bifacially modified piece

BECS (06)
- (044) becs

COMPOSITE TOOLS (07)
- (045) sundry composite tool
- (046) burin + other composite tool
- (047) backed + other composite tool
- (048) scraper + other composite tool

OUTILS ECAILLES (08)
- (049) outils écaillés

HEAVY DUTY TOOLS (09)
- (050) core/large scraper
- (051) biface/pick
- (052) core chopper

OTHER (10)
- (053) sundry modified
- (054) cutting edge
- (055) bulbar thin/talon reduced
- (056) tool fragment

CORES
PERIPHERALLY WORKED (11)
- (057) part-peripheral core
- (058) radial/biconic core
- (059) disc core
- (060) Levallois core

PATTERNED PLATFORM (12)
- (061) pyramidal/prismatic single platform core
- (062) divers single platform core
- (063) single platform core/core scraper
- (064) opposed double platform core
- (065) opposed double platform core/core scraper

(066) adjacent double platform core
(067) adjacent double platform core/core scraper
(068) multiple platform core

INTERMEDIATE (13)
(069) platform/peripheral core
(070) platform/peripheral core/core scraper
(071) platform/bipolar core
(072) platform/bipolar core/core scraper
(073) bipolar/peripheral

BIPOLAR (14)
(074) bipolar core
(075) bipolar core fragment

AMORPHOUS (15)
(076) amorphous/casual

DEBITAGE
ANGULAR (16)
(077) core fragment
(078) angular fragment
(079) trimmed/utilized angular fragment
(080) blade segment-medial or distal
(081) trimmed/utilized blade segment

SPECIALISED FLAKES (17)
(082) plain burin spall
(083) tool spall

FLAKES (18)
(084) whole flake
(085) trimmed/utilized flake
(086) flake talon fragment
(087) trimmed/utilized flake talon fragment

BLADES (19)
(088) whole blade
(089) trimmed/utilized blade
(090) blade talon fragment
(091) trimmed/utilized blade talon fragment

LEVALLOIS FLAKES (20)
(092) Levallois flake
(093) trimmed/utilized Levallois flake

NONFLAKED STONE
HAMMERSTONES (21)
ANVIL STONES (22)
PESTLE RUBBERS (23)
POLISHED AXES (24)
STONE DISC (25)
SUNDRY (26)
MANUPORTS (27)

TECHNOLOGICAL ATTRIBUTES

8. Fracture
  - (01) conchoidal
  - (02) conchoidal to subconchoidal
  - (03) wedging/bending
  - (04) irregular/blocky

9. Size grade
  - (01) < 5 mm
  - (02) 6 – 10 mm
  - (03) 11 – 15 mm
  - (04) 16 – 20 mm
  - (05) 21 – 25 mm
  - (06) 26 – 35 mm
  - (07) 36 – 50 mm
  - (08) > 50 mm

10. Core completeness
  - (00) not applicable
  - (01) complete
  - (02) incomplete

11. Debitage completeness
  - (00) non applicable
  - (01) debris
  - (02) complete flake/blade
  - (03) proximal flake/blade
  - (04) distal/medial flake/blade
  - (05) split flake

MACROSCOPIC ANALYSIS

12. General rock type

(00) unknown
(01) igneous
(02) metamorphic
(03) sedimentary

12.1 Igenous rock classification: attributes

1. Igneous rock type
   (01) Rhyolite
   (02) Granite
   (03) Andesite
   (04) Basalt
   (05) Diorite
   (06) Dolerite
   (07) Granodiorite
   (08) Micrognanite
   (09) Phonolite
   (10) Lamprophyre
   (11) Other

2. Color
   (01) dark: dark gray to black; rare light minerals
   (02) intermediate: white to black ratio ~ 50%
   (03) light: white, gray, pink; black minerals rare

3. Grain size (Texture)
   (01) glassy: obsidian
   (02) vesicular: cellular; full of holes; may be light weight
   (03) aphantic (fine): no crystals visible; uniform
   (04) phaneritic (coarse): crystals visible to naked eye
   (05) porphyritic: two grain sizes
   (06) fragmental: volcanic fragments cemented together

4. Lustre:
   (01) dull
   (02) waxy
   (03) vitreous
   (04) earthy
   (05) dull to vitreous
   (06) dull to waxy
   (07) dull to earthy
   (08) vitreous to waxy
   (09) vitreous to earthy

(10) earthy to waxy
(11) chalky
(12) resinous
(13) resinous to waxy
(14) waxy to chalky
(15) dull to chalky
(16) vitreous to chalky

12.2 Metamorphic rock classification: attributes

1. Metamorphic rock type
    (01) Slate
    (02) Phyllite
    (03) Schist
    (04) Amphibolite
    (05) Gneiss
    (06) Hornfels
    (07) Marble
    (08) Quartzite
    (09) Greenschist
    (10) Blueschist
    (11) Serpentinite
    (12) Eclogite
    (13) Granulite
    (14) Migamatite
    (15) Other

1.1 Metamorphic rock sub-type
    (01) Meta I (C)
    (02) Meta II (D)
    (03) Meta III (E)
    (04) Meta IV (F)
    (05) Meta V (G)

2. Color
    (01) dark: dull, opaque
    (02) intermediate: many colors, may be banded
    (03) light: translucent, pale

3. Grain size (Texture)
    (01) fine
    (02) coarse
    (03) medium

4. Lustre
    (01) dull

(02) waxy
(03) vitreous
(04) earthy
(05) dull to vitreous
(06) dull to waxy
(07) dull to earthy
(08) vitreous to waxy
(09) vitreous to earthy
(10) earthy to waxy
(11) chalky
(12) resinous
(13) resinous to waxy
(14) waxy to chalky
(15) dull to chalky
(16) vitreous to chalky

5. Micas: presence/absence of biotite and/or muscovite
(00) absent
(01) present: sparse
(02) present: abundant

6. Foliated
(00) no
(01) yes

12.3 Sedimentary rock classification: attributes

1. Sedimentary rock type
(01) Mudrocks
(02) Sandstones
(03) Conglomerates
(04) Limestones
(05) Dolomites
(06) Chert
(07) CCS (cryptocrystalline silicate)
(08) Other

1.1 Sedimentary rock sub-type

MUDROCKS

(01) Siltstone
(02) Mudstone
(03) Claystone

CONGLOMERATES

(04) Oligomictic
(05) Polygomictic

CHERT
- (06) I
- (07) II
- (08) III
- (09) IV
- (10) V
- (11) VI

1.2 Chert III subtypes
- (01) IIIi
- (02) IIIii
- (03) IIIiii
- (04) IIIiv

2. Color
   - (01) dark: grey, green, black common
   - (02) intermediate I: pink and red common
   - (03) intermediate II: brown to dark brown
   - (04) light: white to tan common
   - (05) intermediate III: grey to blue-grey
   - (06) other

3. Grain size (Texture): Wentworth Scale
   - (01) clay (1/256 mm) or silt (1/256 – 1/6 mm) (microscopic)
   - (02) sand (1/16 – 2 mm)
   - (03) granule (2 – 4 mm)
   - (04) pebble (4 – 64 mm)
   - (05) cobble (64 – 256 mm)
   - (06) boulder (> 256 mm)

4. Grain shape: Sphericity
   - (00) not identifiable
   - (01) prismoidal
   - (02) subprismoidal
   - (03) spherical
   - (04) subdiscoidal
   - (05) discoidal

5. Grain shape: Angularity/roundness
   - (00) not identifiable
   - (01) very angular
   - (02) angular
   - (03) subangular
   - (04) subrounded
   - (05) rounded

(06) well rounded

6. Sorting
   - (00) homogeneous
   - (01) very well sorted
   - (02) well sorted
   - (03) moderately sorted
   - (04) poorly sorted
   - (05) very poorly sorted

12.3.I Siliceous rock (Chert, CCS) classification: attributes

7. Mottling
   - (00) absent
   - (01) present

8. Speckling
   - (00) absent
   - (01) present

9. Banding or striped
   - (00) absent
   - (01) present

10. Lustre
   - (01) dull
   - (02) waxy
   - (03) vitreous
   - (04) earthy
   - (05) dull to vitreous
   - (06) dull to waxy
   - (07) dull to earthy
   - (08) vitreous to waxy ("glossy")
   - (09) vitreous to earthy
   - (10) earthy to waxy
   - (11) chalky
   - (12) resinous
   - (13) resinous to waxy
   - (14) waxy to chalky
   - (15) dull to chalky
   - (16) vitreous to chalky
   - (17) dull to resinous
   - (18) dull to waxy to vitreous

11. Translucence
(00) absent
(01) present

12. Patination: This attribute refers to an alteration in color and texture on the surface of the chert resulting from chemical and physical (mechanical) weathering processes (Eley and von Bitter 1989:6). Because these weathering processes affect the impurities in the chert and these impurities are characteristic to different formations, patination can be seen as a suitable attribute for chert type differentiation, despite its subjective nature.
(00) absent
(01) light (<50% coverage)
(02) heavy (>50% coverage)

13. Patina color:
(00) absent
(01) white
(02) light buff
(03) buff
(04) yellow
(05) light yellow orange-brown
(06) dark yellow orange-brown
(07) grey
(08) olive grey
(09) reddish brown
(10) light brown
(11) other

14. Inclusions: Inclusions may or may not be visible until the sample is examined under thin section.
(00) absent
(01) present

MICROSCOPIC ANALYSIS

13.1 Igneous rock classification: attributes

1. Igneous rock type
   - (01) Rhyolite
   - (02) Granite (A)
   - (03) Andesite (B)
   - (04) Basalt
   - (05) Diorite
   - (06) Dolerite
   - (07) Granodiorite
   - (08) Microgranite
   - (09) Phonolite
   - (10) Lamprophyre
   - (11) Other

2. Degree of crystallinity
   - (01) Holocrystalline
   - (02) Holohyaline
   - (03) Hypocrystalline
   - (04) Hypohyaline

3. Granularity
   - (01) Phaneritic
   - (02) Aphanitic: microcrystalline
   - (03) Aphanitic: cryptocrystalline

3.1 Absolute Size
   - (01) Fine: less than 1mm
   - (02) Medium: 1 to 5mm
   - (03) Coarse: greater than 5mm

3.2 Relative Size
   - (01) Equigranular
   - (02) Inequigranular

4. Crystal shape/quality/fabric
   - (01) Euhedral
   - (02) Anhedral
   - (03) Subhedral

5. Texture
   - (01) Equigranular

(02) Inequigranular
(03) Oriented, aligned, and directed
(04) Intergrowth
(05) Radiate
(06) Overgrowth
(07) Banded
(08) Cavity

5.1 Subtexture

EQUIGRANULAR
(01) Euhedral granular
(02) Subhedral granular
(03) (Anhedral) Granular
INEQUIGRANULAR
(04) Seriate
(05) Porphyritic: megaphenocrysts, vitrophyric
(06) Porphyritic: megaphenocrysts, fesophyric
(07) Porphyritic: microphenocrysts, vitrophyric
(08) Porphyritic: microphenocrysts, felsophyric
(09) Glomeroporphyritic
(10) Poikilitic
(11) Ophitic
(12) Subophitic
(13) Interstitial
ORIENTED, ALIGNED, AND DIRECTED
(14) Trachytic
(15) Trachytoid
(16) Parallel-growth
(17) Comb
(18) Orbicular
INTERGROWTH
(19) Consertal
(20) Micrographic
(21) Granophyric
(22) Myrmekitic
(23) Intrafasciculate
(24) Lamellar and blubby
(25) Symplectite
RADIATE
(26) Fan
(27) Plume
(28) Spray
(29) Bow-tie
(30) Spherical
(31) Sheaf-like

(32) Radiate
(33) Radial
(34) Axiolitic
(35) Spherulitic
(36) Variolitic

OVERGROWTH

(37) Skeletal or dendritic
(38) Corona
(39) Crystal zoning

BANDED

(40) Banded

CAVITY

(41) Vesicular
(42) Amygdaloidal
(43) Miarolitic
(44) Lithophysa

6. Characterizing minerals
   6.1 Presence/absence of quartz, olivine, and nepheline

   6.2 Type and proportion of feldspars

7. Accessory minerals

8. Volcanic fragments
   (01) Pumice
   (02) Glass shards
   (03) Fiamme (bent and flattened glass)

13.2 Metamorphic rock classification: attributes

1. Metamorphic rock type
   (01) Slate
   (02) Phyllite
   (03) Schist
   (04) Amphibolite
   (05) Gneiss
   (06) Hornfels
   (07) Marble
   (08) Quartzite (K)
   (09) Greenschist
   (10) Blueschist
   (11) Serpentinite
   (12) Eclogite
   (13) Granulite
   (14) Migamatite

(15) Other

1.1 Metamorphic rock sub-type
- (01) Meta I (C)
- (02) Meta II (D)
- (03) Meta III (E)
- (04) Meta IV (F)
- (05) Meta V (G)

2. Crystal shape
   - (01) Porphyroblastic
   - (02) Idioblastic
   - (03) Hypidoblastic
   - (04) Xenoblastic
   - (05) Lepidoblastic
   - (06) Poikiloblastic or sieve
   - (07) Decussate
   - (08) Granoblastic or mosaic
   - (09) Crystalloblastic
   - (10) Nematoblastic
   - (11) Blastoporphryritic
   - (12) Blastophitic

3. Foliation
   - (00) None/absent
   - (01) Present

4. Protoliths
   - (01) Paraprotoliths
   - (02) Orthoprotoliths: ultramafic
   - (03) Orthoprotoliths: Mafic or basite
   - (04) Orthoprotoliths: Pelitic
   - (05) Orthoprotoliths: Carbonate
   - (06) Quartofeldspathic
   - (07) Other

5. Relict textures
   - (01) Igneous
   - (02) Sedimentary
   - (03) Metamorphic

6. Characterizing minerals

7. Retrograde/replacement minerals

8. Accessory minerals

13.3 Sedimentary rock classification: attributes

1. Sedimentary rock type
   - (01) Mudrocks
   - (02) Sandstones (J)
   - (03) Conglomerates
   - (04) Limestones
   - (05) Dolomites
   - (06) Chert (M)
   - (07) CCS (cryptocrystalline silica) (L)
   - (08) Other

1.1 Sedimentary rock subtype

MUDROCKS
- (01) Siltstone (I)
- (02) Mudstone (H)
- (03) Claystone

CONGLOMERATES
- (04) Oligomictic
- (05) Polygomictic

CHERT
- (06) I
- (07) II
- (08) III
- (09) IV
- (10) V
- (11) VI

1.2 Chert III subtypes
- (01) IIIi
- (02) IIIii
- (03) IIIiii
- (04) IIIiv

2. Texture

2A. Clastic

2A.1 Grain size
- (01) Very fine
- (02) Fine
- (03) Coarse
- (04) Very coarse

2A.2. Sorting
- (01) Homogeneous
- (02) Very well sorted

(03) Well sorted
(04) Moderately sorted
(05) Poorly sorted
(06) Very poorly sorted

2A.3 Roundness
(01) Very angular
(02) Angular
(03) Subangular
(04) Subrounded
(05) Rounded
(06) Well rounded

2A.4 Sphericity
(01) Euhedral
(02) Anhedral
(03) Subhedral

2A.5 Packing

2A.6 Orientation
(01) Laminae
(02) Graded
(03) Cross-lamination
(04) Convolute lamination
(05) Imbricate

2A.7 Textural maturity

2A.8 Grain type(s)
(01) Quartz
(02) Feldspars
(03) Lithic fragments
(04) Chert/chalcedony
(05) Volcanic glass/pumice
(06) Micas
(07) Other

2A.9 Matrix
(01) Argillaceous (matrix supported)
(02) Grain supported

2A.10 Cement (authigenic minerals)
(01) Quartz

(02) Chalcedony
(03) Calcite
(04) Other carbonate
(05) Phyllosilicate (clays)
(06) Gypsum, anhydrite
(07) Iron oxide (hematite)
(08) Other

2B. Non-clastic

(01) Crystalline granular
(02) Microcrystalline
(03) Cryptocrystalline

2B.1 Grain types

(01) Lithoclasts
(02) Intraclasts
(03) Extraclasts
(04) Coated grains

2B.1.1 Grain subtypes

COATED GRAINS

(01) Ooids
(02) Oncoids
(03) Cortoids
(04) Peloids
(05) Aggregrate grains and lumps
(06) Skeletal grains (fossils)

2B.2 Texture

(01) Microcrystalline calcite or micrite(mud supported)
(02) Sparry calcite (grain supported)
(03) Megaquartz
(04) Microquartz
(05) Chacedonic (includes spherulitic chalcedony)
(06) Drusy quartz mosaic (DQM)
(07) Microquartz and chalcedonic
(08) Microquartz, chalcedonic and DQM
(09) Microquartz and DQM
(10) Microquartz, macroquartz, and megaquartz

3. Characterizing minerals

4. Accessory minerals

Additional technological attributes recorded by Dr. Pamela Willoughby:

For all artifacts:

14. Length (mm)

15. Breadth (mm)

16. Thickness (mm)

17. Weight (mm)

18. Abrasion
    (01) Fresh
    (02) Worn

For cores:

19. % cortex

20. # of flake scars

For whole flakes/blades and flake/blade tools:

21. Toth flake #
    (01) I: cortical platform and totally cortical dorsal surface. First flake to come off a cobble.
    (02) II: cortical platform, partially cortical dorsal surface. Secondary flakes removed by unifacial flaking.
    (03) III: cortical platform, non-cortical dorsal surface. These flakes can be created by unifacially flaking a cobble if little cortex is left on that face, or by removing flakes from the ventral surface of a flake with cortex on its dorsal surface (the cortex becoming the butt of the flake).
    (04) IV: Non-cortical platform, totally cortical dorsal surface. Normally the first flake to come off the second face of a cobble when beginning bifacial flaking; it can also be produced by starting to unifacially work a flake by removing flakes from a cortical dorsal surface.
    (05) V: Non-cortical platform, partially cortical dorsal surface. Normally the result of bifacial flaking a cobble or unifacially working a flake with cortex on its dorsal surface.
    (06) VI: Non-cortical platform, non-cortical dorsal surface. Produced during later stages of flaking, where cores and flake starting forms have little or no cortex left.
    (07) VII (includes missing for tools): developed by P. Willoughby. Whole flakes that could not be classified in the above categories, usually because the platforms were absent, too small, or punctiform.

22. Platform length (mm)

23. Platform breadth (mm)

24. Platform area (mm^2)

25. Platform angle

26. # of platform facets

27. # of dorsal flake scars

28. Dorsal scar pattern
    (00) unknown
    (01) radial
    (02) same platform, simple
    (03) same platform, parallel
    (04) opposed platform
    (05) travnsverse
    (06) plain
    (07) cortical

For retouched tools only:

29. Planform
    (01) convergent
    (02) parallel
    (03) divergent
    (04) intermediate
    (05) circular
    (06) unknown

30. Angle of retouch

31. Type of retouch
    (01) marginal
    (02) semi-invasive
    (03) invasive

APPENDIX B: Lithic Raw Material Type Characteristics: A Guide to Iringa Region Toolstones

Macroscopic Raw Material Types

1. Granite
2. Andesite
3. Tuff
4. Metamorphic
5. Mudstone
6. Siltstone
7. Sandstone
8. Quartzite
9. CCS
10. Chert

Microscopic Raw Material Types

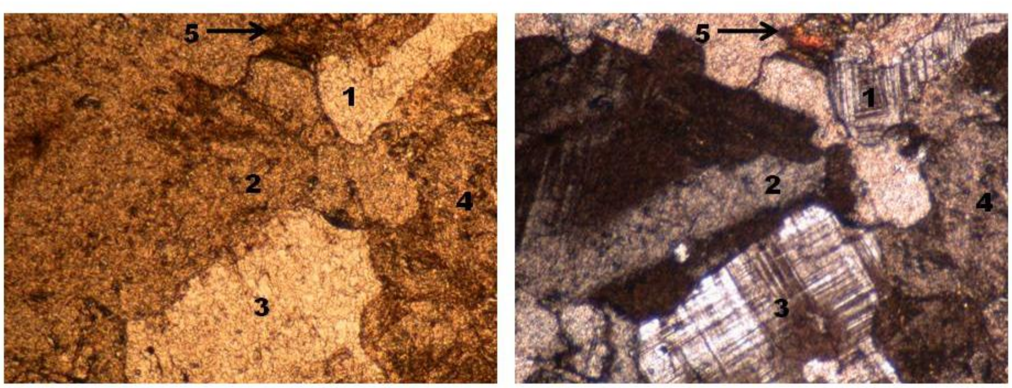
- A. Granite
- B. Andesite
- C. Tuff
- D. Metamorphic I: Metadiorite
- E. Metamorphic II: Greenschist
- F. Metamorphic III: Amphibolite
- G. Metamorphic IV: Metavolcanic
- H. Mudstone
- I. Siltstone
- J. Sandstone
- K. Quartzite
  - a. Orthoquartzite
  - b. Metaquartzite
- L. CCS
- M. Chert
  - a. M.I.
  - b. M.II.
  - c. M.III.
    - i. M.III.i
    - ii. M.III.ii
    - iii. M.III.iii
    - iv. M.III.iv
  - d. M.IV

a – g = unique or unidentifiable rocks

	Macroscopic	Microscopic PPL XPL
A. Granite		
B. Andesite		
C. Tuff		
D-G. Metamorphic		
H. Mudstone		
I. Siltstone		
J. Sandstone		
K. Quartzite		
L. CCS		
M. Chert		

NAME: Granite
MACROSCOPIC CHARACTERISTICS
COLOR: light (white to grey to pink)
PATINA: none
LUSTRE: dull to vitreous
FRACTURE: subconchoidal
TEXTURE: phaneritic, coarse grained
INCLUSIONS: none
KEY CRITERIA: light color, coarse texture
MICROSCOPIC CHARACTERISTICS:
TEXTURE: phaneritic (holocrystalline), granular (subhedral to euhedral)
MAJOR MINERALS: quartz, feldspars (microcline, plagioclase, albite)
MINOR/ACCESSORY MINERALS: biotite
INCLUSIONS: opaques
KEY CRITERIA: granular texture, quartzofeldspathic composition

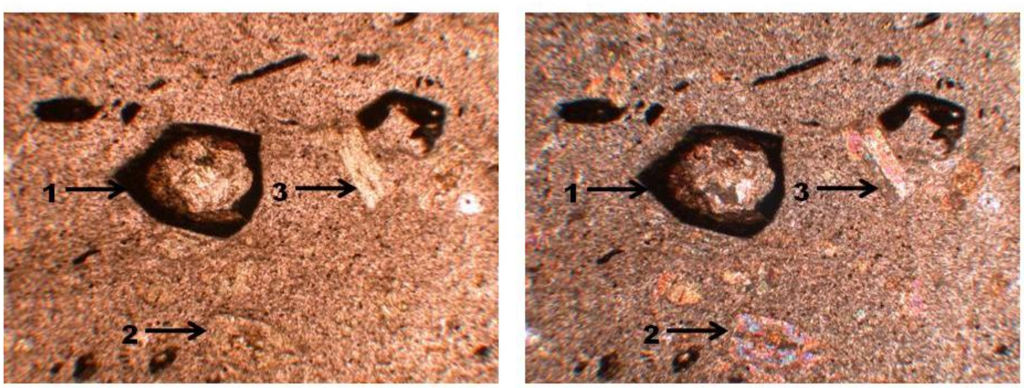
Granite (type 1/A); XCM026.



Microphotograph of XCM026. 40x, PPL (left), XPL (right). 1: Zoned plagioclase feldspar. 2: Twinned plagioclase (albite). 3: Microcline with tartan twinning. 4: Quartz. 5: Biotite.

NAME: Andesite
MACROSCOPIC CHARACTERISTICS
COLOR: light grey to dark grey
PATINA: buff to orange-brown
LUSTRE: dull to vitreous
FRACTURE: subconchoidal
TEXTURE: aphanitic (fine grained) to porphyritic
INCLUSIONS: quartz crystal
KEY CRITERIA: porphyritic texture
MICROSCOPIC CHARACTERISTICS:
TEXTURE: aphanitic (microcrystalline, hypohyaline), porphyritic
MAJOR MINERALS: pyroxenes (clinopyroxene, orthopyroxene) OR amphibole (hornblende)
MINOR/ACCESSORY MINERALS: augite, plagioclase
INCLUSIONS: opaques
KEY CRITERIA: texture – glassy groundmass with large phenocrysts of pyroxene/amphibole; oxidation rims present on some phenocrysts

Andesite (type 2/B); XOF178.



Microphotograph of XOF178. 32x, PPL (left), XPL (right). 1: Phenocryst with oxidation rim. 2: Pyroxene phenocryst. 3:Plagioclase feldspar phenocryst with twinning.

NAME: Tuff

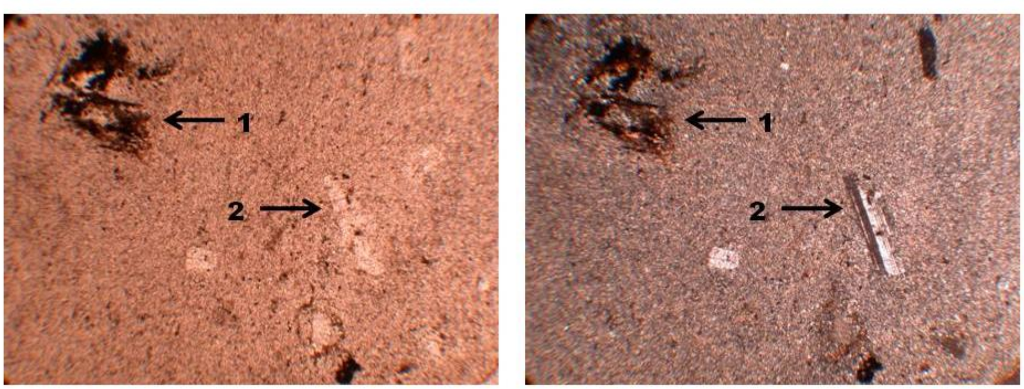
MACROSCOPIC CHARACTERISTICS

COLOR: light grey to blue-grey to greenish grey to dark grey to black
PATINA: rusty
LUSTRE: dull to waxy
FRACTURE: subconchoidal to conchoidal
TEXTURE: porphyritic to vesicular
INCLUSIONS: quartz crystal
KEY CRITERIA: porphyritic texture

MICROSCOPIC CHARACTERISTICS:

TEXTURE: aphanitic (microcrystalline), porphyritic
MAJOR MINERALS: quartz, feldspar (heavily altered)
MINOR/ACCESSORY MINERALS: carbonates, biotite, muscovite
INCLUSIONS: opaques, clay minerals
KEY CRITERIA: porphyritic texture, turbid groundmass, plagioclase phenocrysts

Volcanic tuff (type 3/C); XOF248.



Photomicrograph of XOF248. 32x, PPL (left), XPL (right). 1: Mica (biotite). 2:Plagioclase feldspar phenocryst.

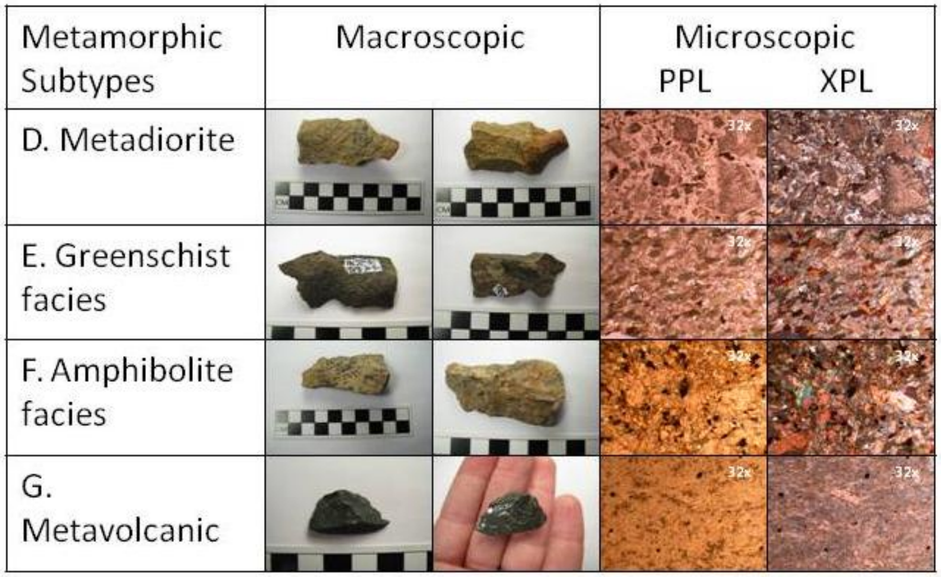
NAME: Metamorphic rock varieties
MACROSCOPIC CHARACTERISTICS:
COLOR: intermediate to dark: light grey to greenish to dark grey to black
PATINA: buff to orangish-brown
LUSTRE: dull to vitreous
FRACTURE: subconchoidal
TEXTURE: aphanitic (fine-grained) to phaneritic (coarse-grained)
INCLUSIONS: none
KEY CRITERIA: dark color, variable grain size

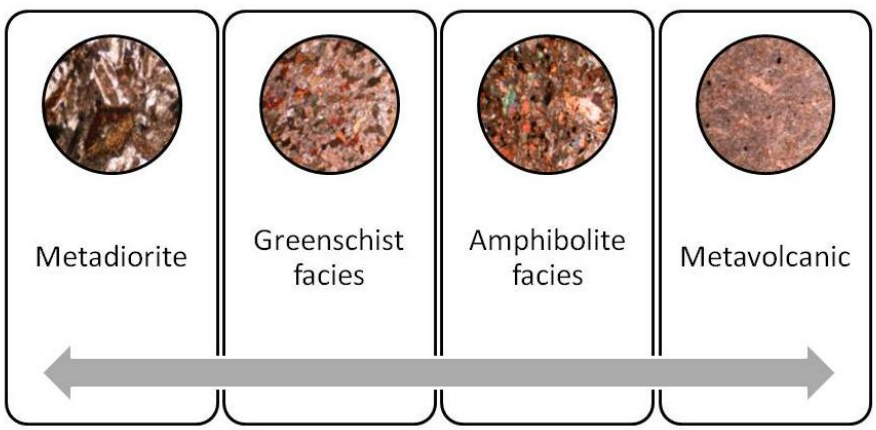
MICROSCOPIC CHARACTERISTICS: Metamorphic I – metadolerite (D)
TEXTURE: aphanitic (macrocrystalline, hypocrystalline), ophitic to subophitic
MAJOR MINERALS: feldspars (heavily altered, likely plagioclase), quartz
MINOR/ACCESSORY MINERALS: green to brownish minerals in ppl with varied birefringence (likely pyroxenes)
INCLUSIONS: opaques
KEY CRITERIA: green in ppl, highly altered feldspar laths

MICROSCOPIC CHARACTERISTICS: Metamorphic II – greenschist (E)
TEXTURE: aphanitic (microcrystalline, hypohyaline), ophitic to subophitic
MAJOR MINERALS: feldspars (heavily altered), quartz
MINOR/ACCESSORY MINERALS: pyroxenes, amphiboles
INCLUSIONS: opaques, organics
KEY CRITERIA: green in ppl, similar to Metamorphic I (D) but with smaller groundmass and large phenocrysts

MICROSCOPIC CHARACTERISTICS: Metamorphic III – amphibolites(F)
TEXTURE: aphanitic (macrocrystalline, holocrystalline), ophitic to subophitic
MAJOR MINERALS: amphiboles, feldspars (heavily altered)
MINOR/ACCESSORY MINERALS: pyroxenes
INCLUSIONS: large opaques, clay minerals
KEY CRITERIA: large amphibole crystals

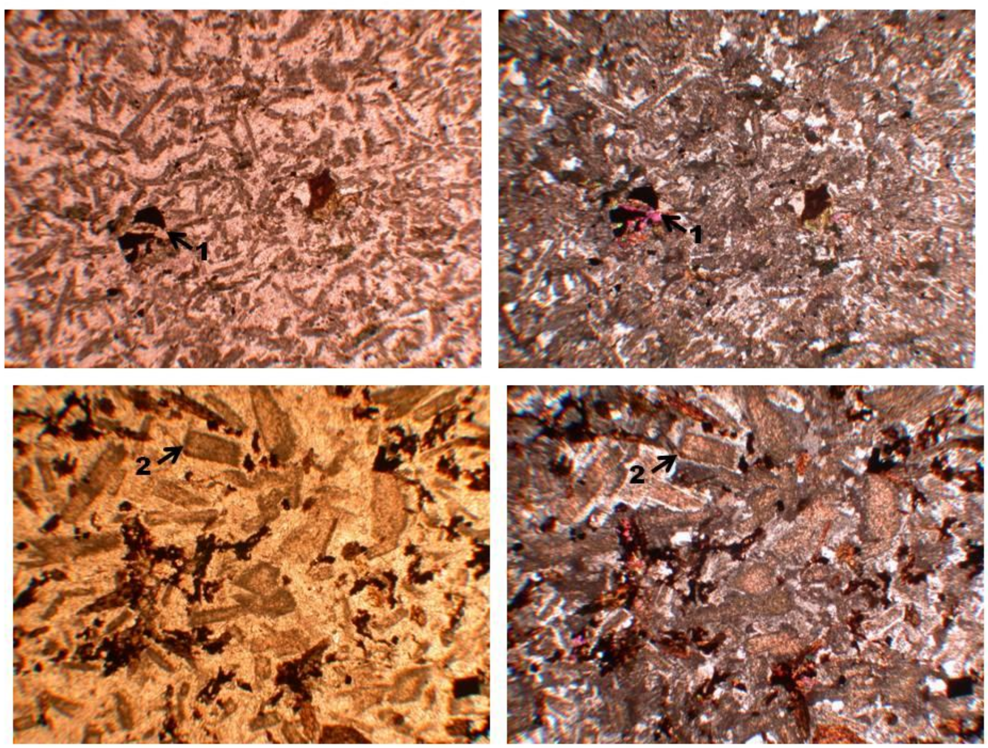
MICROSCOPIC CHARACTERISTICS: Metamorphic IV (G) – metavolcanic
TEXTURE: aphanitic (microcrystalline)
MAJOR MINERALS: feldspar, quartz
MINOR/ACCESSORY MINERALS: pyroxene
INCLUSIONS: subrounded to elongate opaques, clay minerals
KEY CRITERIA: altered, aligned feldspar laths in glassy groundmass (trachyitic texture), few inclusions





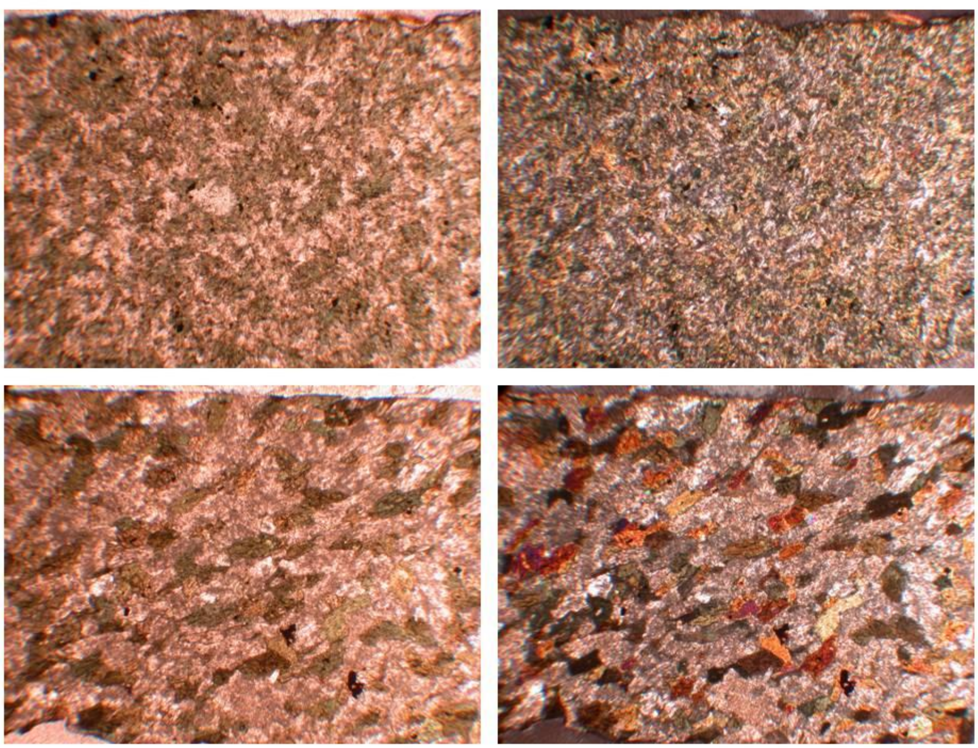
Continuum of metamorphic rock types. Relates to quality with lower quality (larger grain size) types on the left and higher quality (smaller grain size, greater homogeneity) towards the right.

Metadiorite (type 4/D). Top: XOF204. Bottom: XOF419.



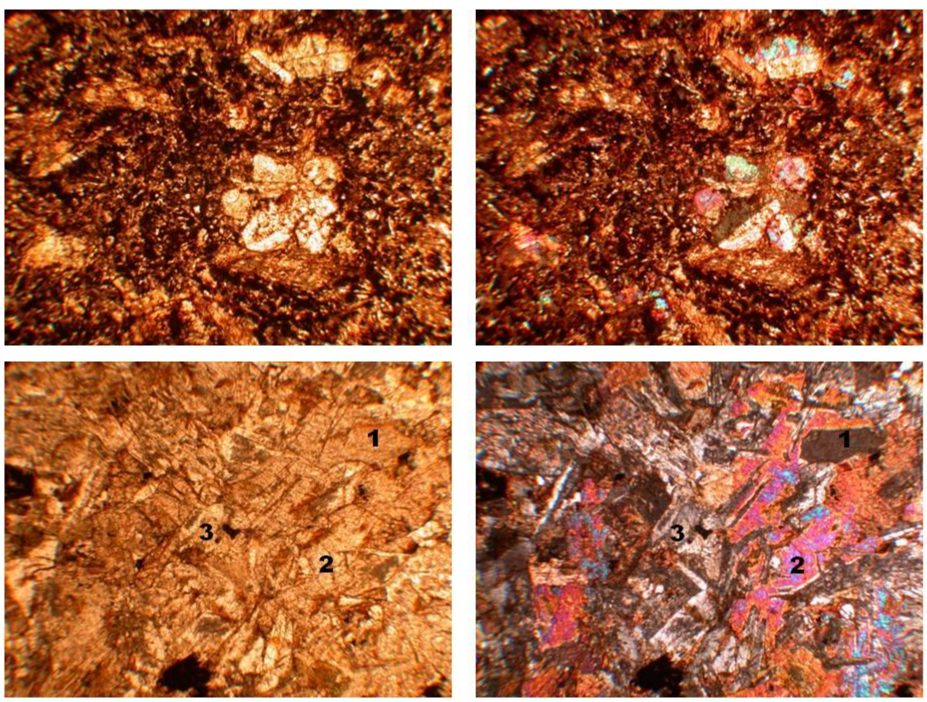
Photomicrograph of metadiorite (type 4/D). Top: XOF204. Bottom: XOF419. 32x, PPL (left), XPL (right). 1: Highly altered pyroxene. 2: Heavily altered feldspar.

Greenschist (type 4/E). Top: XOF284. Bottom: XOF223.

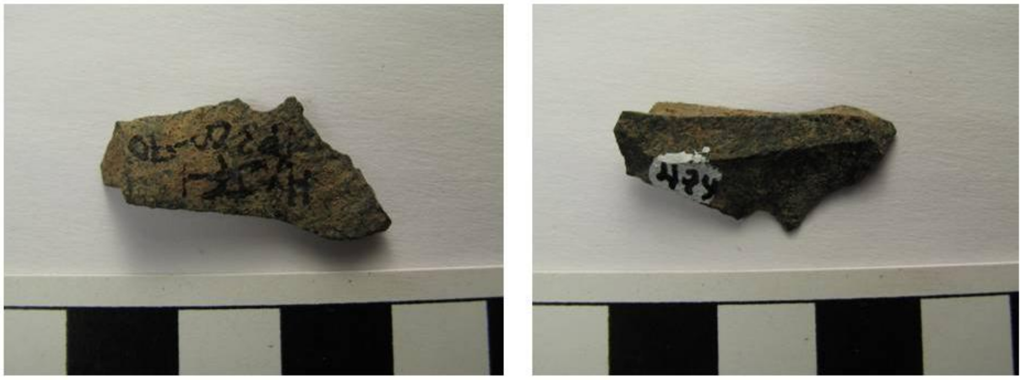


Photomicrograph of greenschist (type 4/E). Top: XOF284. Bottom: XOF223. 32x, PPL (left), XPL (right). Green minerals in PPL are hornblende, epidote, and/or chlorite.

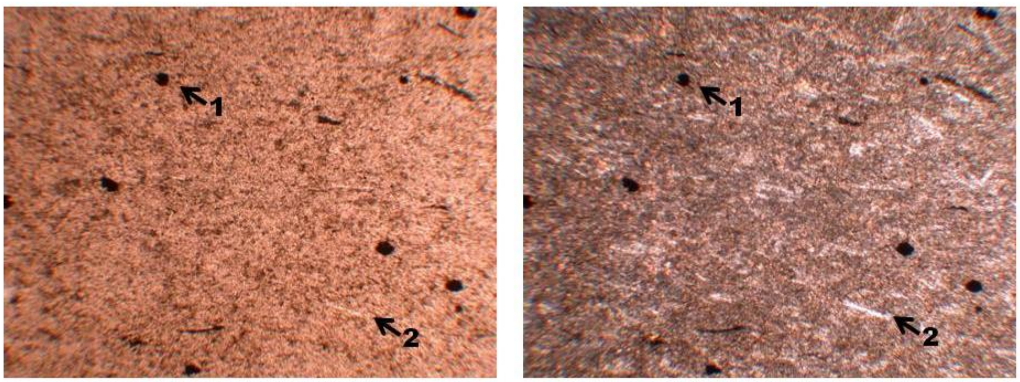
Amphibolite (type 4/F). Top: XOF211. Bottom: XOF212.



Photomicrograph of amphibolite (type 4/F). Top: XOF211, showing dark staining (clay minerals or iron oxides. Bottom: XOF212. 32x, PPL (left), XPL (right). 1: Quartz. 2: Hornblende (amphibole). 3: Altered plagioclase feldspar.



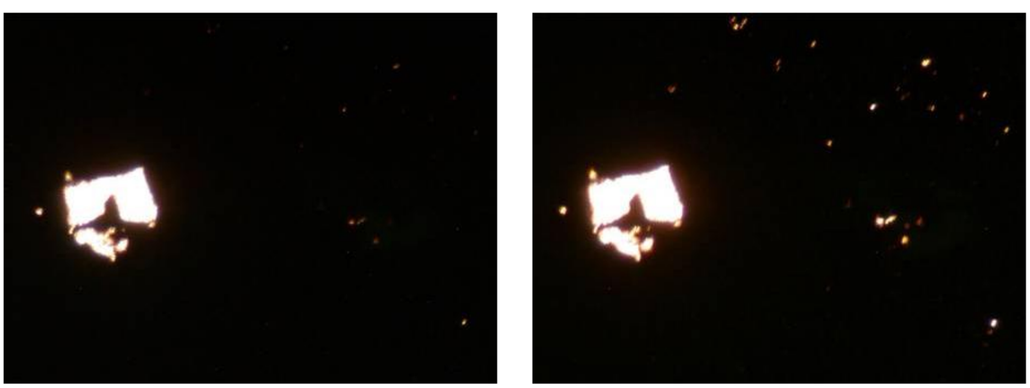
Metavolcanic (type 4/G); XOF307.



Photomicrograph of a metavolcanic rock (type 4/G); XOF307. 32x, PPL (left), XPL (right). 1: Rounded iron oxide inclusion. 2: Feldspar lath. Note alignment of feldspar laths.

NAME: Mudstone
MACROSCOPIC CHARACTERISTICS:
COLOR: black
PATINA: none
LUSTRE: dull to greasy/resinous
FRACTURE: Subconchoidal
TEXTURE: fine-grained
INCLUSIONS: none
KEY CRITERIA: lustre
MICROSCOPIC CHARACTERISTICS:
TEXTURE: clastic (matrix supported), cryptocrystalline
MAJOR MINERALS: clay
MINOR/ACCESSORY MINERALS: none
INCLUSIONS: none
KEY CRITERIA: homogeneous, opaque in ppl and xpl

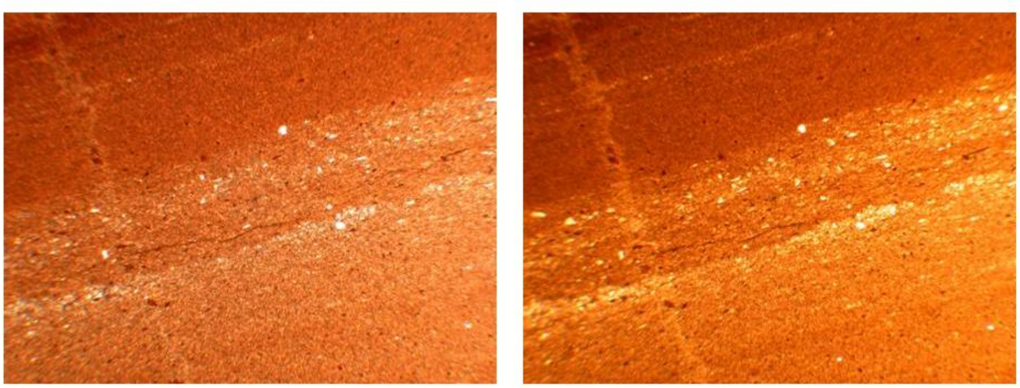
Mudstone (type 5/H); XCM 32.



Photomicrograph of mudstone (type 5/H); XCM32. 40x, PPL (left), XPL (right). Note large altered quartz crystal to left of image.

NAME: Siltstone
MACROSCOPIC CHARACTERISTICS:
COLOR: brown, mottled
PATINA: none
LUSTRE: dull
FRACTURE: subconchoidal
TEXTURE: fine grained
INCLUSIONS: none
KEY CRITERIA: texture
MICROSCOPIC CHARACTERISTICS:
TEXTURE: Clastic, cryptocrystalline to microcrystalline
MAJOR MINERALS: quartz
MINOR/ACCESSORY MINERALS: none
INCLUSIONS: possible clay minerals
KEY CRITERIA: foliated, homogeneous

Siltstone (type 6/I); XOF060.



Photomicrograph of siltstone (type 6/I); XOF060). 32x, PPL (left), XPL (right).

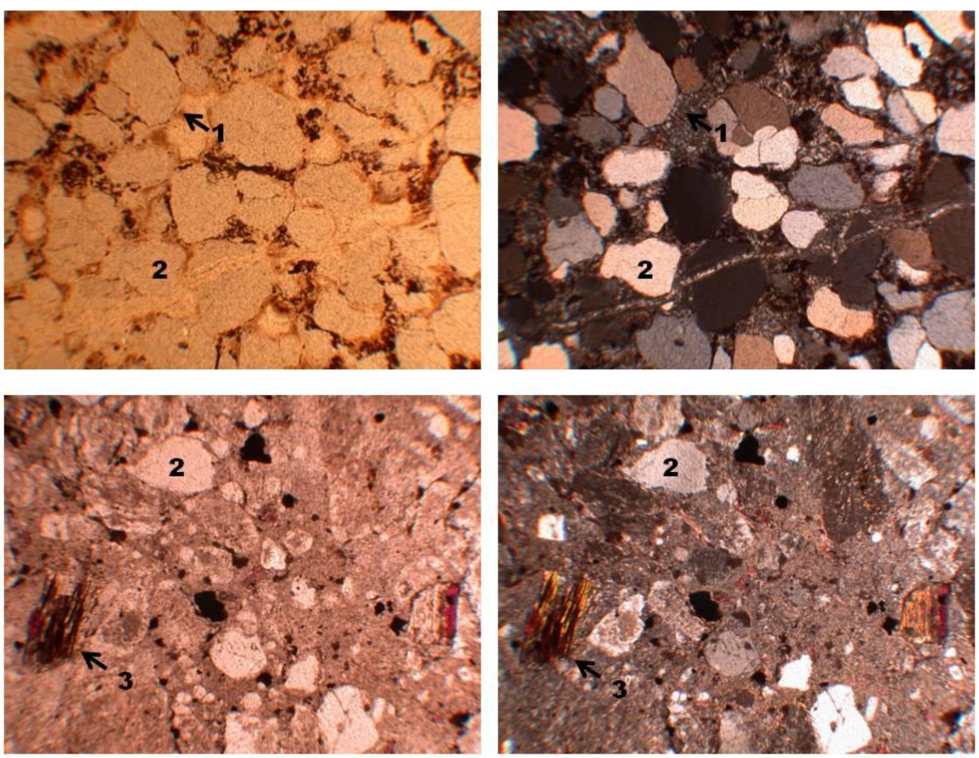
NAME: Sandstone
MACROSCOPIC CHARACTERISTICS:

- COLOR: white to pink
- PATINA: white
- LUSTRE: dull to vitreous
- FRACTURE: subconchoidal
- TEXTURE: fine- to medium-grained
- INCLUSIONS: none
- KEY CRITERIA: texture

MICROSCOPIC CHARACTERISTICS:

- TEXTURE: clastic, microcrystalline
- GROUNDMASS: quartz, chert/chalcedony
- MAJOR MINERALS: quartz
- MINOR/ACCESSORY MINERALS: muscovite
- INCLUSIONS: clay minerals, organics
- KEY CRITERIA: clastic texture (matrix supported with feldspar ± composite clasts of volcanic origin); arkosic

Sandstone (type 7/J). Top: XOF035. Bottom: XOF194.



Photomicrograph of sandstone (type 7/J). Top: XOF35. Bottom: XOF194. 32x, PPL (left), XPL (right). 1: Chalcedony/chert groundmass. 2: Quartz. 3. Mica (biotite).

NAME: Quartzite

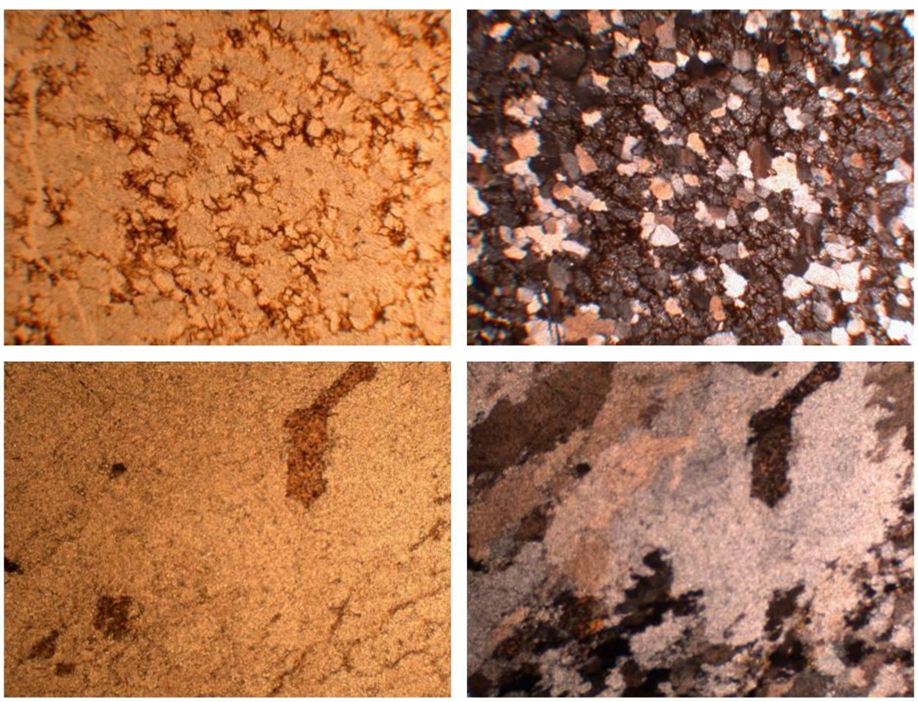
MACROSCOPIC CHARACTERISTICS:

- COLOR: white to greyish
- PATINA: rusty
- LUSTRE: dull to vitreous
- FRACTURE: subconchoidal
- TEXTURE: medium- to coarse-grained
- INCLUSIONS: generally absent
- KEY CRITERIA: semi-translucent

MICROSCOPIC CHARACTERISTICS:

- TEXTURE: granular (altered), micrographic
- GROUNDMASS: cryptocrystalline
- MAJOR MINERALS: quartz
- MINOR/ACCESSORY MINERALS: feldspar
- INCLUSIONS: clay minerals
- KEY CRITERIA: granular texture with micrographic subtexture

Quartzite (type 8/K). Top: Orthoquartzite (type 8/Ka); XOF023. Bottom: Metaquartzite (type 8/Kb); XCM001.

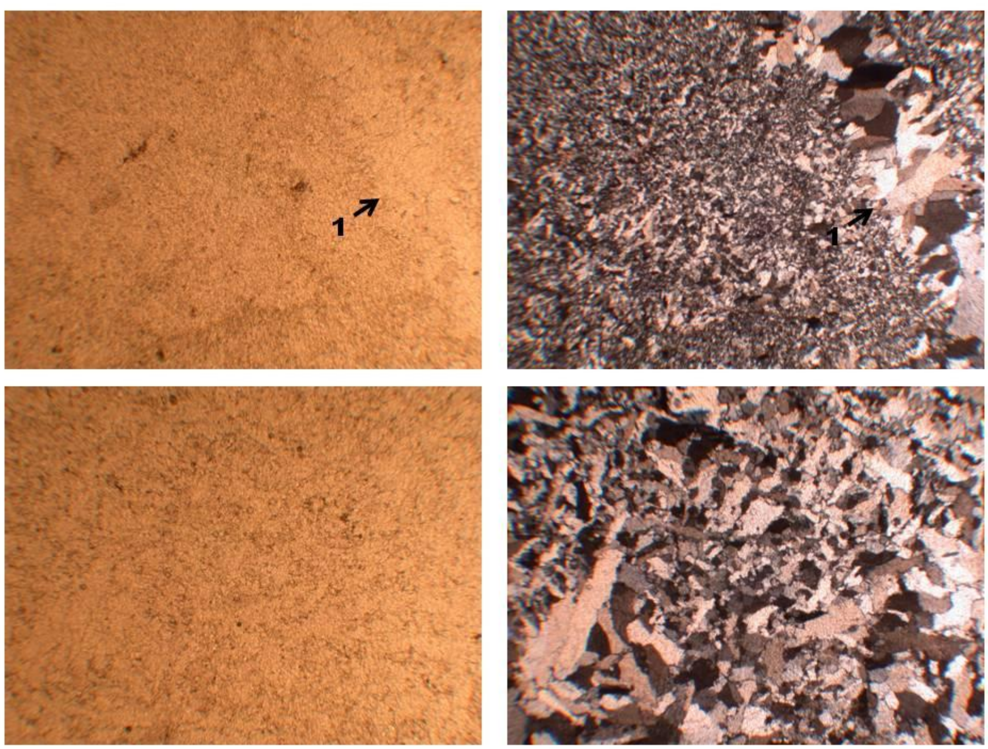


Photomicrograph of quartzite (type 8/K). Top: orthoquartzite (type 8/Ka); XOF023. Note chalcedony cement. Bottom: metaquartzite (type 8/Kb); XCM001. Notice deformation features including undulating extinction associated with the quartz grains.

NAME: Cryptocrystalline Silica (CCS)
MACROSCOPIC CHARACTERISTICS:
- COLOR: clear to white to grey to greenish to pink to red
- PATINA: yellow to orange to red (rusty)
- LUSTRE: dull to waxy
- FRACTURE: subconchoidal to conchoidal
- INCLUSIONS: none
- KEY CRITERIA: semi-translucent
- COMMENTS: May be mottled

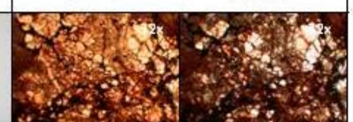
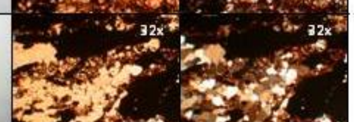
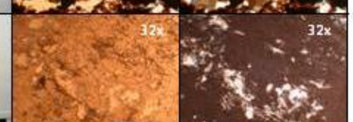
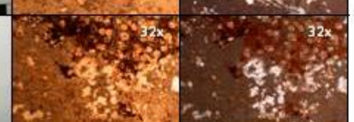
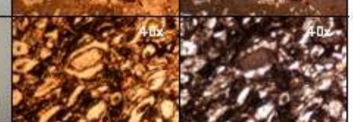
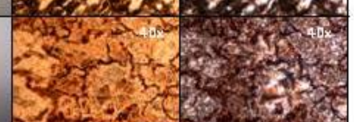
MICROSCOPIC CHARACTERISTICS:
- TEXTURE: granular, non-clastic
- GROUNDMASS: cryptocrystalline silica
- MAJOR MINERLS: quartz
- MINOR/ACCESSORY MINERALS: none
- INCLUSIONS: clay minerals, hematite/ferruginous (iron oxides)
- KEY CRITERIA: not as granular as quartzite; more macroquartz and megaquartz than chert

Variation in CCS (type 9/L). Top: XOF104. Bottom: XOF135.



Photomicrograph of CCS (type 9/L). Top: XOF104. Bottom: XOF135; borderline quartzite owing to large quartz grain size. 32x, PPL (left), XPL (right). 1: Quartz vein inclusion.

NAME: Chert (general)
MACROSCOPIC CHARACTERISTICS:
COLOR: highly variable (white to buff to yellow to orange to brown to red to pink to purple to grey to blue-grey to black)
PATINA: white to buff to orange to red
LUSTRE: dull to chalky to waxy to vitreous
FRACTURE: conchoidal
TEXTURE: fine-grained
INCLUSIONS: quartz vein and quartz crystal
KEY CRITERIA: color and texture
COMMENTS: frequently mottled, speckled, and banded
MICROSCOPIC CHARACTERISTICS:
TEXTURE: non-clastic, cryptocrystalline
GROUNDMASS: cryptocrystalline silica, chalcedony
MAJOR MINERALS: silica (quartz, chert, chalcedony)
MINOR/ACCESSORY MINERALS: none
INCLUSIONS: opaques, clay minerals, hematite/ferruginous (iron oxides)
KEY CRITERIA: cryptocrystalline silica with replacement and void-infilling textures

Chert Subtypes	Macroscopic	Microscopic PPL XPL
M.I		
M.II		
M.III.i		
M.III.ii		
M.III.iii		
M.III.iv		
M.IV		

NAME: Chert I

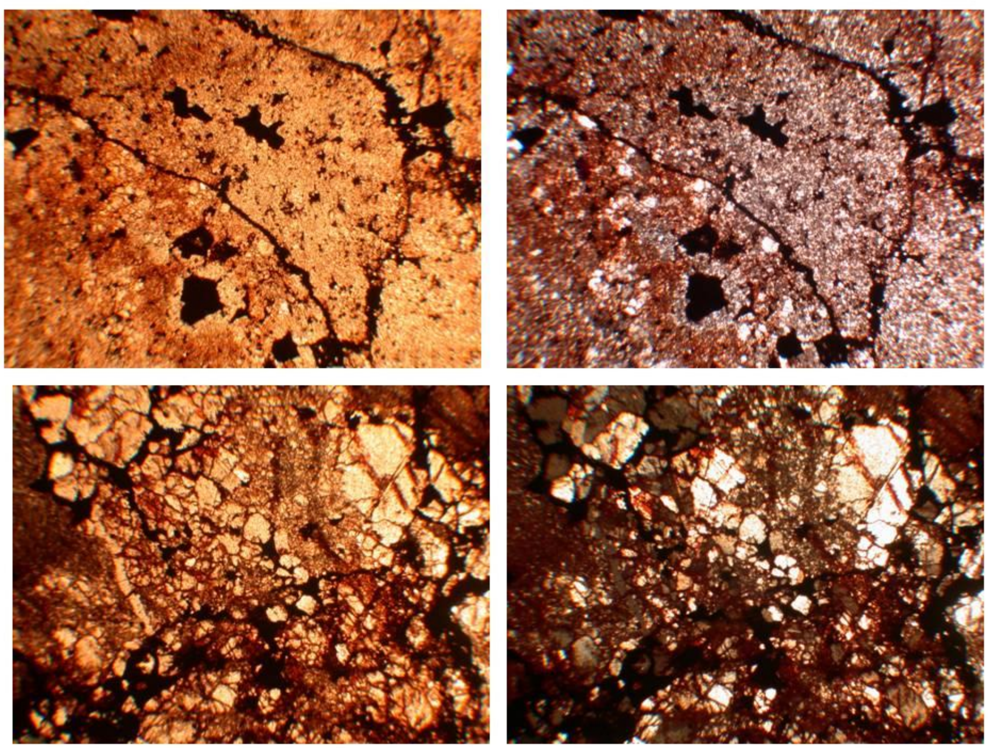
MACROSCOPIC CHARACTERISTICS:

- COLOR: red to pink
- PATINA: none
- LUSTRE: dull to chalky
- INCLUSIONS: none
- COMMENTS: appears heavily weathered (but not patinated), few voids visible

MICROSCOPIC CHARACTERISTICS:

- GROUNDMASS: cryptocrystalline silica
- CARBONATE: none
- ADDITIONAL SILICA FABRICS: replacement quartz
- INCLUSIONS: feldspar (plagioclase), hematite (iron oxide) staining, clay minerals
- COMMENTS: few voids visible

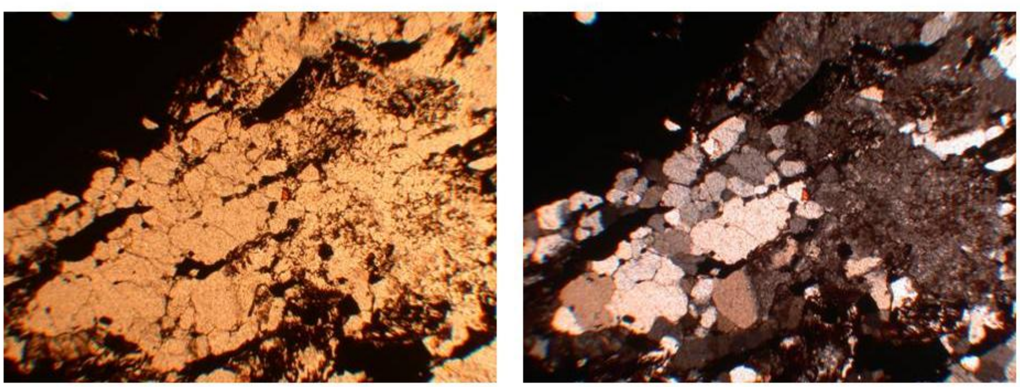
Chert I (type 10/M.I). Top: XOF099. Bottom: XOF011.



Photomicrograph of chert I (type 10/M.I). Top: XOF099. Bottom: XOF011. 32x, PPL (left), XPL (right). Note abundant iron oxide/hematite staining.

NAME: Chert II
MACROSCOPIC CHARACTERISTICS:
COLOR: pink to dark red/purple or greenish to dark grey (weathered?)
PATINA: none
LUSTRE: dull
INCLUSIONS: none
MICROSCOPIC CHARACTERISTICS:
GROUNDMASS: cryptocrystalline silica
CARBONATE: none
ADDITIONAL SILICA FABRICS: replacement quartz
INCLUSIONS: opaques (iron oxides, metals)
KEY CRITERIA: large opaques (in both ppl and xpl)

Chert II (type 10/M.II); XOF188.



Photomicrograph of chert II (type 10/M.II); XOF188. 32x, PPL (left), XPL (right).

NAME: Chert III
MACROSCOPIC CHARACTERISTICS: (general)

COLOR: highly variable
PATINA: absent to white to pink to yellowish
LUSTRE: highly variable
INCLUSIONS: variable
COMMENTS: macroscopically this represents the most highly variable group; can only be grouped and subdivided according to microscopic characteristics

MICROSCOPIC CHARACTERISTICS:

GROUNDMASS: carbonate (matrix dolomite/micritic sediment) and cryptocrystalline silica
CARBONATE: relict/ghost texture (clast)
ADDITIONAL SILICA FABRICS: chalcedony (void infilling)
INCLUSIONS: none

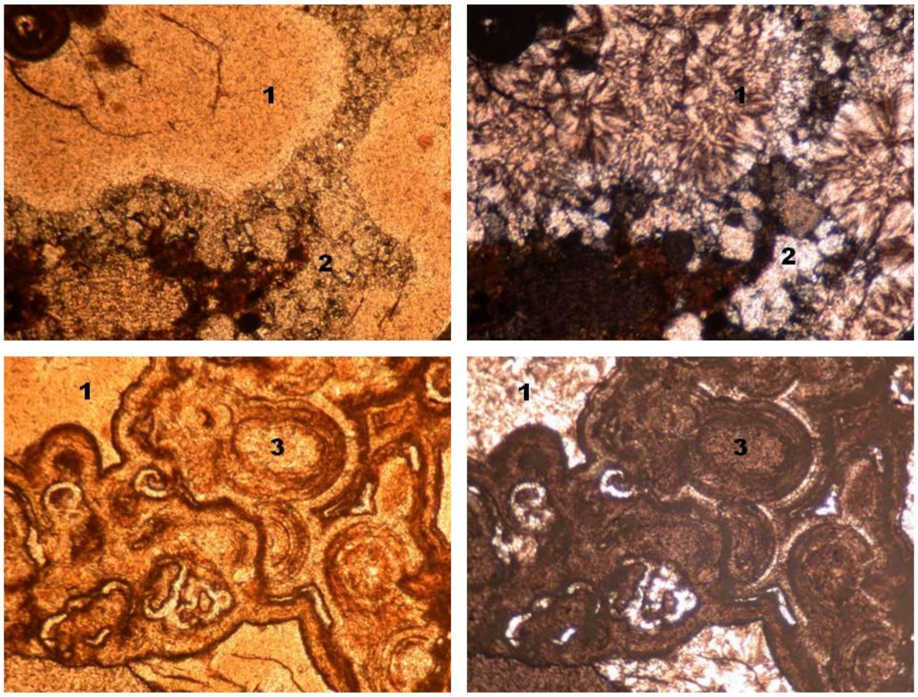
COMMENTS: subdivisions likely represent a continuum of replacement or possibly different members within the same formation

Continuum of replacement in chert variety III (subtypes III.i – III.iv).

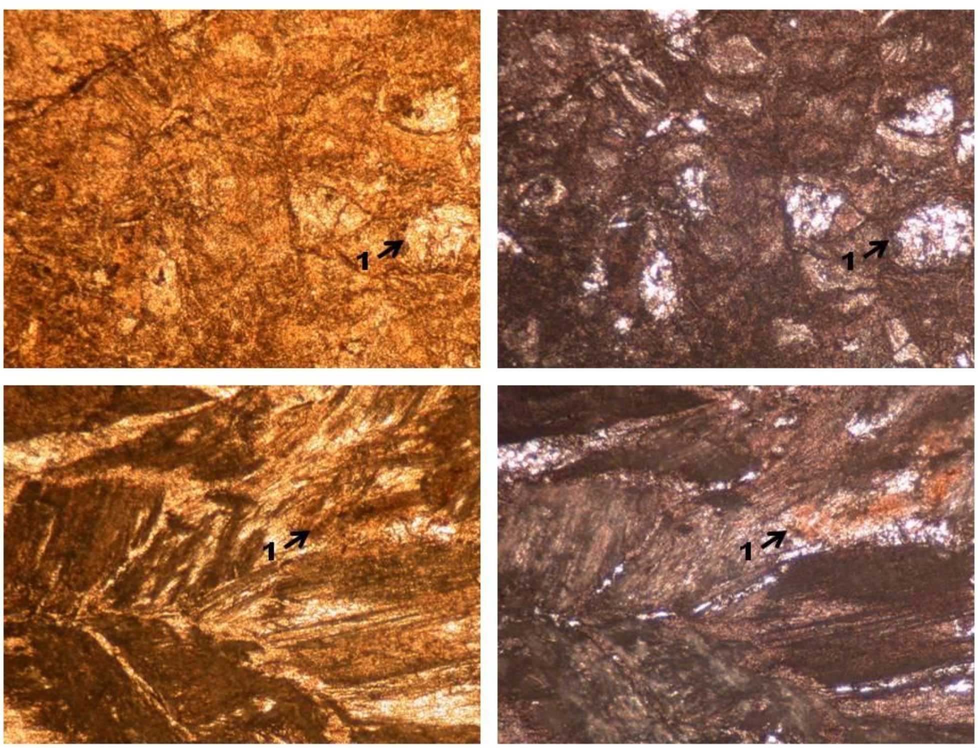
NAME: Chert III.i
MACROSCOPIC CHARACTERISTICS:
- COLOR: white to buff to yellow to brown (caramel) to pinkish brown to grey
- PATINA: none
- LUSTRE: waxy to dull
- INCLUSIONS: quartz vein, peloidal
- KEY CRITERIA: peloidal subtexture
- COMMENTS: may be mottled, speckled

MICROSCOPIC CHARACTERISTICS:
- GROUNDMASS: carbonate (matrix dolomite/micritic sediment)
- CARBONATE: relict clast replacement texture
- ADDITIONAL SILICA FABRICS: chalcedony (void infilling)
- INCLUSIONS: none
- KEY CRITERIA: basically is a carbonate mudstone

Chert subtype i (type 10/M.III). Top: XCM111. Bottom: XOF013.



Photomicrograph of chert subtype i (type 10/M.III) demonstrating variability in silica fabrics/texture within a single artifact (XCM111). 40x, PPL (left), XPL (right). 1: Chalcedony. 2: DQM. 3: Possible ooid or peloid.



Photomicrograph illustrating differences in relict textures present in chert subtype i (type 10/M.III). Top: XCM068. Bottom: XCM200. 40x, PPL (left), XPL (right). 1: Void-infilling chalcedony.

NAME: Chert III.ii

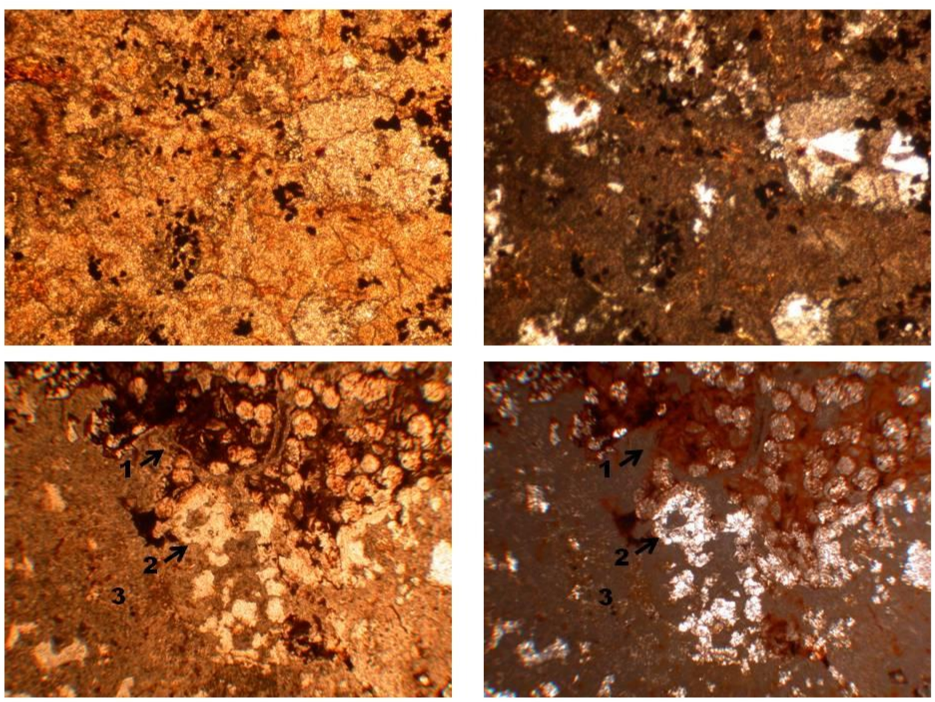
MACROSCOPIC CHARACTERISTICS:

- COLOR: dark red to purple
- PATINA: white to pink
- LUSTRE: dull to waxy
- INCLUSIONS: none
- KEY CRITERIA: patina
- COMMENTS: mottled

MICROSCOPIC CHARACTERISTICS:

- GROUNDMASS: carbonate (matrix dolomite/micritic sediment) and cryptocrystalline silica
- CARBONATE: relict texture
- ADDITIONAL SILICA FABRICS: chalcedony (void infilling)
- INCLUSIONS: hematite (iron oxide)

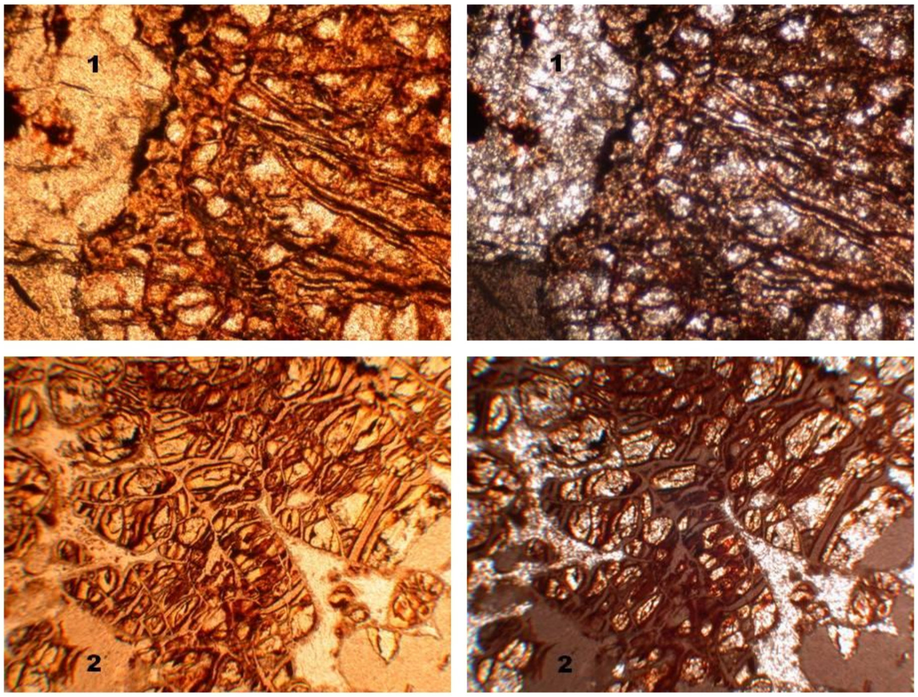
Chert subtype ii (type 10/M.III). Top: XCM105. Bottom: XOF164.



Photomicrograph of chert subtype ii (type 10/M.III). Top: XCM105, 40x. Bottom: XOF164, 32x. PPL (right), XPL (left). 1: Iron oxide/hematite staining highlighting relict texture. 2: Void-infilling chalcedony. 3. Carbonate/micritic sediment.

NAME: Chert III.iii
MACROSCOPIC CHARACTERISTICS:
    COLOR: white to yellow to brown to red to pink to black
    PATINA: none
    LUSTRE: dull to waxy
    INCLUSIONS: black veins
    COMMENTS: mottled, banded, speckled
MICROSCOPIC CHARACTERISTICS:
    GROUNDMASS: cryptocrystalline silica and chalcedony
    CARBONATE: high birefringence, altered
    ADDITIONAL SILICA FABRICS: none
    INCLUSIONS: none
    KEY CRITERIA: serpentinite-like texture

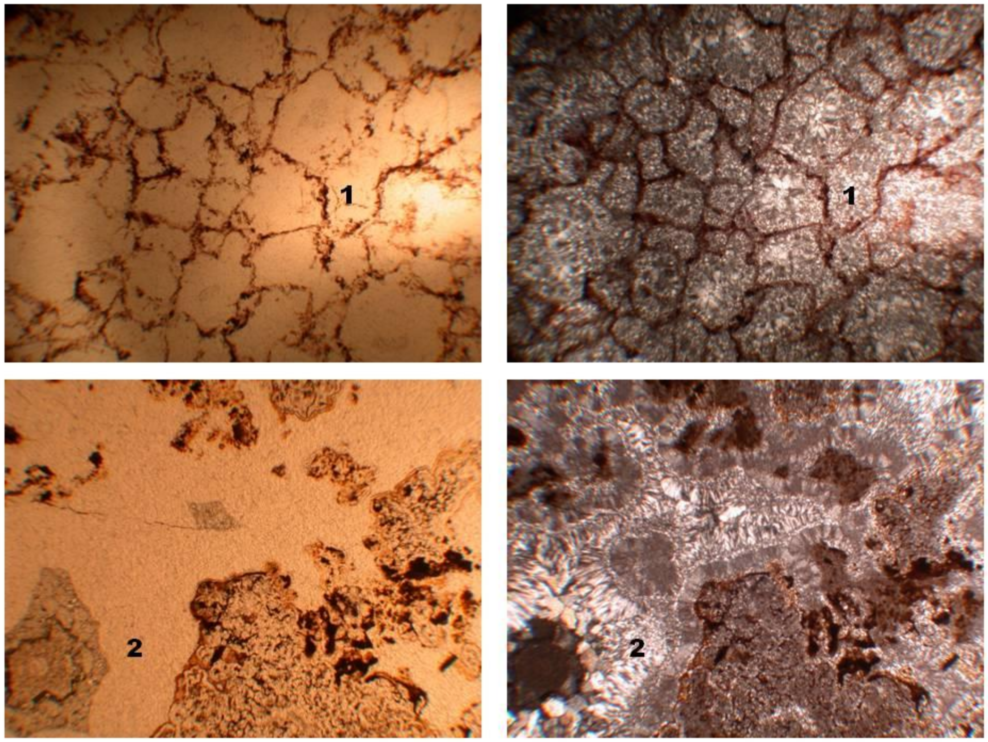
Chert subtype iii (type 10/M.III). Top: XCM127. Bottom: XOF058.



Photomicrograph of chert subtype iii (type 10/M.III). Top: XCM127, 32x. Bottom: XOF058, 40x. PPL (left), XPL (right). 1. Chalcedony. 2. Void.

NAME: Chert III.iv
MACROSCOPIC CHARACTERISTICS:
COLOR: white to yellow to orange to brown to red to pink to purple to greenish-grey to black
PATINA: buff to light yellow, buff to white
LUSTRE: dull to waxy
INCLUSIONS: quartz vein, black vein
COMMENTS: mottled, banded, speckled
MICROSCOPIC CHARACTERISTICS:
GROUNDMASS: cryptocrystalline silica
CARBONATE: none
ADDITIONAL SILICA FABRICS: chalcedony, DQM, pseudo-DQM
INCLUSIONS: hematite (iron oxide) staining

Chert subtype iv (type 10/M.III).
Top: XOF001. Centre: XOF108. Bottom: XOF004.



Photomicrograph of chert subtype iv (type 10/M.III). Top: XOF001. Bottom: XOF108. 32x, PPL (left), XPL (right). 1: Chalcedony. 2: DQM.

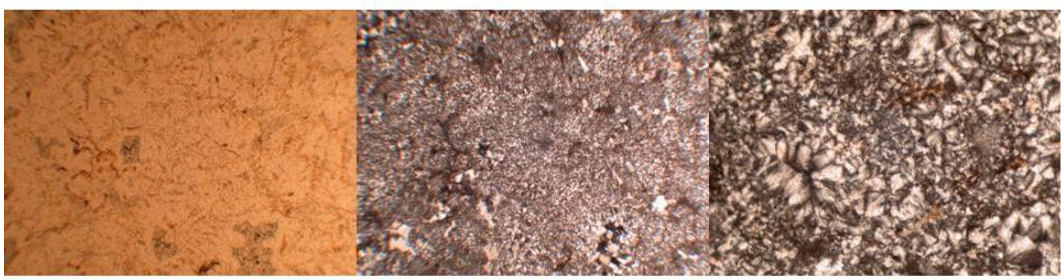
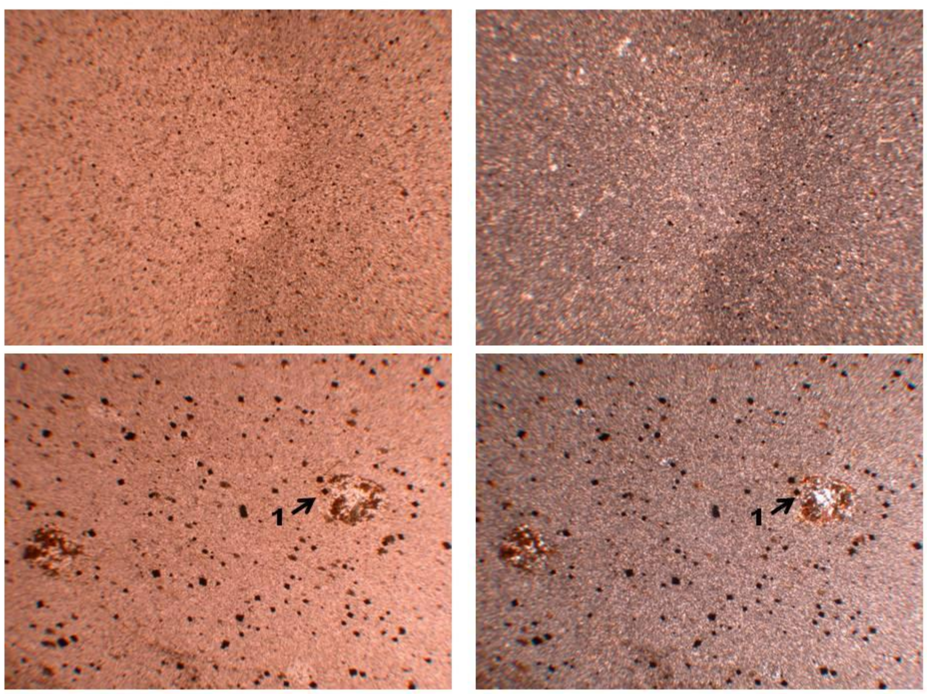


Illustration of chalcedonic groundmass in chert subtype iv (type 10/M.III); XOFOO4. Left: 32x PPL. Centre: 32x XPL. Right: 100x XPL.

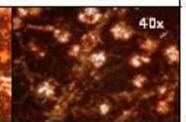
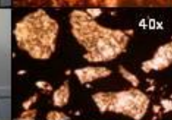
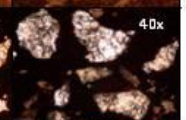
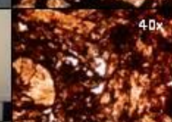
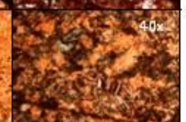
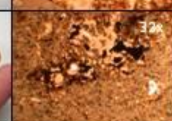
NAME: Chert IV
MACROSCOPIC CHARACTERISTICS:
  COLOR: blue-grey to dark grey to black
  PATINA: buff to yellow
  LUSTRE: dull to waxy
  INCLUSIONS: none
  KEY CRITERIA: color (greys to black)
  COMMENTS: classic “flint”
MICROSCOPIC CHARACTERISTICS:
  GROUNDMASS: cryptocrystalline silica
  CARBONATE: none
  ADDITIONAL SILICA FABRICS: none
  INCLUSIONS: abundant small rounded iron oxides
  KEY CRITERIA: groundmass and inclusions

Characteristic blue-grey to grey to black coloration of flint (type 10/M.IV). Top: XOF029. Bottom: XOF041.



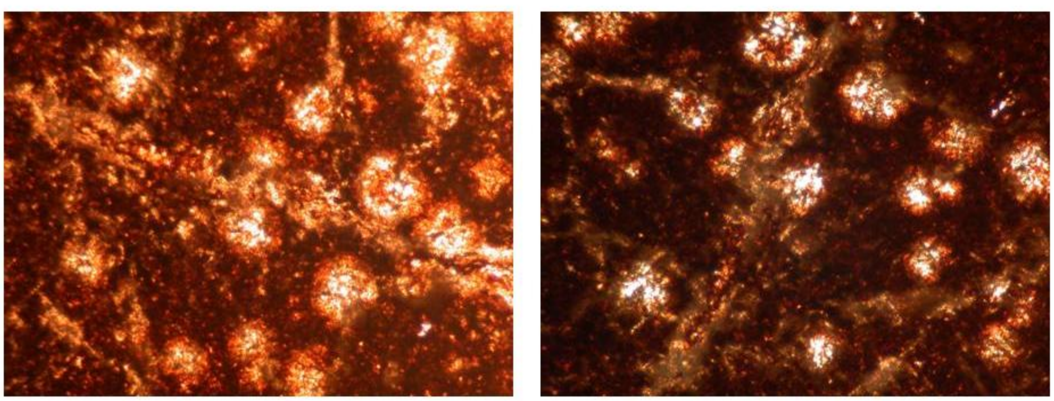
Photomicrograph of chert IV (type 10/M.IV). Top: XOF029. Bottom: XOF041. 32x, PPL (left), XPL (right). 1. Pseudo-DQM with hematite/iron oxide staining. Note large number of rounded iron oxide inclusions.

Unique or Unidentifiable Varieties: a – g

Unknown/ Unique Types	Macroscopic		Microscopic PPL	Microscopic XPL
a				
b				
c				
d				
e				
f				
g				

NAME: Unique a – radiolarian chert
MACROSCOPIC CHARACTERISTICS:
COLOR: dark black to dark brown to yellow
PATINA: none
LUSTRE: waxy to vitreous to resinous
INCLUSIONS: none
KEY CRITERIA: lustre and color
COMMENTS: mottled
MICROSCOPIC CHARACTERISTICS:
TEXTURE: cherty
GROUNDMASS: cryptocrystalline (authigenic silica)
SILICA FABRIC: chalcedony (void infilling)
INCLUSIONS: reddish brown iron oxides
KEY CRITERIA: fossil radiolarian structures

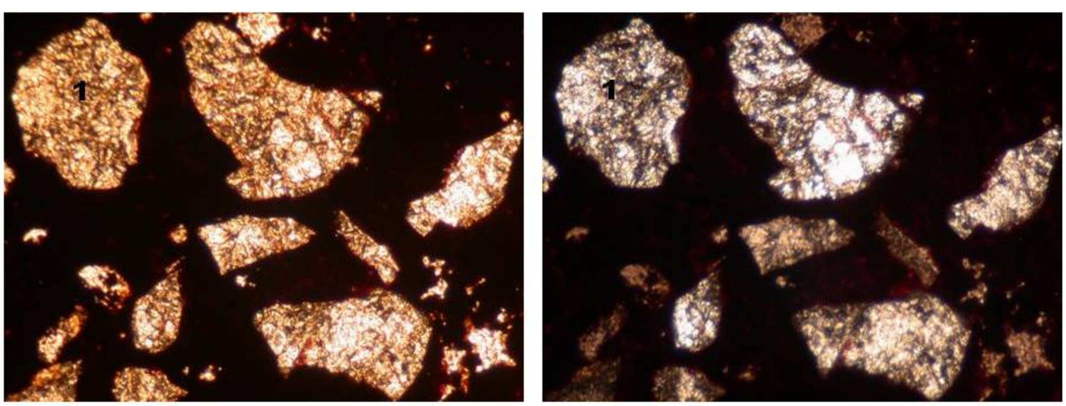
Unique "a" (XCM140).



Photomicrograph of unique "a" (XCM140). 40x, PPL (left), XPL (right). Note replacement of radiolarian structures with chalcedony.

NAME: Unique b – chert
MACROSCOPIC CHARACTERISTICS:
COLOR: reddish black
PATINA: none
LUSTRE: vitreous
INCLUSIONS: visible white speckles (not identifiable)
KEY CRITERIA: color
COMMENTS: speckled
MICROSCOPIC CHARACTERISTICS:
TEXTURE: cryptocrystalline
GROUNDMASS: red mineral (heavily stained chert or carbonate?)
INCLUSIONS: quartz crystals, chert rock fragments
COMMENTS: contains microscopic voids

Unique "b" (XCM165).

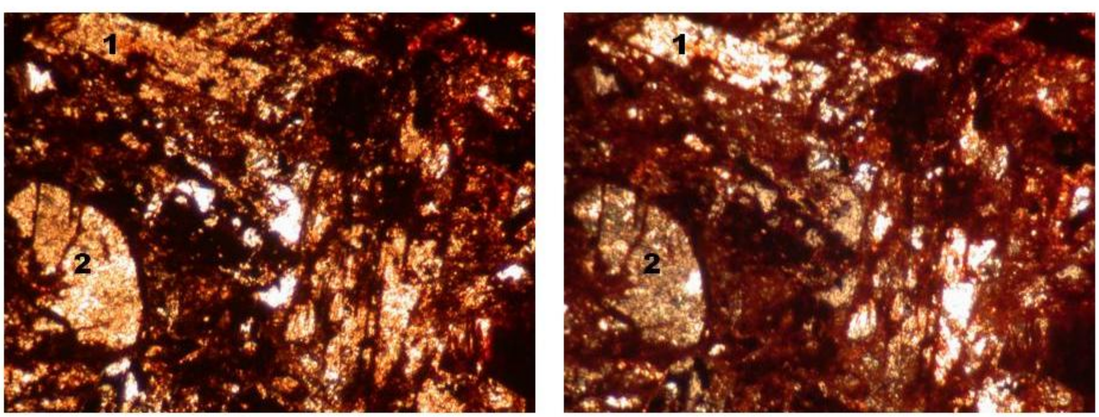


Photomicrograph of unique "b" (XCM165). 32x, PPL (left), XPL (right). 1: Void-infilling chalcedony.

NAME: Unique c – unknown, possible ochre
MACROSCOPIC CHARACTERISTICS:
- COLOR: reddish-orange
- PATINA: none
- LUSTRE: dull
- FRACTURE: subconchoidal
- TEXTURE: fine to medium grained
- INCLUSIONS:none
- KEY CRITERIA: texture

MICROSCOPIC CHARACTERISTICS:
- TEXTURE: aphanitic (macrocrystalline, holocrystalline), ophitic to subophitic
- MAJOR MINERALS: feldspar (heavily altered)
- MINOR/ACCESSORY MINERALS: quartz
- INCLUSIONS: hematite (iron oxide) staining
- COMMENTS: contains microscopic voids

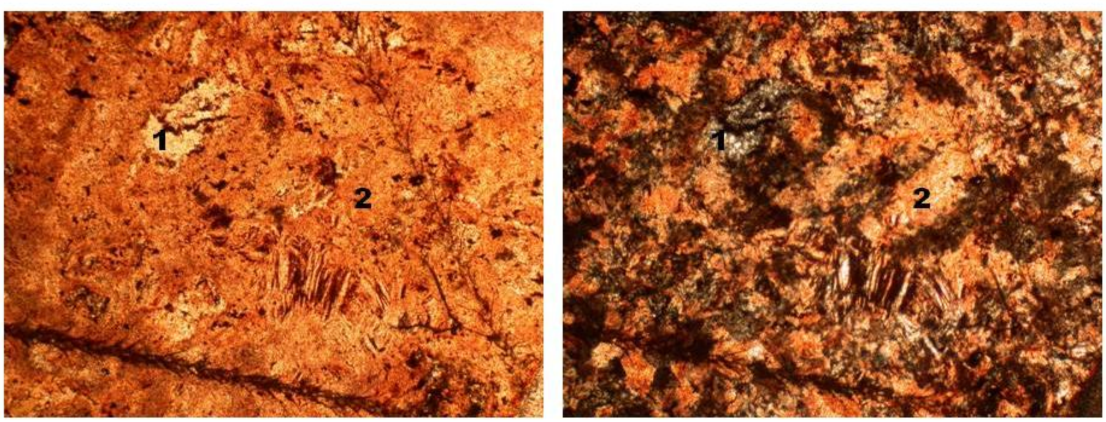
Unique “c” (XCM048).



Photomicrography of unique “c” (XCM048). 40x, PPL (left), XPL (right). 1: Chalcedony replacement of feldspar lath. 2: Void-infilling chalcedony.

NAME: Unique d – unknown, possible ochre
MACROSCOPIC CHARACTERISTICS:
COLOR: reddish orange
PATINA: none
LUSTRE: dull
FRACTURE: subconchoidal
TEXTURE: fine to medium grained
INCLUSIONS: none
KEY CRITERIA: texture
MICROSCOPIC CHARACTERISTICS:
TEXTURE: aphanitic (micro- to macrocrystalline)
GROUNDMASS: cryptocrystalline silica
MAJOR MINERALS: carbonates, chalcedony
INCLUSIONS: extensive hematite (iron oxide) staining
COMMENTS: contains microscopic voids

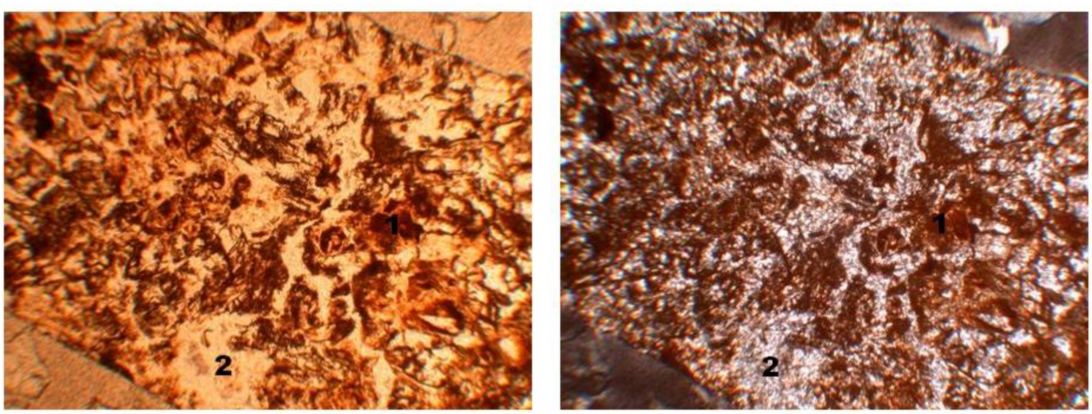
Unique “d” (XCM015).



Photomicrograph of unique “d” (XCM015). 40x, PPL (left), XPL (right). 1. Void-infilling chalcedony. 2: Carbonate.

NAME: Unique e – chert
MACROSCOPIC CHARACTERISTICS:
COLOR: yellow
PATINA: reddish brown
LUSTRE: dull to waxy
FRACTURE: conchoidal
INCLUSIONS: quartz vein and quartz crystal
COMMENTS: mottled
MICROSCOPIC CHARACTERISTICS:
GROUNDMASS: carbonate
CARBONATE: dolomite matrix/micritic cement, sparry dolomite
ADDITIONAL SILICA FABRICS: DQM, chalcedony
INCLUSIONS: iron oxide staining and inclusions
KEY CRITERIA: relict texture

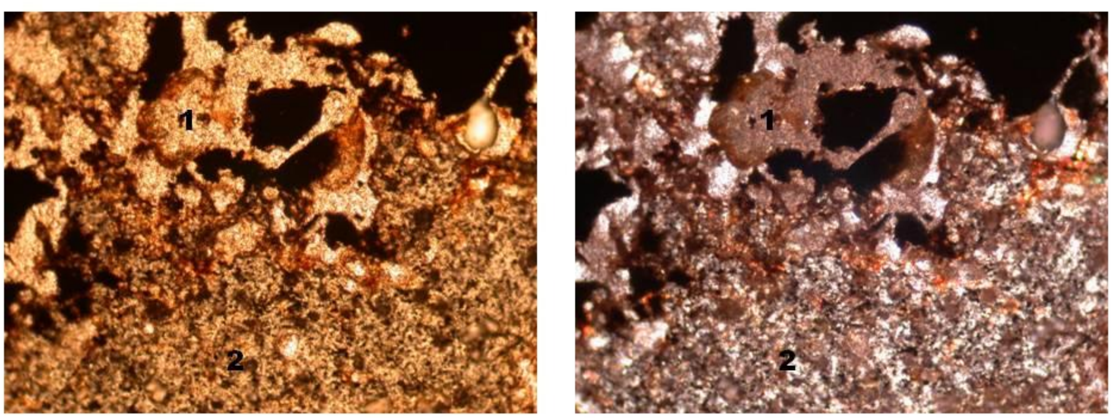
Unique "e" (XOF077).



Photomicrograph of unique "e" (XOF077). 32x, PPL (left), XPL (right). 1: Hematite/iron oxide staining indicating relict texture. 2: Chalcedonic groundmass.

NAME: Unique f – unknown igneous(?)
MACROSCOPIC CHARACTERISTICS:
COLOR: black
PATINA: rusty
LUSTRE: dull
FRACTURE: subconchoidal
TEXTURE: fine grained
INCLUSIONS: none
MICROSCOPIC CHARACTERISTICS:
TEXTURE: glassy/cryptocrystalline
INCLUSIONS: iron oxide staining and inclusions
COMMENTS: contains microscopic voids

Unique “f” (XOF093).



Photomicrograph of unique “f” (XOF093). 32x, PPL (left), XPL (right). 1: Void.
2: Chalcedonic groundmass.

NAME: Unique g – unknown metamorphic(?)

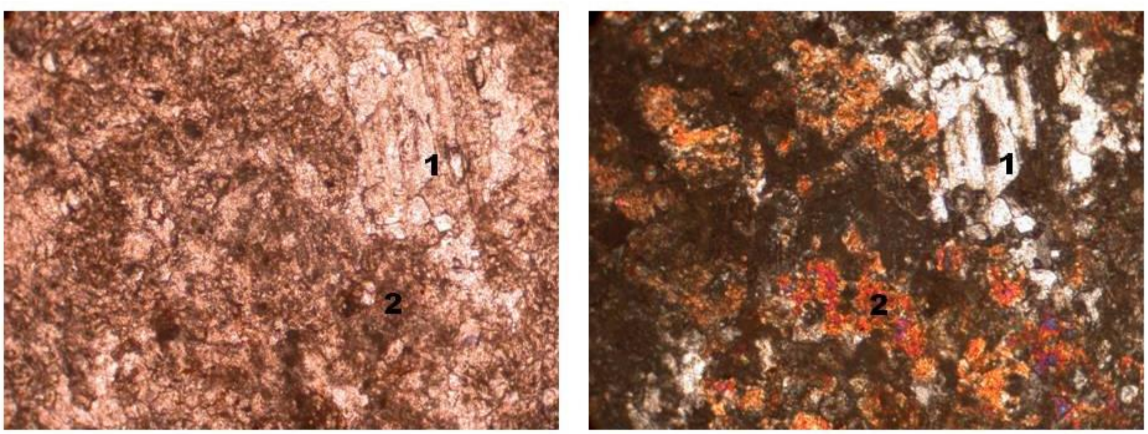
MACROSCOPIC CHARACTERISTICS:

- COLOR: pale yellow
- PATINA: orangeish-brown
- LUSTRE: dull
- FRACTURE: subconchoidal
- TEXTURE: fine to medium grained
- INCLUSIONS: none
- KEY CRITERIA: texture

MICROSCOPIC CHARACTERISTICS:

- TEXTURE: aphanitic (macrocrystalline)
- MAJOR MINERALS: quartz, feldspar, pyroxene
- INCLUSIONS: none
- KEY CRITERIA: slightly foliated
- COMMENTS: contains microscopic voids

Unique “g” (XOF398).



Photomicrograph of unique “g” (XOF398). 32x, PPL (left), XPL (right). 1: Pseudo-DQM. 2: Carbonate.

APPENDIX C: Catalogue

Table C.1: Summary of all artifacts sampled for analyzed from all sites.

Site	Location	Test Pit	Level	Total # of Artifacts	# of Artifacts in Sample (macro)	%	%# of Artifacts in Sample (micro)	% of macro
HwJf-02	Outside of rockshelter	-	Surface	17	1	6	0	100
HwJf-02	Mlambalasi Room 1	-	Surface	509	48	9	8	40
HwJf-02	Mlambalasi Room 1/Slope	-	Surface	38	5	13	0	40
HwJf-02	Mlambalasi Room 2	-	Surface	599	6	1	1	17
HwJf-02	Mlambalasi Slope	-	Surface	604	86	14	10	28
HwJf-02	Mlambalasi Room 1	Test Pit # 1	0 – 5 cm	31	3	10	2	67
HwJf-02	Mlambalasi Room 1	Test Pit # 1	5 – 10 cm	68	6	9	2	33
HwJf-02	Mlambalasi Room 1	Test Pit # 1	10 – 15 cm	90	3	3	2	67
HwJf-02	Mlambalasi Room 1	Test Pit # 1	15 – 20 cm	141	8	6	3	38
HwJf-02	Mlambalasi Room 1	Test Pit # 1	20 – 40 cm	192	8	4	2	25
HwJf-02	Mlambalasi Room 1	Test Pit # 1	40 – 45 cm	129	5	4	2	40
HwJf-02	Mlambalasi Room 1	Test Pit # 1	45 – 55 cm	311	20	6	5	25
HwJf-02	Mlambalasi Room 1	Test Pit # 1	55 – 60 cm	95	8	8	3	38
HwJf-02	Mlambalasi Room 1	Test Pit # 1	60 – 65 cm	156	7	4	2	39
HwJf-02	Mlambalasi Room 1	Test Pit # 1	65 – 70 cm	244	11	5	4	36
HwJf-02	Mlambalasi Room 1	Test Pit # 1	70 – 75 cm	199	8	4	2	25
HwJf-02	Mlambalasi Room 1	Test Pit # 1	75 – 80 cm	104	2	2	1	50
HwJf-02	Mlambalasi Room 1	Test Pit # 1	85 cm	174	16	9	8	63
HwJf-02	Mlambalasi Room 1	Test Pit # 1	90 – 100 cm	379	17	4	6	35
HwJf-02	Mlambalasi Room 1	Test Pit # 1	100 – 110 cm	57	1	2	1	100
HwJf-02	Mlambalasi Room 1	Test Pit # 1	110 – 120 cm	296	14	5	3	21
HwJf-02	Mlambalasi Room 1	Test Pit #1	S Wall Clean	43	1	2	1	100
HwJf-02	Mlambalasi Room 1	Test Pit #1	Unit E of TP1	9	2	22	1	50
HwJf-02	Mlambalasi Slope	Test Pit # 2	0 – 20 cm	460	59	13	10	17
HwJf-02	Mlambalasi Slope	Test Pit # 2	20 – 30 cm	328	48	15	9	19
HwJf-02	Mlambalasi Slope	Test Pit # 2	30 – 40 cm	337	56	17	8	14
HwJf-02	Mlambalasi Slope	Test Pit # 2	40 – 50 cm	590	119	20	23	19
HwJf-02	Mlambalasi Slope	Test Pit # 2	50 – 60 cm	539	109	20	16	15
HwJf-02	Mlambalasi Slope	Test Pit # 2	60 – 70 cm	741	152	21	28	18
HwJf-02	Mlambalasi Slope	Test Pit # 2	70 – 80 cm	264	36	14	8	22
HwJf-02	Mlambalasi Slope	Test Pit # 2	80 – 90 cm	557	64	12	9	14
HwJf-02	Mlambalasi Slope	Test Pit # 2	90 – 110 cm	544	40	7	10	25
HwJf-02	Mlambalasi Slope	Test Pit # 2	110 – 120 cm	365	35	10	6	17
HwJf-02	Mlambalasi Slope	Test Pit # 2	120 – 130 cm	358	25	7	5	20
HwJf-02	Mlambalasi Slope	Test Pit # 2	130 – 140 cm	547	14	3	3	21
HwJf-02	Mlambalasi Slope	Test Pit # 2	140 – 150 cm	560	18	3	7	39

HwJf-02	Mlambalasi Slope	Test Pit # 2	150 – 160 cm	905	18	2	4	22
HwJf-02	Mlambalasi	-	Unknown	-	23	0	2	9
HxJf-01	Magubike Rockshelter	-	Surface	790	247	31	28	11
HxJf-01	Magubike Rockshelter	Test Pit # 1	0 – 10 cm	271	28	10	3	11
HxJf-01	Magubike Rockshelter	Test Pit # 1	10 – 20 cm	85	13	15	3	23
HxJf-01	Magubike Rockshelter	Test Pit # 1	20 – 30 cm	84	3	4	2	67
HxJf-01	Magubike Rockshelter	Test Pit # 1	30 – 40 cm	181	3	2	2	67
HxJf-01	Magubike Rockshelter	Test Pit # 1	40 – 50 cm	320	13	4	2	15
HxJf-01	Magubike Rockshelter	Test Pit # 1	50 – 60 cm	419	19	5	3	16
HxJf-01	Magubike Rockshelter	Test Pit # 1	60 – 70 cm	458	20	4	5	25
HxJf-01	Magubike Rockshelter	Test Pit # 1	70 – 80 cm	78	6	8	3	50
HxJf-01	Magubike Rockshelter	Test Pit # 1	80 – 90 cm	18	3	17	2	67
HxJf-01	Magubike Rockshelter	Test Pit # 1	90 – 100 cm	42	7	17	2	29
HxJf-01	Magubike Rockshelter	Test Pit # 1	100 – 110 cm	36	13	36	2	15
HxJf-01	Magubike Rockshelter	Test Pit # 1	110 – 120 cm	436	138	32	8	6
HxJf-01	Magubike Rockshelter	Test Pit # 1	120 – 130 cm	726	189	26	12	6
HxJf-01	Magubike Rockshelter	Test Pit # 1	130 – 140 cm	1517	343	23	27	8
HxJf-01	Magubike Rockshelter	Test Pit # 1	140 – 150 cm	1149	248	22	10	4
HxJf-01	Magubike Rockshelter	Test Pit # 1	150 – 160 cm	531	100	19	8	8
HxJf-01	Magubike Rockshelter	Test Pit # 1	160 – 170 cm	215	27	13	3	11
HxJf-01	Magubike Rockshelter	Test Pit # 1	170 – 180 cm	8	3	38	2	67
HxJf-01	Magubike Rockshelter	Test Pit # 1	Unknown	-	5		0	0
HxJf-01	Magubike Rockshelter	Test Pit # 2	0 – 10 cm	43	3	7	3	100
HxJf-01	Magubike Rockshelter	Test Pit # 2	10 – 20 cm	190	31	16	3	10
HxJf-01	Magubike Rockshelter	Test Pit # 2	20 – 30 cm	172	21	12	4	19
HxJf-01	Magubike Rockshelter	Test Pit # 2	30 – 40 cm	136	17	13	3	18
HxJf-01	Magubike Rockshelter	Test Pit # 2	40 – 50 cm	211	27	13	3	11
HxJf-01	Magubike Rockshelter	Test Pit # 2	50 – 60 cm	186	67	36	5	7
HxJf-01	Magubike Rockshelter	Test Pit # 3	0 – 10 cm	89	3	3	3	100
HxJf-01	Magubike Rockshelter	Test Pit # 3	10 – 20 cm	211	34	16	3	9
HxJf-01	Magubike Rockshelter	Test Pit # 3	20 – 30 cm	152	13	9	4	31
HxJf-01	Magubike Rockshelter	Test Pit # 3	30 – 40 cm	131	5	4	2	40
HxJf-01	Magubike Rockshelter	Test Pit # 3	40 – 50 cm	191	11	6	5	45
HxJf-01	Magubike Rockshelter	Test Pit # 3	50 – 60 cm	195	23	12	4	17
HxJf-01	Magubike Rockshelter	Test Pit # 3	60 – 70 cm	370	94	25	12	13
HxJf-01	Magubike Rockshelter	Test Pit # 3	70 – 80 cm	728	340	47	26	8
HxJf-01	Magubike Rockshelter	Test Pit # 3	80 – 90 cm	484	201	42	12	6
HxJf-01	Magubike Rockshelter	Test Pit # 3	90 – 100 cm	767	219	29	22	10
HxJf-01	Magubike Rockshelter	Test Pit # 3	100 – 110 cm	657	127	19	11	9

HxJf-01	Magubike Rockshelter	Test Pit # 3	110 – 120 cm	696	190	27	13	7
HxJf-01	Magubike Rockshelter	Test Pit # 3	120 – 130 cm	825	256	31	13	5
HxJf-01	Magubike Rockshelter	Test Pit # 3	130 – 140 cm	902	399	44	18	5
HxJf-01	Magubike Rockshelter	Test Pit # 3	140 – 150 cm	365	202	55	11	5
HxJf-01	Magubike Rockshelter	Test Pit # 3	150 – 160 cm	638	363	57	20	6
HxJf-01	Magubike Rockshelter	Test Pit # 3	160 – 170 cm	705	394	56	15	4
HxJf-01	Magubike Rockshelter	Test Pit # 3	170 – 180 cm	1160	649	56	30	5
HxJf-01	Magubike Rockshelter	Test Pit # 3	180 – 190 cm	1278	514	40	21	4
HxJf-01	Magubike Rockshelter	Test Pit # 3	190 – 200 cm	812	456	56	18	4
HxJf-01	Magubike Rockshelter	Test Pit # 3	200 – 210 cm	61	31	51	8	26
HxJf-01	Magubike Rockshelter	Test Pit # 3	Unknown	-	11		0	0
HxJf-02	Walk back from HxJf-02	-	Surface	13	8	62	0	0
HxJf-02	Rockshelter	-	Surface	40	0	0	0	0
HxJf-02	Walk to rockshelter	-	Surface	16	0	0	0	0
HxJf-03	Magubike Shamba	-	Surface	243	67	28	0	0
HxJf-04	Rockshelter above HxJf-02	-	Surface	28	0	0	0	0
HxJh-01	Kitelewasi	-	Surface	578	7	1	0	0
			Total	32175	7313	23	634	

Table C.2: Mlambalasi Artifacts Selected for Microscopic Analysis

Artifact Designation	Sample Number	Initial Description	Type Macro	Type Micro	Cultural Designation
HwJf-02.RockRemoval85.34	XCM001	Unknown	8	K (b)	LSA
HwJf-02.Room1.Surface.20	XCM002	Unknown	1	A	IA + LSA
HwJf-02.Room1.Surface.295	XCM003	Unknown	4	E	IA + LSA
HwJf-02.Room1.Surface.358	XCM004	Unknown	1	A	IA + LSA
HwJf-02.Room1.Surface.414	XCM005	Unknown	10	L	IA + LSA
HwJf-02.Room1.Surface.425	XCM006	Unknown	1	A	IA + LSA
HwJf-02.Room1.Surface.430	XCM007	Unknown	4	E	IA + LSA
HwJf-02.Room1.Surface.478	XCM008	Unknown	4	E	IA + LSA
HwJf-02.Room2.Surface.422	XCM009	Unknown	9	L	IA + LSA
HwJf-02.Slope.Surface.16	XCM010	Unknown	8	J (a)	IA/LSA/MSA
HwJf-02.Slope.Surface.414	XCM011	Unknown	10	M (IIIiv)	IA/LSA/MSA
HwJf-02.Slope.Surface.538	XCM012	Unknown	4	E	IA/LSA/MSA
HwJf-02.Slope.Surface.568	XCM013	Unknown	10	M (IIIiv)	IA/LSA/MSA
HwJf-02.TP#1.40-45cm.63	XCM014	Unknown	2	B	IA
HwJf-02.TP#1.45-55cm.245	XCM015	Unknown		d	LSA
HwJf-02.TP#1.45-55cm.297	XCM016	Unknown	8	J (a)	LSA
HwJf-02.TP#1.45-55cm.300	XCM017	Unknown	4	E	LSA
HwJf-02.TP#1.55-60cm.3	XCM018	Unknown	8	J	LSA
HwJf-02.TP#1.65-70cm.164	XCM019	Unknown	8	J	LSA
HwJf-02.TP#1.65-70cm.222	XCM020	Unknown	1	A	LSA
HwJf-02.TP#1.90-100cm.237	XCM021	Unknown	10	M (IIIiv)	LSA
HwJf-02.TP#2.0-20cm.188	XCM022	Unknown	4	F	IA
HwJf-02.TP#2.0-20cm.447	XCM023	Unknown	10	M (IIIiii)	IA
HwJf-02.TP#2.20-30cm.218	XCM024	Unknown	4	E	IA
HwJf-02.TP#1.20-30cm.304	XCM025	Unknown	1	A	IA
HwJf-02.TP#2.40-50cm.528	XCM026	Unknown	1	A	IA
HwJf-02.TP#2.40-50cm.550	XCM027	Unknown	1	A	IA
HwJf-02.TP#2.40-50cm.576	XCM028	Unknown	4	E	IA
HwJf-02.TP#2.50-60cm.402	XCM029	Unknown	7	J	IA
HwJf-02.TP#2.50-60cm.501	XCM030	Unknown	4	E	IA
HwJf-02.TP#2.50-60cm.523	XCM031	Unknown	1	A	IA
HwJf-02.TP#2.60-70cm.200	XCM032	Unknown	5	H	IA
HwJf-02.TP#2.60-70cm.500	XCM033	Unknown	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.663	XCM034	Unknown	4	E	IA
HwJf-02.TP#2.60-70cm.732	XCM035	Unknown	4	E	IA

HwJf-02.TP#2.70-80cm.251	XCM036	Unknown	1	A	IA + LSA
HwJf-02.TP#2.80-90cm.392	XCM037	Unknown	4	E	IA + LSA
HwJf-02.TP#2.80-90cm.507	XCM038	Unknown	4	E	IA + LSA
HwJf-02.TP#2.80-90cm.451	XCM039	Unknown	4	F	IA + LSA
HwJf-02.TP#2.90-110cm.184	XCM040	Unknown	4	F	IA + LSA
HwJf-02.TP#2.90-110cm.250	XCM041	Unknown	4	E	IA + LSA
HwJf-02.TP#2.90-110cm.380	XCM042	Unknown	4	E	IA + LSA
HwJf-02.TP#2.90-110cm.445	XCM043	Unknown	4	E	IA + LSA
HwJf-02.TP#2.90-110cm.492	XCM044	Unknown	1	A	IA + LSA
HwJf-02.TP#2.110-120cm.356	XCM045	Unknown	1	A	LSA + MSA
HwJf-02.TP#2.110-120cm.363	XCM046	Unknown	4	E	LSA + MSA
HwJf-02.TP#2.120-130cm.341	XCM047	Unknown	1	A	LSA + MSA
HwJf-02.TP#2.120-130cm.343	XCM048	Unknown		c	LSA + MSA
HwJf-02.TP#2.130-140cm.111	XCM049	Unknown	10	M (IIIiv)	LSA + MSA
HwJf-02.TP#2.130-140cm.447	XCM050	Unknown	10	M (IIIiii)	LSA + MSA
HwJf-02.TP#2.130-140cm.530	XCM051	Unknown	1	A	LSA + MSA
HwJf-02.TP#2.140-150cm.290	XCM052	Unknown	1	A	LSA + MSA
HwJf-02.TP#2.140-150cm.291	XCM053	Unknown	10	M (IIIiv)	LSA + MSA
HwJf-02.TP#2.140-150cm.294	XCM054	Unknown	10	M (IV)	LSA + MSA
HwJf-02.TP#2.140-150cm.423	XCM055	Unknown	8	D	LSA + MSA
HwJf-02.TP#2.140-150cm.432	XCM056	Unknown	4	G	LSA + MSA
HwJf-02.TP#2.150-160cm.266	XCM057	Unknown	4	D	LSA + MSA
HwJf-02.UnitEofTP#1.8	XCM058	Unknown	LOST	-	
HwJf-02.Room1.Surface.438	XCM059	Chert	LOST	-	
HwJf-02.Slope.Surface.391	XCM060	"Odd" rock	10	M (IIIiv)	IA/LSA/MSA
HwJf-02.Slope.Surface.400	XCM061	Chert	10	M (IIIiv)	IA/LSA/MSA
HwJf-02.Slope.Surface.433	XCM062	Chert	10	M (IIIiii)	IA/LSA/MSA
HwJf-02.Slope.Surface.566	XCM063	Chert	10	M (IIIiv)	IA/LSA/MSA
HwJf-02.Slope.Surface.592	XCM064	"Odd" rock	LOST	-	
HwJf-02.Slope.Surface.601	XCM065	Chert	LOST	-	
HwJf-02.TP#1.0-5cm.29	XCM066	Chert	10	M (IIIiv)	IA
HwJf-02.TP#1.0-5cm.30	XCM067	Chert	10	M (IIIiv)	IA
HwJf-02.TP#1.5-10cm.50	XCM068	"Odd" rock	10	M (IIIi)	IA
HwJf-02.TP#1.5-10cm.67	XCM069	Chert	10	M (IIIiv)	IA
HwJf-02.TP#1.10-15cm.60	XCM070	Chert	10	M (IIIiii)	IA
HwJf-02.TP#1.10-15cm.77	XCM071	Chert	10	M (IIIiii)	IA
HwJf-02.TP#1.15-20cm.43	XCM072	Chert	10	M (IIIiv)	IA
HwJf-02.TP#1.15-20cm.97	XCM073	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#1.15-20cm.134	XCM074	Chert	10	M (IIIiv)	IA
HwJf-02.TP#1.20-40cm.137	XCM075	Chert	10	M (IIIiv)	IA
HwJf-02.TP#1.20-40cm.179	XCM076	Chert	10	M (IIIiv)	IA
HwJf-02.TP#1.40-45cm.8	XCM077	Chert	10	M (IIIiv)	IA
HwJf-02.TP#1.45-55cm.239	XCM078	Chert	10	M (IIIiv)	LSA
HwJf-02.TP#1.45-55cm.297	XCM079	"Odd" rock	10	M (IIIiv)	LSA
HwJf-02.TP#1.55-60cm.7	XCM080	Chert	10	M (IIIii)	LSA
HwJf-02.TP#1.55-60cm.56	XCM081	Chert	10	M (IIIiv)	LSA
HwJf-02.TP#1.60-65cm.117	XCM082	Chert	10	M (IIIiv)	LSA
HwJf-02.TP#1.60-65cm.153	XCM083	"Odd" rock	10	M (IIIiv)	LSA
HwJf-02.TP#1.65-70cm.152	XCM084	Chert	10	M (IIIiv)	LSA
HwJf-02.TP#1.65-70cm.215	XCM085	Chert	10	M (IIIiv)	LSA
HwJf-02.TP#1.70-75cm.118	XCM086	"Odd" rock	10	M (IIIii)	LSA
HwJf-02.TP#1.70-75cm.161	XCM087	Chert	10	M (IIIiv)	LSA
HwJf-02.TP#1.75-80cm.36	XCM088	Chert	10	M (IIIiv)	LSA
HwJf-02.TP#1.80-90cm.9	XCM089	Chert	10	M (IIIiv)	LSA
HwJf-02.TP#1.85cm.49	XCM090	Chert	10	M (IIIiv)	LSA
HwJf-02.TP#1.85cm.78	XCM091	Chert	10	M (IIIiv)	LSA
HwJf-02.TP#1.90-100cm.21	XCM092	"Odd" rock	10	M (IIIiv)	LSA
HwJf-02.TP#1.90-100cm.346	XCM093	Chert	10	M (IIIiv)	LSA
HwJf-02.TP#1.90-100cm.347	XCM094	Chert	10	M (IIIiv)	LSA
HwJf-02.TP#1.90-100cm.359	XCM095	"Odd" rock	10	M (IIIiv)	LSA
HwJf-02.TP#1.90-100cm.372	XCM096	"Odd" rock	10	M (IIIiv)	LSA
HwJf-02.TP#1.100-110cm.16	XCM097	Chert	10	M (IIIiii)	LSA
HwJf-02.TP#1.110-120cm.103	XCM098	"Odd" rock	10	M (IIIiv)	LSA
HwJf-02.TP#1.110-120cm.274	XCM099	"Odd" rock	10	M (IIIiii)	LSA
HwJf-02.TP#1.110-120cm.277	XCM100	Chert	10	M (IIIiv)	LSA
HwJf-02.TP#1.RockRemoval85.31	XCM101	Chert	10	M (IIIiv)	MSA
HwJf-02.TP#1.RockRemoval85.43	XCM102	Chert	10	M (IIIiv)	MSA
HwJf-02.TP#1.RockRemoval85.54	XCM103	"Odd" rock	10	M (IIIi)	MSA
HwJf-	XCM104	Chert	10	M (IIIiv)	MSA

02.TP#1.RockRemoval85.109					
HwJf-02.TP#1.SWallClean.40	XCM105	Chert	10	M (IIIii)	MSA
HwJf-02.TP#2.0-20cm.13	XCM106	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.0-20cm.41	XCM107	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.0-20cm.67	XCM108	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.0-20cm.137	XCM109	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.0-20cm.145	XCM110	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.0-20cm.192	XCM111	Chert	10	M (IIIi)	IA
HwJf-02.TP#2.0-20cm.314	XCM112	Chert	10	M (IIIi)	IA
HwJf-02.TP#2.0-20cm.454	XCM113	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.20-30cm.138	XCM114	Chert	10	M (IIIi)	IA
HwJf-02.TP#2.20-30cm.210	XCM115	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.20-30cm.226	XCM116	Chert	10	M (IIIiii)	IA
HwJf-02.TP#2.20-30cm.227	XCM117	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.20-30cm.285	XCM118	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.20-30cm.287	XCM119	Chert	10	M (IIIiii)	IA
HwJf-02.TP#2.20-30cm.313	XCM120	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.30-40cm.222	XCM121	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.30-40cm.254	XCM122	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.30-40cm.305	XCM123	Chert	10	M (IIIiii)	IA
HwJf-02.TP#2.30-40cm.308	XCM124	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.30-40cm.311	XCM125	Chert	10	M (IIIi)	IA
HwJf-02.TP#2.30-40cm.321	XCM126	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.30-40cm.325	XCM127	"Odd" rock	10	M (IIIiii)	IA
HwJf-02.TP#2.30-40cm.334	XCM128	Chert	10	M (IIIiii)	IA
HwJf-02.TP#2.40-50cm.11	XCM129	Chert	10	M (IIIi)	IA
HwJf-02.TP#2.40-50cm.34	XCM130	Chert	10	M (IIIiii)	IA
HwJf-02.TP#2.40-50cm.64	XCM131	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.40-50cm.72	XCM132	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.40-50cm.108	XCM133	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.40-50cm.210	XCM134	Chert	10	M (IIIi)	IA
HwJf-02.TP#2.40-50cm.226	XCM135	Chert	10	M (IIIi)	IA
HwJf-02.TP#2.40-50cm.271	XCM136	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.40-50cm.351	XCM137	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.40-50cm.359	XCM138	Chert	10	M (IIIi)	IA
HwJf-02.TP#2.40-50cm.393	XCM139	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.40-50cm.422	XCM140	Chert	10	a	IA
HwJf-02.TP#2.40-50cm.423	XCM141	"Odd" rock	10	M (IIIiii)	IA
HwJf-02.TP#2.40-50cm.520	XCM142	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.40-50cm.521	XCM143	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.40-50cm.531	XCM144	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.40-50cm.537	XCM145	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.40-50cm.546	XCM146	Chert	10	M (IIIi)	IA
HwJf-02.TP#2.40-50cm.548	XCM147	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.40-50cm.557	XCM148	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.50-60cm.29	XCM149	Chert	10	M (IIIiii)	IA
HwJf-02.TP#2.50-60cm.97	XCM150	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.50-60cm.107	XCM151	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.50-60cm.109	XCM152	Chert	10	M (IIIiii)	IA
HwJf-02.TP#2.50-60cm.314	XCM153	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.50-60cm.322	XCM154	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.50-60cm.373	XCM155	"Odd" rock	10	M (IIIiii)	IA
HwJf-02.TP#2.50-60cm.377	XCM156	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2. 50-60cm.400	XCM157	Chert	10	M (IIIi)	IA
HwJf-02.TP#2.50-60cm.422	XCM158	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.50-60cm.428	XCM159	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.50-60cm.476	XCM160	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.50-60cm.507	XCM161	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.24	XCM162	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.84	XCM163	Chert	10	M (IIIiii)	IA
HwJf-02.TP#2.60-70cm.143	XCM164	Chert	10	M (IIIiii)/ M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.240	XCM165	Chert		b	IA
HwJf-02.TP#2.60-70cm.265	XCM166	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.318	XCM167	Chert	10	M (IIIi)	IA
HwJf-02.TP#2.60-70cm.380	XCM168	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.476	XCM169	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.479	XCM170	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.485	XCM171	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.510	XCM172	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.517	XCM173	"Odd" rock	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.536	XCM174	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.556	XCM175	"Odd" rock	10	M (IV)	IA
HwJf-02.TP#2.60-70cm.558	XCM176	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.572	XCM177	Chert	10	M (IIIiv)	IA

HwJf-02.TP#2.60-70cm.609	XCM178	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.617	XCM179	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.685	XCM180	"Odd" rock	10	M (IIIiii)	IA
HwJf-02.TP#2.60-70cm.688	XCM181	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.695	XCM182	Chert	10	M (IIIi)	IA
HwJf-02.TP#2.60-70cm.720	XCM183	Chert	10	M (IIIiv)	IA
HwJf-02.TP#2.60-70cm.734	XCM184	Chert	10	M (IIIiii)	IA
HwJf-02.TP#2.60-70cm.789/178	XCM185	Chert	10	M (IIIi)	IA
HwJf-02.TP#2.70-80cm.31	XCM186	Chert	10	M (IIIiv)	IA + LSA
HwJf-02.TP#2.70-80cm.155	XCM187	"Odd" rock	10	M (IIIiv)	IA + LSA
HwJf-02.TP#2.70-80cm.195	XCM188	"Odd" rock	10	M (IIIiv)	IA + LSA
HwJf-02.TP#2.70-80cm.223	XCM189	Chert	10	M (IIIiv)	IA + LSA
HwJf-02.TP#2.70-80cm.226	XCM190	Chert	10	M (IIIiv)	IA + LSA
HwJf-02.TP#2.70-80cm.242	XCM191	Chert	10	M (IIIiv)	IA + LSA
HwJf-02.TP#2.70-80cm.257	XCM192	"Odd" rock	10	M (IIIiii)	IA + LSA
HwJf-02.TP#2.80-90cm.44	XCM193	"Odd" rock	10	M (IIIii)	IA + LSA
HwJf-02.TP#2.80-90cm.54	XCM194	"Odd" rock	10	M (IIIiv)	IA + LSA
HwJf-02.TP#2.80-90cm.330	XCM195	Chert	10	M (IIIiv)	IA + LSA
HwJf-02.TP#2.80-90cm.514	XCM196	Chert	10	M (IIIi)	IA + LSA
HwJf-02.TP#2.80-90cm.521	XCM197	"Odd" rock	10	M (IIIiv)	IA + LSA
HwJf-02.TP#2.80-90cm.544	XCM198	Chert	10	M (IIIiii)	IA + LSA
HwJf-02.TP#2.90-110cm.45	XCM199	"Odd" rock	10	M (IIIiv)	IA + LSA
HwJf-02.TP#2.90-110cm.446	XCM200	Chert	10	M (IIIi)	IA + LSA
HwJf-02.TP#2.90-110cm.448	XCM201	Chert	10	M (IIIiv)	IA + LSA
HwJf-02.TP#2.90-110cm.468	XCM202	Chert	10	M (IIIiv)	IA + LSA
HwJf-02.TP#2.90-110cm.482	XCM203	"Odd" rock	10	M (IIIiv)	IA + LSA
HwJf-02.TP#2.110-120cm.104	XCM204	Chert	10	M (IIIiv)	LSA + MSA
HwJf-02.TP#2.110-120cm.151	XCM205	Chert	10	M (IIIiv)	LSA + MSA
HwJf-02.TP#2.110-120cm.280	XCM206	Chert	10	M (IIIi)	LSA + MSA
HwJf-02.TP#2.110-120cm.357	XCM207	Chert	10	M (IIIiv)	LSA + MSA
HwJf-02.TP#2.120-130cm.99	XCM208	Chert	10	M (IIIiv)	LSA + MSA
HwJf-02.TP#2.120-130cm.335	XCM209	Chert	10	M (IIIiii)	LSA + MSA
HwJf-02.TP#2.130-140cm.535	XCM210	Chert	10	M (IIIiv)	LSA + MSA
HwJf-02.TP#2.140-150cm.34	XCM211	Chert	10	M (IIIii)	LSA + MSA
HwJf-02.TP#2.140-150cm.513	XCM212	Chert	10	M (IIIiv)	LSA + MSA
HwJf-02.TP#2.150-160cm.153	XCM213	Chert	10	M (IIIii)	LSA + MSA
HwJf-02.TP#2.150-160cm.778	XCM214	Chert	10	M (IIIiv)	LSA + MSA
HwJf-02.TP#2.150-160cm.874	XCM215	Chert	10	M (IIIiv)	LSA + MSA

- Unknown = metamorphic or volcanic; thin section required to determine what it is
- "Odd" rock = when only one artifact of that raw material type is present in the entire assemblage

Table C.3: Magubike Artifacts Selected for Microscopic Analysis

Artifact Designation	Sample Number	Description	Type Macro	Type Micro	Cultural Designation
HxJf-01.Surface.7	XOF001	Chert Odd Rock	10	M (IIIiv)	IA + LSA
HxJf-01.Surface.446	XOF002	Chert Odd Rock	10	M (IIIiv)	IA + LSA
HxJf-01.Surface.458	XOF003	Chert odd Rock	9	L	IA + LSA
HxJf-01.Surface.639	XOF004	Chert Odd Rock	10	M (IIIiv)	IA + LSA
HxJf-01.Surface.661	XOF005	Chert Odd Rock	10	M (IIIiv)	IA + LSA
HxJf-01.Surface.698	XOF006	Chert Odd Rock	10	M (IIIiv)	IA + LSA
HxJf-01.Surface.712	XOF007	Chert Odd Rock	10	M (IIIiv)	IA + LSA
HxJf-01.Surface.735	XOF008	Chert Odd Rock	10	M (IIIiv)	IA + LSA
HxJf-01.TP#1.40-50cm.178	XOF009	Chert Odd Rock	10	M (I)	IA
HxJf-01.TP#1.50-60cm.19	XOF010	Chert Odd Rock	10	M (IIIi)	LSA
HxJf-01.TP#1.60-70cm.302	XOF011	Chert Odd Rock	10	M (I)	LSA
HxJf-01.TP#1.130-140cm.706	XOF012	Chert Odd Rock	10	M (IIIiv)	MSA
HxJf-01.TP#1.130-140cm.743/793	XOF013	Chert Odd Rock	10	M (IIIi)	MSA
HxJf-01.TP#1.130-140cm.1456/1536	XOF014	Chert Odd Rock	10	L	MSA
HxJf-01.TP#2.0-10cm.27	XOF015	Chert Odd Rock	9	L	IA
HxJf-01.TP#2.0-10cm.31	XOF016	Chert Odd Rock	10	M (IIIiv)	IA
HxJf-01.TP#2.10-20cm.158	XOF017	Chert odd rock	10	M (IIIi)	IA
HxJf-01.TP#2.30-40cm.118	XOF018	Chert Odd Rock	10	M (IIIiv)	IA
HxJf-01.TP#2.30-40cm.119	XOF019	Chert Odd Rock	10	M (IIIiv)	IA
HxJf-01.TP#2.50-60cm.55	XOF020	Chert odd Rock	10	M (IIIi)	MSA
HxJf-01.TP#3.60-70cm.264	XOF021	Chert odd Rock	3	C	MSA
HxJf-01.TP#3.70-80cm.173	XOF022	Chert Odd Rock	10	M (IIIiv)	MSA
HxJf-01.TP#3.90-100cm.36	XOF023	Chert odd Rock	8	K (a)	MSA
HxJf-01.TP#3.90-100cm.614	XOF024	Chert Odd Rock	10	M (IIIiii)	MSA
HxJf-01.TP#3.130-140cm.711	XOF025	Chert Odd Rock	10	M (IIIiv)	MSA
HxJf-01.TP#3.170-180cm.266	XOF026	Chert Odd Rock	9	L	MSA

HxJf-01.TP#3.180-190cm.205	XOF027	Chert Odd Rock	10	M (IIIiii)	MSA
HxJf-01.Surface.126	XOF028	Chert	9	L	IA + LSA
HxJf-01.Surface.189	XOF029	Chert	10	M (IV)	IA + LSA
HxJf-01.Surface.221	XOF030	Chert	9	L	IA + LSA
HxJf-01.Surface.390	XOF031	Chert	3	C	IA + LSA
HxJf-01.Surface.457	XOF032	Chert	10	M (IIIi)	IA + LSA
HxJf-01.Surface.469	XOF033	Chert	4	G	IA + LSA
HxJf-01.Surface.542	XOF034	Chert	10	M (IIIiv)	IA + LSA
HxJf-01.Surface.645	XOF035	Chert	7	J	IA + LSA
HxJf-01.Surface.678	XOF036	Chert	4	G	IA + LSA
HxJf-01.Surface.679	XOF037	Chert	10	M (IIIiv)	IA + LSA
HxJf-01.Surface.727	XOF038	Chert	10	M (IIIiv)	IA + LSA
HxJf-01.Surface.754	XOF039	Chert	10	M (IIIiv)	IA + LSA
HxJf-01.TP#1.0-10cm.42	XOF040	Chert	10	M (IV)	IA
HxJf-01.TP#1.0-10cm.235	XOF041	Chert	10	M (IV)	IA
HxJf-01.TP#1.10-20cm.77	XOF042	Chert	9	L	IA
HxJf-01.TP#1.10-20cm.80	XOF043	Chert	10	M (IIIiv)	IA
HxJf-01.TP#1.20-30cm.27	XOF044	Chert	9	L	IA
HxJf-01.TP#1.30-40cm.5	XOF045	Chert	9	L	IA
HxJf-01.TP#1.50-60cm.403	XOF046	Chert	4	E	LSA
HxJf-01.TP#1.60-70cm.324	XOF047	Chert	10	M (IIIiv)	LSA
HxJf-01.TP#1.70-80cm.64	XOF048	Chert	10	M (IIIi)	LSA + MSA
HxJf-01.TP#1.70-80cm.76	XOF049	Chert	10	M (IIIiv)	LSA + MSA
HxJf-01.TP#1.80-90cm.17	XOF050	Chert	10	M (IIIiv)	LSA + MSA
HxJf-01.TP#1.90-100cm.35	XOF051	Chert	10	C	LSA + MSA
HxJf-01.TP#1.100-110cm.36	XOF052	Chert	10	M (IIIi)	MSA
HxJf-01.TP#1.110-120cm.80	XOF053	Chert	10	M (IIIii)	MSA
Hxjf-01.TP#1.110-120cm.383	XOF054	Chert	10	M (IIIi)	MSA
hxJf-01.TP#1.120-130cm.136	XOF055	Chert	10	M (IIIi)	MSA
HxJf-01.TP#1.120-130cm.184	XOF056	Chert	9	L	MSA
HxJf-01.TP#1.120-130cm.252	XOF057	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#1.120-130cm.262	XOF058	Chert	10	M (IIIiii)	MSA
HxJf-01.TP#1.120-130cm.405	XOF059	Chert	10	M (IIIi)	MSA
HxJf-01.TP#1.130-140cm.106	XOF060	Chert	6	I	MSA
HxJf-01.TP#1.130-140cm.147	XOF061	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#1.130-140cm.577	XOF062	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#1.130-140cm.760	XOF063	Chert	10	M (IIIi)	MSA
HxJf-01.TP#1.130-140cm.818	XOF064	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#1.130-140cm.1140	XOF065	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#1.130-140cm.1232	XOF066	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#1.130-140cm.1346	XOF067	Chert	10	M (IIIi)	MSA
HxJf-01.TP#1.130-140cm.1363	XOF068	Chert	10	M (IIIi)	MSA
HxJf-01.TP#1.130-140cm.1424	XOF069	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#1.140-150cm.89	XOF070	Chert	9	L	MSA
HxJf-01.TP#1.140-150cm.153	XOF071	Chert	10	M (IIIi)	MSA
HxJf-01.TP#1.140-150cm.766	XOF072	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#1.150-160cm.108	XOF073	Chert	10	M (IIIi)	MSA
HxJf-01.TP#1.150-160cm.223	XOF074	Chert	9	L	MSA
HxJf-01.TP#1.150-160cm.392	XOF075	Chert	10	M (IIIi)	MSA
HxJf-01.TP#1.160-170cm.53	XOF076	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#1.170-180cm.7	XOF077	Chert	10	e	MSA
HxJf-01.TP#2.0-10cm.2	XOF078	Chert	10	M (IIIiii)	IA
HxJf-01.TP#2.10-20cm.173	XOF079	Chert	10	M (IV)	IA
HxJf-01.TP#2.20-30cm.128	XOF080	Chert	10	M (IIIiii)	IA
HxJf-01.TP#2.20-30cm.171	XOF081	Chert	10	M (IV)	IA
HxJf-01.TP#2.40-50cm.195	XOF082	Chert	10	L	IA
HxJf-01.TP#2.50-60cm.95	XOF083	Chert	8	J	MSA
HxJf-01.TP#2.50-60cm.132	XOF084	Chert	3	C	MSA
HxJf-01.TP#3.0-10cm.22	XOF085	Chert	10	M (IIIiv)	IA
HxJf-01.TP#3.0-10cm.85	XOF086	Chert	10	M (IV)	IA
HxJf-01.TP#3.10-20cm.102	XOF087	Chert	10	M (IIIiv)	IA
HxJf-01.TP#3.10-20cm.207	XOF088	Chert	10	M (IV)	IA
HxJf-01.TP#3.20-30cm.43	XOF089	Chert	10	M (IIIiv)	IA
HxJf-01.TP#3.20-30cm.139	XOF090	Chert	10	L	IA
HxJf-01.TP#3.20-30cm.1041?	XOF091	Chert	10	M (IV)	IA
HxJf-01.TP#3.30-40cm.71	XOF092	Chert	4	D	IA
HxJf-01.TP#3.40-50cm.130?	XOF093	Chert		f	IA
HxJf-01.TP#3.40-50cm.183	XOF094	Chert	9	L	IA
HxJf-01.TP#3.40-50cm.186	XOF095	Chert	10	L	IA
HxJf-01.TP#3.50-60cm.187	XOF096	Chert	10	M (IIIiv)	IA
HxJf-01.TP#3.60-70cm.88	XOF097	Chert	4	G	MSA

HxJf-01.TP#3.60-70cm.239	XOF098	Chert	8	J	MSA
HxJf-01.TP#3.60-70cm.292	XOF099	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.60-70cm.338	XOF100	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.60-70cm.360	XOF101	Chert	9	L	MSA
HxJf-01.TP#3.70-80cm.31	XOF102	Chert	8	J	MSA
HxJf-01.TP#3.70-80cm.317	XOF103	Chert	8	J	MSA
HxJf-01.TP#3.70-80cm.482	XOF104	Chert	9	L	MSA
HxJf-01.TP#3.70-80cm.523	XOF105	Chert	3	C	MSA
HxJf-01.TP#3.70-80cm.589	XOF106	Chert	9	L	MSA
HxJf-01.TP#3.70-80cm.695/569	XOF107	Chert	10	L	MSA
HxJf-01.TP#3.80-90cm.380	XOF108	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.80-90cm.415	XOF109	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.90-100cm.32	XOF110	Chert	9	L	MSA
HxJf-01.TP#3.90-100cm.142	XOF111	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.90-100cm.349	XOF112	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.90-100cm.368	XOF113	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.90-100cm.378	XOF114	Chert	8	J	MSA
HxJf-01.TP#3.90-100cm.522	XOF115	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.90-100cm.633	XOF116	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.100-110cm.27	XOF117	Chert	9	L	MSA
HxJf-01.TP#3.100-110cm.119	XOF118	Chert	10	M (II)	MSA
HxJf-01.TP#3.100-110cm.439	XOF119	Chert	9	L	MSA
HxJf-01.TP#3.100-110cm.578	XOF120	Chert	10	M (IIIiii)	MSA
HxJf-01.TP#3.110-120cm.276	XOF121	Chert	9	L	MSA
HxJf-01.TP#3.110-120cm.328	XOF122	Chert	10	M (IIIi)	MSA
HxJf-01.TP#3.110-120cm.573	XOF123	Chert	9	L	MSA
HxJf-01.TP#3.120-130cm.345	XOF124	Chert	8	J	MSA
HxJf-01.TP#3.120-130cm.454	XOF125	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.120-130cm.596	XOF126	Chert	10	L	MSA
HxJf-01.TP#3.120-130cm.712	XOF127	Chert	4	E	MSA
HxJf-01.TP#3.130-140cm.242	XOF128	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.130-140cm.694	XOF129	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.130-140cm.744	XOF130	Chert	9	L	MSA
HxJf-01.TP#3.130-140cm.797	XOF131	Chert	9	L	MSA
HxJf-01.TP#3.130-140cm.814	XOF132	Chert	9	L	MSA
HxJf-01.TP#3.130-140cm.1039	XOF133	Chert	10	L	MSA
HxJf-01.TP#3.140-150cm.64	XOF134	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.140-150cm.223	XOF135	Chert	9	L	MSA
HxJf-01.TP#3.140-150cm.362	XOF136	Chert	9	L	MSA
HxJf-01.TP#3.150-160cm.14	XOF137	Chert	10	M (IIIi)	MSA
HxJf-01.TP#3.150-160cm.94	XOF138	Chert	10	L	MSA
HxJf-01.TP#3.150-160cm.564	XOF139	Chert	3	C	MSA
HxJf-01.TP#3.150-160cm.602	XOF140	Chert	9	L	MSA
HxJf-01.TP#3.160-170cm.90	XOF141	Chert	3	C	MSA
HxJf-01.TP#3.160-170cm.134	XOF142	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.160-170cm.645	XOF143	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.170-180cm.270	XOF144	Chert	3	C	MSA
HxJf-01.TP#3.170-180cm.382	XOF145	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.170-180cm.556	XOF146	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.170-180cm.618	XOF147	Chert	10	L	MSA
HxJf-01.TP#3.170-180cm.762	XOF148	Chert	9	L	MSA
HxJf-01.TP#3.170-180cm.980	XOF149	Chert	10	L	MSA
HxJf-01.TP#3.170-180cm.1138	XOF150	Chert	3	C	MSA
HxJf-01.TP#3.180-190cm.226	XOF151	Chert	10	L	MSA
HxJf-01.TP#3.180-190cm.305	XOF152	Chert	10	M (IIIi)	MSA
HxJf-01.TP#3.180-190cm.430	XOF153	Chert	8	J	MSA
HxJf-01.TP#3.180-190cm.442	XOF154	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.180-190cm.934	XOF155	Chert	3	C	MSA
HxJf-01.TP#3.180-190cm.955	XOF156	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.180-190cm.1023	XOF157	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.180-190cm.1157	XOF158	Chert	8	J	MSA
HxJf-01.TP#3.180-190cm.1174	XOF159	Chert	3	C	MSA
HxJf-01.TP#3.180-190cm.1217	XOF160	Chert	10	L	MSA
HxJf-01.TP#3.180-190cm.1252	XOF161	Chert	10	L	MSA
HxJf-01.TP#3.180-190cm.1264	XOF162	Chert	9	L	MSA
HxJf-01.TP#3.190-200cm.79	XOF163	Chert	10	M (IIIi)	MSA
HxJf-01.TP#3.190-200cm.94	XOF164	Chert	10	M (IIIii)	MSA
HxJf-01.TP#3.190-200cm.140	XOF165	Chert	10	M (IIIi)	MSA
HxJf-01.TP#3.190-200cm.330	XOF166	Chert	3	C	MSA
HxJf-01.TP#3.190-200cm.375	XOF167	Chert	9	L	MSA
HxJf-01.TP#3.190-200cm.435	XOF168	Chert	10	L	MSA
HxJf-01.TP#3.190-200cm.610	XOF169	Chert	4	D	MSA
HxJf-01.TP#3.190-200cm.742	XOF170	Chert	10	M (IIIiv)	MSA
HxJf-01.TP#3.200-210cm.15/51	XOF171	Chert	3	C	MSA
HxJf-01.TP#3.200-210cm.61	XOF172	Chert	9	L	MSA

HxJf-01.Surface.23	XOF173	Odd Rock	4	F	IA + LSA
HxJf-01.Surface.409	XOF174	Odd Rock	4	D	IA + LSA
HxJf-01.Surface.419	XOF175	Odd Rock	1	A	IA + LSA
HxJf-01.Surface.541	XOF418	Odd Rock	4	D	IA + LSA
HxJf-01.Surface.643	XOF419	Odd Rock	4	D	IA + LSA
HxJf-01.TP#1.60-70cm.239	XOF176	Odd Rock	9	L	LSA
HxJf-01.TP#1.60-70cm.280	XOF177	Odd Rock	9	L	LSA
HxJf-01.TP#1.110-120cm.7	XOF178	Odd Rock	2	B	MSA
HxJf-01.TP#1.120-130cm.545	XOF179	Odd Rock	1	A	MSA
HxJf-01.TP#1.130-140cm.140	XOF180	Unknown	4	F	MSA
HxJf-01.TP#1.130-140cm.1146	XOF181	Unknown	4	F	MSA
HxJf-01.TP#1.140-150cm.112	XOF182	Odd Rock	8	K (a)	MSA
HxJf-01.TP#1.150-160cm.504	XOF183	Unknown	4	F	MSA
HxJf-01.TP#2.20-30cm.156	XOF184	Odd Rock	10	L	IA
HxJf-01.TP#2.40-50cm.180	XOF185	Odd Rock	10	L	IA
HxJf-01.TP#3.50-60cm.157	XOF186	Odd Rock	4	D	MSA
HxJf-01.TP#3.60-70cm.127	XOF187	Odd Rock	8	K?	MSA
HxJf-01.TP#3.60-70cm.210	XOF188	Odd Rock	10	M (II)	MSA
HxJf-01.TP#3.60-70cm.214	XOF189	Odd Rock	1	A	MSA
HxJf-01.TP#3.70-80cm.442	XOF190	Odd Rock	8	J	MSA
HxJf-01.TP#3.70-80cm.508	XOF191	Odd Rock	4	F	MSA
HxJf-01.TP#3.70-80cm.529	XOF192	Odd Rock	4	D	MSA
HxJf-01.TP#3.70-80cm.539	XOF193	Odd Rock	4	G	MSA
HxJf-01.TP#3.70-80cm.670	XOF194	Odd Rock	7	J	MSA
HxJf-01.TP#3.80-90cm.17	XOF195	Odd Rock	4	D	MSA
HxJf-01.TP#3.90-100cm.14	XOF196	Odd Rock	4	G	MSA
HxJf-01.TP#3.90-100cm.207	XOF197	Odd Rock	4	D	MSA
HxJf-01.TP#3.90-100cm.288	XOF198	Odd Rock	9	L	MSA
HxJf-01.TP#3.90-100cm.607	XOF199	Unknown	4	D	MSA
HxJf-01.TP#3.100-110cm.151	XOF200	Unknown	2	B	MSA
HxJf-01.TP#3.110-120cm.391	XOF201	Unknown	4	E	MSA
HxJf-01.TP#3.120-130cm.554	XOF202	Unknown	4	D	MSA
HxJf-01.TP#3.130-140cm.895	XOF203	Unknown	4	D	MSA
HxJf-01.TP#3.140-150cm.216	XOF204	Unknown	4	D	MSA
HxJf-01.TP#3.150-160cm.97	XOF205	Unknown	4	F	MSA
HxJf-01.TP#3.150-160cm.131	XOF206	Odd Rock	9	L	MSA
HxJf-01.TP#3.160-170cm.597	XOF207	Unknown	4	F	MSA
HxJf-01.TP#3.170-180cm.264	XOF208	Odd Rock	8	J	MSA
HxJf-01.TP#3.170-180cm.557	XOF209	Odd Rock	8	J	MSA
HxJf-01.TP#3.170-180cm.808	XOF210	Odd Rock	8	J	MSA
HxJf-01.TP#3.170-180cm.875	XOF211	Unknown	4	F	MSA
HxJf-01.TP#3.180-190cm.704	XOF212	Odd Rock	4	F	MSA
HxJf-01.TP#3.190-200cm.16	XOF213	Unknown	4	F	MSA
HxJf-01.TP#3.190-200cm.48	XOF214	Unknown	4	F	MSA
HxJf-01.TP#3.190-200cm.655	XOF215	Odd Rock	10	M (II)	MSA
HxJf-01.TP#3.200-210cm.11	XOF216	Unknown	9	L	MSA
HxJf-01.TP#3.200-210cm.52	XOF217	Odd Rock	1	A	MSA
HxJf-01.Surface.51	XOF218	Other	4	D	IA + LSA
HxJf-01.Surface.692	XOF219	Other	4	F	IA + LSA
HxJf-01.Surface.756	XOF220	Other	4	F	IA + LSA
HxJf-01.TP#1.0-10cm.262	XOF221	Other	4	F	IA
HxJf-01.TP#1.10-20cm.82	XOF222	Other	4	F	IA
HxJf-01.TP#1.20-30cm.33	XOF223	Other	4	E	IA
HxJf-01.TP#1.30-40cm.160	XOF224	Other	4	D	IA
HxJf-01.TP#1.40-50cm.207	XOF225	Other	4	D	IA
HxJf-01.TP#1.50-60cm.392	XOF226	Other	8	J	LSA
HxJf-01.TP#1.60-70cm.441	XOF227	Other	4	F	LSA
HxJf-01.TP#1.70-80cm.62	XOF228	Other	8	J	LSA + MSA
HxJf-01.TP#1.80-90cm.2	XOF229	Other	4	D	LSA + MSA
HxJf-01.TP#1.90-100cm.36	XOF230	Other	8	J	LSA + MSA
HxJf-01.TP#1.100-110cm.29	XOF231	Other	4	D	MSA
HxJf-01.TP#1.110-120cm.12	XOF232	Other	8	J	MSA
HxJf-01.TP#1.110-120cm.248	XOF233	Other	8	J	MSA
HxJf-01.TP#1.110-120cm.338	XOF234	Other	4	D	MSA
HxJf-01.TP#1.110-120cm.344	XOF235	Other	4	D	MSA
HxJf-01.TP#1.110-120cm.387	XOF236	Other	4	D	MSA
HxJf-01.TP#1.120-130cm.427	XOF237	Other	8	J	MSA
HxJf-01.TP#1.120-130cm.534	XOF238	Other	4	D	MSA
HxJf-01.TP#1.120-130cm.603	XOF239	Other	8	J	MSA
HxJf-01.TP#1.120-130cm.632	XOF240	Other	4	F	MSA
HxJf-01.TP#1.120-130cm.648	XOF241	Other	3	C	MSA
HxJf-01.TP#1.120-130cm.653	XOF242	Other	4	D	MSA

HxJf-01.TP#1.130-140cm.275	XOF243	Other	8	J	MSA
HxJf-01.TP#1.130-140cm.324	XOF244	Other	8	J	MSA
HxJf-01.TP#1.130-140cm.604	XOF245	Other	8	J	MSA
HxJf-01.TP#1.130-140cm.1045	XOF246	Other	8	J	MSA
HxJf-01.TP#1.130-140cm.1124	XOF247	Other	4	D	MSA
HxJf-01.TP#1.130-140cm.1152	XOF248	Other	3	C	MSA
HxJf-01.TP#1.130-140cm.1153	XOF249	Other	4	D	MSA
HxJf-01.TP#1.130-140cm.1163	XOF250	Other	8	J	MSA
HxJf-01.TP#1.130-140cm.1176	XOF251	Other	4	G	MSA
HxJf-01.TP#1.130-140cm.1340	XOF252	Other	8	J	MSA
HxJf-01.TP#1.130-140cm.1348	XOF253	Other	3	C	MSA
HxJf-01.TP#1.130-140cm.1427	XOF254	Other	8	J	MSA
HxJf-01.TP#1.140-150cm.23	XOF255	Other	4	D	MSA
HxJf-01.TP#1.140-150cm.206	XOF256	Other	4	G	MSA
HxJf-01.TP#1.140-150cm.509	XOF257	Other	3	C	MSA
HxJf-01.TP#1.140-150cm.985	XOF258	Other	8	J	MSA
HxJf-01.TP#1.140-150cm.1012	XOF259	Other	3	C	MSA
HxJf-01.TP#1.140-150cm.1014	XOF260	Other	4	E	MSA
HxJf-01.TP#1.150-160cm.27	XOF261	Other	4	E	MSA
HxJf-01.TP#1.150-160cm.491	XOF262	Other	8	J	MSA
HxJf-01.TP#1.150-160cm.509	XOF263	Other	8	J	MSA
HxJf-01.TP#1.150-160cm.514	XOF264	Other	4	E	MSA
HxJf-01.TP#1.160-170cm.8	XOF265	Other	4	D	MSA
HxJf-01.TP#1.160-170cm.206	XOF266	Other	3	C	MSA
HxJf-01.TP#1.170-180cm.80	XOF267	Other	3	C	MSA
HxJf-01.TP#2.10-20cm.185	XOF268	Other	4	F	IA
HxJf-01.TP#2.20-30cm.135	XOF269	Other	8	J	IA
HxJf-01.TP#2.30-40cm.124	XOF270	Other	4	D	IA
HxJf-01.TP#2.40-50cm.183	XOF271	Other	4	F	IA
HxJf-01.TP#2.50-60cm.62	XOF272	Other	4	G	MSA
HxJf-01.TP#2.50-60cm.117	XOF273	Other	4	D	MSA
HxJf-01.TP#3.0-10cm.83	XOF274	Other	4	F	IA
HxJf-01.TP#3.10-20cm.182	XOF275	Other	4	F	IA
HxJf-01.TP#3.20-30cm.75	XOF276	Other	4	F	IA
HxJf-01.TP#3.30-40cm.119	XOF277	Other	4	F	IA
HxJf-01.TP#3.40-50cm.160	XOF278	Other	4	F	IA
HxJf-01.TP#3.40-50cm.175	XOF279	Other	4	D	IA
HxJf-01.TP#3.50-60cm.190	XOF280	Other	4	D	IA
HxJf-01.TP#3.50-60cm.195	XOF281	Other	4	G	IA
HxJf-01.TP#3.60-70cm.92	XOF282	Other	4	G	MSA
HxJf-01.TP#3.60-70cm.290	XOF283	Other	4	D	MSA
HxJf-01.TP#3.60-70cm.310	XOF284	Other	4	E	MSA
HxJf-01.TP#3.70-80cm.48	XOF285	Other	8	J	MSA
HxJf-01.TP#3.70-80cm.109/601?	XOF286	Other	8	J	MSA
HxJf-01.TP#3.70-80cm.459	XOF287	Other	4	G	MSA
HxJf-01.TP#3.70-80cm.488	XOF288	Other	3	C	MSA
HxJf-01.TP#3.70-80cm.499	XOF289	Other	4	G	MSA
HxJf-01.TP#3.70-80cm.512	XOF290	Other	4	F	MSA
HxJf-01.TP#3.70-80cm.532	XOF292	Other	4	E	MSA
HxJf-01.TP#3.70-80cm.617	XOF293	Other	4	G	MSA
HxJf-01.TP#3.70-80cm.629	XOF294	Other	8	J	MSA
HxJf-01.TP#3.70-80cm.630	XOF295	Other	4	D	MSA
HxJf-01.TP#3.70-80cm.651	XOF296	Other	8	J	MSA
HxJf-01.TP#3.70-80cm.652	XOF297	Other	4	G	MSA
HxJf-01.TP#3.70-80cm.677	XOF298	Other	4	E	MSA
HxJf-01.TP#3.80-90cm.38	XOF299	Other	3	C	MSA
HxJf-01.TP#3.80-90cm.59	XOF300	Other	8	J	MSA
HxJf-01.TP#3.80-90cm.358	XOF301	Other	4	F	MSA
HxJf-01.TP#3.80-90cm.359	XOF302	Other	8	J	MSA
HxJf-01.TP#3.80-90cm.367	XOF303	Other	4	F	MSA
HxJf-01.TP#3.80-90cm.393	XOF304	Other	4	F	MSA
HxJf-01.TP#3.80-90cm.436	XOF305	Other	4	D	MSA
HxJf-01.TP#3.80-90cm.440	XOF306	Other	4	F	MSA
HxJf-01.TP#3.80-90cm.474	XOF307	Other	4	G	MSA
HxJf-01.TP#3.90-100cm.116	XOF308	Other	8	K (a)	MSA
HxJf-01.TP#3.90-100cm.388	XOF309	Other	4	D	MSA
HxJf-01.TP#3.90-100cm.446	XOF310	Other	3	C	MSA
HxJf-01.TP#3.90-100cm.501	XOF311	Other	4	D	MSA
HxJf-01.TP#3.90-100cm.533	XOF312	Other	4	E	MSA
HxJf-01.TP#3.90-100cm.676	XOF313	Other	4	D	MSA
HxJf-01.TP#3.90-100cm.679	XOF314	Other	4	G	MSA
HxJf-01.TP#3.90-100cm.740	XOF315	Other	4	F	MSA
HxJf-01.TP#3.90-100cm.749	XOF316	Other	8	J	MSA
HxJf-01.TP#3.100-110cm.37	XOF317	Other	8	J	MSA
HxJf-01.TP#3.100-110cm.285	XOF318	Other	4	E	MSA

HxJf-01.TP#3.100-110cm.454	XOF319	Other	4	E	MSA
HxJf-01.TP#3.100-110cm.512	XOF320	Other	8	J	MSA
HxJf-01.TP#3.100-110cm.522	XOF321	Other	4	D	MSA
HxJf-01.TP#3.100-110cm.562	XOF322	Other	4	G	MSA
HxJf-01.TP#3.110-120cm.37	XOF323	Other	4	D	MSA
HxJf-01.TP#3.110-120cm.77	XOF324	Other	4	D	MSA
HxJf-01.TP#3.110-120cm.88	XOF325	Other	3	G	MSA
HxJf-01.TP#3.110-120cm.137	XOF326	Other	2	B	MSA
HxJf-01.TP#3.110-120cm.423	XOF327	Other	4	D	MSA
HxJf-01.TP#3.110-120cm.550	XOF328	Other	8	J	MSA
HxJf-01.TP#3.110-120cm.563	XOF329	Other	4	F	MSA
HxJf-01.TP#3.110-120cm.566	XOF330	Other	4	D	MSA
HxJf-01.TP#3.110-120cm.587	XOF331	Other	4	D	MSA
HxJf-01.TP#3.120-130cm.41	XOF332	Other	4	D	MSA
HxJf-01.TP#3.120-130cm.87	XOF333	Other	2	B	MSA
HxJf-01.TP#3.120-130cm.186	XOF334	Other	2	B	MSA
HxJf-01.TP#3.120-130cm.207	XOF335	Other	8	J	MSA
HxJf-01.TP#3.120-130cm.243	XOF336	Other	8	J	MSA
HxJf-01.TP#3.120-130cm.586	XOF337	Other	4	F	MSA
HxJf-01.TP#3.120-130cm.604	XOF338	Other	4	E	MSA
HxJf-01.TP#3.120-130cm.693	XOF339	Other	4	D	MSA
HxJf-01.TP#3.130-140cm.150	XOF340	Other	4	D	MSA
HxJf-01.TP#3.130-140cm.368	XOF341	Other	3	C	MSA
HxJf-01.TP#3.130-140cm.416	XOF342	Other	4	G	MSA
HxJf-01.TP#3.130-140cm.513	XOF343	Other	4	D	MSA
HxJf-01.TP#3.130-140cm.601	XOF344	Other	4	D	MSA
HxJf-01.TP#3.130-140cm.730	XOF345	Other	4	F	MSA
HxJf-01.TP#3.130-140cm.753	XOF346	Other	4	E	MSA
HxJf-01.TP#3.130-140cm.812	XOF347	Other	8	J	MSA
HxJf-01.TP#3.130-140cm.883	XOF348	Other	4	F	MSA
HxJf-01.TP#3.130-140cm.884	XOF349	Other	4	E	MSA
HxJf-01.TP#3.140-150cm.60	XOF350	Other	4	E	MSA
HxJf-01.TP#3.140-150cm.67	XOF351	Other	4	D	MSA
HxJf-01.TP#3.140-150cm.224	XOF352	Other	4	D	MSA
HxJf-01.TP#3.140-150cm.260	XOF353	Other	8	J	MSA
HxJf-01.TP#3.140-150cm.268	XOF354	Other	3	C	MSA
HxJf-01.TP#3.140-150cm.361	XOF355	Other	4	D	MSA
HxJf-01.TP#3.140-150cm.364	XOF356	Other	3	C	MSA
HxJf-01.TP#3.150-160cm.100	XOF357	Other	4	D	MSA
HxJf-01.TP#3.150-160cm.105	XOF358	Other	3	C	MSA
HxJf-01.TP#3.150-160cm.110	XOF359	Other	8	J	MSA
HxJf-01.TP#3.150-160cm.221	XOF360	Other	3	C	MSA
HxJf-01.TP#3.150-160cm.349	XOF361	Other	8	J	MSA
HxJf-01.TP#3.150-160cm.353	XOF362	Other	8	J	MSA
HxJf-01.TP#3.150-160cm.440	XOF363	Other	8	J	MSA
HxJf-01.TP#3.150-160cm.450	XOF364	Other	3	C	MSA
HxJf-01.TP#3.150-160cm.500	XOF365	Other	8	J	MSA
HxJf-01.TP#3.150-160cm.514	XOF366	Other	8	J	MSA
HxJf-01.TP#3.150-160cm.582	XOF367	Other	4	F	MSA
HxJf-01.TP#3.150-160cm.610	XOF368	Other	4	D	MSA
HxJf-01.TP#3.150-160cm.635	XOF369	Other	8	J	MSA
HxJf-01.TP#3.150-160cm.645/553	XOF370	Other	8	J	MSA
HxJf-01.TP#3.160-170cm.142	XOF371	Other	8	J	MSA
HxJf-01.TP#3.160-170cm.208	XOF372	Other	8	J	MSA
HxJf-01.TP#3.160-170cm.218	XOF373	Other	3	C	MSA
HxJf-01.TP#3.160-170cm.332	XOF374	Other	8	J	MSA
HxJf-01.TP#3.160-170cm.491	XOF375	Other	4	G	MSA
HxJf-01.TP#3.160-170cm.501	XOF376	Other	8	J	MSA
HxJf-01.TP#3.160-170cm.507/537?	XOF377	Other	4	E	MSA
HxJf-01.TP#3.160-170cm.608	XOF378	Other	3	C	MSA
HxJf-01.TP#3.160-170cm.620	XOF379	Other	3	C	MSA
HxJf-01.TP#3.160-170cm.627	XOF380	Other	4	G	MSA
HxJf-01.TP#3.160-170cm.658	XOF381	Other	4	G	MSA
HxJf-01.TP#3.170-180cm.48	XOF382	Other	8	J	MSA
HxJf-01.TP#3.170-180cm.218	XOF383	Other	8	J	MSA
HxJf-01.TP#3.170-180cm.390	XOF384	Other	8	J	MSA
HxJf-01.TP#3.170-180cm.609	XOF385	Other	4	E	MSA
HxJf-01.TP#3.170-180cm.782	XOF386	Other	4	D	MSA
HxJf-01.TP#3.170-180cm.792	XOF387	Other	8	J	MSA
HxJf-01.TP#3.170-180cm.796	XOF388	Other	4	G	MSA
HxJf-01.TP#3.170-180cm.814	XOF389	Other	4	D	MSA
HxJf-01.TP#3.170-180cm.844	XOF390	Other	3	C	MSA
HxJf-01.TP#3.170-180cm.849	XOF391	Other	3	C	MSA
HxJf-01.TP#3.170-180cm.923	XOF392	Other	4	D	MSA
HxJf-01.TP#3.170-180cm.965	XOF393	Other	8	J	MSA

HxJf-01.TP#3.170-180cm.1103	XOF394	Other	8	J	MSA
HxJf-01.TP#3.170-180cm.1118	XOF395	Other	4	E	MSA
HxJf-01.TP#3.170-180cm.1130	XOF396	Other	4	E	MSA
HxJf-01.TP#3.170-180cm.1142	XOF397	Other	8	J	MSA
HxJf-01.TP#3.170-180cm.1144	XOF398	Other		g	MSA
HxJf-01.TP#3.170-180cm.1693	XOF399	Other	4	E	MSA
HxJf-01.TP#3.180-190cm.48	XOF400	Other	8	J	MSA
HxJf-01.TP#3.180-190cm.874	XOF401	Other	8	J	MSA
HxJf-01.TP#3.180-190cm.990?	XOF402	Other	4	D	MSA
HxJf-01.TP#3.180-190cm.1014	XOF403	Other	3	C	MSA
HxJf-01.TP#3.180-190cm.1052	XOF404	Other	4	E	MSA
HxJf-01.TP#3.180-190cm.1074	XOF405	Other	4	D	MSA
HxJf-01.TP#3.180-190cm.1265	XOF406	Other	4	F	MSA
HxJf-01.TP#3.190-200cm.17	XOF407	Other	8	J	MSA
HxJf-01.TP#3.190-200cm.516	XOF408	Other	4	G	MSA
HxJf-01.TP#3.190-200cm.549	XOF409	Other	3	C	MSA
HxJf-01.TP#3.190-200cm.619	XOF410	Other	4	G	MSA
HxJf-01.TP#3.190-200cm.621&156	XOF411	Other	4	F	MSA
HxJf-01.TP#3.190-200cm.674	XOF412	Other	4	F	MSA
HxJf-01.TP#3.190-200cm.693	XOF413	Other	4	F	MSA
HxJf-01.TP#3.200-210cm.43	XOF414	Other	8	J	MSA
HxJf-01.TP#3.200-210cm.50	XOF415	Other	4	D	MSA
HxJf-01.TP#3.200-210cm.55	XOF416	Other	4	E	MSA
HxJf-01.TP#3.200-210cm.57	XOF417	Other	4	F	MSA

- Unknown = metamorphic or volcanic; thin section required to determine what it is
- “Odd” rock = when only one artifact of that raw material type is present in the entire assemblage

Appendix D: Survey forms

D.1 Lithic Source Survey Form

1. Site No.
2. Region/Country:
3. Location (UTM):
4. Location (SASES):
5. Type of outcrop: Eroded exposure __ Road cut __ Cave __ Modern quarry __ Other ______
6. Type of deposit: Bedrock (in situ) __ Residual __ Redeposited (secondary) _______________
7. Outcrop thickness (m):
8. Outcrop extent (m):
9. Size:
10. Quality:
11. Scarcity:
12. Difficulty of terrain:
13. Cost of extraction: 1 2 3
14. Stratigraphy:
15. Profile drawing:
16. Plan sketch:
17. Photographs:
18. Evidence of prehistoric activity:

Lavin 1983(329)

- in situ = chert found in its original bedrock location
- residual = geographically in situ chert whose bedrock has been eroded away by various weathering processes
- redeposited = chert that has been eroded away by various weathering processes

Wilson 2007

- Quality:
  - Very poor= 0
  - Poor =1
  - Fair=2
  - Good=4
  - Very Good=8
  - Excellent=16
- Extent of source:
  - Small (less than 10m in diameter)=1
  - Medium (10 to 50m in diameter)=2
  - Extensive (50 to 100m in diameter)=3
  - Very extensive (+100m in diameter)=4
- Size = max. dimension (cm) of nodule or pieces at the source (give for both biggest pieces avail. and most abundant pieces avail.)
- Scarcity:
  - Very abundant (>50% of surface area of source consists of potential raw material)
  - Abundant (25 – 50%)
  - Medium (5 – 25%)
  - Scarce (<5%)
- Difficulty of terrain: (see Wilson 2007:399)
- Cost of extraction:
  - 1 = rocks collected as loose surface material
  - 2= easy quarrying
  - 3= hard quarrying

D.2 Site Survey Form

1. Site No. 2. Region/Country:
3. Location (UTM):
4. Location (SASES):
5. Type of site: isolated___ surface scatter___ rockshelter___ other_________
6. Surface finds: lithics ___ pottery___ iron___ other_________________
7. Cultural component: ESA___ MSA___ LSA___ Iron Age___
8. Density:
9. Disturbance:
10. Photographs:
11. Comments:

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