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Archaeological Investigation of the Buri Peninsula and Gulf of Zula, Red Sea Coast of Eritrea

A Dissertation Presented

by

Amanuel Yosief Beyin

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Abstract of the Dissertation

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This dissertation reports the results of archaeological survey and excavations on the Buri Peninsula and Gulf of Zula, Red Sea coast of Eritrea. Its primary goals were to seek evidence for prehistoric human settlement, and to define the geological, chronological and cultural contexts of the sites. The Red Sea Coast of Africa is thought to be an important refugium for humans dispersing from the interior of East Africa into Arabia and the Levant. Previous archaeological investigations in the Horn of Africa were mainly concentrated in the interior landscapes. Thus, our knowledge of human adaption on the African side of the Red Sea has been limited compared to the interior areas of the Horn. This project documented more than a dozen prehistoric sites representing Middle and Later Stone Age (LSA) cultures. A distinctive Middle

Stone Age (MSA) occupation was identified from surface lithic evidence at Asfet. Prepared cores, points and blades on a variety of raw materials characterize the Asfet surface assemblage. Excavation of three selected sites (Asfet Unit F, Gelalo NW and Misse East) revealed LSA occupations associated with coastal economy. Blade production and microlithic technology characterize the LSA sites. Based on radiometric age determinations and lithic composition, two Holocene occupations are recognized on the Zula-Buri littoral: i) eighth millennium settlement at Gelalo NW and Misse East, and ii) a mid-Holocene or sixth millennium settlement at Asfet Unit F. Inter-site lithic comparison of the coastal sites shows clear directional change through time in core technology, tool design and raw material utilization among Asfet surface, the two older LSA sites (Gelalo and Misse) and Asfet Unit F. The observed directional change hints at a possible adaptive shift through time, from high reliance on stone tools at Asfet surface, Gelalo and Misse to less dependence on lithics in the later phase corresponding to the Asfet Unit F. Mollusk shells were the only organic remains discovered at the LSA sites.

Specific shell types were found at the excavated sites. *Atactodea glabrata*, a small bivalve found buried in the sands of intertidal zone dominates the Misse shell midden, whereas the Asfet and Gelalo assemblages were represented by *Terebralia palustris,* a large gastropod living among mangroves and muddy substrate. The exploitation of specific shell types at each site suggests cultural choices that characterize specific human groups adapted to distinct coastal habitats. The results of this study provide valuable insight into human coastal adaptation of the Red Coast of Eritrea in the Late Pleistocene (Asfet surface), and Holocene (Asfet Unit F, Gelalo and Misse). This is the first systematic study to document repeated human occupation of the Red Sea Coast of Eritrea. Later Pleistocene and early mid-Holocene settlements along the Eritrean Coast may reflect humans moving to the coast during humid periods due to population pressure in the interior highlands, or during aridity-induced periods of ecological stress in the hinterlands. Further research is needed in order to further investigate the prehistoric potential of the Red Sea Basin on the African and Arabian sides, and clarify modes of human adaptive variability.

Dedication

For my parents, W/ro Okba Yosief and Ato Beyin Yosief, and my late uncle Ato Kidane Tedla for their relentless moral and financial support throughout my academic career.

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Chapter 1
Introduction

Theoretical Orientation: prehistoric coastal adaptation

Coastal environments have long been considered important in the demographic and geographic expansion of early humans (Bailey and Parkington 1988; Erlandson 2001; Hardy 1960; Kingdon 1993; Sauer 1962). Carl O. Sauer once described the role of aquatic habitat in the following words; “our kind had its origins and earliest home in an interior land. However, the discovery of the sea, whenever it happened afforded a living beyond that ...The sea, in particular the tidal shore, presented the best opportunity to eat, settle, increase and learn” (Sauer 1962:45). Currently, there is increasing evidence from various parts of the world that suggests that coastal habitats played an important role in human evolution; as bases of diverse resources, and stable refugia facilitating human dispersals and sedentism (see Erlandson 2001 for review). Compared to the Pleistocene period, there is more widespread coastal evidence from postglacial-Holocene contexts at a global scale (Bailey and Craighead 2003; Erlandson 2001; Yesner 1980). While some researchers (example, Erlandson 2001) posit that recurrent sea level changes in the Quaternary period hindered our ability to obtain rich Pleistocene coastal evidence, many researchers consider intensive maritime adaptation as an emergent feature of postglacial wet phase “broad spectrum revolution” that resulted in population increase and sedentary life (Binford 1968; Osborn 1977; Yesner 1980). Others associate it with increased technological innovations by Later Pleistocene humans (Klein 1999).

One of the oldest sites to provide evidence for coastal exploitation by archaic *Homo sapiens* is Terra Amata, along the Mediterranean coast of France dated to about 300 ka BP (de Lumley 1969). The earliest well-dated evidence for coastal adaptation by African humans comes from South Africa, at the site of Pinnacle Point dated to 164 $\pm$ 12 ka BP (Marean, et al. 2007). Located on a quartzitic coastal cliff (+15 m above mean sea level), the site of Pinnacle Point yielded well preserved cultural and faunal remains representing adaptation to cold and dry glacial event, Marine Isotope Stage(MIS) 6 (ibid.). Evidence for maritime exploitation has been documented at numerous other sites in South Africa, such as Klasies River Mouth (Singer and Wymer 1982), Die Kelders (Goldberg 2000), Herolds Bay (Brink and Deacon 1982), Blombos Cave (Henshilwood and Sealey 1997), and the Sea Harvest and Hoedjies Punt sites (Volman 1978). In general, South Africa has the highest number of coastal sites in Africa associated with the Middle Stone Age (MSA) culture. Likewise, the best studied Holocene sites of coastal foragers have come from the coastal littoral of Cape Province and adjacent regions (Deacon 1984; Parkington, et al. 1988). This may reflect recurrent expansion of Later Pleistocene and Holocene humans into southern Africa or preservation bias due to the availability of extensive limestone caves (karst bedrock).

In northern Africa, evidence for shellfish use during the early Upper Pleistocene comes from several cave sites along the circum-Mediterranean littoral. These include Haua Fteah (McBurney 1967) in Libya, Mugharet el' Aliya (Howe 1967), La Grotte Zouhrah (Debenath and Sbihi-Alaoui 1979) and Kebibat (Souville 1973) three of them in Morocco, and more in Algeria (see Erlandson 2001, Table I). Most of these sites preserve Middle Paleolithic (MP) artifacts (Aterian and Mousterian) in association with shellfish remains. A recent review of the archaeological potential of the Mediterranean coast (Flemming, et al. 2003:69) indicates that the continental shelf was occupied by humans to a depth of at least 40 m below present sea level in the early Upper Pleistocene. Despite all this potential, known Upper Paleolithic coastal sites are less abundant along the Mediterranean coast of northern Africa (Barton, et al. 2005; Barton, et al. 2001). As Barton, et al. (2005:97) state; "while it would be very tempting to explain any repopulation of the northwestern Maghreb in the Late Upper Palaeolithic in terms of an intensification of economic activities at the coast, there is as yet very little direct evidence in support of this hypothesis." Although they do not represent pure coastal adaptation, numerous early Holocene midden sites have been documented from inland setting along the circum-Mediterranean littoral (Lubell 2004; Lubell, et al. 1976). Edible land snails, representing food remains are common in those sites. Lubell (2004:1) referred those to as *Escargotières* and interpreted them as signature for broad spectrum subsistence.

There is not a simple or single definition of coastal adaptation. This is partly because models of maritime adaptation in Africa, Eurasia and the Americas were developed to deal with specific archaeological data in the past (Bailey 1983; Osborn 1977; Parkington 1976). Moreover, many overlapping activities at coastal environments make it difficult to formulate a unifying concept pertaining to coastal adaptation. Theoretically, one expects to find physical remains of aquatic foods (fish, marine mammals or mollusks) within a reasonable distance from the shorelines. Although evidence for coastal exploitation can be detected archaeologically, it can be problematic to discern the role of coastal versus terrestrial resources in prehistoric life-ways. In some areas, isotopic and trace element analyses have been successfully employed to determine the role of marine resources in prehistoric human diet (Rick, et al. 2006; Sealy and van der Merwe 1986). For instance, using $^{13}C/^{12}C$ ratio, Sealy and van der Merwe (1986) have demonstrated that marine resources were an important component of South African foragers throughout the Holocene. The question of how far from the current shorelines coastal sites occur is important to our understanding of coastal adaptation. Ethnographic studies show that coastal foragers rarely travel more than 5-10 km daily (Bigalke 1973). Thus, stable coastal adaptation should occur within 5-10 km of the coastline. Beyond this, trade networks could be assumed as the main causes for marine resources transportation to the hinterlands.

Coastal environments display enormous diversity, and not all coastal areas are habitable or equally preferable by humans (Westley and Dix 2006). Coastal bathymetry, water salinity, and local geology have varying impacts on coastal productivity and site preservation (ibid.). As such most existing approaches to coastal studies operate on local environmental contexts. Yesner (1980) identifies the following features commonly associated with coastal habitats: high resource diversity, environmental stability, sedentism, and extended social cooperation networks. Aquatic foods offer immense nutritional advantage as excellent sources of protein and minerals (Erlandson 2001). Furthermore, coastal settings are considered as “excellent contexts for stimulating symbolic expression through material culture” (Marean, et al. 2007: 907).

Quaternary climate, sea level changes and coastal migrations

The climate of the Pleistocene epoch was characterized by periodic sea level changes due to alternating increases and decreases of the polar ice sheets (Lambeck and Chappell 2001). Each glacial cycle in the last 900 ka lasted for about 100,000 years (Lambeck, et al. 2002). Globally, sea levels during glacial-interglacial cycles in the last 150 ka have oscillated within a range of 40–60 m below present levels, and high sea level stands lasted for only shorter periods (Bailey, et al. 2007). The human lineage had undergone a number of bottlenecks and turnovers as a result of such glacial-interglacial cycles (Ambrose 1998). As has been inferred for the Last Glacial Maximum (LGM) or MIS 2 - between ca. 22 and 18 ka, about 55 x 10^6 km^3 of fluid water could be locked up in ice sheets of the polar caps during major glacial events. This could cause sea levels to drop as much as 130 m below their present height (ibid.). Such events created vast areas of new land, which in turn affected the ecology, geology, pedology and hydrology of global shorelines (Faure, et al. 2002). When resources in the continental interior deteriorated due to desertification (another consequence of glaciation) coastal exposures may have attracted human settlement and stimulated dispersals. Coastal sites formed during Ice Ages are, however, vulnerable to inundation during interglacial high-stands. Using the case of the Pacific Coast of North America, Bailey and Flemming (2008:6) note that "coastlines formed as recently as 13 ka are now at least 120 m below present sea level, while those formed at 10 ka are now 20 m above present sea." Hence, many potential coastlines inhabited by pre-Holocene humans could be either below sea level or void of any archaeological evidence at present. Coastal site preservation is influenced by a variety of geophysical phenomena. Glacio-isostatic rebound (postglacial volumetric expansion of land surface), coastal tectonics (uplift and subsidence) and diapiric structures (ancient salt domes) are just some these potential effects (Bailey and Flemming 2008). Coastal site visibility is greater in areas with greater isostatic rebound (northern and southern latitudes), and in places with higher regional uplift. The Red Sea coasts show very little evidence of regional uplift over the past 100 ka (ibid.: 7). Therefore, coastal sites formed during low sea level in the Middle and Upper Pleistocene could be found underwater now. One way to find Middle and Upper Pleistocene sites is by surveying submerged locations along potential coastal regions (Bailey, et al. 2007).

Increasing evidence shows that coastal habitats served as crossing points for long and short term prehistoric dispersals (Bulbeck 2007; Sauer 1963; Westley and Dix 2006). According to Westley and Dix (2006), the key to coastal migrations is the ecological stability along departure points, which attracts human occupation prior to their dispersals. Upper Pleistocene human dispersals out of Africa, the occupation of Australia and the Americas are some of the well-known events facilitated through coastal movement (Erlandson 2001). Decades ago, Sauer (1963:311-112) proposed that "the dispersal of early man took place most readily by following along the seashore…coastwise there was a scarcely a barrier to the spread of early man through tropical and subtropical latitudes." Sauer's idea was later advanced by an Africanist biogeographer Jonathan Kingdon who related the Out-of-African migration of early humans to mammalian dispersal patterns from East Africa to Southeast Asia (Kingdon 1993). Kingdon (1993) argued that the main prerequisites to human dispersal Out-of-Africa were adaptation to coastal environments and raft building technology. He proposed a Circum-Indian Ocean coastal dispersal for the colonization of Southeast Asia and Australia by early humans. Recently, Bulbeck (2007) upon adopting Kingdon's view, proposed an estuarine based model for the eastward dispersal of early humans from Africa to Southeast Asia up to Australia. Accordingly, adaptation to resource rich estuaries is thought to be the "main impetus for the migratory movement" of *Homo sapiens* towards Southeast Asia (ibid.: 315). The arrival of modern humans in Australia around 45 ka BP (O'Connell and Allen 2004) must have required use of watercrafts and marine resource exploitation.

The principal conclusions from the above review are that, i) coastal habitats were exploited for a long time, ii) recurrent sea level changes in the Pleistocene greatly affected the preservation chances of pre-Holocene coastal sites, and iii) coastal environments facilitated prehistoric dispersals. What remain unclear at this time are the degree to which coastal resources comprised key components of human subsistence, and the degree early humans' evolutionary fortunes depended on coastal productivity. Now that research interest into coastal environments is gradually growing, coastal evidence is steadily accumulating from different parts of the world (Bailey, et al. 2007; Erlandson

2001; Marean, et al. 2007; Walter, et al. 2000). As such, coastal archaeology is shedding new light on different phases of human prehistory.

The Red Sea Coast and adjacent regions

The Red Sea is a narrow basin that separates northeast Africa from the Arabian Peninsula (Fig. 1.1). Its marine environment contains extremely productive habitats for shellfish, fish, sea mammals and coral reef growth (Head 1987). The geographic position of the Red Sea makes it an important place in the context of current debate on human origins and dispersal hypotheses. Genetic, paleontological and archaeological evidence supports an African origin of modern humans and their successive dispersals through multiple routes (Cann, et al. 1987; Flemming, et al. 2003; Macaulay, et al. 2005; McBrearty and Brooks 2000). The Bab al Mandab Strait at southern end of the Red Sea has been proposed as a plausible gate through which prehistoric maritime connections were possible between Africa and the Arabian Peninsula (Lahr and Foley 1994; Macaulay, et al. 2005; Mithen and Reed 2002). Environmental models suggest that the gap between Africa and southern Arabia can be narrowed to less than 10 km during major glacial events (Bailey, et al. 2007). If early humans used the Bab al Mandab to enter the Arabian Peninsula, they must have successfully settled along the coastal margins of both the African and Arabian sides of the Red Sea coasts. Recent isotopic studies show that the Red Sea remained open to water exchange with the Indian Ocean throughout the Pleistocene (Fernandes, et al. 2006). Thus, any Pleistocene migration through the Bab al Mandab must have involved crossing a body of water.

A topic of particular interest related to prehistoric human adaptation along the Red Sea coast is the recently formulated *Coastal Oasis Model (COM)* (Faure, et al. 2002). According to this model, during glacial events, when sea level drops several meters below the present level, the discharge of fresh water from terrestrial aquifers created favorable habitats along continental shelves. This hypothesis is based on the fact that fresh water is continuously discharged from the continental aquifers into the oceans. Secondly, hydraulic principles predict that groundwater increased at the coast when sea level drops because the piezometric head increases by the equivalent depth of sea-level lowering (ibid.: 47). Sea level is now at high interglacial position, but during Ice Ages the falling sea level can remove enormous hydrostatic pressure from the shelf (ibid.). This eases fresh water flow from terrestrial aquifers along the coastal water-table gradient. During glacial episodes, when nearby inland habitats deteriorated, fresh water springs are thought to have formed along the exposed coastal landscapes, thus creating new habitats for terrestrial mammals and humans. This model suggests the Red Sea Coast of the Horn of Africa would have offered favorable locations for human survival during major glacial periods (example, MIS 6, 4 and 2), when most of the interior regions could be desertified.

The underlying concept of the COM argues for a close relationship between sea level decline and fresh water discharge on the exposed steep gradient. Beyond this, it does not offer specific scenario that can be tested archaeologically. As such, if there were fresh water springs along the coasts as the model predicted, what archaeological remains would one expect to find? How were human settlements distributed with respect to fresh water springs, and if someone can find archaeological evidence, does it affirm the presence of fresh water springs? How far should the sites be located from the present shorelines? Perhaps, the absence of prehistoric sites along the coast today may not negate the possibility of fresh water springs and vice versa. Evidently, such landscapes may have been inundated after the Holocene high-stand. Human responses could vary from region to region depending on the landscape, drainage pattern and resource distribution. In modern times freshwater is critical resource for human survival; the same is likely to have been true in the past. But, if the source springs are near locations unsuitable for human activity, it may not be possible to find preserved archaeological evidence for them. Therefore, although the COM provides potentially valid scenario for prehistoric human coastal adaptation, it is less clear where and what kind of archaeological evidence to expect on those paleoshorelines. In fact the proponents of the model have clearly stated the constraints underlying the COM; "direct observation and verification of our model is difficult and must rely on explorations of terrain that are now deeply submerged on continental shelves" (Faure, et al. 2002: 47).

The archaeological record of the African side of the Red Sea is poorly known. Recurrent political instability in the region has precluded long term research projects.

Moreover, the environmental adversity of the coastal regions has created a logistical barrier for researchers. Most of the coastal area is rugged terrain and lacks transportation access beyond major routes.

Recently, a geological survey at the Abdur area, along the Gulf of Zula Coast of Eritrea has identified Paleolithic artifacts embedded in the Last Interglacial Limestone Reef Formation dated to 125 ka BP (Bruggemann, et al. 2004; Walter, et al. 2000). The deposit belongs to a marine transgression of the Last Interglacial (MIS 5e) that covered a large part of the Buri Peninsula and the Dahlak Islands to the north (ibid.). Today, the Abdur Reef Limestone overlies a volcanic layer referred to as the Abdur Volcanic Complex dated to 1.27- 0.44 Ma (ibid.). The Abdur team recognized two kinds of occupations: one consisting of bifaces and cores of the Achuelian Industry associated with oyster beds and lag deposits, and the other featuring MSA implements- blades and flakes on obsidian associated with nearshore beach context. Large land mammals and marine invertebrates occur in association with the MSA occupation. It is unclear; however, if the Abdur evidence represents a pre-MIS 5e adaptation or that of the Last Interglacial period itself. The most plausible assumption is that the stone tools and large mammal fossils must have been present on the nearby peripheries prior to the Last Interglacial sea level increase, perhaps during the terminal stage of MIS-6 cold period. The archaeological remains could have been washed into close association with the growing coral reef deposits by the rising sea level.

Although the Abdur site has been cited many times as an important relic of prehistoric coastal adaptation, there are questions about the geological context of the archaeology there. The association of the cultural remains with the coral reef deposits is poorly understood. It is unclear whether the artifacts were embedded into the reef by natural processes or through human activities. No excavation has been carried out at Abdur so far, and except for a few specimens collected for museum display, insufficient lithic artifacts have been recovered from the site to allow detailed technological examination of the assemblage. Although Walter, et al. (2000) originally claimed that the oyster shells represent food residues exploited using stone tools; the oyster deposits were later reported to be natural death assemblages (Bruggeman, et al. 2004). Therefore, the noted artifacts could have been used for tasks unrelated to coastal activities. During a brief visit to the site, the author noted the lithic distribution there to be sparse and highly disturbed. The few exposed artifacts lack any diagnostic features. They consist of miscellaneous flakes and manuports that could have been washed from the nearby volcanic ridges. No technologically distinctive artifacts of prehistoric cultural entity were noted. This calls into questioning Walter's team's claim of MSA occupation.

To date, only a few Holocene sites have been reported from the African side of the Red Sea coast. Over half a century ago, a Later Stone Age (LSA) site that features microlithic industry had been reported from the Dahlak Archipelagos of Eritrea, off the coast of the Buri Peninsula (Blanc 1955; Clark 1954). The lithic material was said to be on obsidian that could have been transported by boat from inland to the island (Clark 1954). No recent research has taken place at the site, and we know little about the archaeological evidence there.

The archaeological potential of the eastern side of the Red Sea along the Arabian Peninsula is relatively better known compared to the African side. As a result of extensive reconnaissance surveys in the 1980s numerous Lower and Middle Paleolithic sites have been documented from the western coasts of Saudi Arabia and Yemen (Nayeem 1990; Petraglia and Alsharekh 2003; Whalen, et al. 1981; Whalen and Pease 1992; Zarins, et al. 1981). The ecological settings of the identified Paleolithic sites include inland basins, coastal plains and mountainous zones. Some sites were documented close to the sea, about 2 m above mean sea level and 75 m distant from the coastline (Zarins, et al. 1981). Characteristic artifact types include Levallois flakes, blades, cores all made on lava, and tanged points produced from flint (Petraglia and Alsharekh 2003). There is limited chronological information on the Arabian MP assemblages because much of the sites there are on unstable eolian deposits (ibid.). The variability in site contexts and artifact type suggests persistent human occupation of the Arabian coasts in the Later Pleistocene. Evidence for Holocene human adaptation along the Arabian coast has been recorded from two major regions, the Tihamah coastal lowland of southwest Yemen (Tosi 1986), and the Farasan Islands, off the western coast of Saudi Arabia (Bailey, et al. 2007). The Tihamah sites represent mid-Holocene middens on an ecoton comprising coastal and continental flood plains (Tosi 1986). The highest concentration of sites was detected around the Wedi Surdud area (east of Salif Peninsula) characterized by alluvial plains and sand dunes (ibid.). The oldest radiocarbon dates from the Tihamah region range 7770 ± 95 BP at the site of Ash-Shumha and 7500±80 BP at Gahabah-1 (ibid.:403). *Terebralia palustris* dominates the molluskan fauna of the Tihamah sites. A recent underwater survey on the Farasan Islands, off the Saudi Arabian Coast has identified numerous large shell mounds with ash layers and animal bone dating to around 8000 BP (Bailey and Flemming 2008; Bailey, et al. 2007). The nature of prehistoric human connections between African and Arabian coastal margins has not been investigated so far.

A few coastal sites have been recorded elsewhere in the Horn of Africa. The earliest comprehensive work of the archaeology of the Horn was by J. Desmond Clark: *The Prehistoric Culture of the Horn of Africa* (Clark, 1954). Based on the accounts of previous explorers (Teilhard de Chardin 1930) and his own fieldwork, Clark (1954) described several archaeological sites from the coastal margins of Djibouti and Somalia. One of the important areas to this interest is a coastal strip on the Obok region of the Gulf of Tajura in Djibouti, then French Somaliland. From this area, Teilhard de Chardin previously recognized coral deposits formed by successive marine transgressions containing stone implements (ibid.). The Obok artifacts were surface finds attributed to the Middle and Later Stone Age. Clark (1954) also identified numerous coastal and near estuary sites along the Nogal and Obbia regions of eastern Somalia representing LSA/Neolithic cultures of "strandlooping" based economies. The majority of these sites lack absolute dates and the aquatic species there were poorly described. Since the publication of Clark's 1954 monograph, coastal research on the Horn of Africa did not progress at the same pace as in the interior of Ethiopia and Somalia.

Some of humanity's ancient cultural and physical remains have been discovered in the Horn of Africa, particularly along the East African Rift system (Abbate, et al. 1998; McDougall, et al. 2005; Semaw, et al. 1997). Middle and Later Stone Age sites featuring highly refined points, prepared cores, blade technology and microlithic production were discovered from various ecological settings in the region (Brandt 1986; Clark 1954; 1988; Wendorf and Schild 1974). Later Stone Age sites belonging to the Holocene are by far more widespread signifying increased human expansion with the onset of early Holocene wet phase (ibid.). In northern Ethiopia, early Holocene sites rich in LSA lithic traces were reported from three neighboring localities near the town of Aksum, namely Gobedra, Baati Nebiat and Anqqer Baati (Finneran 2000; Phillipson 1977). Blade technology dominates those LSA occurrences. Finneran (2001) has recently named the early Holocene assemblages as *The Aksum Long Blade Industry*. The Long Blade Industry is thought to be precursor to the LSA microlithic industry in the region, and its age is estimated between 10-7.5 ka bp at Gobedra (Phillipson 1977) and 9.5 ka BP at Baati Nebiat (Finneran 2000). The blade bearing sequence at Gobedra is believed to be replaced by microlithic industry after 7.5 ka bp (Phillipson 1977), but Brandt (1986) challenges this assertion, questioning if there had ever been any change in artifact composition between 10 and 7 ka bp. Recently, Negash (1997, 2001) documented a handful of LSA-Neolithic sites in the Temben region of Tigray (northern Ethiopia). The site contexts include open air and rock-shelters. One of the Temben sites, Danie Kawlos yielded a radiocarbon age of 3380 years bp (ibid.). Using artifact traits and ceramic association, Negash (2001:206) classified the Temben sites into three cultural periods spanning early to late Holocene phases. These include, Pre-Pottery Neolithic (>5000 BP), Neolithic with Pottery (ca.5000 - 2500 BP) and Post Neolithic (~2500 and later BP).

The LSA findings from the Afar Rift and northern Ethiopia; Gobedra, Baati Nebiat and Temben offer strong evidence for early Holocene human occupation of the Ethiopian interior rift and highland plateaus. Moreover, current botanical research suggests that the Ethiopian and Eritrean highlands were the primary foci for early plant domestication and agricultural inventions in Sub-Saharan Africa (Orabi, et al. 2007; Sauer 1952). The archaeological antiquity and ecological diversity of the Horn of Africa suggest that this region was a stable place for long-term human settlement, making it a promising place for exploring human prehistory in a wide range of contexts. At present, we know very little about human adaptation of the eastern coastal lowlands of Eritrea, and the connection between the highland and coastal settlements. Thus, research along the Red Sea coast is desperately needed in order to clarify the relationship between inland and coastal adaptations in the region. The current research explores a key area in the Horn of Africa, the Buri Peninsula and the Gulf of Zula on the Red Sea Coast of Eritrea.

Project Description

Background

Eritrea is located in northeastern Africa bordering Sudan to the West, Ethiopia and Djibouti to the South, and the Red Sea to the East (Fig. 1.2). Archaeological interests into Eritrea's historic and proto historic sites date back to the 19th century (Paribeni 1907), yet no Stone Age research was undertaken in the Eritrean territory until the country gained its Independence in 1991. The last thirty years of protracted war (1961-91) impeded archaeological activity in Eritrea while explorations were in progress in the neighboring countries. Archaeological initiatives after Independence recovered rich evidence representing different prehistoric stages (Abbate, et al. 1998; Curtis and Libsekal 1999; Schmidt and Curtis 2001). Recent regional survey and excavation projects around the Greater Asmara area have revealed wide-ranging remains of first-millennium BC and early first-millennium AD settlements (Schmidt, et al. 2008). Similarly, Stone Age research has shown some progress with a primary focus on the Danakil Depression (Abbate, et al. 1998; Walter, et al. 2000). The Buia expedition, launched in 1994 under the auspice of some mining companies in the Danakil Depression, was one of the Post Independence projects to document fossil and cultural evidence of older antiquity (Abbate, et al. 1998). A *Homo erectus* cranium found in an Acheulian cultural context from the site of Buia is one of the important initial discoveries. The site of Buia has been dated to about 1.0 Ma (ibid.). The Abdur coastal site discussed above was the second major discovery to show the prehistoric potential of the Eritrean Coast (Walter, et al. 2000). While the Buia project is still active (until 2009), the Abdur site fell short of further research commitment after brief visits between 1999 and 2001.

The Abdur evidence inspired the author to initiate the project in the Buri Peninsula and Gulf of Zula. Upon reviewing the Abdur report, two broad questions remain critical in exploring the mode and tempo of human coastal adaptation on the Eritrean Coast. First, we know very little about the nature of human occupation in the Late Pleistocene and early Holocene. Second, the link between coastal adaptation and climate change in the region has not been demonstrated. Testing the continuity of human adaptation in the Gulf of Zula through time and space required strong ground evidence outside the Abdur proximity. For this, a reconnaissance survey was initiated in 2005 by a research team from Stony Brook University under the directorship of John Shea and the author. Archaeologists often find it difficult to frame a series of hypotheses in a region which lacks adequate background evidence and well defined culture history (Negash 2001). The primary step to cope up with such limitation is to find potential sites before proceeding to any hypothesis testing endeavor. As such, the initial task in this project was to find well preserved archaeological sites of Pleistocene and Holocene age. This required searching for long and short term habitation sites along the coastal margins of the Gulf of Zula and adjacent interior landscapes of the Buri Peninsula.

Moreover, the Coastal Oasis Model discussed above sets possible scenario for human adaptation along the Eritrean Coast during glacial times due to the presence of freshwater springs. As such, it may be possible to find traces of human activities along the coastal landscapes representing Ice Age scenarios or intermittent dry episodes in the Holocene when adjacent interior regions at higher elevations were desertified. A major caveat with this hypothesis is that human settlements formed during glacial period are less visible now because most areas exposed during sea level lowering can be inundated once sea level rose during the early Holocene high stand. Only sites located far inland during glacial periods can be detected by pedestrian survey.

Research scope and methodology

The following specific research questions guided the scope of this study.

i. How are the sites distributed in the focal area, and with respect to the coast?
ii. What is the nature of subsistence strategy at the sites, coastal or terrestrial?
iii. What is the techno-typological and raw material variability at the sites?
iv. What is chronological placement of the sites?
v. What is the intra and inter-site variability among the focal sites, and sites from the neighboring regions (Horn of Africa, Nile Valley and Arabian Peninsula)?

This project has been conducted in a two-stage program: i) a reconnaissance survey that commenced in 2005 with the aim of locating archeological sites in the Buri Peninsula and Gulf of Zula, ii) two seasons of detailed survey and excavation works carried out in 2006, focusing on Asfet, Gelalo NW and Misse East. The primary aim of the initial fieldwork was to document archaeological sites in the focal region, whereas the second phase was focused on artifact/faunal recovery from surface and subsurface contexts.

In light of the above outlined research issues, the principal goals of the project can be summarized as follows:

i. Document well preserved sites relevant to study prehistoric human adaptation.
ii. Investigated the geological and archaeological context of the sites.
iii. Characterize lithic and faunal variability at the sites so that they can be integrated into models of human adaptive systems in the region.
iv. Determine the chronological placement of the sites.
v. In long term, establish culture history of the coastal lowlands of Eritrea and compare those with other neighboring regions.

During the reconnaissance work, sites were documented using an off-site (non-site) survey strategy (Foley 1981; McNiven 1992). In a non-site survey strategy the artifact could be the minimal unit of site definition as opposed to clusters of cultural remains. In selecting survey areas, we employed a judgmental sampling strategy focusing on summits of flat ridges and coastal terraces (gullies). Field documentation of sites and artifacts relied on Global Positioning System (GPS) coordinates, and photographs and drawings of artifacts made on-site. No test excavations were performed during the reconnaissance survey. That being the case, our field documentation strategy had the advantage of preserving site visibility. The reconnaissance survey covered about 400 sq km, and documented more than 17 large and small sites from near coastal and inland contexts (Fig. 1.2; Table 1.2). Four major study areas were visited: Irafailo, Meka Enile, Dagat and Ingel. The documented sites belong mainly to the LSA and Neolithic cultural phases. Several MSA occurrences and a few isolated Acheulian bifaces were also documented from surfaces. The data compiled during the reconnaissance has been published, see Beyin and Shea (2007). Upon reviewing the results of the reconnaissance work, three sites: Asfet, Gelalo NW and Misse East were selected for detailed investigation (Fig. 1.2). The sites were selected based on five criteria: i) artifact and raw material diversity as noted from surface occurrence, ii) stable geological context, iii) presence of non-lithic remains, mainly mollusk shells, iv) their varying geographic location from the modern coastline and v) ease of access.

More structured survey procedures were employed in the later phases of fieldwork at Asfet, Gelalo NW and Misse East. This involved topographic mapping, artifact distribution plots and excavation. Because this research was originally formulated based on coastal phenomena, it was necessary to describe the geomorphic settings of the sites with respect to the present coastline. For this, distances from the current coast were estimated using GPS and current satellite imagery. Although attempts were made to obtain bathymetric charts for the Gulf of Zula, no pertinent sources were accessible. The ones available are for the main trough of the Red Sea Basin. The geological context of the sites was characterized in the field and compared with the geological maps of the region afterwards. Sites are located at varying distances from the current coast.

Excavations were conducted on judgmentally selected high surface density areas. Standard excavation procedures were followed and sediments were dry sieved using a ¼ cm mesh. Arbitrary units of 10 cm (if concentration is high) and 15 cm (in sections with low concentration) thickness were used to designate levels during excavation.

Stone tools constitute the main archaeological findings at the investigated sites. Lithic investigation involved typological classification and attribute analysis. The Asfet collection was analyzed in the National Museum of Eritrea (NME), whereas those from Gelalo and Misse were transported to Stony Brook Unversity where they were subjected to detailed study. Lithic analytic protocols are thoroughly discussed in Appendix IV.

The main organic findings from the focal sites were mollusk shells. Samples of the shell assemblages from excavation were studied in the NME and a small portion at Stony Brook University by a malacologist Dr. Daniella Bar-Yosef Mayer of the University of Haifa. Because mollusks provide clear evidence for coastal activity, their presence was particularly significant in the context of the project's central theme. It was expected that, variation in site location and shell types would reflect cultural choice and/or human response to resource availability along the coast vis-á-vis in the hinterlands. This is because "ecological models of resource availability suggest that organisms narrow or widen their procurement strategies in response to scarcity or abundance of resources" (Stewart 1989:2).

Age determination of the sites was crucial in order to establish the culture history of the focal region, and compare the evidence with other regions in the Horn (Somalia, Ethiopia), Sudan and Yemen. Moreover, it is necessary to determine site chronologies in order to assess site formation history (single vs multiple occupation episodes). Since there are not many previously documented prehistoric sites of known age from the region, age reference is crucial to any type-sites that may subsequently be discovered.

Charcoal or any other organic remains were not preserved, and mollusk shell was the only material suitable for radiocarbon dating. Dating shell samples were carefully collected and submitted to chronometric laboratories in the United States. Radiocarbon dates were reported in ^{14}C age (BP) based upon the Libby Half Life (5570 years) for ^{14}C along with ^{13}C corrections. A marine calibration dataset called Marine04 (Hughen, et al. 2004) compatible with Calib5.0 program (Stuiver, et al. 2005) was employed for calibrating the ^{14}C ages. The calculation of radiocarbon dates for marine samples assumes that:-

> "organisms from marine or lacustrine environments have been exposed to different levels of ^{14}C than their counterparts in the atmosphere. Thus, radiocarbon ages of samples formed in the ocean, such as shells, fish, etc., are generally several hundred years older than their terrestrial counterparts. This apparent old age is due to the high old-carbon reservoir of the oceans. To accommodate local effects, the difference (ΔR) in reservoir age of the local region of interest and the model ocean should be determined. In practice, ΔR values were calculated from the difference in the ^{14}C age of known-age, pre-nuclear marine samples" (Reimer, et al. 2004; Stuiver and Braziunas 1993; Stuiver, et al. 2005-cited at http://calib.qub.ac.uk/calib/manual).

In this study, a 127 ± 1 difference (ΔR) in reservoir age for Port Sudan (~4^0 north of the study area) was used to calibrate the reservoir effect of the source area for the dated samples. This information was accessed from a global web database at http://www.calib.qub.ac.uk/marine (Reimer, et al. 2004; Stuiver and Braziunas 1993).

Thesis organization

The thesis comprises a total of 8 chapters organized as follows:

Chapter 2 describes the physical environment of the study regions, such as bedrock geology, topographic variability and the general habitat. A list of common flora and fauna in the study region assembled by the research team is provided. Moreover, the chapter reviews Late Pleistocene and Holocene climatic history of the Horn of Africa in order to provide an interpretive framework for the archaeological data at hand. An understanding of the region's paleoclimate and habitat is important to explain human occupation of the Red Sea Coast.

Chapter 3 reports the geological context and surface lithic findings from the Asfet Site Complex. The Asfet Site was intensively surveyed and a large quantity of lithic assemblage has been collected from surface alone. The surface material reveals a wide range of techno-typological variability distinct from the excavated sample. For this reason, it is separately treated from the excavated assemblage (described in chapter 4).

Chapters 4-6 describe excavation activities, subsurface findings and site chronologies of the Asfet Unit F, Gelalo NW, and Misse East sites respectively. Lithic analytic results from the respective sites are thoroughly discussed following stratigraphic and chronological descriptions of each site.

Chapter 7 reports intra-site and inter-site assemblage variability. Lithic assemblages from the excavated sites are compared using techno-typological attributes in order to discover behavioral pattern among the settlements. Lithic comparison is also drawn from LSA sites in northern Ethiopia, Lake Besaka and three localities in Kenya.

Chapter 8 presents the general conclusions of the study with a brief note of culture-historical and climatic context of human adaption on the Eritrean Coast.

Results of collaborative studies, such as shell analysis, raw material source analysis and microwear study are included in Appendices I-III respectively. Appendix IV presents lithic analytic protocols employed in this research.

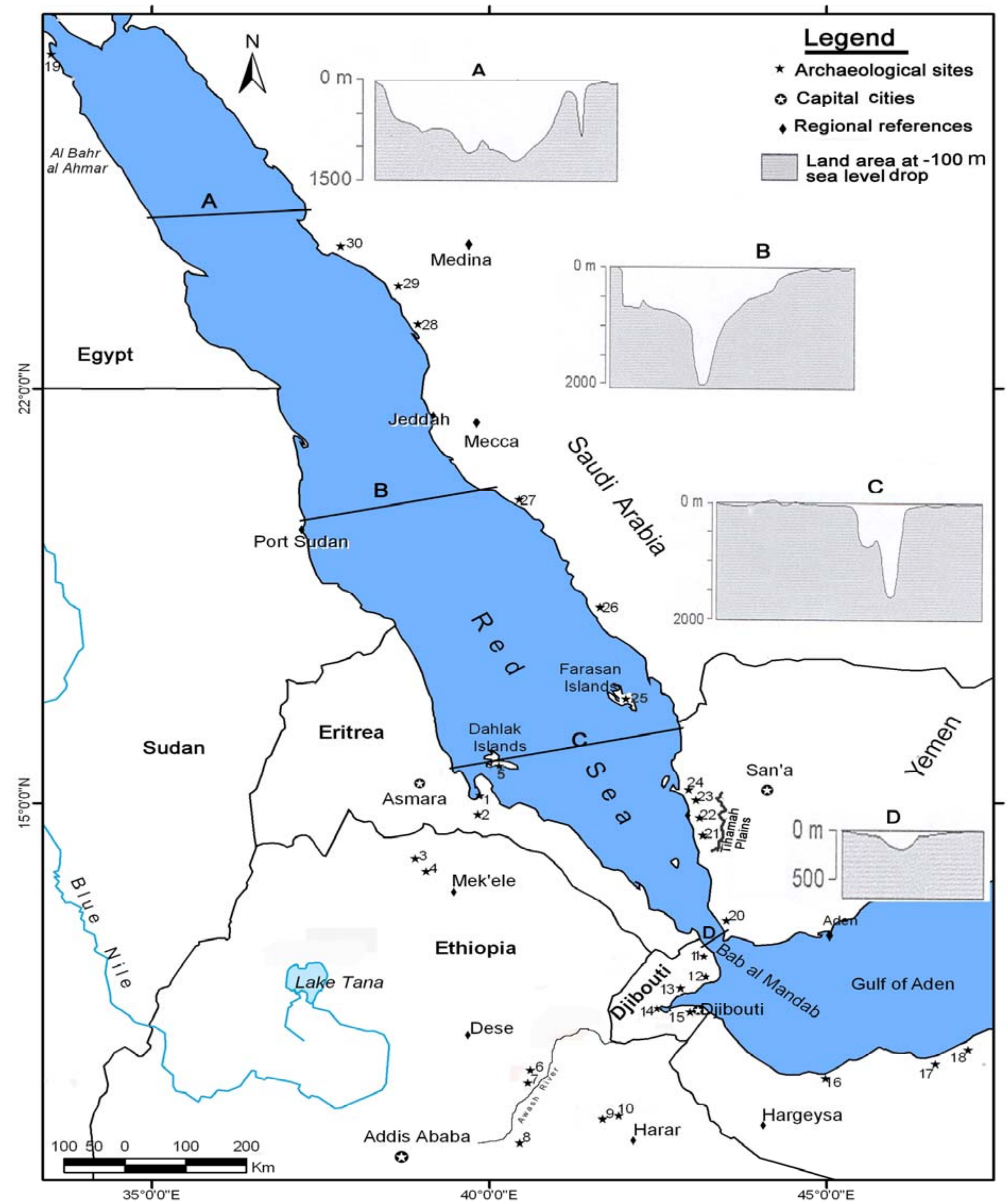

Figure 1. 1. Representative archaeological sites around the Red Sea and bathymetric variability of the basin when sea level dropped -100 m (bathymetric profile after Head 1987). Note the extensive land that can be exposed during sea level lowering across Massawa and Arabia (section C).

No. in Fig. 1.1	Site Name	Age ka BP	Cultural Phase	Reference
1	Abdur	125	MSA in a coral reef	Walter, et al. 2000
2	Buia	1000	Acheulian	Abbate, et al. 1998
3	Aksum Sites (Gobedra, Baati Nebiat)	10-6	LSA-Neolithic	Phillipson 1977 (Gobedra); Finneran 2000 (Baati Nebiat)
4	Danie Kawlos (Temben)	<4	LSA-Neolithic	Negash 2001
5	Dahlak Islands	?	LSA-Neolithic	Blanc 1955
6	Ala Kanasa	?	MSA	Clark, et al. 1984
7	Aduma	100-80	MSA	Yellen, et al. 2005
8	Lake Besaka*	22-7	LSA-Neolithic	Brandt 1982
9	Laga Oda	15-10, 3	LSA-Neolithic	Clak and Prince 1978
10	Porc Epic*	77-60	MSA	Clark, et al. 1984
11	Djebel Djinn	?	LSA-Neolithic	Clark 1954
12	Obok	?	MSA-LSA	Clark 1954
13	Gulf of Tajura	?	MSA-LSA	Clark 1954
14	Dankalelo*		Neolithic	Poisblaud, et al. 2002
15	Ras Kiro	?	LSA-Neolithic	Clark 1954
16	Guban	?	Achuelian-MSA	Clark 1954
17	Raguda Tug	?	LSA-Neolithic	Clark 1954
18	Shimbir Beris	?	LSA-Neolithic	Clark 1954
19	El Gouna*	6	LSA	Vermeersch, et al. 2005
20	Subr		MP/MSA	Whalen and Pease 1992
21	Wadi Jurb*		LSA-Neolithic	Tosi 1986
22	Wadi Sihan*	7.7	LSA-Neolithic	Tosi 1986
23	Wadi Surdud*	6.3	LSA-Neolithic	Tosi 1986
24	Salif*	2.2	LSA-Neolithic	Tosi 1986
25	Farasan Islands*	8	LSA-Neolithic	Bailey, et al. 2007
26	Red Sea Coast	?	Acheulian	Zarins, et al. 1981
27	Al-Lith	?	Acheulian	Whalen, et al. 1981
28	Khulays	?	Acheulian-MSA	Nayeem 1990
29	Rabigh	?	Acheulian	Nayeem 1990
30	Sharm Yanbu	?	Acheulian	Nayeem 1990
	* = shell midden			

Table 1.1. List of sites depicted in Figure 1.1 with chronological and cultural information.

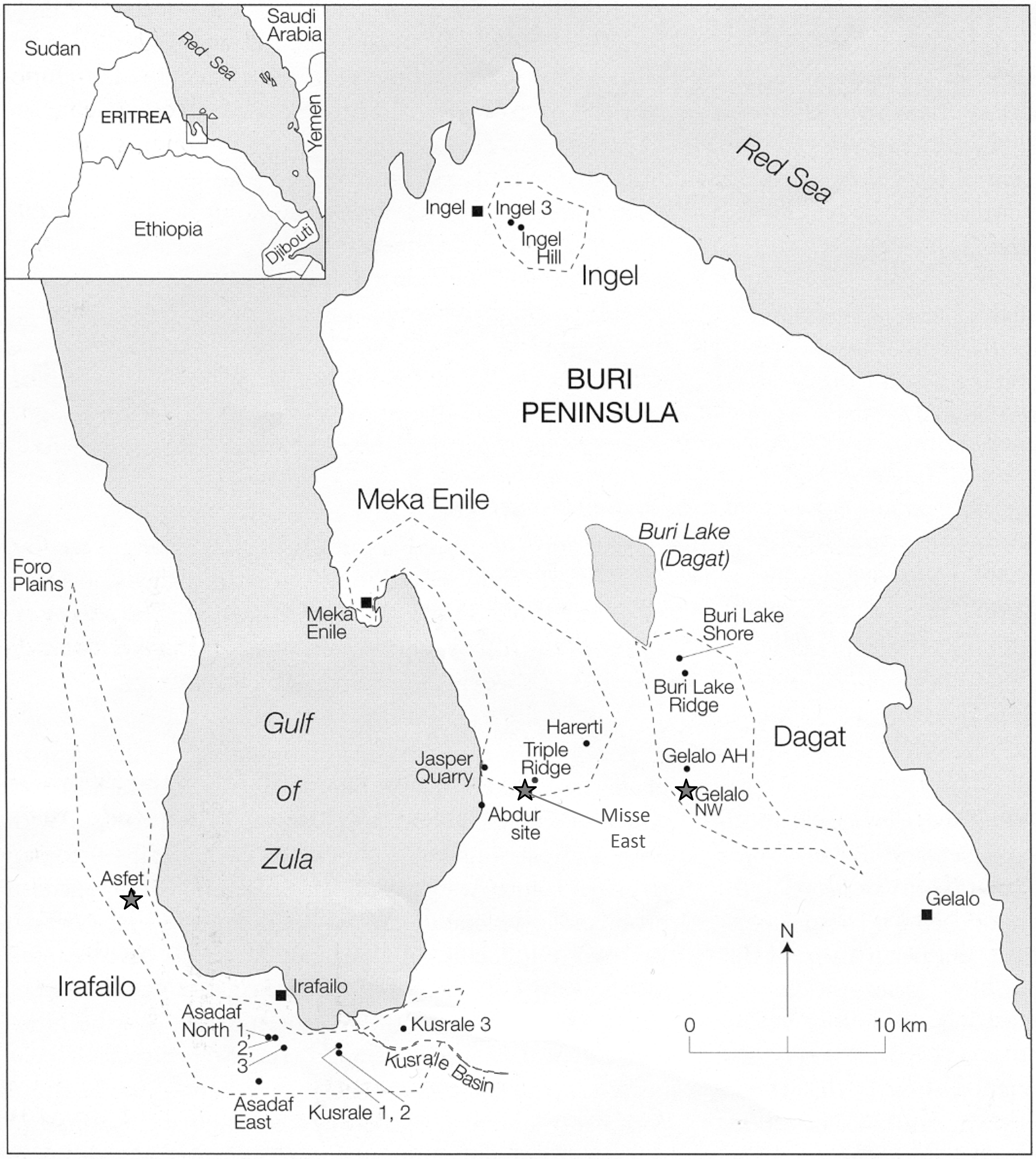

Figure 1.2. Map showing sites documented by the reconnaissance survey in 2005. Dotted outline shows the boundary of surveyed areas: Irafailo, Meka Enile, Dagat and Ingel (After Beyin and Shea 2007:2). ★= sites selected for detailed study in phase II.

Site Names	Raw Materials	Pebble cores	Handaxes	Levallois cores	Small bifaces	Levallois flakes	Blade cores	Bipolar cores	Prismatic blades	Side scrapers	End scrapers	Microliths	Mollusc shells	Pottery	Cultural Affinities	Size estimate (m^2)	#artifacts/m^2
Asfet	Basalt, Obsidian Green schist, Quarz, Rhyolite, Chert,		x	x		x		x		x	x		x		ESA MSA LSA	25,000	60
Asadaf East	Obsidian, Quartz			x							x				MSA	2,500	10
Asadaf North 1	Quartizite		x												ESA	?	1
Asadaf North 2	Obsidian											x	x	x	Neolithic	11,000	10
Asadaf North 3	Rhyolite	x													ESA?	3,000	6
Kusrale 1	Obsidian			x			x		x		x				LSA	300	20
Kusrale 2	Obsidian						x		x			x	x		LSA	400	10
Kusrale 3	Obsidian			x	x	x	x		x						MSA–LSA	12,000	10
Jasper Quarry	Jasper	x		x		x	x		x						MSA–LSA	5,000	110
Triple Ridge Site	Obsidian						x		x			x			LSA	4,000	10
Misse East	Obsidian						x	x	x	x	x	x	x		LSA	350	>100
Harerti	Obsidian, Quartz								x			x			LSA	5, 000	10
Gelalo NW	Obsidian, Basalt						x	x	x			x	x		LSA	400	100
Gelalo AH	Obsidian								y			x			LSA	150	30
Buri Lake Ridge	Obsidian, Quartz, Jasper						x	x	x		x	x	x		LSA	8,000	15
Buri Lake Shore	Obsidian								x			x	x		LSA	10,000	10
Ingel 3	Obsidain, Quartz								x			x	x		LSA	500	60
Ingel Hill site	Obsidian, Quartz								x			x	x		LSA	2,000	50

Table 1. 2. Artifact type and raw material variability on the Buri Peninsula and Gulf of Zula sites documented during the reconnaissance survey in 2005.

Chapter 2

Physical Environment of the Study Region

Introduction

The name Eritrea is derived from the ancient Latin name for the Red Sea- *Mare Erythraeum*[1]. Eritrea has a total area of 121,320 sq km with 1,347 km of coastline and about 355 islands in the Red Sea. Its territory includes the northernmost African extension of the African Rift System and the Danakil Depression. According to the *Periplus of the Erythraean Sea* (a travel guide of the Indian Ocean in the first century), the coastline of Eritrea was an important trade zone connecting early civilizations in the Mediterranean world with the Horn of Africa and the Arabian Peninsula (Schoff 1912). The highlands and coastal margins of Eritrea were parts of the Aksumite Empire between the 1st and 7th century AD. Subsequently, a series of powers established control over various parts of the country in the last five centuries, beginning with the Ottomon Turkish (1563-1840), Egypt (1840-1870), Italy (1890-1941), Britain (1941-52), under Ethiopian Federation (1952-1961), and Ethiopian colony (1961-91). The present-day territorial boundary of Eritrea was formally defined in the early 20th century when it became an Italian colony. The country gained its independence in 1991, and is populated by nine major ethnic groups namely, Afar, Bilen, Hadarib, Kunama, Nara, Rashaida, Saho, Tigre and Tigrigna.

This chapter describes the physical environment of the study region. Bedrock geology, topographic variation and ecological setting of the Buri Peninsula and Gulf of Zula are discussed. The chapter concludes with a brief review of the Later Pleistocene and Holocene climate history of the Horn of Africa as inferred from the Afar and Ethiopian Rift lakes.

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[1] Red Sea" 2009. Encyclopædia Britannica Online. 08 Apr. 2009 http://www.britannica.com/EBchecked/topic/494479/Red-Sea.

The Geological Background

Rocks in Eritrea are classified into Pre-Cambrian basement rocks, Mesozoic sedimentary beds, and Cenozoic volcanic and sedimentary deposits (Mohr 1971). Cenozoic rocks are further subdivided into the Oligocene Flood Basalt (Trap series) that extruded prior to the formation of the Rift system, Neogene (Miocene and Pliocene) volcano-sedimentary rocks, and recent (Pleistocene) volcanic rocks referred to as the Rift series. The Precambrian metamorphic rocks cover most parts of Eritrea, and in many places the upper parts of these rocks are lateritized. The eastern and western lowlands of Eritrea are mainly covered by Neoproterozoic (900 - 550 Ma) gneisses and schist. Metamorphosed Neoproterozoic volcano-sedimentary rocks cover the highland plateau and the Red Sea escarpments. The Mesozoic sedimentary rocks are found unconformably overlying the Neoproterozoic basement rocks in southern highlands and the Danakil region of Eritrea. According to Ghebreab, et al. (2002), the Pre-rift sedimentary rocks are represented by Lower to Middle Jurassic sandstones known as the Adigrat Sandstone overlain by Upper Jurassic marine transgressive deposits referred to as Antalo Limestone and shale. This is overlain by Cretaceous regressive continental sandstones referred to as Upper Sandstone. According to Mohr (1971), these Mesozoic rocks were deposited during the Tethys Sea transgression in the Mesozoic era. The Tethys Sea spread over the Arabia-Nubian shield, the coastal peripheries of East Africa, and as far south as Madagascar (ibid.).

During the Upper Eocene and Early Oligocene, an immense volcanic uplifting occurred in the Afro-Arabian shields forming extensive landscape relief of the present day Eritrea and Ethiopia (Mohr 1971). The vast lava ejected during this time (the Trap series) rest horizontally with slight unconformity upon the Mesozoic sedimentary and Basement rocks. They form the floor of the Rift systems, and the highland plateau of Eritrea and northern Ethiopia (ibid.). In some places along the Red Sea coast, the Trap series is covered by Syn and Post-Rift volcanic sedimentary formations. A few kilometers inland from the city of Massawa, there are Syn-Rift (late Oligocene - Miocene) sedimentary deposits referred to as the Dogali Formation

(Ghebreab, et al. 2002). Lacustrine and inter-bedded volcanoclastic sediments characterize these deposits. An important fossil proboscidean claimed to be a missing link in the evolution of elephants has recently been uncovered from the Dogali Formation (Shoshani, et al. 2006).

The research area encompasses the Buri Peninsula and Gulf of Zula. This region is geologically and topographically diverse, with a low laying coastal plain of the Gulf of Zula separated from the highland plateau by a N-S stretching steep escarpment (Figs. 2.1-2). The topography and geological history of the region had been greatly affected by volcanic activities throughout the Tertiary and Quaternary periods (Ghebretensae 2002). As such, the physiographic features of the Buri Peninsula and Gulf of Zula are related to the geotectonic events that formed the East African Rift System since the Oligocene ~ 33 Ma (Barberi and Varet 1977).

The Buri Peninsula

The Buri Peninsula is an elongated landmass that protrudes north into the Red Sea Basin from the Danakil Depression. It is composed of Neogene volcanites (lava fields) overlain by Quaternary sediments and evaporites (Abbate, et al. 2004). Although the peninsula has generally low topographic relief, hilly lava ridges and rugged terrain intercepted by erosional gullies are common features. The flat fields are covered by unstable sand that causes massive sandstorms during dry seasons. At the center of the Buri Peninsula lies a brackish lake, locally called "Dagat". Evaporates and low volcanic ridges surround the lake to South and North. Dagat is fed by local drainage from the high hills on the southern edge of the Peninsula. Meandering limestone cliffs are common on the eastern and western coastal margins of the peninsula (Fig. 2.1). Stone rings believed to be mortuary architecture of recent pastoralists were observed widely distributed near the lake margins. The northern periphery of the Peninsula features indented stretch of coastlines with many inlets, promontories and small sheltered bays. Isolated carbonate islands (and possibly lagoons) are visible on satellite maps off the eastern and northern margins of the

Peninsula. The Dahlak archipelago, comprising clusters of carbonate and volcanic islands is located to the north of the peninsula.

The Gulf of Zula

The Gulf of Zula is a long bay (about 40 km north-south) situated between the Buri Peninsula on the East and the Foro Plains on the West. Its southern tip forms a vast flood plain (around the town of Irafailo) linked to the Zula-Alid-Bada graben where the Danakil Depression merges with the Red Sea Basin (Abbate, et al. 2004). Acidic and basic volcanic flows cover the eastern and southern peripheries of the floodplain respectively. The eastern margins of the Gulf are characterized by heterogeneous landforms encompassing rugged sand beaches, estuary basins and steep limestone/coral reef shelves. Bruggmann et al. (2004) reported a detailed geological map of the eastern margin of the Gulf of Zula around the Abdur area. The geological survey at the Abdur coast has identified a marine deposit referred to as the Abdur Reef Limestone (ARL) Formation (Bruggemann, et al. 2004; Walter, et al. 2000). The ARL Formation is now exposed up to 10 m above high tide and extends up to 19 m further inland (ibid.), see Figure 2.3. The deposit belongs to a marine transgression of the Last Interglacial (~125 ka BP) that covered a large part of the Buri Peninsula and the Dahlak Islands (ibid.). Stone tools believed to be Acheulian and MSA were discovered in association with shellfish and terrestrial fauna embedded in the ARL Formation (Walter, et al. 2000). The ARL Formation overlies a volcanic deposit called Abdur Volcanic Complex dated to 1.27 Ma at Abdur North and 0.44 Ma at Abdur South (the horizontal distance between these two localities is less than 5 km). The Abdur Volcanic Complex in turn overlies the Buri Sequence which is composed of marine, estuarine and fluvial sediments dated to 0.9 - 0.72 Ma (Ghebretensae 2002). The successions at Abdur suggest evidence of intermittent erosion, faulting and folding in the Pleistocene (ibid.).

The Abdur research group did not show any post MIS-5 marine transgression on their section maps. The absence of post MIS-5 deposits in the Abdur area suggests that no major marine transgression occurred after the Last Interglacial. In another parts of the Red Sea, slightly north of the study area (18^0 44.5' N, 39^0 20.6' E) sea level reconstruction based on $\delta^{18}O$ record suggests that there were repeated periods of sea level decline between the Terminal Pleistocene and early Holocene (Siddall, et al. 2003). According to Siddal, et al. (2003: 845) the Red Sea was as low as 20 m below its present level during 8, 7, and 6.5 ka BP. Thus, it is possible that relics of such low sea level events exist on coastal margins with low topographic relief. Indeed, our survey around the Meka Enila coast (about 10 km north of Abdur along the Gulf of Zula coast) has shown scattered shell accumulations up to 1.5 km inland and 8 m asl (Fig. 2.4). In light of their extensive distribution, the shell accretions appear to be natural deposits. The land is relatively shallow and small-scale Holocene sea level increase could have deposited the Meka Enile shell accumulations.

The landform along the western side of the Gulf can be described as shallow flatland, with fewer coral cliffs, and mainly alluvium plains and mangrove vegetation. This area is archaeologically less investigated compared to the eastern margin of the gulf. Near the village of Zula lies the prominent historical site of Adulis dated to the early 1st millennium AD (Blue, et al. 2008). On the northwestern edge of the Gulf is the Ghedem Mountain, a massive Precambrian deposit about 900 m high. The southern margin of the gulf is a low laying floodplain bound by a steep mountain chain to the west (the eastern highland escarpment). The volcanic hills and Mesozoic deposits around the Irafailo flood plain feature numerous erosional caves. The Gulf of Zula is situated along the *Axial Volcanic Range* zone, which is an actively propagating fault along the Danakil Depression (Mengist Teklay personal communication, Asmara 2006). In the long term, this fault may take over the Red-Sea-forming fault. Because of its location on a tectonically active zone, the area around the Gulf of Zula contains numerous active hot springs along the coastal peripheries. The presence of hot springs suggests that the magma chamber is close to the surface. Elsewhere around the Danakil Depression, the magma chamber is estimated to be 5-10 km below surface (Shoshani and Woldhaimanot 2003).

The Red Sea Basin

The coastal ecology of Eritrea is greatly affected by the Red Sea Basin. For this, it is important to provide a brief description of the environmental aspects of the Basin. Its coastal margins preserve extensive mangrove vegetation, Pleistocene fossil beaches and coral reef sequences (Bruggemann, et al. 2004; Head 1987; Sharabati 1984). The extreme marine productivity of the Red Sea could have made its coastal margins attractive for human settlement in the past. Thus, systematic survey of the area along the African and Arabian coasts has great potential for preserving Stone Age sites. The basin runs NNW-SSE between Northeast Africa and the Arabian Peninsula. It is connected to the Indian Ocean on the south by a narrow passage called the Bab al Mandab Strait. Girdler and Styles (1974:7) recognize two major stages of sea-floor spreading in the Red Sea proper, "the first from about 41 to 34 million years ago and the second from about 4 to 5 million years ago to the present day." During much of the Miocene (25-5 Ma), the basin remained relatively stable and semi-enclosed resulting in the formation of thick salt deposits due to high rate of evaporation (Bailey, et al. 2007). A major phase in the formation of the Red Sea Basin was a spreading crack from the Indian Ocean, which opened the Gulf of Aden by about 13 Ma (Braithwaite 1987; Wicander and Monroe 2000). The Red Sea basin resumed spreading till late Miocene (5 Ma) and subsequent volcanic processes in the Pliocene triggered extensional forces that formed the remaining features of the basin (Braithwaite 1987). In the Quaternary (including at present times) the average opening rate of the Red Sea is estimated about 10 mm/yr (De Mets, et al. 1990). The widest portion of the sea is about 354 km between Massawa (Eritrea) and Jeddah (Saudi Arabia) (Bailey, et al. 2007). The shortest gap occurs at the Bab al Mandab Strait, nowadays about 30 km wide and 137 m deep (ibid.).

The name Red Sea *(*Greek=*Erythra Thalassa)* is believed to have been coined in reference to the red colored *Cyanobacteria trichodesmium erythraeum* that seasonally bloom near the water surfaces of tropical oceans[2]. The surface water temperature of the Red Sea remains relatively constant year round with an average of 21-25 ^{0}C (70-77 ^{0}F). Visibility underwater is usually good up to 200 m, which makes it attractive for coastal tourism (Edwards 1987; Sharabati 1984). The sea is known for its strong seasonal winds (Northeasterlies and Southwesterlies), which help disperse molluskan and fish eggs over a wider distance to and from the Indian Ocean (ibid.). Due to its water clarity and narrow structure, the Red Sea is very favorable habitat for the growth of diverse molluskan species, sea grasses, pelagic fish, and sea mammals such as dugongs and cetaceans (Bailey, et al. 2007; Mastaller 1987; Sharabati 1984). The Red Sea is considered as one of the most saline oceanic water bodies due to high evaporation rate and the absence of major rivers and streams flowing into it (Braithwaite 1987; Edwards 1987). Its greater depth and efficient water exchange with the Indian ocean and Gulf of Aden, however make it suitable place for the growth of diverse marine ecology (Head 1987; Sharabati 1984). This is particularly true in the southern portion of the basin, which is less salty compared to the northern section due to its continuous water exchange with the Indian Ocean through the Bab al Mandab Strait (Bailey and Flemming 2008). During glacial times the width of the Bab al-Mandab could be narrowed to 5 km for a length of 150 km along north – south extensions on the Arabian and Africa sides (Flemming, et al. 2003). Such extensive coastal exposures may have attracted human settlements during glacial episodes (sea level lowering) in the Pleistocene.

Present habitat in the study region

Eritrea exhibits considerable environmental diversity. As such, human-land relationships are complex and constantly changing. Today, Eritrea has a tropical climate and desert to semi-desert landscape. It is divided into four broadly defined ecological zones (Fig. 2.5). These include: the Southwestern Lowlands (1,500-2,000

[2] Red Sea". Encyclopædia Britannica Online Library Edition. http://www.library.eb.com/eb/article-9106296. Retrieved on 2008-01-14.

m asl), the Northwestern Lowlands (900- 1,500 m asl), Central and Northern Highlands (1,800 – 2,000 m asl) and the Coastal Zone (<900 m asl) (Government of Eritrea 1999). The study area lies in the Coastal Zone adjacent to the Red Sea shoreline between the towns of Foro and Gelalo. It encompasses about 400 sq km stretching along the Gulf of Zula and Buri Peninsula. Much of the area has less than 200 mm average annual rainfall and a temperature exceeding 50°C during the hottest season (April – October). The Northeastern monsoonal winds act for a longer season of the year providing a short rainy period between November and March. During this period much of the highland plateau is dry. The central highlands and western portions of Eritrea receive rain between May and September as a result of the northward movement of the Intertropical Convergence Zone which pulls the Southwesterly winds further north. The Southwesterlies originate from the Gulf of Guinea (on the Atlantic Ocean) and brings moisture rich air to the highlands of Eritrea and Ethiopia in the summer. Generally, rainfall decreases with altitude as one move from western to the eastern lowlands of Eritrea, partly due to the rain-shadow effect of the central highland plateaus.

The common fauna and flora in the study region are listed in Tables 2.1-2. Plant cover consists of sparsely distributed halophytic A*cacia* communities, such as *A. tortilis, A. mellifera*, *A. nubica* (mainly around gullies), low shrubs and grass (Yohannes 2003). Scattered mangrove vegetation patches are also common along the immediate coastal margins. Common wild animals include ostrich, Soemmerring's and Dorcas gazelle, Hamadryas baboon, dik dik, spotted hyena, and one of the last free-ranging populations of African wild ass (*Equus africanus).* About 56 numerous species of birds have been identified along the Buri coast (Yohannes 2003:39). More are believed to remain unlisted. Although there are no elephants in the region today, oral accounts indicate that they inhabited the Zula Basin in the recent past. The name for one town in our survey area-Irafailo, is derived from two Turkish words (*Ira* = "I am looking", *Fil*= "Elephant"). By toponymic implication, elephants may have been present around Irafailo by the time of Turkish occupation of the Eastern Lowlands in the 16thcentury AD. As such, the area may have been relatively rich in freshwater and lush vegetation.

Nowadays, the coastal lowland is the driest zone with precipitation less than 200 mm and length of growing period below 75 days (Government of Eritrea 1999). Until 2006 there were only a few protected areas along the Eritrean Coast. In 2006, Eritrea declared its entire coast an environmentally protected zone. By this decree, about 1, 347 km coastline and more than 350 islands are protected.

Sparsely settled agro-pastoral communities of the Afar and Saho tribes inhabit the Gulf of Zula and Buri Peninsula today. It is not known when these tribes first settled the area. They cultivate maize and sorghum around river terraces and raise cattle, goat, camel and sheep. The soil is low to medium fertility dominated by xerosols, solonchaks, lithosol, and cambisol. During wet seasons (November – March) pastoralists from the southern highlands (such as Hazemo, Qohiato and Senafe) migrate to the area for pasture. The mode of agriculture is traditional and water diversion is a common mode of feeding agricultural fields along the major floodplains. Potable water for humans and animals is obtained from springs and deep wells near the coastal fields. Fishing is a common alternative subsistence activity by the local communities. The Massawa-Assab road that runs along the coastal terrain is the major highway that facilitates land connection in the area.

A Review of Terminal Pleistocene and Holocene Climate of the Horn

This section reviews the climatic history of the Terminal Pleistocene and Holocene (18 - 5 ka BP) of the Horn of Africa. This time span is crucial to understand human prehistory, because it was during this period that humans undertook major demographic and geographic expansion worldwide (Clark 1980; Phillipson 1995). Certainly, climate played an important role in these scenarios. The Horn of Africa is rich in paleo-lakes, cave sites and coastal landforms that could offer multiple opportunities for peleoclimatic reconstruction (Umer, et al. 2004). The majority of the data included here is from lacustrine record of the Ethiopian and Central Afar Rift lakes (Gasse 1977; Gasse 2000; Gasse, et al. 1980; Umer, et al. 2004). In the absence of a sufficient paleoclimatic record for the Eritrean Red Sea Coast, a regional review of past climate is useful in order to infer the paleoenvironmental history of the study area, the Buri Peninsula and Gulf of Zula.

All lacustrine proxies from the Horn suggest that the climate turned cold and hyperarid at the Terminal Pleistocene (MIS 2: 20 -12 ka BP) ensuing the LGM (Gasse 2000; Gasse, et al. 1980; Umer, et al. 2004). During this arid period, the Ethiopian Rift and the Central Afar lakes began to dry up and became ephemeral reservoirs (Gasse, et al. 1980). This arid episode is also manifested by glacier developments on some of the Ethiopian mountains such as Bale, Arusi and Semien (Umer, et al. 2004). The presence of a paleosol, with *in situ* grass remains dated to between 17 and 16 ka BP at Lake Abhe (Central Afar) suggests that the lake had dried considerably during the LGM, Figure 2.6 (ibid.: 163). Towards the final phase of the Upper Pleistocene (14 ka BP), the high mountain peaks of Ethiopia started to deglaciate and the modern vegetation pattern began to expand. Similarly, the sedimentary record at the Gogeshiis Qabe cave site (southern Somalia) suggests a wetter climate by 14 ka BP attested by a shift from coarser to finer sediments in the cave (Brook, et al. 1997). As monsoonal winds started to provide constant rain, the major lakes in the Afar Rift began to rise considerably. Following this ameliorating condition, a short dry period (the Younger Dryas) occurred between 12-11.7 ka BP (Umer, et al. 2004). This dry period is shown by sedimentary coarsening of the Gogeshiis Qabe cave, and minor regression of the Ethiopian Rift lakes (ibid.).

Wetter conditions prevailed at the onset of the Holocene (around 11 ka BP) as evidenced by increased development of speleothems, vegetation expansion and increase of the watersheds of major lakes in the Afar Rift (example, Abhe, Asal, Afrera and Shala) (Gasse 1977; Gasse, et al. 1980). Lake Abhe, for example, increased 160 m above its present level at the onset of the Holocene wet phase (ibid.). Similarly, the Ziway-Shala lacustrine record in the Main Ethiopian Rift suggests a significant water level increase (~112 m) during early Holocene (Gasse 1980). This high-stand was interrupted by a series of short-term regression events around 8.7 - 8.1, 6.7 and 5.5- 4.5 ka years BP calibrated (Umer, et al. 2004). These appear to be associated with the increase in the strength of the northern monsoon winds which inhibited the extension of Westerlies and summer rainfall distribution (ibid.).

Likewise, coral reef terraces along the northern Somali coast suggest that sea level reached its present level around 7 ka BP (Brook, et al. 1996). Generally, intermittent dry periods as a result of abrupt oscillations characterize the early mid-Holocene globally. Hassan (1997) identifies six major drought events in the monsoon-dominated areas of Africa between the Terminal Pleistocene and late Holocene: 12000-11500, 8500, 7500, 4500, 4000-3700 and 2000 bp radiocarbon years.

The carbonate record from Lake Awassa (central Ethiopia) indicates climatic aridity around 5 ka years BP calibrated (Umer, et al. 2004). Similarly, a diatom record of Lake Abiyata (central Ethiopia) shows brief drier periods indicated by maximum water deficit in the lake around 5.3 - 4.9, 3.2 - 3 and 2 - 1.8 ka years BP calibrated. The overall evidence from the Ethiopian Rift suggests that the majority of the lakes began to recede after mid-Holocene, turning into ephemeral water bodies.

Recent geomorphological and archaeological investigations in the Tigray region of northern Ethiopia suggest wet climate and dense vegetation during the early mid-Holocene period (Bard, et al. 2000; Beraki, et al. 1998). This is confirmed by the formation of travertine and buried soils overlying alluvial sediments of the Terminal Pleistocene (Bard, et al. 2000). A proxy evidence for thick vegetation cover on the Tigray plateau has been recorded from travertine formations at the Mai Maikden area, 20 km north of the Mekele city (Beraki, et al. 1998). Here, travertine deposits rich in carbondioxide demonstrate the presence of thick vegetation cover supported by sustainable rainfall. The travertine deposits were dated to between 7310$\pm$90 - 5160$\pm$80 BP radiocarbon years (ibid.:127) (calibrated to 8144 ± 103 at 1-σ BP, www.calpal-online.de/). The study indicates that soil erosion intensified on the highlands starting in the third millennium BC due to the reduction in vegetation cover. This period is also marked by a hiatus in the formation of travertine and peats, signifying conditions similar to the present. The combined effect of climate and human activity (food production) is believed to have caused the apparent contraction in vegetation towards the mid-Holocene and afterwards (ibid.).

The main conclusion from the above review is that most of the Afar Depression, the Ethiopian Rift, and the Tigray-Eritrean highlands experienced constant fluctuation in climate during early mid-Holocene. Humid and wet phases in the early Holocene were followed by intermittent dry episodes towards the mid-Holocene. The Afar Depression lies close to the focal region, the Buri Peninsula and Gulf of Zula. Therefore, in the past, the Buri-Zula littoral might have experienced similar climatic dynamics as in the Afar/Ethiopian Rift. Today, the Northeastern monsoonal winds originating from the Arabia Peninsula across the Red Sea Basin provide small scale rainfall along the Eritrean Coast. These winds have relatively little effect on the Afar/Ethiopian Rift. Therefore, although similar climatic trend could be expected in both areas in the past, the situation along the Buri-Zula littoral may have slightly differed from the interior due to the effects of the Northeastern monsoonal winds that supply small scale rain along the coast. Apparently, the Red Sea Coast may have been more hospitable compared to the Danakil Depression during arid periods due to the availability of freshwater springs (Faure, et al. 2002) and marine resources that are exploitable for longer seasons. As such, there is greater opportunity of finding prehistoric sites representing different climatic periods on the coast.

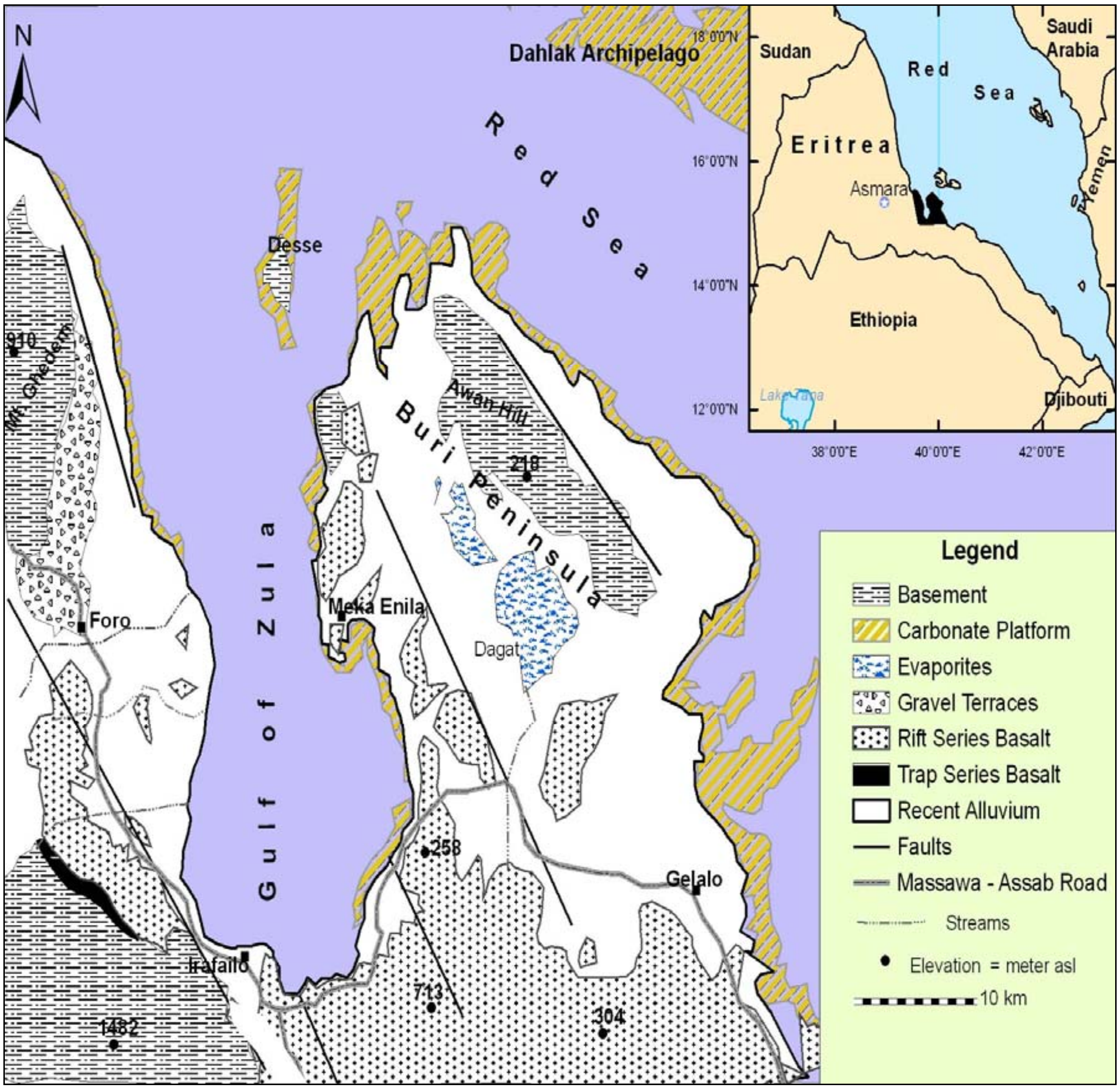


Figure 2.1. The geological features of the study region modified from Ghebreab 1999:5; and Barberi, et al. 1971.

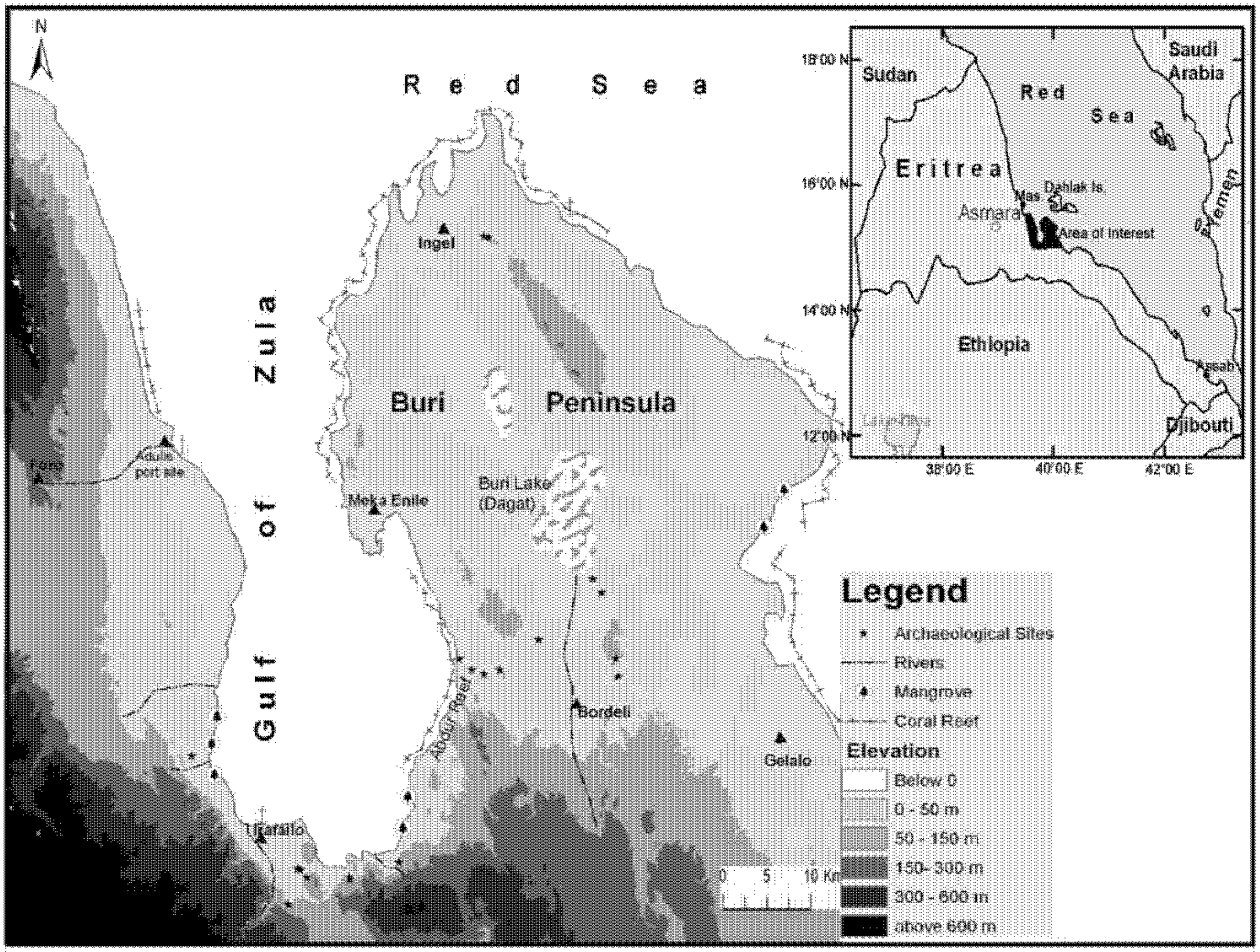


Figure 2.2. Map showing physiographic and topographic setting of the project area.

Figure 2.3. The Abdur Reef Limestone Formation, eastern coast of the Gulf of Zula.

Figure 2.4. Shell accretion at the Meka Enila survey area, north of Abdur along the Gulf of Zula. The shell-accretions appear to be deposited by sea transgression.

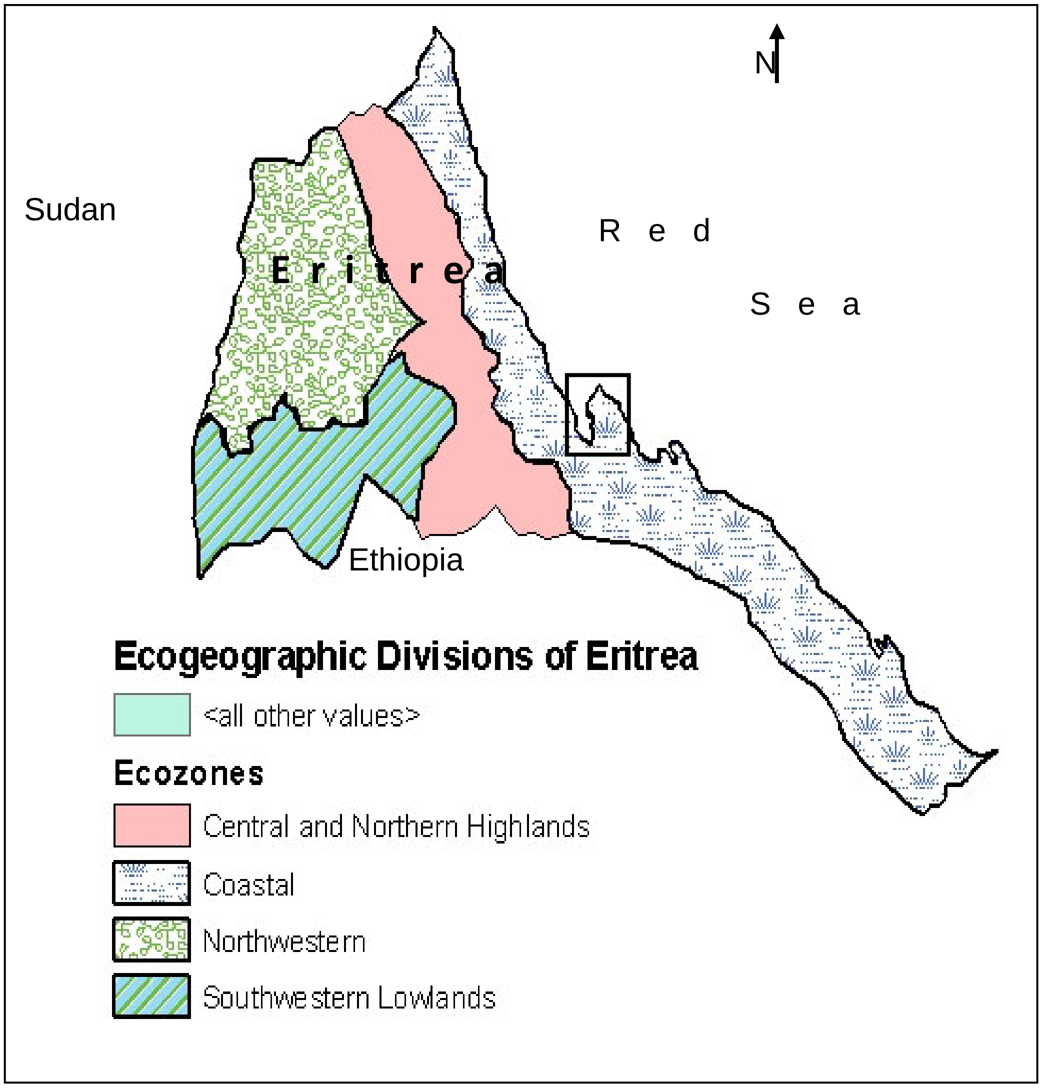


Figure 2.5. Current ecogeographic divisions of Eritrea (Government of Eritrea 1999).

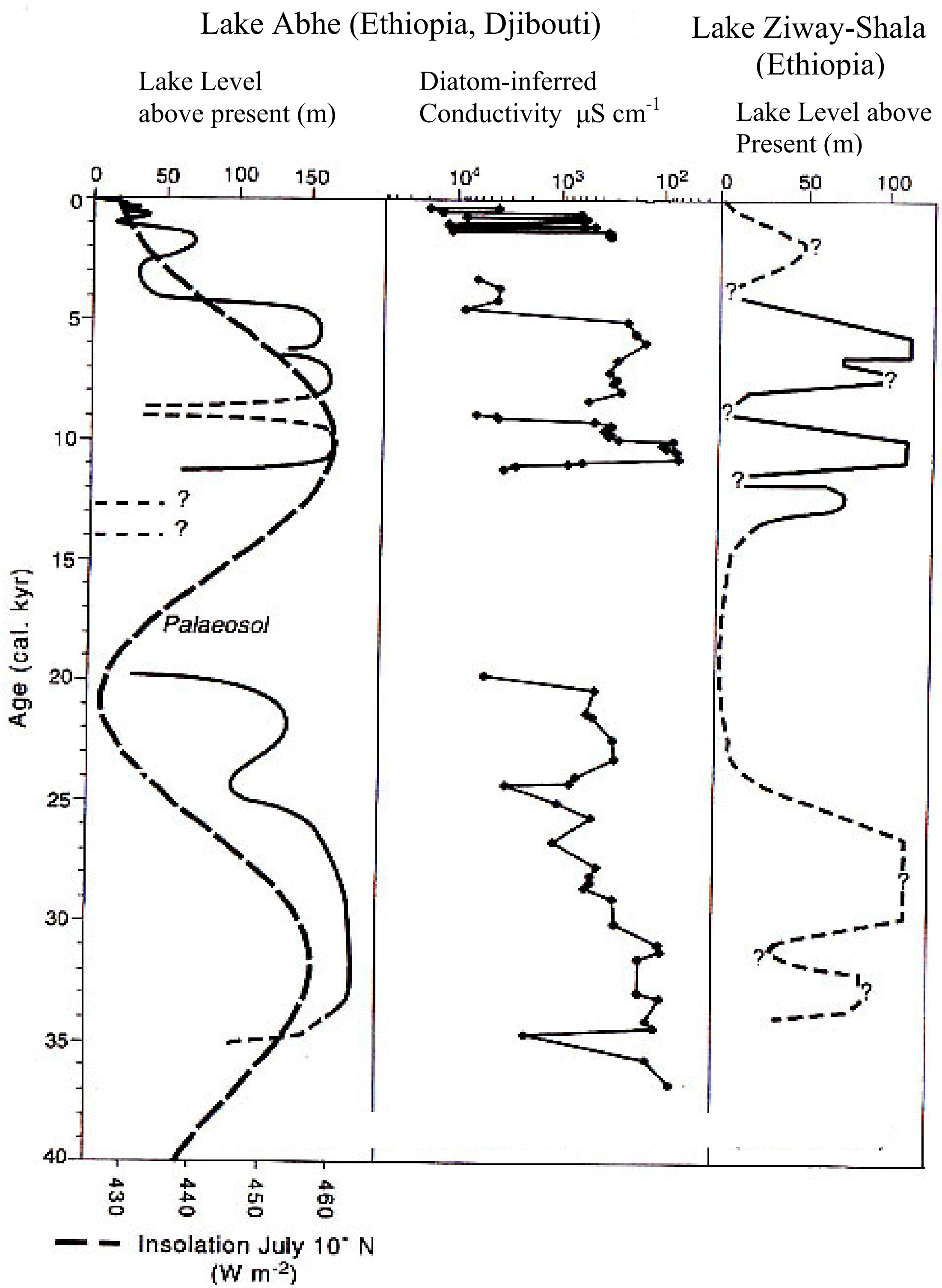


Figure 2.6. Climate history of the Horn of Africa in the past 40 ka based on water level record of the Afar and Ethiopian rift lakes (Umer, et al. 2004). Primary sources: Lake Abhe (Gasse 1977; Gasse 2000), Lake Ziway-Shala (Street 1979).

Species name	Family name	Tigrigna name	Human use
Phacochoerus africanus	Common warthog	Mefles	Food
Equus africanus	Wildass	Adgi-Bereka	?
Gazella dorcas	Dorcas gazelle	Hatsar Erab	Food
Gazella soemmerringii	Soemmerring's gazelle	Newah Erab	Food
Struthio camelus	Ostrich	Segen	Food
Crocuta crocuta	Spotted hayna	Tunkae Zbei	None
Canis mesomelas	Black-backed jackal	Wekaria	None
Procavia capensis	Rock hyrax	Gihe Bereka	Food
Lepus habesinicus	Abyssinian hare	Mantile	Food
Xerus rutilus	Squirrel	Mutsutsulay	None
Papio hamadryas	Hamadryas baboon	Hibey	None
Various birds			Food
Various reptiles			?
Various insects			Bees (honey)

Table 2.1. List of common fauna in the study area. Assembled with the assistance of Mr. Desale Yosief, Department of Biology, University of Asmara.

Species name	Family name	Tigrigna name	Human use
Dombey torrida	Sterculiaceae	Hamboke	Firewood
Rhizophora mangles	*Rhizophoraceae*	Mangrove	Medicine
Grewia tenax	Tiliaceae	Huda	Fire wood, timber
Cissus quadrangularis	Vitaceae	A'la	Firewood
Senna alexandrina	*Caesalpinoideae*	Sano	Firewood
Zizyphus spina-christi	Rhamnaceae	Gaba	Food, firewood,
Acacia abyssinica	Fabaceae	Che'a	Firewood, timber
Acacia oerfota	Fabaceae	Gemero	Firewood
Suaeda monica	Chenopodiaceae	Alkei	Firewood
Commiphora erythraea	Burseraceae	Kurbet	Firewood, timber
Ephorobia polycanta	Euphorbiaceae	Kolkal	Firewood, timber
Tamarix aphylla	Tamaricaceae	Obel	-
Tribulus terrestris	Zygophyllaceae	Qwakiito	none
Calotropis procera	Asclepiadaceae	Gindea'	poisoning, timber
Ficus glumosa	Moraceae	Chekemte	Firewood, food
Succulent species		Meaguti may	?
Cordia species	Boraginaceae	Alet awhi	Food, timber

Table 2.2. List of common flora in the study area. Assembled with the assistance of Mr. Desale Yosief, Department of Biology, University of Asmara.

Chapter 3

The Site of Asfet: Survey and Surface Archaeology

Introduction

This chapter reports the geological context and surface lithic findings from the Asfet Site complex. Site survey and artifact collection strategies employed in the course of the fieldwork are described. The Asfet Site was intensively surveyed and two localities A05 and A06 were recognized based on artifact distribution pattern. Locality A05, covering a large section of the sandy basin, produced dense distribution of MSA lithic remains comprising triangular points, prepared core products (Levallois elements) and prismatic blades. Small quantities of Acheulian handaxes and heavy duty miscellaneous tools were also recovered from surface in association with the MSA artifacts. The surface material reveals a wide range of techno-typological variability distinct from the excavated sample. For this reason, it is separately treated from the excavated assemblage (described in chapter 4).

Geology and physiography

The Asfet study area is located about 10 km northwest of Irafailo along the southern coast of the Gulf of Zula. The site is situated on a low laying sandy basin between two N-S running basalt ridges. The western ridge gently slopes eastward while forming steep rolling cliffs on the western side. Semi-continuous flat outcrops characterize the ridge tops. The low basin between the ridges is entirely filled with alluvium. The southern section of the basin is covered by eroding basalt scree and sediments that appear more consolidated. No major stream flows through the Asfet fault system at present, and it is possible that the sediments covering the basin floor were blown into the basin from the vast open fields to the north. The parallel running ridges open into a low laying outlet to the north. Sea water could have entered the basin through this corridor during periods of high stands as well, but there is no evidence to suggest any recent movement of sea water into the basin. There is a small secondary ridge protruding from the western ridge that acts as an embankment for sediment accumulation along the lower base of the western ridge.

The modern seacoast is about 800 m east of the main site. There is a hot spring flowing from a small erosional channel on the southeast of the site. The spring serves as a stable water source for the growth of shrubs and mangrove trees. It is also used as healing water by the local community. Laboratory analysis of samples from the hot spring shows high percentage of nitrate compounds indicating underground sea water infiltration into the vicinity of the hot spring. To the west, the Asfet basalt hill is ringed by a narrow fault-depression filled with alluvium. The Asaghede River on the south and Adayto to the north are the two main drainage systems around the site (Fig. 3.1). Both channels originate from the Berhaga Mountain on the west and enter the Gulf coast at a low laying mangrove field. The Adayto River is particularly important because it flows for a longer season making it a stable source of freshwater for the pastoralists around the area. The river becomes shallower and bends southward as it approaches the coastal margin.

Geological survey started immediately after our arrival at the Asfet site in spring 2006. Geological contacts were recorded using GPS and mapped on a plan view using *ArcGIS* software. Mr. Ghebretinsae Woldu of the University of Asmara offered geological assistance and prepared a field report for the project. Three main basaltic lava flows are identified in the area: i) the Lower Flow, ii) the Scoriacious Flow, and iii) the Upper Flow. All flows share one common feature, that is, they are olivine phyric basalt.

i) *The Lower Flow*. This basaltic flow has fine-grained groundmass with olivine porphyry. It is about 2m thick, black when fresh and gray when weathered.

ii) *The Scoriacious Flow*. This flow is easily recognized by its very rough and scoriacious surface. Though its fresh color is black and shows olivine porphyry, the superficial color of the flow varies from red, black to gray. In some cases where the upper flow is eroded away, for example near the main Massawa–Assab Road, the scoriacious lava outcrops on the surface. It is approximately 0.5 m thick.

iii) *The Upper Flow*. This layer is also olivine phyric basalt, but vesicular in groundmass. In some instances the vesicles are filled with amygdule. The color of the rock is black when fresh and brown to gray when weathered. The bottom part of this flow show baking effect suggesting that the upper flow fell on the hot scoriacious lava without a time gap. The maximum thickness observed is about 4 m.

All the basaltic flows are fractured by two sets of joints: N-W and an E-W trending joints which are related to the active Red Sea and Gulf of Aden tectonics respectively. Those associated with the Red Sea tectonics form three parallel faults that strike NNW (340^0-350^0). They dissect the site platform into the two distinct ridges and one smaller ridge just protruding from the western slope. The faults have created the small basins at the center that have accumulated thick alluvium where dense archaeological remains (mainly lithics and shells) are distributed. The easternmost fault, which is adjacent to the site datum, generated the basin.

To the west of the Asfet area is a prominent mountain chain called Berhaga whose summit ranges 286 m asl. The mountain is built of Neoproterozoic gneiss with the intercalation of schist. The metamorphic basement rocks may have served as a source for some of the lithic artifacts found at the site (see below). The orientation of the metamorphic rocks here is N $60^0/45^0$ NW. On top of the mountain chain, the Flood Basalt (Trap series) is found on top of the Neoproterozoic Basement with unconformity. One peculiar feature of the basalt here is the spheroidal weathering which is characteristic feature of the Flood Basalt. The scoriacious flow that outcrops around the Asfet area (which is peculiar to the Rift series) does not exist on the mountain. Apparently, there is no Mesozoic sedimentary sequence on the mountain chain. This is probably because the Tethys sea transgression, which occupied a large part of the Eastern African continental margins during the Mesozoic did not reach the escarpment. Moving northwest of Asfet is a low relief field covered by intermittent lave flows and alluvial outcrops.

Satellite image interpretation and field observation reveal that there is a NW striking normal fault on the southern edge of the Gulf of Zula dipping toward the sea.

This fault has down thrown the Asfet-Irafailo basin. Miocene and Pleistocene sedimentary formations and the Rift series basalt are absent from the mountain chain west of Asfet suggesting that the faulting took place before the Miocene (possibly Late Oligocene) making the Asfet-Irafailo half graben a basin since then. The Late Oligocene half graben was intersected by the Miocene age NNW trending Gulf of Zula – Danakil graben making the Asfet–Irafailo basin deeper and wider that eventually produced the Gulf of Zula–Danakil basin from the Miocene onward. The Miocene and Pleistocene formations are found restricted to the Gulf of Zula–Danakil basin floor. The geological investigation concludes that the Rift series basalts outcropping in the Asfet area are overlying the Flood Basalts (Trap series) as well as the Miocene and Pleistocene evaporates and sedimentary formations.

Sediment characterization

The fieldwork did not involve a controlled study of site stratigraphy, because the description of the bedrock geology was sufficient to understand the geomorphic setting of the site. Near surface and subsurface sediment analysis was, however conducted to assess if there was any event of sea water intrusion into the site. Four spots were selected for sediment sampling (Fig. 3.2). They were designated as “Log Sections” and exposed to varying horizontal levels, but usually between 30 and 50 cm in vertical depth. Two of the exposed log sections were along the sandy basin while the other two were exposed on the eastern and western ridges respectively. Sediments sampled from the log sections were sent for analysis to the National Agricultural Research Institute at Halhale, Eritrea. Laboratory results are shown in (Fig. 3.2). Three parameters were selected with the help of a professional soil analyst, Samuel Habte. These are soil texture, PH value and Electrical Conductivity (EC). The texture analysis is useful to describe sediment variability across different profiles from which we can infer the depositional processes. PH analysis was intended to measure alkalinity level of the soil, although its validity has been questioned later due to the unstable nature of soil PH. This is because soil PH can be affected by seasonal climatic fluctuations and vegetation cover (Rapp and Hill 1998). The EC value is used as a proxy to measure salinity level of the sediments from which to infer any event of marine deposition (Lal and Shukla 2004).

The texture of the analyzed sediments ranges between sandy loam and clay loam, which means that sand dominates the soil matrix. The sample from the central basin show higher percentage of sand, while samples from the basalt periphery tend to be silt and clay dominated (Table 3.1). Two sections (Log 01 and 02) on the basalt slopes were exposed along 50 cm x 9 m wide grids to a maximum depth of 30 cm. Those two sections do not show any stratigraphic structure, instead they are characterized by moderately consolidated clay and silt deposits. The sediments from the eastern ridge slope tend to be slightly sandier than the western ridge. Log 03, a 1m x 70 cm trench was dug to 50 cm below surface on unstable channel bed and was excluded from the analysis. Log 04 which was dug 80 cm below surface in the middle of the sandy area has shown some bedding structures that appear to be related to climatic fluctuations. There, alternating sand and silt laminations were noted suggesting cyclical variation in the intensity of the depositional agent, in this case aeolian processes associated with a backwater flood plain (Rapp and Hill 1998). The sediments here tend to be generally low in clay content and there is no trace of marine clasts or carbonates. Thus, there is no strong evidence for stable aqueous depositional conditions up to 80 cm below surface on the sandy basin. Conversely, some compacted pedogenic layers noted in this section suggest periodic landscape stability (ibid.).

The PH and EC values show high variation within the sampled sections. The EC value as expressed in milliSiemens per centimeter or meter (ms/cm or ms/m) estimates the amount of total dissolved salt ions from the sample matrix in a priori deionized water (Lal and Shukla 2004). The flow of electric current through the solution is proportional to the concentration of dissolved ions. The conductivity test is performed by measuring current flow rate between two 1 cm or 1 m spaced electrodes introduced into a solution containing the sampled sediments. In our case it was in centimeters. By agricultural standards, “saline soils are those which have an EC of 4 dSM^{-1} at 25 ^{0}C, with exchangeable Sodium percentage less than 15 and PH about 8.5” (ibid.: 644). Table 3.1 shows the results of EC analysis for 10 samples collected from Asfet. Several of the samples have produced higher EC values that fall within saline scale by agricultural standards. It is unclear however, whether sea-vapor or sea water intrusion caused this high salinity level. Otherwise, the texture of the sediments does not suggest any marine deposition. Sediments from the upper surface of the eastern and western ridges show higher EC than the basin. This could be due to the constant addition of salt particles by sea-vapor onto the upper soil layers of the ridge periphery. As the basalt ridges stand higher in elevation, they can easily trap salt rich wind blowing from the sea. The low EC value observed at the deeper level of Log 04 associated with those laminated features hints that no sea water has entered the basin in the history of this deposit. Therefore wind and running water are the likely agents for depositing the sediments into the basin.

In summary, the limited texture and EC data suggest that there was no sea water intrusion into the Asfet basin in the recent past. Therefore, we do not know how prehistoric human occupation of the site might have been related to the configuration of the sea shore. The original placement of the site with respect to the past shoreline could not be clarified from the archaeological findings or from the bedrock geology. Artifacts found in association with shell remains on the surface could not fully demonstrate the placement of the sea coast before, during or after the site's occupation. While the interpretation of the EC results needs to be confirmed by additional data from stratigraphic analysis in future works, it is possible that the sea shore had occasionally moved to the site vicinity.

Survey strategies and surface collection

The extent of the Asfet site could not be determined during the reconnaissance survey due time constraint. Although the initial survey documented rich artifact distribution at the center of the site, our picture of the site boundary and spatial configuration of artifacts was incomplete. The first plan in the subsequent research phase was to determine the site boundary prior to any other activity. The primary datum was specified on an elevated spot at the southern edge of the eastern ridge. Transect lines running 320^0 S-N and 40 m x 40 m grid spaces were established dividing the entire Asfet vicinity into 133 square grids (Fig. 3.2). The SW corner of each grid was given a coordinate in order to guide surveyors. A topographic map of 52-hectare area, incorporating the basalt surface and the central basin was produced at a 1m interval. During the survey, density areas and geological features were traced by a hand held *Trimble GPS* loaded with *ArcPad* 6.1 and saved as a polygon format. The geological substrate and artifact distribution in each grid were regularly noted on predesigned survey forms (Appendix V). The ESRI® *ArcGIS 9.1* mapping software was employed to manage GPS data and produce field maps.

Controlled collection of surface sample was performed on the high density areas. The aim of such a strategy was to empirically assess the surface integrity of artifacts. Instead of simply describing surface distribution on an ordinal scale (high, medium and low), a controlled approach would provide an accurate picture of artifact variability and spatial configuration. A controlled surface collection approach has been widely advocated by field archaeologists (Redman and Watson 1970; Redman 1987). Diagnostic artifacts were collected during the transect survey and transported to the NME for detailed study. All the collected artifacts were individually mapped unless they came from a dense cluster (less than 2 m^2) in which case they were all given a single provenience point. A combination of a systematic and a judgmental approach worked well in determining the number and type of materials to be collected. The sample size had to match the quality and quantity of materials represented in each grid or cluster unit. In grids where the surface material was densely distributed, proportionally greater numbers of artifacts were collected. The most representative artifacts and raw material types were collected from each grid because the NME guideline prohibited large sample collections. Representative shell remains were also systematically collected and analyzed in the NME by a malacologist (see Appendix I).

In order to expand the lithic sample size from the surface, we analyzed selected artifacts *in situ*. For this, over 600 artifacts were analyzed on site. Artifacts were picked up for examination and left in place without moving them any farther.

Artifact provenience, typological attributes and technological measurements were recorded on predesigned lithic forms. In doing so, the research team was divided into two groups. The survey group, whose task was to map and document artifact distribution and to collect representative artifacts, consisted of a GPS operator, a recorder, an artifact collector, and two individuals posting locations of diagnostic artifacts and grid references. The on-site analyst group, consisting of the author and two recorders, examined representative artifacts flagged by the survey group. Field assistants were assigned tasks based on their field experience and training. Most of the assistants were archaeology graduates from the University of Asmara with prior training and work experience. Although there were narrow chances of revising the records of artifacts analyzed on site (whereas museum analysis offers much flexibility in rescreening analytic records), our strategy had the advantage in terms of preserving site visibility.

Site definition

After concluding the transect survey, the site boundary was delineated along the margins where artifact distribution is minimal. Several distinct artifact scatters were identified during the transect survey. Archaeologists refer to areas featuring one or more archaeological occurrences or scatters of cultural materials as "Localities" or "Loci" (Caton-Thompson 1952; Kleindienst 2004). In our case, the area representing wide spread surface occurrence comprising the central basin and the southern portions of the ridges between Grid 20 and 89 has been designated as Locality A05, and the northern edge of the western ridge-top as Locality A06 (Fig. 3.3). The letter "A" stands for Asfet and the sequential numbers refer to the year of discovery of that particular locality. The range of surface scatters in Locality A05 was noted during the reconnaissance survey in 2005, whereas those artifact scatters on the ridge tops were discovered during the transect survey in 2006. The entire Asfet Site is designated as a Site Complex to recognize the different lithic industries represented there.

Locality A05, representing the main site at Asfet has an area of 7.2 ha (Fig. 3. 3). The E-W extension of the locality varies from 120 to 250 m depending on the distribution of artifacts on the basalt outcrops. Artifacts were recovered from the higher basalt slopes and the sandy basin at various concentration levels. The area referred to as Locality A06 on the northern periphery of the western basalt ridge (between 15 and 30 m elevation) is characterized by scattered archaeological occurrences and two cluster spots. It covers an area of about 0.8 ha. The substrate is hard volcanic rubble and lava bedrock with the exception of those secluded flat areas with shallow sediments. Artifact distribution is sparse throughout the basalt slope except at some isolated spots on the ridge top.

About 20 small to medium Cluster Areas were identified during the survey. Most of these areas are located on either sides of the basin periphery or the ridge tops. They range in size from 300 sq m (such as in Grid 54) to some 10 sq m (mainly along the ridge tops). Two cluster spots were located outside the boundaries of Locality A05 and A06 on isolated spots in Grids 85 and 127. Many shell-dominated high density areas occur along the basin floor. A prominent example is the big cluster area noted in Grid 54. Situated on a loose sandy substrate in the sandy basin, this cluster area contains enormous shell and lithic remains on the surface seemingly on secondary context. The source of the high archaeological density at Grid 54 is unclear, but from the small size of artifacts forming the clusters, it appears that fluvial and wind erosions were the primary depositional agents. A controlled surface collection in Grid 54 shows a uniform association of shell and lithic remains (Fig. 3.4). Those cluster areas found on the ridge tops seem to represent primary context and tend to be much smaller, mainly dominated by shell fragments.

Asfet Surface Archaeology

This section describes surface lithic findings from the Asfet Site complex. Locality A05 of the site has been the main focus of intensive survey and surface collection. A considerable quantity of lithic assemblage has been collected from the surface alone. The surface material reveals a wide range of techno-typological variability distinct from the excavated sample. The excavated assemblage solely known from Unit F at Locality A06 is reported in chapter 4.

The western periphery of the sandy basin contains higher artifact density (Figs. 3.3-4). The survey result shows some pattern in artifact distribution at discrete portions of the basin. Two distinct patterns were noted: one dominated by large size tools noted along the lower margin of the western ridge and the other featuring smaller tools and debitage densely scattered along the basin floor. Artifact distribution is generally sparse on the eastern ridge compared to the western side. The majority of artifacts recovered from the eastern ridge were blank flakes and sparse cores. A few patches of shell and lithic clusters were noted on the upper peripheries as well. The association of artifacts and shells is not uniform in the cluster areas. And there is no pattern with respect to the type of artifacts found in association with the shell remains, although generally smaller flakes and fragments made on obsidian are abundant. Shells of a wide size range were observed in the cluster areas.

Artifact density is low around the northern part of the western ridge in Locality A06 except those isolated find-spots (Fig. 3.3). The few scattered findings occur on highly eroded surfaces and are presumably on a secondary context. The artifacts there show closer affinity to those noted in Locality A05; they consist of cores and miscellaneous large tools made from basalt. One peculiar find was a green obsidian piece (core fragment) found on the northern edge of the ridge.

Three of the cluster areas, two from the sandy basin and one on the ridge top of locality A06 were selected for test excavations after the survey. However, only one cluster area – Unit F on the northern edge of the western ridge (27 m asl) produced subsurface archaeology dating to the mid-Holocene span (chapter 4).

Cores and miscellaneous tools

This class comprises specialized cores (prismatic, Levallois, discoid) and other unstandardized or miscellaneous core types. A total of 137 core artifacts were collected mainly from Locality A05 using judgmental sampling. More than half (78) were analyzed in the field and 59 transported to the NME. Table 3.2 summarizes the composition of cores and miscellaneous tools with respect to raw material type. Basalt is the dominant raw material (69%) followed by quartz (11%), and rhyolite and obsidian contributing smaller percentages in the core class. Other rock types reduced include chert and green schist, in a very small proportion.

Cores and heavy duty tools were mainly found along the lower margins of the western ridge interstratified with basalt rubbles (Fig. 3.5). A few cores were recovered from the sandy basin. The distribution of raw material seems proportional to the general configuration of artifact density on surface. There is no pattern among the represented core artifacts that suggest specific raw material was selectively exploited or discarded in any particular location. On areas where there is dense concentration of cores and heavy duty tools, basalt is always dominant. Generally, artifacts appear in fresh condition with minor abrasion and low surface patina.

Levallois (n=12). Although represented in smaller quantity (9%), Levallois cores were the most diagnostic types in the analyzed core sample. The majority of them are lineal type. Lineal cores are distinguished by the presence of one prominent negative scar along the flake release surface (Fig. 3.6). One unique finding was a core resembling Nubian Type II of the Nile Valley Middle Paleolithic complex (Van Peer 1998) that has been recovered from Grid 21 (Fig. 3.6-21.18). More than half (58%) fall within the length range of 61-100 mm (Fig. 3.23). The majority (42%) of the analyzed Levallois cores weigh between 71-150 g. A small proportion (25%) belongs to the mass range of 31-70 g (Table 3.3). Most of the Levallois cores (83%) display less than 33% cortical surface (Fig. 3.24). This is not surprising because Levallois technique involves extensive preparation of the core surface in search of suitable striking platform and a large part of the cortical surface can be removed from the core in the course of release surface preparation.

Blade Cores (n=21). Cores displaying more than 2 parallel running-elongated negative scars characterize the blade cores (Fig. 3.7-9) representing 15% of the general core class (Table 3.2). This includes prismatic and non prismatic ones. The majority of blade cores preserve more than one and opposing striking platform surfaces, and multi-directional scar pattern. There is modest variation in blade core dimension (Fig. 3.23). A large percentage the blade cores (78%) weigh above 70 g (Table 3.3) and a high percentage of it (81%) displays less than 33% cortical surface implying that cores were greatly exploited.

Discoid (n=17). Discoid cores feature a biconvex cross section and biconical profile with multiple flake removals oriented towards the center on one or two surfaces (Fig 3.11). Usually a round cortical surface is visible on the center of one or both faces of the core. Discoid cores represent 12% of the core class, the majority made on basalt (Table 3.2). Most of the discoid cores (47%) fall within the length range of 61-100 mm (Fig. 3.23). The remaining 41% are less than 60 mm. This means that the majority of flakes removed from discoid cores were below 40 mm in length. Over 58% of the discoidal cores weigh below 150 g (Table 3.3), and 82% contain less than 33% cortical surface. A small proportion (6%) contains greater than 67% cortical surface (Fig. 3.24). This suggests that not all of the discoid cores were completely exploited. Sometimes, flake removal is more concentrated on one surface leaving the other face unworked, thus preserving substantial cortical area.

Choppers (n=21). Several chopper tools were analyzed accounting for 17 % of the general core class. Chopper manufacturing is characterized by unificial and parti-bifacial removal of broad and invasive flakes (>20 mm) forming a straight working edge (Fig. 3.12). Basalt and quartz dominate this tool class (Table 3.2). A large percentage of the chopper class (67%) weighs over 600 g and some (29%) between 71-150 g (Table 3.3). The majority of the chopper tools (76%) are longer than 100 mm, and the rest (24%) between 60 and 100 mm (Fig. 3.23). When we look at variability in cortex distribution, 57% of the chopper tools posses less than 33%, and 24% between 33 and 67% (Fig. 3.24). This means that these tools were modestly worked. In general, both morphological and dimensional analyses show variability in chopper tools. Morphologically, some of the tools classified as choppers appear to be tested cores. A few partly reduced bifacial implements were seldom encountered as well (Fig. 3.12). Some of the heavier cores and tested cobbles (greater than 2 kg) may have been knapped using an anvil technique due to their heavy weight for direct hammer percussion.

Core on Flakes (n=12). Artifacts considered in this category include flakes that preserve negative scars (usually greater than 20 mm) on the ventral face. Core on flakes comprise 9% of the general core class. Raw material is almost entirely on basalt (83%). The majority (58%) of core on flakes are within the length range of 61-100 mm (Fig. 3.23). When we look at mass variability, 33% fall within the range of 31-70 g, 25% between 71 and 150 g, and a small quantity (17%) below 30 g (Table 3.3). Most of the tools (75%) contain less than 33% cortical surface (Fig. 3.24).

Other Unspecialized Cores and Large Tools (n=54). This group comprises all cores that cannot be classified to any of the above categories. They display large scar marks, but lack standardized form. Some of these include less diagnostic pieces such as polyhedrons. They preserve more than two flake release surfaces and irregular scar ridges suggesting opportunistic flake removal. They may represent heavy duty tools and tested cores. Some researchers refer such tools to as "modified tools" (Clark and Kleindienst 1974), "miscellaneous trimmed pieces" (Isaac 1977) and "expedient tools" (Parry and Kelly 1987). Such idiosyncratic types have been commonly encountered in many Stone Age sites in East Africa. At Asfet, those tools were all made on local raw material (lava). Some flake scars extend to the center of the tools suggesting that they could have been sources of flakes. A large number of those tools appear longer than 100 mm and heavier than 600 g (Table 3.3; Fig. 3.23). Most of those preserve less than 33% cortical surface (Fig. 3.24).

Hammerstones (n=10). Hammerstones were rarely found, but those occasionally encountered pieces show pitted and pounded surfaces, suggesting intentional use as hammering objects (Fig. 3.13). Quartz is the dominant raw material accounting for 40 % followed by basalt which constitutes 20%. See Tables 3.4-5 for mass and size variability in the hammerstone group.

While in the field, 91 cores and large tools were mapped *in situ*. The majority were found along the western periphery of the sandy basin, and raw material composition is 98% basalt.

In summary, the analyzed core sample shows considerable variability in morphology and size. A large percentage of the analyzed cores range 61-100 mm in length (Fig. 3.23). In terms of mass, the chopper tools show a contrasting pattern in that the majority is heavier than 600 g and about one third falls below 300 g. The majority of specialized cores display less contrast in mass. The general tendency in the core classes is that many of them contain less than 33% cortical surface. This means the cores were intensively reduced. Miscellaneous cores and large implements have been abundantly recovered from surface at Asfet. These may possibly represent generalized –multipurpose tools.

Shaped tools

This class includes all artifacts displaying modified edge by secondary retouch or those preferentially reduced tools, such as bifaces. A total of 185 shaped tools were sampled, mainly from the southern and central peripheries of the basin. Out of this, 129 were collected and subjected to detailed analysis in the NME. The rest were analyzed in the field. Table 3.6 summarizes the composition of shaped tools with respect to the raw material variability. Scrapers, large shaped tools and points make up higher proportions. Basalt (43%), obsidian (23), quartz (17%) and chert (9%) respectively make up large percentages of raw materials in the retouched tool types (Table 3.6). A few rhyolite, shale and chert rocks were also identified contributing small proportions. One notable observation is that highly designed tools were selectively manufactured from rhyolite, shale and chert. Rhyolite is locally available, but the source of shale and chert is unknown. This may imply that non-local raw materials were prized over locally available rocks (for example, basalt) for making well designed tools.

Large shaped tools. This comprises all diagnostic heavy duty artifacts (Large Cutting Tools), such as handaxes, cleavers and picks (all >100 g in mass) (Fig. 3.14-15). The large tools constitute 13% of the general shaped tool class (Table 3.6). A common occurrence during our survey was the discovery of numerous trihedral picks with parti-bifacial scar removal. Basalt accounts for 92% of the raw materials used for large tool production.

None of the obsidian, chert or quartz raw materials which contribute large percentages in the other tool classes were used for large tool production. There is a modest variability in mass, with the majority (58%) weighing over 600 g and some (29%) falling within the range of 100-300 g (Table 3.7). The mean size for the large cutting tool class ranges 129 mm in length, 80 mm in width and 43 mm in thickness (Table 3.8). The observed high standard deviation (SD=33) signifies widely spread length value, which is also demonstrated in the large gap between the maximum (190 mm) and minimum (66 mm) values. Overall, there is a positive relationship among length, width and thickness attributes, but statistically not significant correlation among them at the 0.01 or 0.05 levels (Table 3.9). Therefore, the long tools are likely to be wider and to a lesser extent thicker. Some of the large cutting tools contain between 4 and 7 dorsal flake scars and less than 33% cortical surface (Table 3.10).

Small Bifaces. Small bifaces include all bifacially worked tools weighing below 100 g and less than 100 mm in size (maximum length). This class accounts for 6% of the shaped tools. Most of the tools are symmetrically shaped with biconvex cross section and secondary retouch along the edges (Fig. 3.16). Some elements appear to be foliate points, while others resemble diminutive cores. Basalt and obsidian raw materials constitute 45% and 27% respectively (Table 3.6). A larger percentage (73%) falls within the length range of 50 -100 mm (Fig. 3.25). A modest quantity preserve dorsal scars greater than 15 mm long (Table 3.10) and nearly all small bifacial tools preserve edge retouch.

Triangular Points (n=28). This class includes all laterally modified pieces with triangular and semi-triangular shape (Fig. 3.17). There is some variation in the triangular point class; some are well finished and others not. Triangular points comprise 15% of the shaped tool class (Table 3.6). Basalt and quartz represent 36%

and 21% respectively, and 85% of the triangular points weigh below 50 g (Table 3.7). Mean values for size attributes are listed in Table 3.8. A correlation test has been run to examine the relationship among the three size attributes: length, width and thickness. Although the r-values obtained suggest an overall positive relationship among these variables, only length and width have statistically significant correlation at the 0.01 level (r=0.6, p=0.002) (Table 3.9). More than half of the point class measure between 50 and 100 mm in length and the majority preserve 1-3 negative dorsal scars (Fig. 3.25, Table 3.10). Notably, all of the triangular points preserve less than 30% cortex (Fig. 3.26) implying that most of them were highly modified or struck off from prior prepared cores.

Perforator Points (n=20). This is the most distinctive type in the entire surface assemblage comprising tools with pointed working tip, but not necessarily triangular in shape. The pointed end is usually formed by dense lateral retouch around the tip (Fig. 3.18-19). Occasionally, especially in the obsidian tools, the retouches were polished forming a cone-shaped tip. In the literature, such implements are referred to as *becs* (if the point is formed by two lateral notches) or borers/*percoirs* if more retouches are applied to produce the pointed feature (Clark and Kleindienst 2001:57). The majority of perforator-points were found around the sandy basin. Obsidian is the dominant raw material making up 45% followed by basalt (30%) and small number of quartz/quartzite. Those made on basalt are relatively large in size and irregular in shape. All of the analyzed perforators weigh below 100 g (75 %= less than 50 g, 25% =50-100 g) (Table 3.7). Mean size measurements range 61 mm length, 33 mm width and 12 mm thickness (Table 3.8). Length measurements appear widely dispersed as indicated by a large value of standard deviation (SD=24). There is positive, but statistically not significant correlation among size attributes at the 0.01 or 0.05 levels (Table 3.9). A large percentage (65%) falls within the range of 50-100 mm and most tools preserve small, multi-generational dorsal scars. As noted with the triangular points, all perforators contain less than 33% cortical surface (Fig. 3.25).

Scrapers (n=68). The scraper group is the most dominant representing 37% of the shaped tool class. In most cases, retouch scars on scraper edges are shallow and short. Various forms of scrapers were noted, side scrapers being the most common types. Raw materials, such as obsidian, basalt and quartz make up 29%, 25% and 24%, respectively (Table 3.6). The bulk of scraper tools (91%) weigh below 50 g and 53% are less than 50 mm in length (Fig. 3.25, Table 3.7). The average size range 53 mm length, 36 mm width and 12 mm thickness (Table 3.8). As indicated by the large standard deviation values (SD=19, 12, 5), there seems to be wide dispersion in length, width and thickness measurements. There is an overall statistically significant correlation among scraper size attributes at the 0.01 level (Table 3.9). A large proportion (72%) preserve dorsal scars between 1 and 3 and 26% do not preserve any flake scars above 15 mm long (Fig. 3.28). The majority of scrapers weigh less than 70 g and measure less than 100 mm.

Notches, Denticulates and Burins (n=21). These categories include variably modified tools which constitute small proportions in the analyzed sample (burins=4%, denticulates=4%, notches=4%). All show some level of intra-group variability in raw material composition and size (Fig. 3.20). Basalt dominates in all these tools and the majorities weigh below 50 g (Table 3.7). Only one denticulate and a single notch weigh over 100 g. Most of the burins and denticulates range between 50 and 100 mm in length, whereas the majority of notches measure below 50 mm in size (Fig. 3.25). All three tool classes preserve several dorsal scar marks (Table 3.10).

Modified tools that could not be categorized as any of the above classes were classified as “other”, such tools account for 7% of the shaped tool class (Table 3.6).

In summary, the Asfet shaped tool classes show diverse techno-typological characteristics. While basalt makes up larger percentage in the majority of the tool classes, obsidian and quartz were preferred for making points (perforators and triangular points). Soft hammer and pressure retouch are inferred from the shallow and invasive retouch marks on some of the points and small bifacial tools (Fig. 3.16). The majority (45%) of the shaped tools fall within the mass range of 11-30 g and scrapers alone account for 54% in this range. There is higher dispersion in length and width measurements in scrapers than in the other shaped tool classes suggesting more variable artifact discard criteria with scrapers (Table 3.8). Most of the shaped tools range between 50 and 100 mm in length. The majority possesses between 1 and 3 dorsal scars, and less than 33% cortical surface.

It has generally been recognized that shaped tools reflect provisioning places to minimize the risk of uneven distribution of raw materials on a landscape (Kuhn 1992, 1995). Mobile humans select certain places on the landscape where resource procurement or processing activities are likely to occur. Based on the anticipated requirements, finished tools or bulk of raw materials are transported to these places where they will be subsequently used when needed. These places do not occur randomly, but are usually selected based on cost and benefit, such as geographic proximity to resources or distribution of raw materials (Elston 1990). In practical sense, shaped tools would be more demanded in areas where food resources are predictable in specific locations, but raw material or manufacturing time is relatively scarce. The occurrence of various types of shaped tools in the site of Asfet may have significant behavioral implications. The site is located close to the coast and there is fresh water source nearby that, humans and animal could use. The vast low field east of the site supports grass and mangrove vegetation on which grazing and browsing fauna can subsist. The site could have been suitable for targeting terrestrial game wandering nearby in search of freshwater and food. The occurrence of specialized tools (points and perforators) in the assemblage is particularly of significant implication. The presence of such well designed points suggests hunting activity nearby (Shea 1998). It is also possible that some of these were used to drill shells, especially the perforators (Fig. 3.18-19).

Flakes and flake fragments (Debitage)

This section describes all unmodified complete flakes and flake fragments. These include specialized blanks (prismatic or Levallois products), cortical and non-cortical pieces, and waste or angular shatter. The flake fragments comprise proximal pieces and pieces that lack striking platform and bulb of percussion. The French term “debitage” is commonly used to designate unmodified flakes and associated fragments (Clark and Kleindienst 2001). Debitage is extensively distributed throughout the sandy basin and the lower peripheries of the basalt ridges in Locality

A05 (Fig. 3.5). A total of 1154 pieces (710=complete flakes and 444=fragments) were collected using a grid based judgmental sampling procedure. Out of the total analyzed sample, 482 were analyzed in the field and the rest transported to the NME. The majority of debitage elements were located in the cluster areas in the basin. As with the shaped tool class, basalt is the dominant raw material (44%) in the debitage class followed by obsidian and quartz. Other raw materials such as green schist, rhyolite and chert are represented in small proportions as well. Flakes produced from basalt were broadly distributed on the southern periphery and the central basin, whereas those blanks produced from obsidian appear to be more concentrated in the central sandy basin.

Fully Cortical Flakes (n=34). The fully cortical flake class consists of all complete flakes with entirely cortex-covered dorsal surface. Cortical flakes are considered to be common evidence of primary core reduction activity (Sullivan and Rozen 1985). Occasionally, random retouch marks are present along the dorsal edges of the flake, but generally no prominent scars should exist. This class accounts for 3% of the debitage class and basalt is the most common raw material representing 65% (Table 3.11). The majority (44%) of cortical flakes falls within 21-50 g mass range and 29% weigh above 100 g (Table 3.12). Most of the cortical flakes (62%) are longer than 60 mm (Table 3.13). As can be seen in Table 3.14, a large proportion of the cortical tools are elongated (length: width ratio greater than 1). Plain striking platform accounts for 68%, and the majority posses feathered distal termination pattern (Table 3.17-18). This implies that appropriate striking platforms were prepared before decorticating the cores.

Partially Cortical Flakes (n=140). These are complete pieces that preserve partly cortical and partly struck dorsal surface. This group represents 12% of the debitage class. Raw material is mainly basalt (69%), followed by quartz (9%). Most of the partially cortical flakes (75%) weigh between 21-50 g (Table 3.10). The number of partially cortical flakes with length ranging 30-60 mm slightly exceeds those over 60 mm long, constituting 51% and 46% respectively (Table 3.13). Seventy-six percent of the partially cortical flakes show greater than 1.5 length to width ratio, implying many of them came off elongated cores. Plain striking platform and feathered termination are common morphological features in this class.

Non-Cortical Flakes (n=264). Debitage classified as non-cortical include all pieces lacking any dorsal cortex, and do not display any morphological attributes pertained to specialized blanks, such as blades and Levallois. Basalt and obsidian dominate the raw material and 62% fall within the mass range of 21-50 g (Table 3.12). A large percentage (59%) of this tool class falls within 30-60 mm size range (Table 3.13) and 67% show greater than 1.5 length to width ratio (Table 3.14). Mean values for length, width and thickness for partially cortical and non-cortical debitage class are shown in Tables 3.15. There is a statistically significant correlation among non-cortical debitage size attributes at the 0.01 level (Table 3.16). Stronger correlation exists between platform thickness and platform width (r=0.8) than between technological width and length (r=0.7). This implies that flakes with thicker platform are likely to be wider in platform surface, and can be broader in the overall size. Plain platform and feathered termination are common morphological features of the Asfet debitage (Table 3.17-18). The non- cortical flakes display a variety of distal morphology comprising expanded feather, pointed and parallel edges with random-shallow retouches regularly noted along the lateral margins (Fig. 3.21-22).

Levallois Points and Flakes (n=154). This tool class comprises all flakes (except those with blade dimension, see below) displaying faceted or dihedral striking platform surface (Fig. 3.21-22). Levallois points and flakes constitute 13% of the debitage class. Those flakes with convergent tip were classified as points in order to draw morphological distinction among the Levallois flakes. Pointedness was usually determined subjectively, but where empirical assessment was conducted, the ratio of mid-point width to width at 3/4 should be greater than 1. The largest percentage of this group falls within the mass range of 21-50 g, and 30-60 mm in length (Tables 3.12-13). Length to width ratio exceeds 1.5 in 85% of the pointed class and in 59% of the regular flakes (Table 3.14). See Table 3.15 for the mean values of size attributes (length, width and thickness). There is an overall statistically significant correlation among Levallois size measurements at the 0.01 level (Table 3.16); more specifically between technological width and length (r=0.7), platform width and technological width (r=0.6), and between platform thickness and platform width (r=0.6) Feathered termination and facetted platform morphology dominate this tool class.

Blades (n=118). This class includes specialized blank flakes that meet the standard definition of a blade, length to width ratio greater than or equal to 2 (Bar-Yosef and Kuhn 1999). Specialized flakes refer to preferentially produced blanks from formal cores suggesting regulated core reduction strategy (Inizan, et al. 1999; Kleindienst 2004). The specialized blades in the Asfet sample make up 11% with prismatic blades contributing 7% and Levallois blades 4% (Table 3.11). Prismatic blades are those flakes with parallel to semi-parallel lateral edges, and dorsal scars running longer than the midpoint of the tool along the technological axis (Bar-Yosef and Kuhn 1999). As has been stated above, Levallois products are distinguished by faceted or dihedral platform (ibid.). Nearly 28% of the prismatic blades and 31% of the Levallois ones fall within the mass range of 21-50 g (Table 3.12). The majority of both prismatic and Levallois classes are over 60 mm in length and they all disply length to width ratio of greater than 1.5 (Table 3.13-14). A summary of size mean values is shown in Table 3.15. There is statistically significant correlation among blade attributes at the 0.01 significance level (Table 3.16), with the highest r score between technological length and width (r=0.8) and mid-point thickness and width (r=0.7), and platform thickness and width (r=0.7). Plain platform and feathered termination are the dominant features in the blade class (Tables 3.17-18).

Miscellaneous Flakes (n=104). This category comprises of core trimming flakes and non-diagnostic pieces such as angular shatter, core split and proximo-distally snapped elements, all constituting 9% of the debitage class. Overall, the miscellaneous tools display similar size range to the non-cortical and Levallois flakes with the majority being flaked from basalt cores and a larger quantity of them falling within the size range of 30-60 mm and 21-50 g (Tables 3.12-13). There is high proportion of flakes with length to width ratio greater than 1.5 in this tool class.

Proximal Fragments (n=41). These are flakes that preserve either striking platform surface or bulb of percussion or both. The majority of proximal flakes are made on obsidian (Table 3.11), a fragile stone which could be easily broken during use and by post-depositional activities. Nearly all proximal fragments (92%) weigh less than 20 g and fall below 30 mm range. Over half of the proximal pieces display plain platform morphology. Proximal fragments have important implications in inferring the total number of complete flake debitage originally present at a site (Holdaway and Stern 2004). Following what faunal analysts call Minimum Number of Individuals (MNI), some lithic analysts (ibid.) suggest estimating Minimum Number of Flakes (MNF) using the proximal end as the most diagnostic zone (taxonomic identifier). This assumption is based on the fact that all complete flakes bear striking platform and bulb of percussion upon the initial removal. Thus, a high density of proximal fragments may reflect an activity area where a lot of complete flakes could be broken into pieces during use, by trampling and/or by erosion.

Indeterminate Fragments (n=299). These are fragments that do not preserve any of the key morphological landmarks of a flake: striking platform and bulb of percussion. They constitute 26% of the debitage class, which is the largest sample in the debitage class. Obsidian is the dominant raw material among the indeterminate fragments (Table 3.9). This could be due to the fragile nature of obsidian to break easily into fragments upon reduction process, use or by post-depositional agents.

In summary, the debitage sample shows some variation in raw materials and tool types. The high variability in tool size, shape and cortex demonstrate that the toolmakers employed a broad range of reduction strategies. Non-cortical and partially cortical flakes make up higher proportion of the whole flake class. Although the dominance of non-cortical pieces signifies that cores were brought to the site partly decorticated, a modest quantity of cortical flakes was also recovered implying that some level of primary reduction took place at the site. Higher proportions of basalt and quartz are represented in the partially cortical class compared to the fully cortical implements. This could reflect differences in raw material manipulation strategies.

The occurrence of a larger number of obsidian fragments (lighter in mass) on the sandy basin suggests accumulation by wind or small scale fluvial movement. The basin accumulates moving sand (unstable substrate), thus artifacts could have been washed to the basin from the ridge peripheries. The other possible explanation for this is that raw materials were treated differently at different locations of the site. Overall, the blank flakes show fresh surface condition, although the obsidian component preserves patination (faded surface), but this could be due to hydration effect on obsidian in general.

Raw Material Characterization

Seven major raw materials were identified in various ranks in the analyzed surface assemblage from Asfet. The most common ones are basalt (44%), obsidian (36%), and quartz (10%) with the four other types constituting small proportions (Table 3.19). Neogene and Precambrian sediments are abundant around the Asfet study area. Most of the raw materials are locally available (within 2 km distance) except for obsidian, for which we did not locate any source around the Asfet vicinity. The nearest source of obsidian that we identified is near Irafailo, 15 km farther south of Asfet. It is possible however that some obsidian outcrops exist further north from Asfet, outside the survey area. Both volcanic and non-volcanic raw materials were reduced in a similar fashion in the large shaped-tool class. However, obsidian, rhyolite, chert and quartz appear to be more preferred for making light duty tools (especially scrapers and points/perforators). This is attested by the relatively higher percentage of scrapers and points from chert, obsidian and quartz (Table 3.6). The most common raw materials (basalt, obsidian, quartz) are briefly described below with particular emphasis on mass, flake scar pattern and cortex distribution.

<u>Basalt</u>. As noted earlier, three types of basalt flows were identified in the Asfet study area: a) Lower Flow, characterized by fine grained groundmass, b) Upper Flow, featuring slightly coarser and vesicular lava, and c) Scoriacious Flow, rough and vesicular type of lava (see above). The fine grained basalt is the most common type in the area and among those selected for making artifacts. The majorities of cores on basalt preserve more than seven scars and weigh over 600 g. All cores weighing below 70 g preserve more than four flake scars. When we look at the cortex scale, most basalt products preserve less than 33% cortical surface. The percentage of basalt cores possessing less than 33% cortical surface is slightly higher than that of quartz and rhyolite. In the shaped tool class, obsidian and quartz products represent

higher percentage of tools in the 33% range than basalt (Fig. 3.28). There is also higher number of basalt cores and tools possessing between 33 and 67% cortical surface. Basalt is considered locally available rock. This correlates with the overall pattern noted, in that the ratio of debitage to cores on basalt is relatively lower than most other raw materials (Table 3.19). Low debitage to core ratio means that most of the basalt nodules were discarded after minimal flake removals. Thus, the low flake to core ratio implies that fewer flakes were produced per a given basalt core.

Obsidian. Fewer obsidian cores were recovered compared to the large number of debitage and tools made from obsidian. Black obsidian is common and most of the obsidian cores weigh below 150 g and preserve more than four dorsal scars (Fig. 3.27). There is only one obsidian core that weighed over 600 g (Fig. 3.7-56.1). The majority of artifacts on obsidian possess below 33% cortical surface; and the shaped tool class slightly outnumbers the other groups in this range (sampling method was judgmental). A few obsidian cores preserve cortical surface exceeding 33% (Fig. 3.28). The small sample size of obsidian cores could not allow further generalization, but from what has been noted, obsidian seems to be exotic raw material to the site. The presence of more debitage and formal tools on obsidian (Table 3.19), but fewer obsidian cores indicates some obsidian artifacts were curated - brought to the site finished. Hence original core nodules may have been discarded at the manufacture place. It is also possible that obsidian raw materials were extensively reduced that some of them were turned into fashioned tools afterwards.

Quartz. Cores on quartz vary widely in mass and dorsal scar distribution. The majority exhibit flake scars ranging between 4 and 7 in number and weighing below 70 g (Fig. 3.27). Quartzite is also treated under this category for reporting purposes. All things being equal, cores weighing below 70 g show the highest variability in flake scar distribution (Fig. 3.27). In this regard, a large quantity of quartz artifacts preserve less than 33% cortical surface. In the debitage class, fully cortical flakes on quartz account for only 2%, whereas partially cortical flakes represent 12%. This implies that some natural blocks of quartz nodules were reduced at the site. Quartz and quartzite exposures are available in the nearby Neoproterozoic basement deposits. Prehistoric knappers may have had easy access to those sources.

Rhyolite**.** The Asfet study area is rich in extrusive volcanic flows, but rhyolite is not abundant in the immediate vicinity of the site. It can be considered local however, because numerous rhyolite nodules were noted around the ephemeral river terraces within 1.5 km south and north of Asfet (around Adayto and Asaghede Rivers). Cores made on rhyolite display wide variation in mass with the majority weighing below 300 g (Fig. 3.26). A large proportion of cores from rhyolite preserve more than 7 flake scars implying that they were highly reduced. The number of cores preserving larger cortical surface (33-67%) is greater with rhyolite than in any other category (Fig. 3.27). Generally, tools made from rhyolite are small and well designed often represented by prismatic blades and points.

Overall, the surface lithic data show that different raw materials were reduced at the site. Some are abundant, in which case more cores and debitage remains are recovered (e. g., basalt), and others are not common in the form of cores, but mainly represented by higher proportion of debitage and finished tools (e. g., obsidian). Raw materials also exhibit wide variation in mass, cortex and scar distribution. At this stage, it is not possible to predict the exact relationship between raw material procurement strategy, reduction techniques employed or the kinds of tasks performed with each rock type. The most likely pattern is that multiple reduction strategies were employed at the site. Settlement models suggest that human movement of raw materials is a function of predicted tool use in the destination site/s (Bamforth 1986; Close 1996). The occurrence of various raw material types (local and non-local) hints that human preference of raw materials was decided by the utility value of each rock type. The degree to which tools from specific raw material were used for specific task is unclear.

Summary and Discussion of Asfet Surface Archaeology

The major surface findings from Asfet are lithic artifacts recovered from Locality A05. A total of 1472 surface artifacts were analyzed, and these revealed a wide range of techno-typological variability. The lithic distribution is not homogeneous throughout the site. Large portions of the basalt slopes contain highly scattered artifacts while the lower margins of the basin periphery contain dense areas. The assemblage is mainly characterized by blade and prepared core technology. Retouched tool class comprises scrapers, points and bifaces (small and large handaxes). The handaxes are characteristic of the Acheulian Industry featuring symmetrical and tear-drop-shaped in cross section, but they represent a small proportion of the assemblage. Specialized cores, such as Levallois and prismatic blade made from basalt, quartz and rhyolite were documented from multiple spots at the site. The Asfet assemblage is dominated by basalt and obsidian raw materials respectively (Table 3.19). Other reduced rocks include quartz, chert, green schist, shale and rhyolite. Although the surface evidence from Asfet lacks absolute dates, we can place the evidence within the cultural framework of African Stone Age using typological traits and technological affinities presumed to be distinguishing features of Middle and Later Pleistocene industries in Sub-Saharan Africa.

Levallois products and points (retouched points and foliate bifaces) are generally considered diagnostic features of the African MSA tradition (McBrearty and Brooks 2000; Wendorf and Schild 1974; Yellen, et al. 2005). Such artifacts have been used to establish Middle – Later Pleistocene site chronologies in Africa (Clark 1954), the Arabian Peninsula (Rose 2006) and the Nile Valley (Kleindienst 2004). In the latter two regions, abundant archaeological evidence comes from surface and archaeologists in these areas heavily rely on typological traits in assigning age to their finds. Points, retouched triangular flakes and Levallois cores featuring a hierarchy of flake release and platform preparation surfaces have been documented at Asfet. The typology and raw material sources for the points vary widely. The production of perforators is an important technological feature of the Asfet material as well. Variation in African MSA point technology is thought to have both cultural and possible functional implications (Clark 1984; McBrearty and Brooks 2000). Based on the discovery of abundant tools representing key features of African MSA Industries, the Asfet surface occurrence is designated here as "Middle Stone Age" *sensu lato*.

Prismatic blade core technology is generally seen as a hallmark of the Later Stone Age (LSA) in Sub-Saharan Africa, but it is also likely the case that East

African Acheulian and MSA assemblages sometimes feature prismatic blade production (Leakey, et al. 1969; McBrearty and Tryon 2006). Therefore, the high percentage of blade artifacts noted in the Asfet assemblage indicates broadly shared MSA-LSA technologies. Handaxes and cleavers are diagnostic artifacts of the Acheulian tradition which date from 1.7 Ma up to less than 200 ka BP (Leakey 1971). Traces of those artifacts have been encountered at Asfet in association with the MSA assemblages. In light of their non-diagnostic aspects, those tools don't seem to represent an explicit cultural entity. Large chopper looking tools are common in later prehistoric cultures (Robbins 2006).

Site formation process

For the most part, the available evidence is inconclusive about the formation history of the site. One major problem with the Asfet surface data is the lack of absolute dating. Shells were observed on the surface in close association with lithic artifacts, but it was not possible to determine if those shells share the same depositional history in the site as the stone tools. Dense artifact clusters were noted along the periphery of the sandy basin at Locality A05. Such clusters imply accumulation by erosion along the ridge slope. It is also possible that multiple occupation phases related to different human groups produced those concentrations spots throughout the sandy basin and the lower basalt peripheries. Humans may have found the lower margins of the basalt ridges suitable for various reasons. The basin is convenient for intercept hunting as the low relief of the basin could offer hunters the advantage of less visibility. The site is located on a strategic proximity to the coast and freshwater sources available nearby. Moreover, during sea transgression, the basin may have offered humans access to coastal resources. The discovery of several perforators suggests that these tools were possibly used for drilling shells. Refitting might have helped to evaluate some of the problems linked to site formation processes, but the analyzed sample from surface was not detailed enough to conduct such investigation. Future research will have to explore this issue.

Movement of artifacts to the basin by water erosion and gravitation fall seems to be more plausible explanation for the dense accumulation of artifacts on the periphery of the basin. Worth noting in this context is site deflation phenomena associated with eolian and fluvial process common in arid geographic areas (Rapp and Hill 1998). Whereas fluvial erosion might have induced downslope rolling of artifacts from the basalt ridges towards the basin periphery, deflation removes surface sediments and jumbles superpositioned artifacts (ibid.). Three test excavations and four auger investigations (chapter 5) failed to reveal any archaeological deposit below surface around the sandy basin where dense surface artifact clusters were observed. The absence of any subsurface evidence there indicates that the dense surface scatters at Locality A05 (especially on the basin periphery) may represent palimpsests of lithic assemblages washed from the ridge slopes. Highly deflated Pleistocene and Early Holocene sites are common throughout the Nile region (Caton-Thompson 1952), the Horn of Africa (Clark 1954) and the Arabian Peninsula (Rose 2006).

The surface data suggest that not all tools were produced and used at the site. Some artifacts, specifically points (triangular and perforators) were made on non-local raw materials such as obsidian and chert. The extensive use of basalt, a locally available raw material hints that frequent quarrying and reduction activities have been taking place at the site. It appears that the site was used for mixed activities with higher emphasis on local resources obtained during daily foraging activities. The site is located close to the coast where fresh-aquatic resource (fish and shells) could have been easily harvested. The spring nearby, which one can only assume to have been more active in times of lower sea level would have supported vegetation on which terrestrial animals could graze or browse.

Lastly, the following conclusions can be drawn about the Asfet surface archaeology.

Blade and point dominated Middle Stone Age Industry. The discovery of typical MSA Points (retouched triangular and perforators), small bifaces and prepared core products place this pattern within the range of MSA tradition of Middle to Later Pleistocene period in the African and possibly Arabian contexts.

Unknown chronology. Although attempts were made to uncover *in situ* material, most of the excavated units in Locality A05 have proven sterile. For this reason, it was not possible to determine the absolute age of the surface assemblage.

Unclear subsistence economy. Shells and stone tools were uncovered from surface, but no other faunal remains. It is unclear if the surface association of the mollusk shells and stone tools represent chronologically related scenarios. The surface distribution and association is not homogeneous throughout the site.

Local raw material dominates the assemblage. Most of the raw materials reduced at Asfet are locally available hard volcanic rocks, with the exception of obsidian for which we did not notice any local source. The nearest possible source for obsidian would be the volcanic outcrops near Irafailo, >15 km south of Asfet.

The observed lithic variability (designed tools, cores, debitage) hints that the site was occupied for an extended span of time. Nowadays the region exhibits contrasting seasonal climate: dry and warm summer and wet and mild winter. If such climatic pattern is projected to prehistoric times, circulating residential mobility pattern is to be expected. In circulating mobility, human settlement is concentrated around non transportable resources, such as freshwater (Marks and Freidel 1977). If so, the lithic assemblage there is expected to be technologically diverse and with higher proportion of local raw material (ibid.). Also, the nearby spring may have supported prolonged multi-seasonal occupation. Future evaluation and analysis will address this issue.

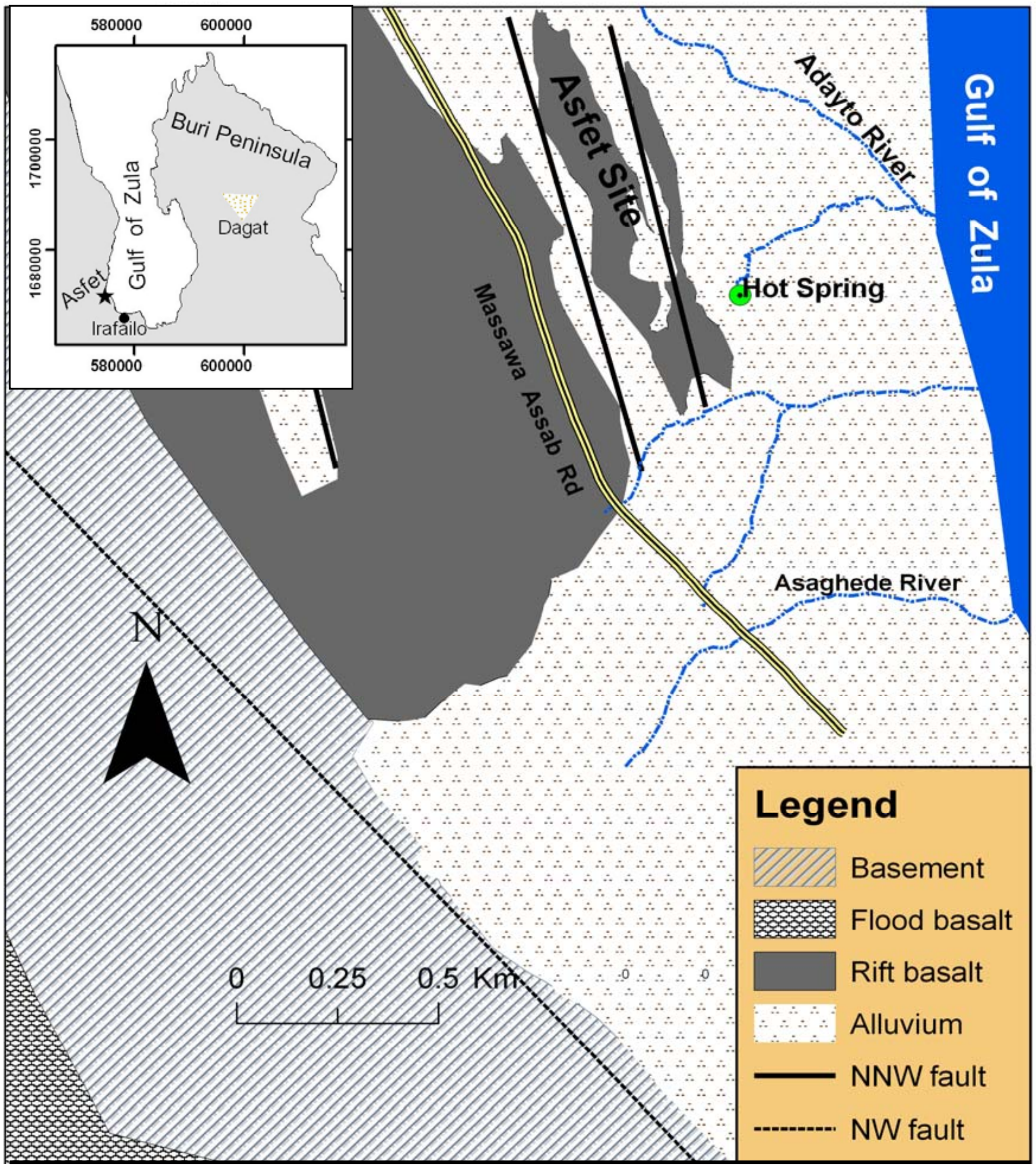


Figure 3.1. Geological setting of the Asfet study area (map by Ghebretensae Woldu).

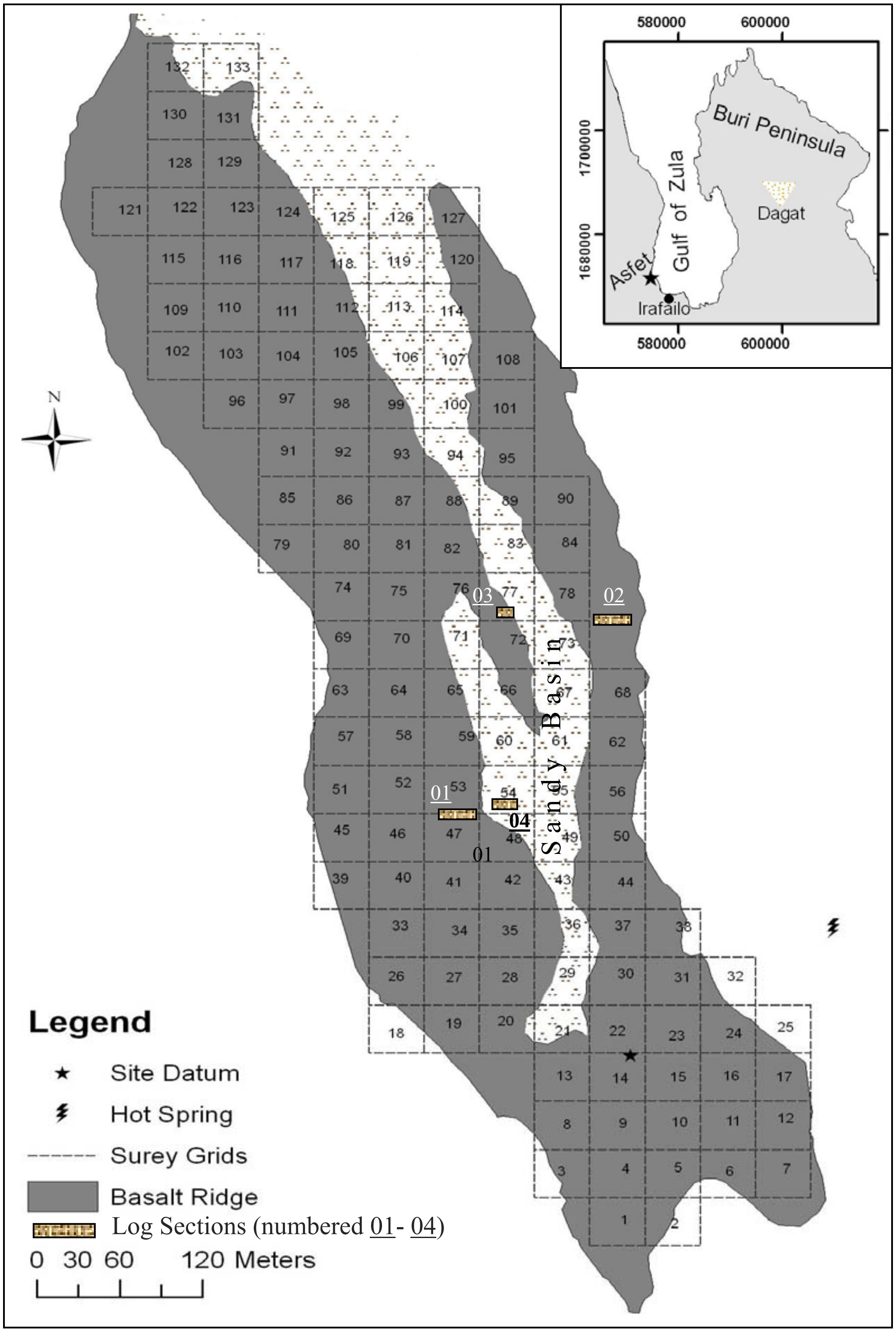


Figure 3.2. Map showing survey grids established at the Asfet site.

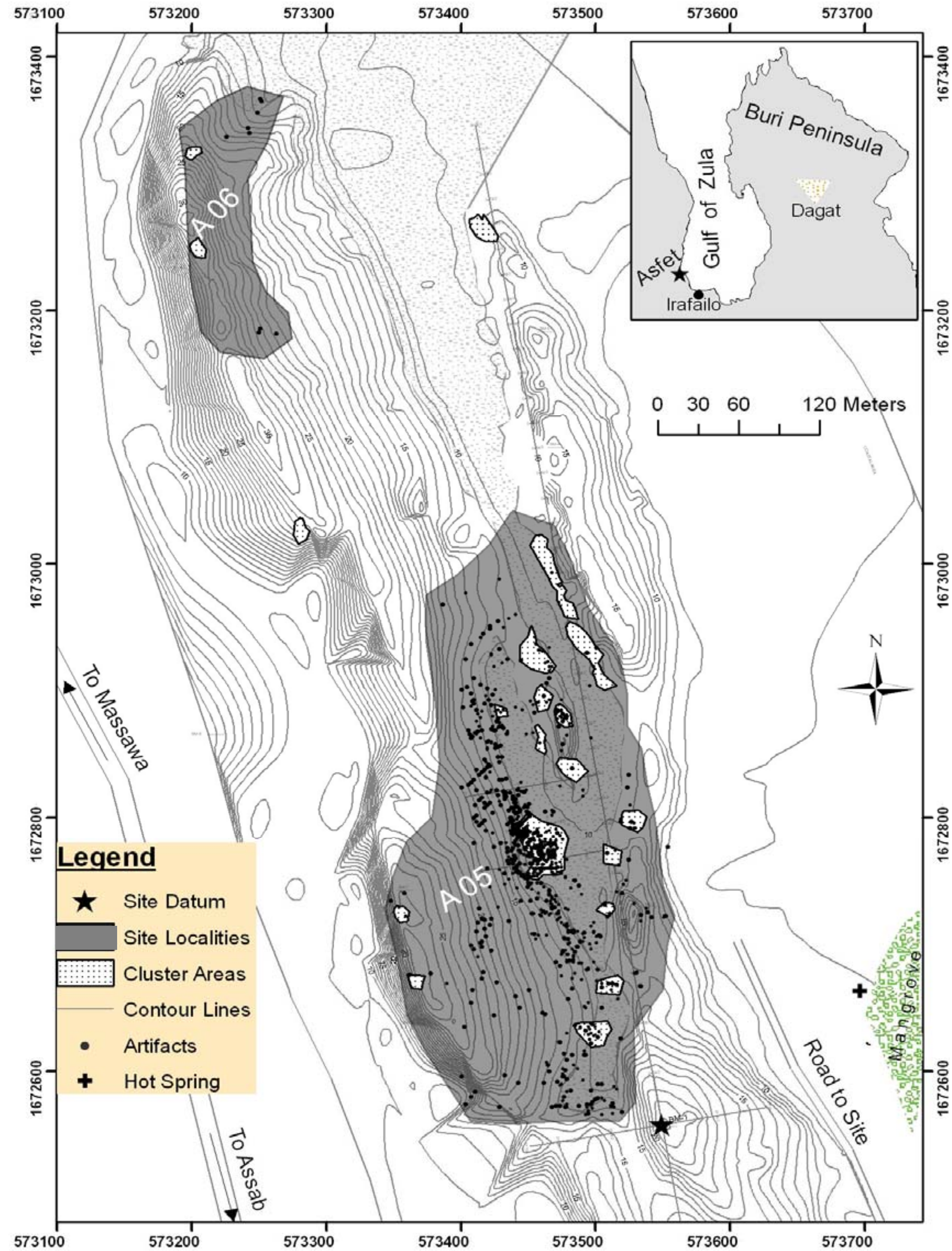


Figure 3.3. Map of the Asfet study area showing Localities A05 and A06. Note the dense artifact distribution along the lower periphery of the Western Ridge in Locality A05. See surface configuration by specific tool type in Figure 3.5.

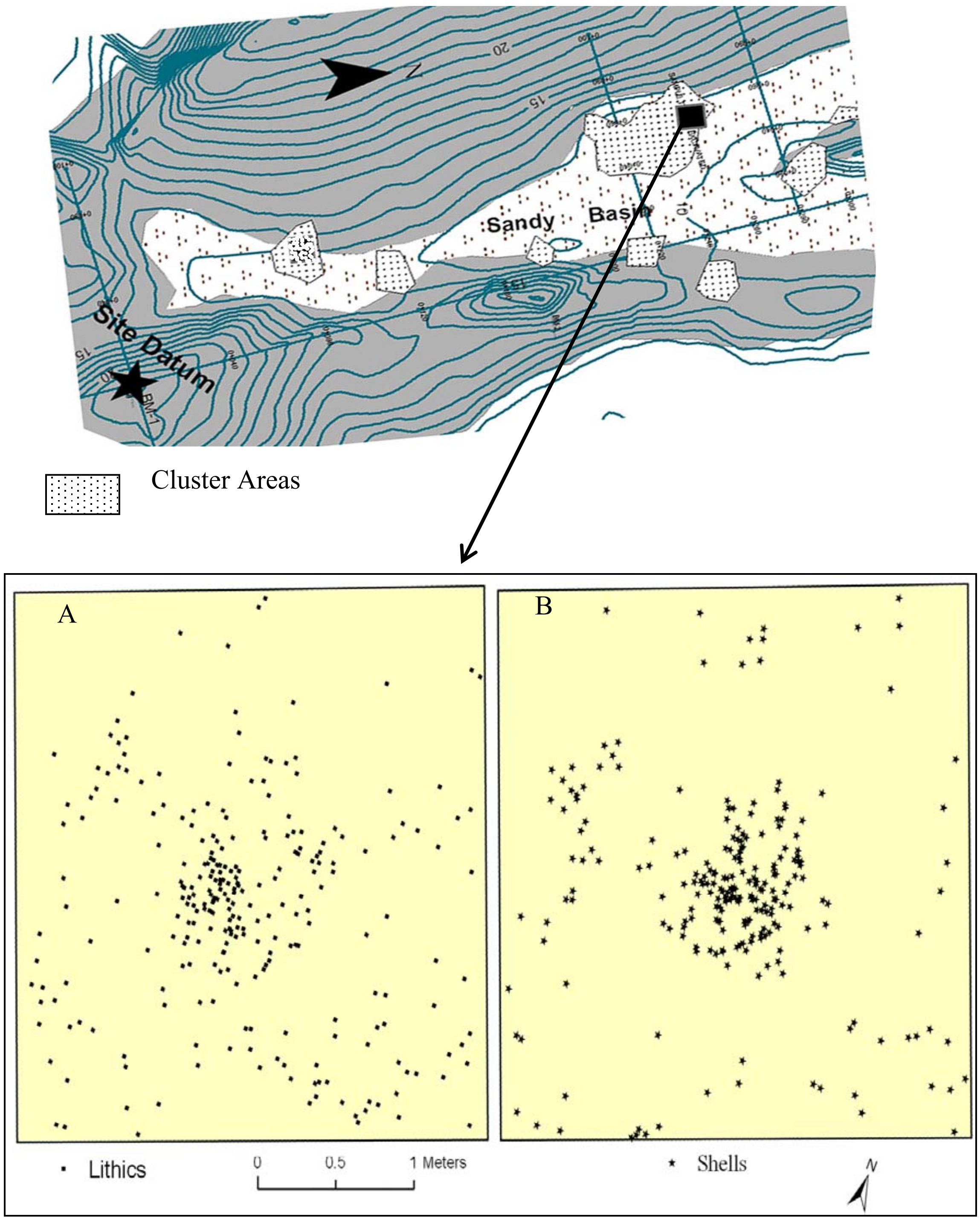


Figure 3.4. Artifact distribution in Grid 54, sandy basin at Asfet. A) lithic concentration, B) shell concentration. Note the similar distribution pattern of lithic and shell remains in the 9 sq m area. A 1 x 1 m excavation on this spot failed to produce subsurface evidence.

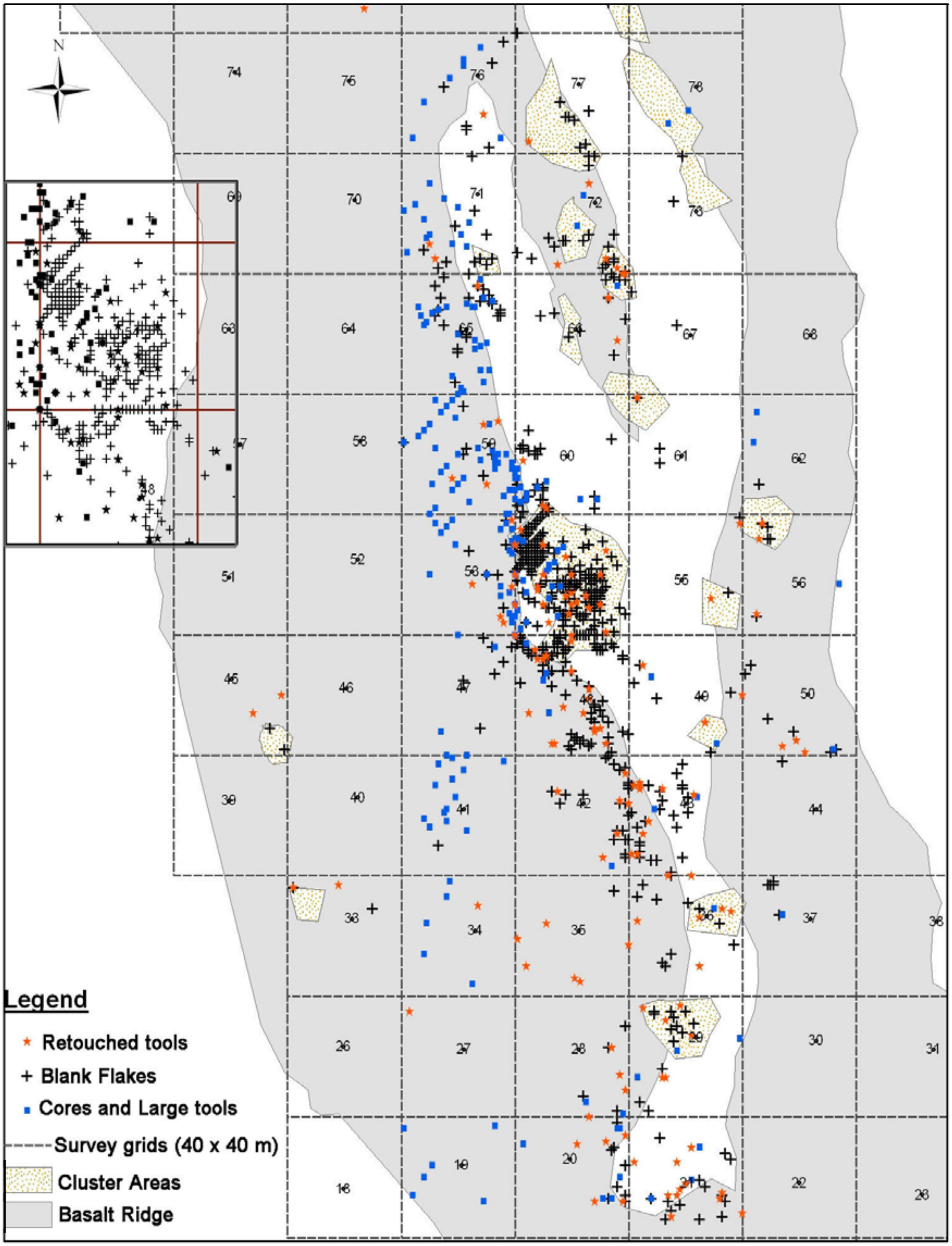


Figure 3.5. Surface lithic distribution by artifact type in Locality A05 of Asfet.

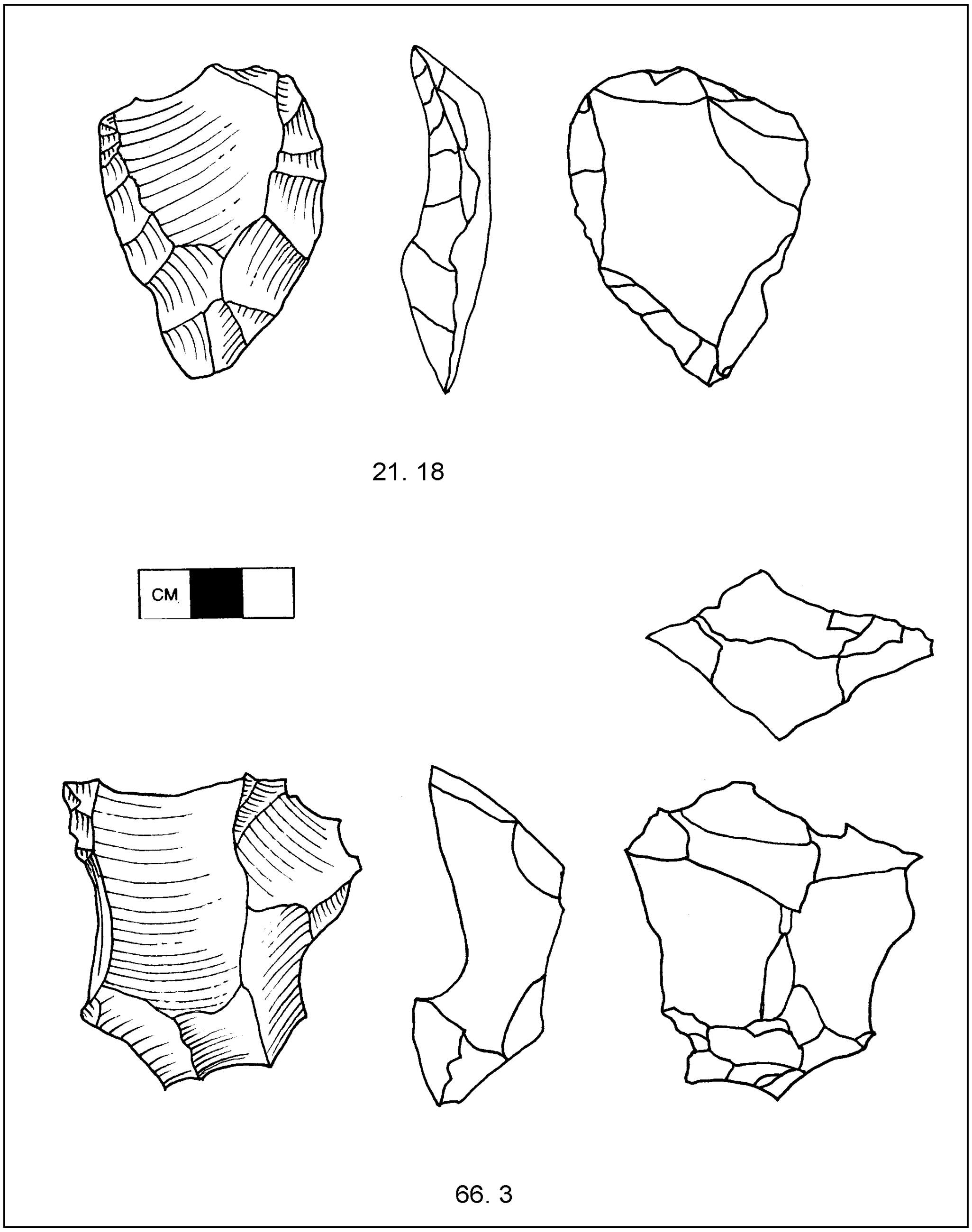


Figure 3.6. Levallois Cores: 21.18 (basalt), 66.3 (rhyolite).

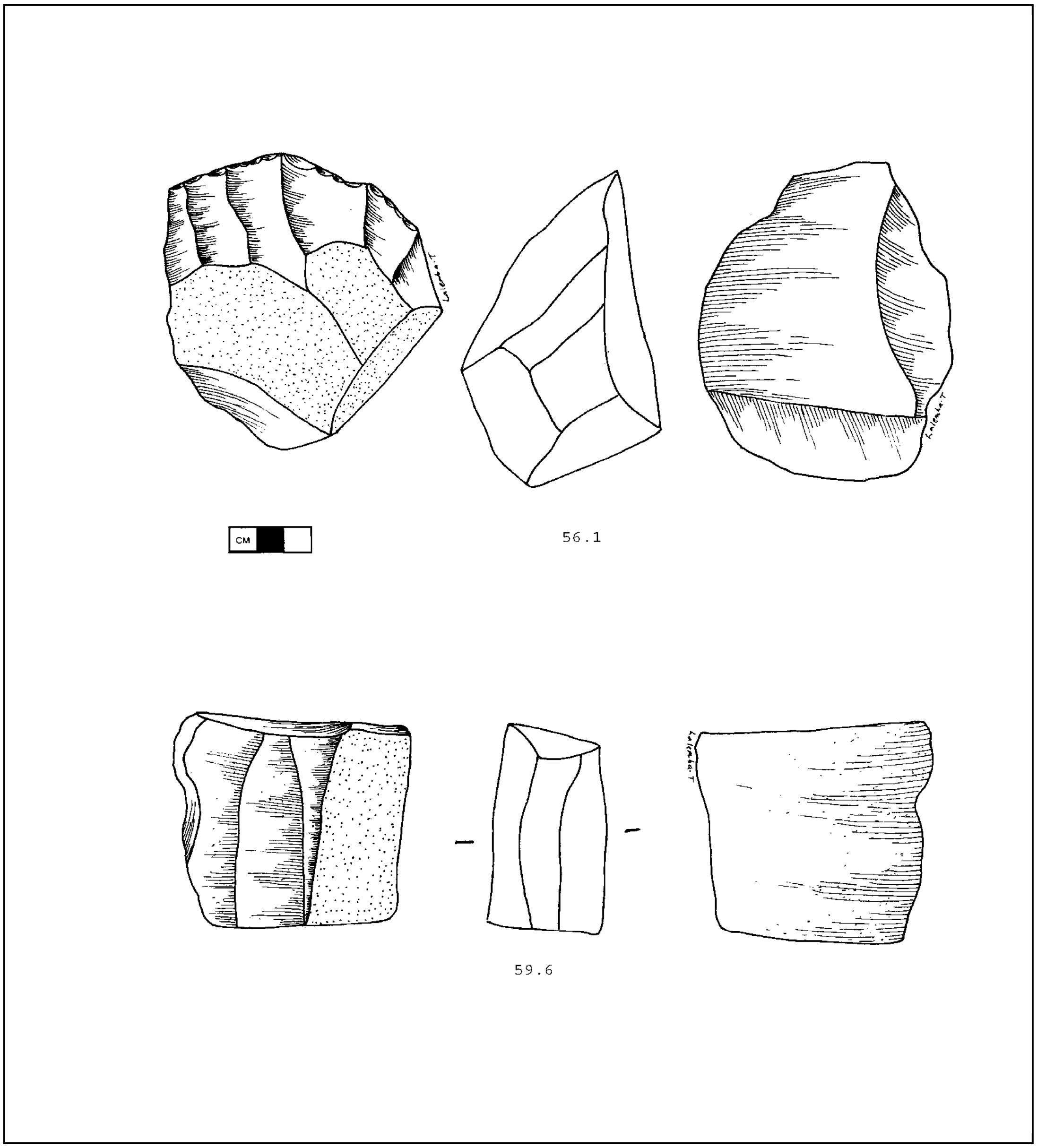


Figure 3.7. Blade Cores: 56.1 (Obsidian- core tool), 59.6 (basalt).

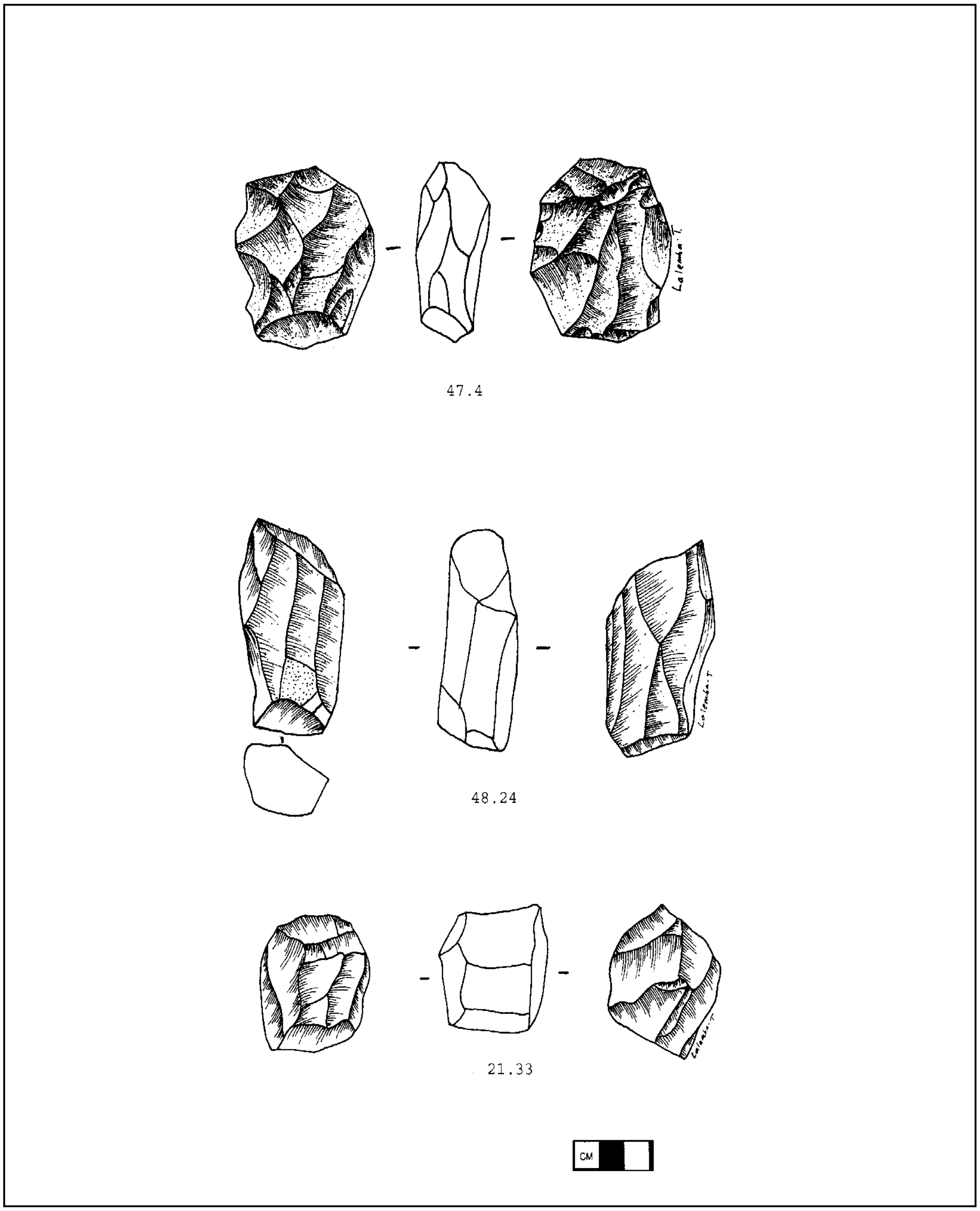


Figure 3.8. Multi-directional blade cores all on basalt.

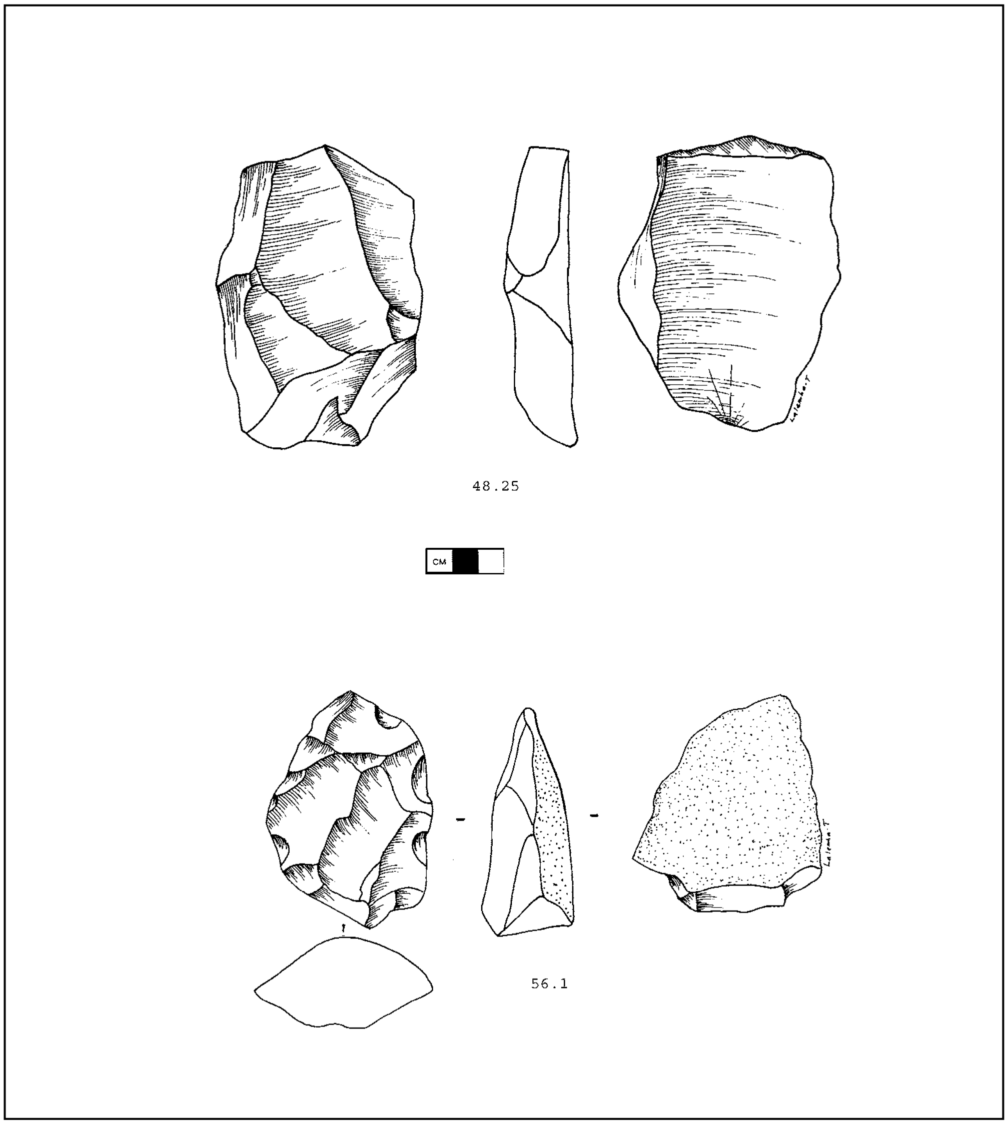


Figure 3.9. Blade Cores both on basalt (48.25 implies prepared core reduction).

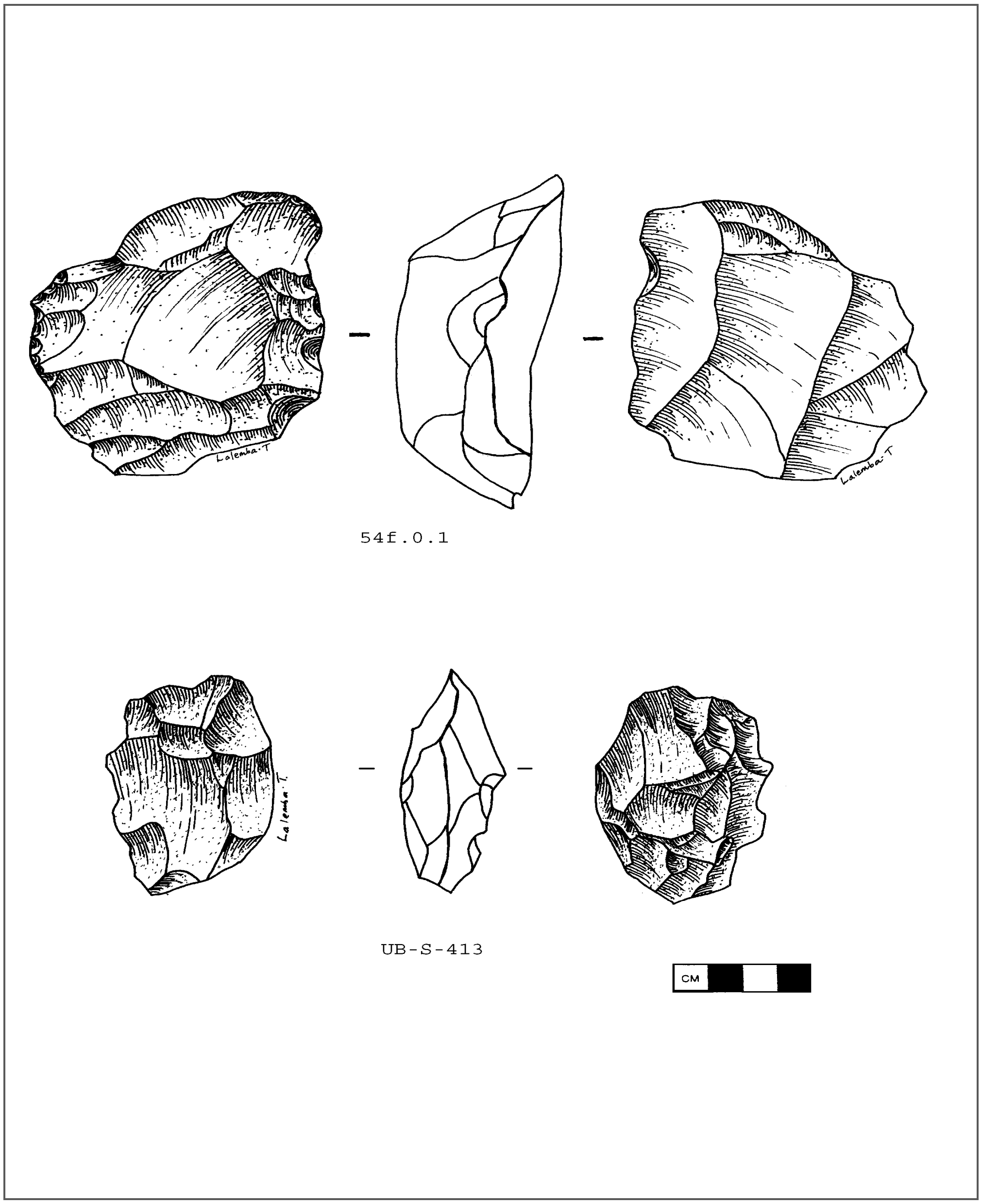


Figure 3.10. Miscellaneous flake-blade cores on basalt (54f.0.1 implies discoidal reduction).

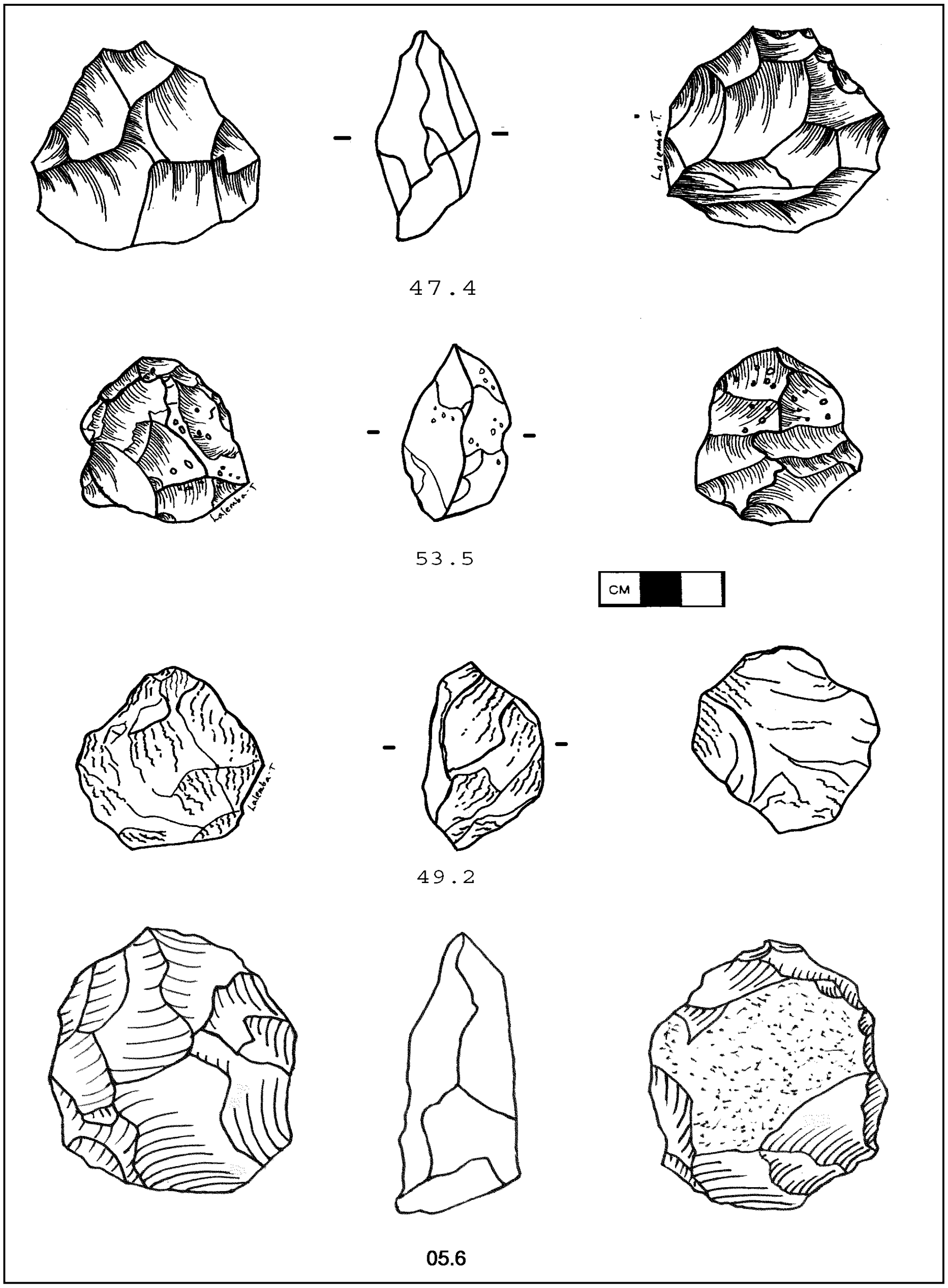


Figure 3.11. Discoidal Cores: 47.4 (basalt), 53.5 (obsidian), 49.2 (quartz), 05.6 (basalt- possible prepared core-not analyzed illustrated only).

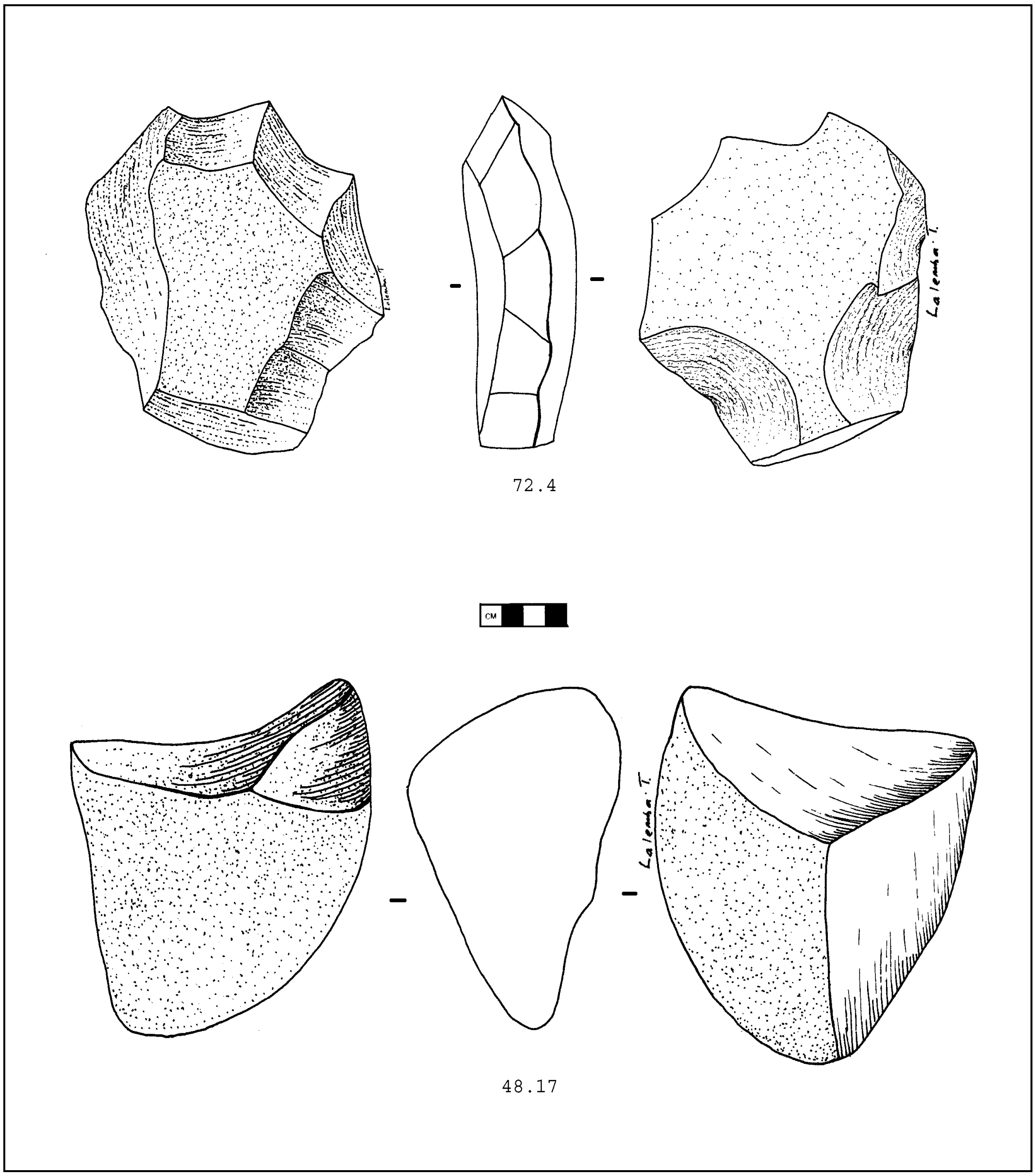


Figure 3.12. Miscellaneous heavy duty tools both on basalt: 72.4 (partibifacial chopper), 48.17 (chopper).

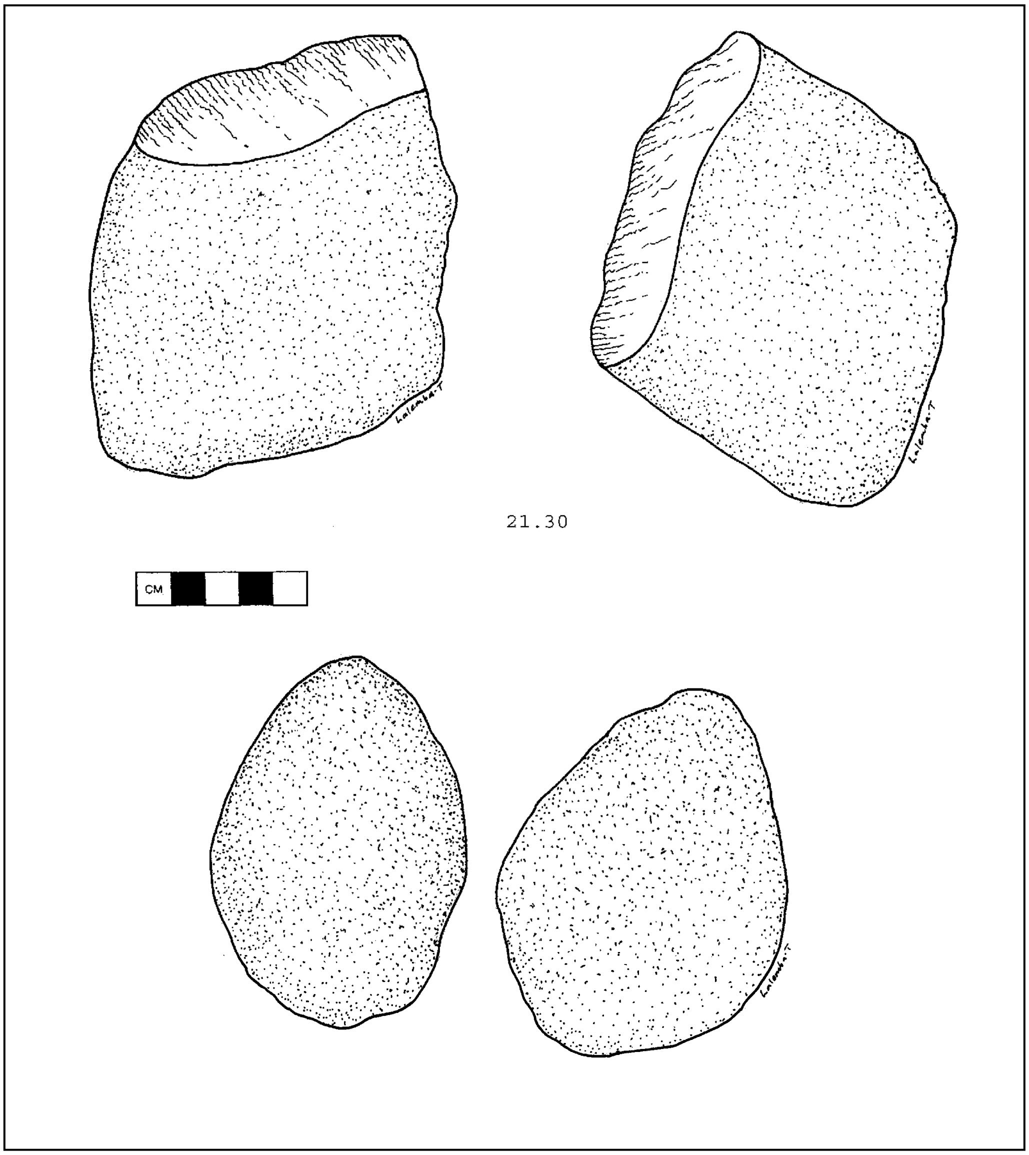


Figure 3.13. Hammerstones on basalt.

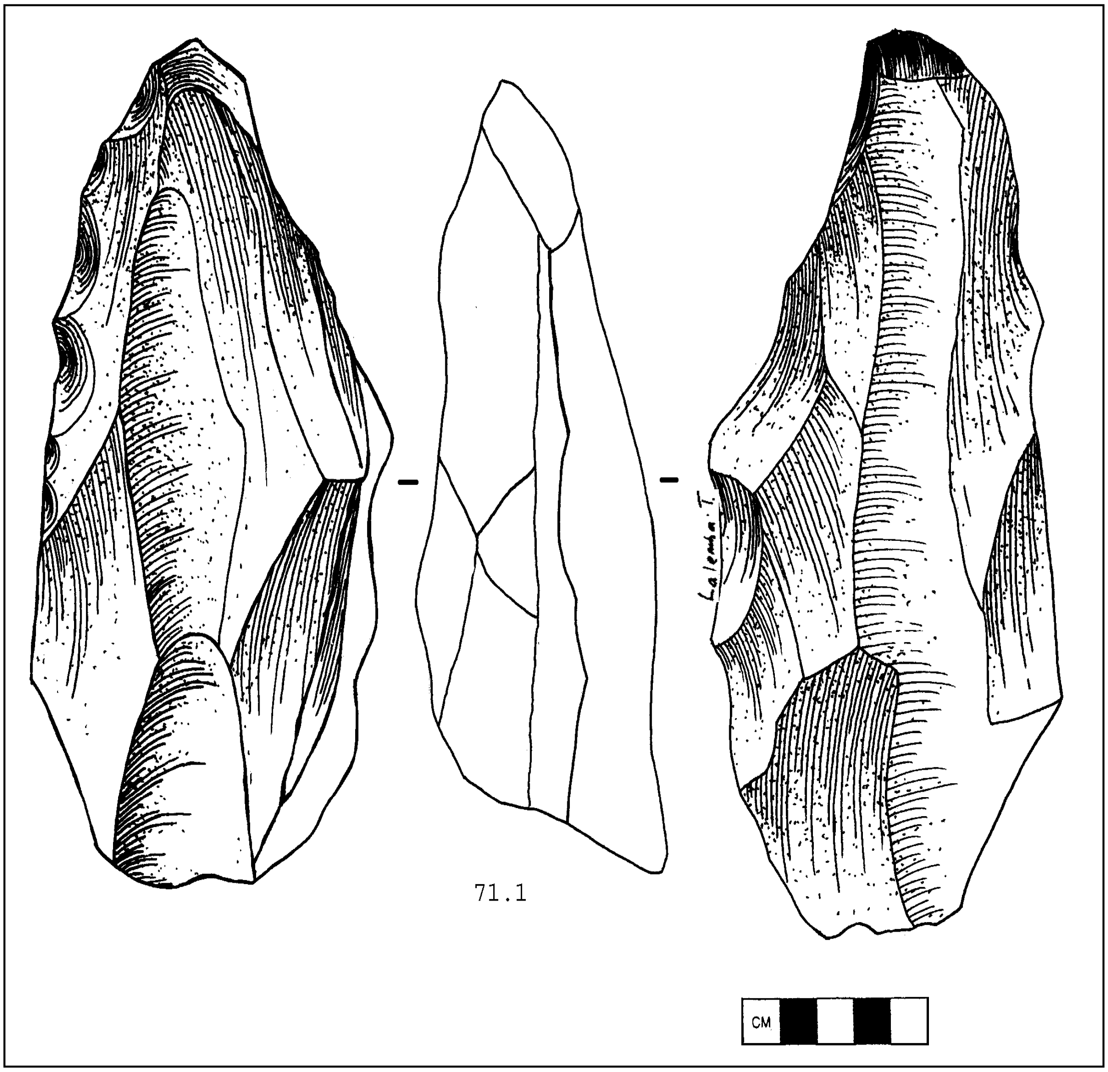


Figure 3.14. A handaxe on basalt.

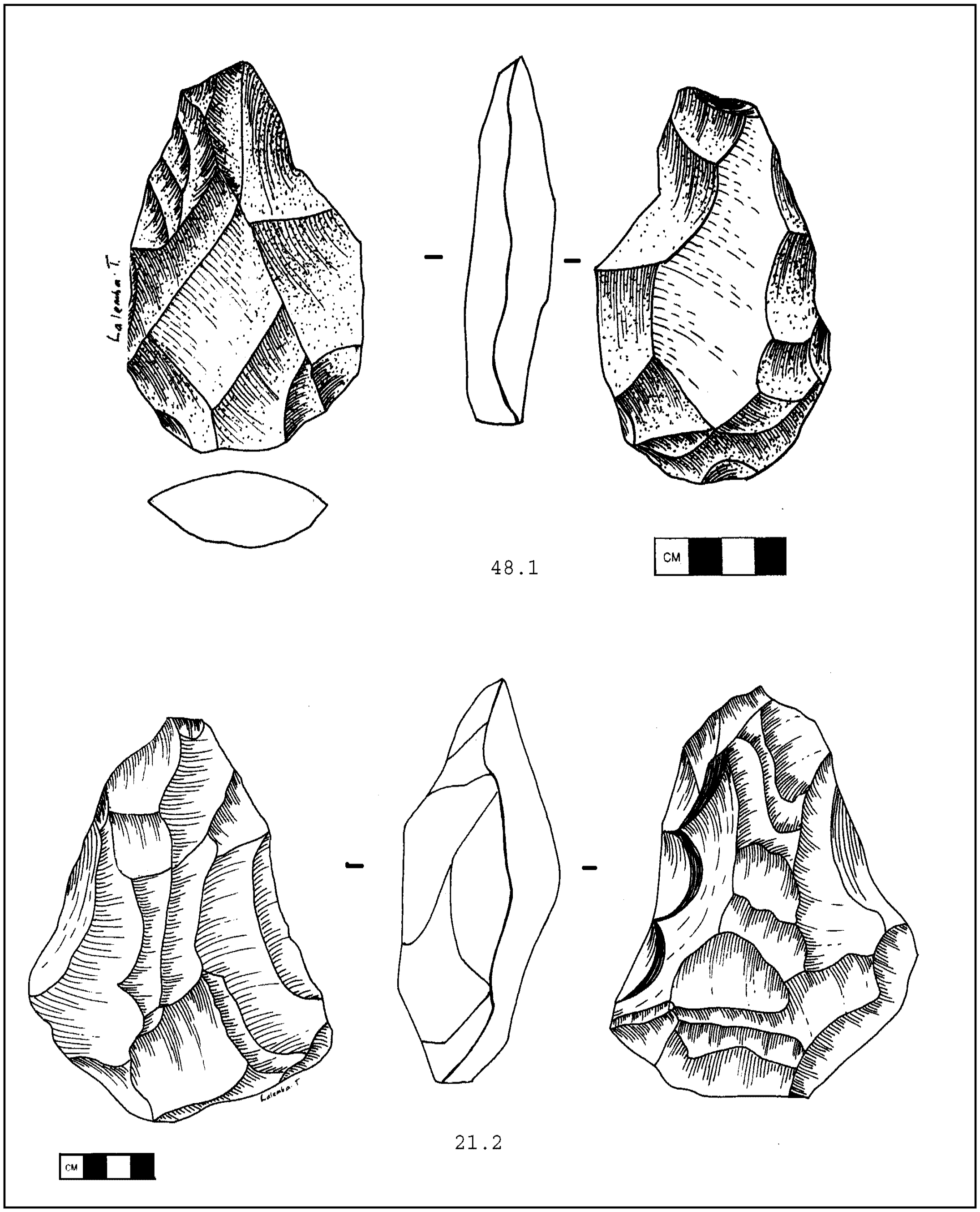


Figure 3.15. Handaxes on basalt (21.2=highly weathered artifact).

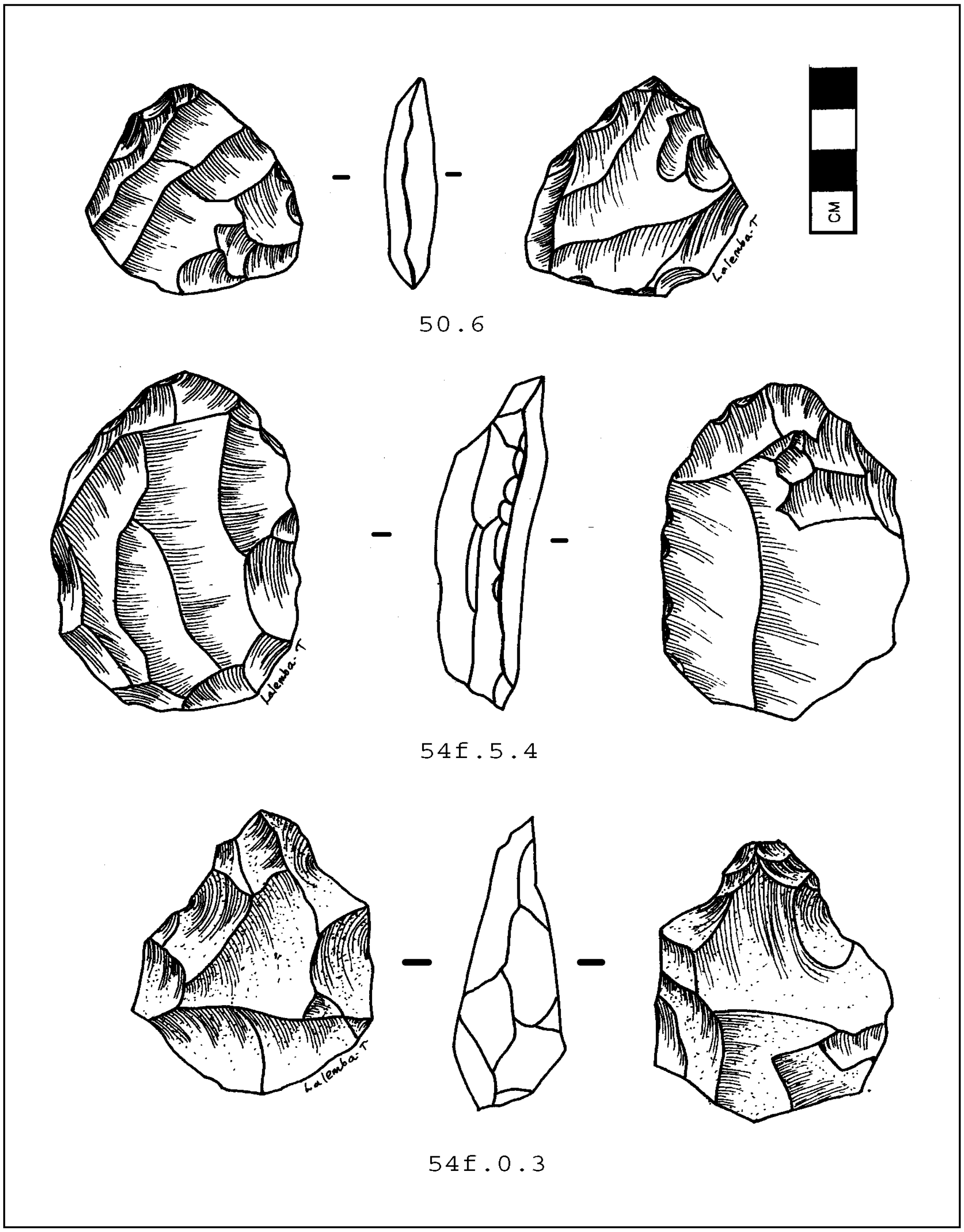


Figure 3.16. Small Bifaces: 50.6 (obsidian), 54f.5.4 (chert), 54f.0.3 (basalt).

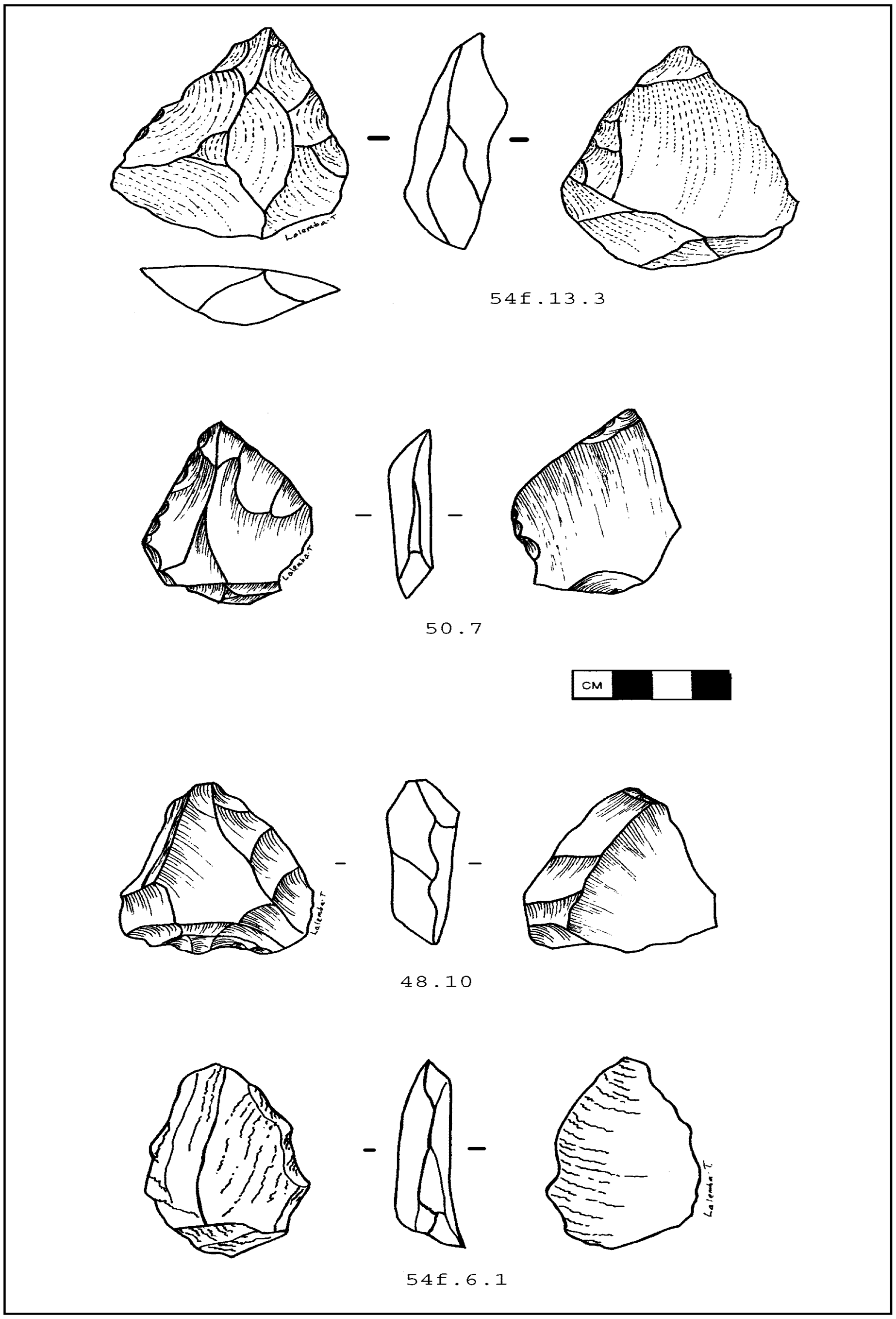


Figure 3.17. Triangular Points: 54f.13.3 and 50.7 (basalt), 48.10 (chert), 54f.6.1 (quartz).

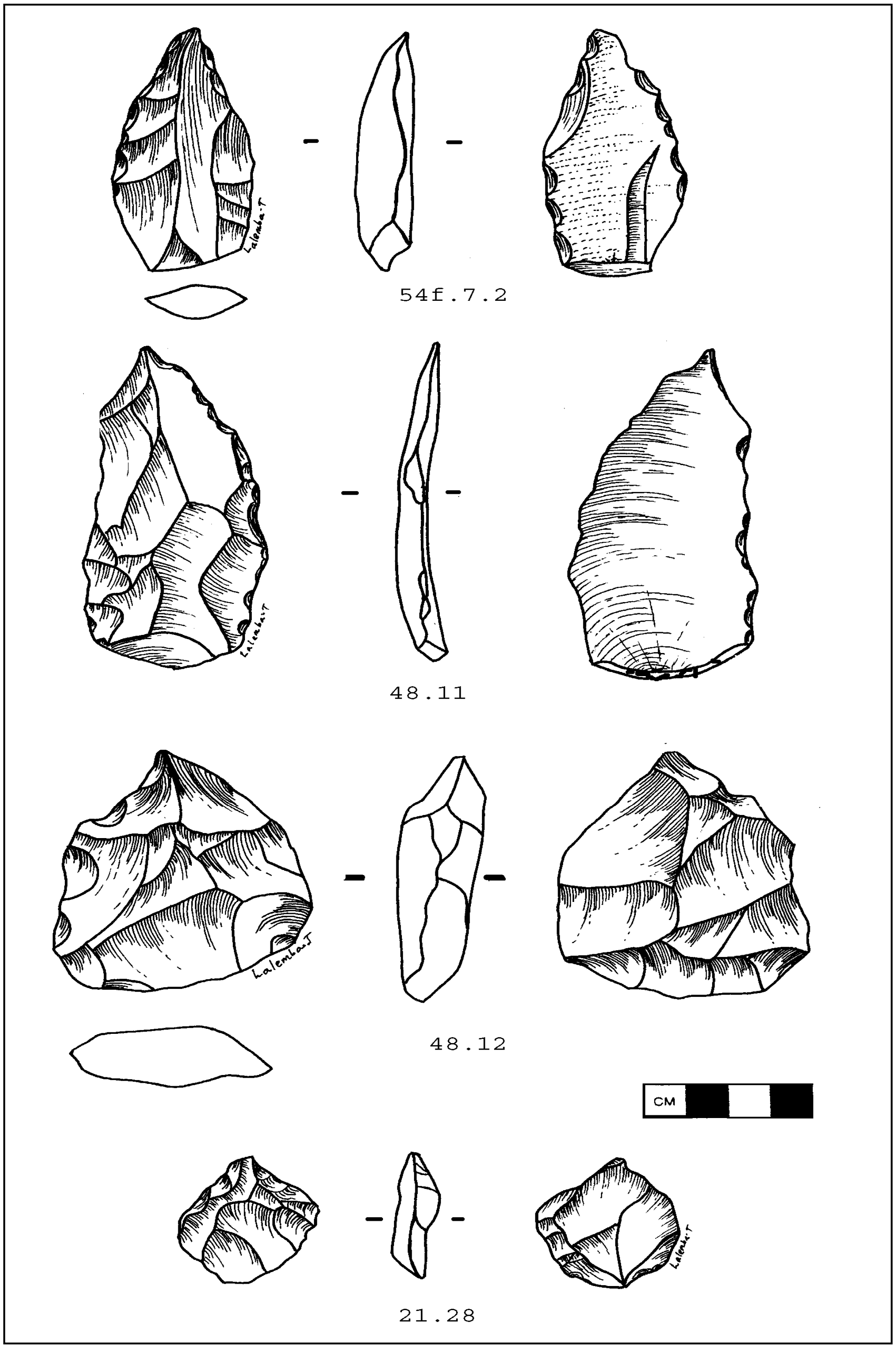


Figure 3.18. Points -perforators: 54f.7.2 (quartzite), 48.11-12 (chert), 21.28 (obsidian).

54f.7.2

54f.7.6

54f.10.2

54f.6.6

Figure 3.19. Perforators: 54f.7.2 (quartzite), 54f.7.6 and 54f.10.2 (obsidian), 54f.6.6 (quartz).

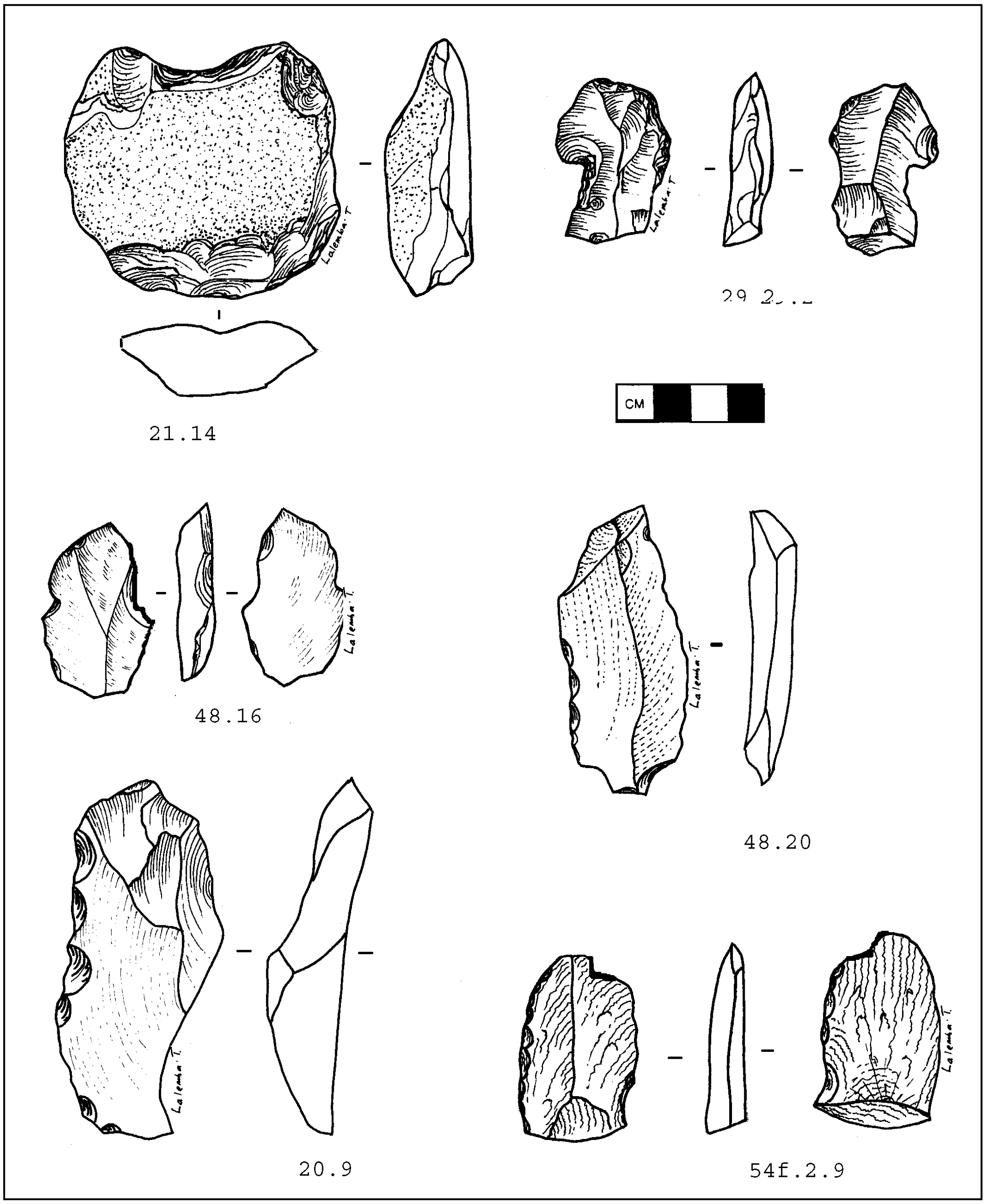


Figure 3.20. Various Tools: 21.14 and 48.16 (notches on basalt), 29.2 (notch on rhyolite), 48. 20 and 20.9 (edge modified tools on basal and obsidian respectively). Note the basal thinning with 48.20). 54f.2.9 (burinated quartz flake).

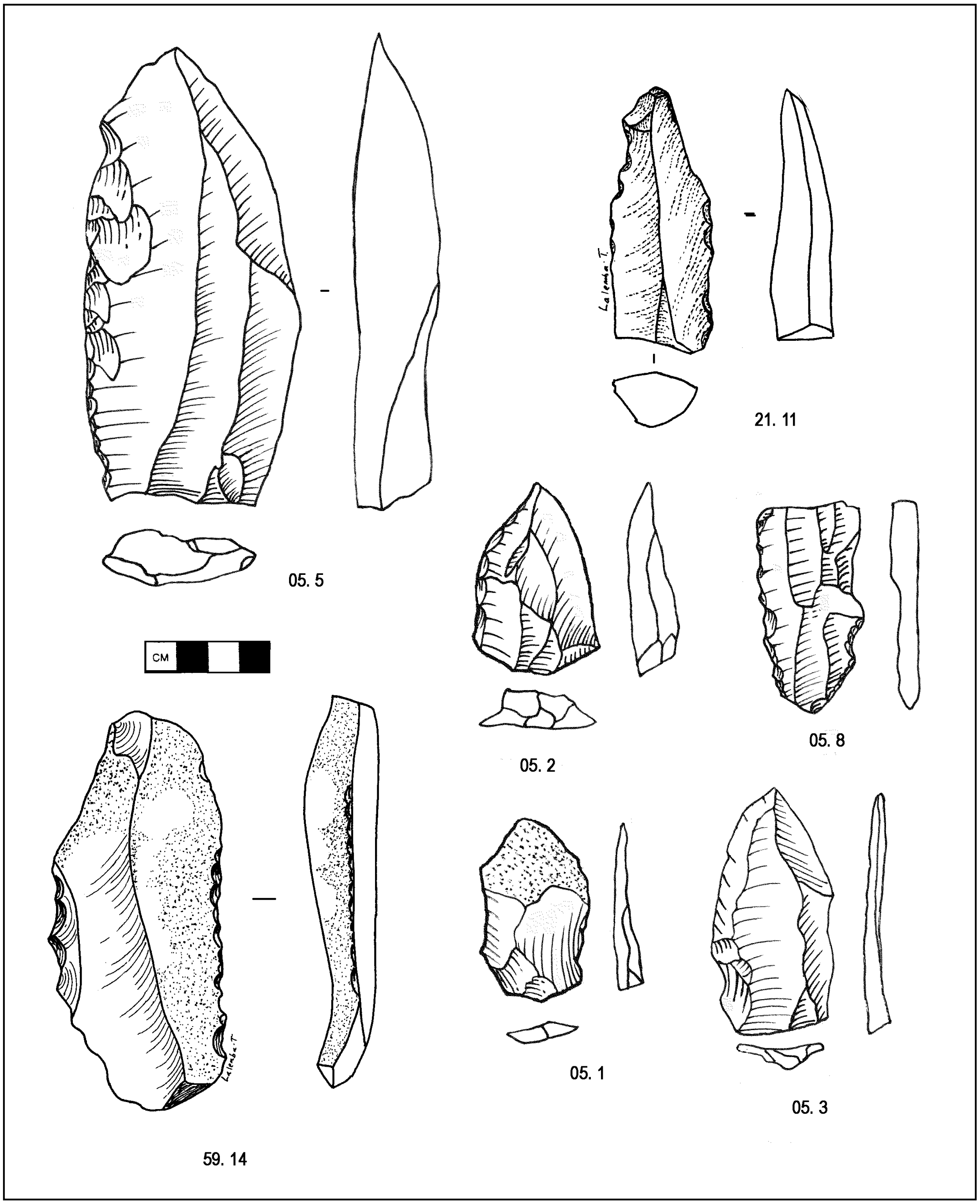


Figure 3.21. Edge modified blanks: 05.1, 05.2, 05.3, 05.5 (retouched basalt flakes-not analyzed), 05.8 (retouched prismatic blade on rhyolite), 21.11 (edge modified blade on basalt), 59.14 (denticulate on basalt).

Figure 3.22. Blades and points: From left to right - Group A. 48.19 (retouched prismatic blade on chert), 21.13 (prismatic blade on basalt), 29.8 (retouched prismatic blade on rhyolite), 54f.14.1 (prismatic blade on chert). Group B (top): 32 (proximally modified point on rhyolite), 12 (retouched point on obsidian), 82 (Levallois point on quartz). Bottom: 3 and 40 (Levallois points on quartzite), 47 (Levallois point on chert).

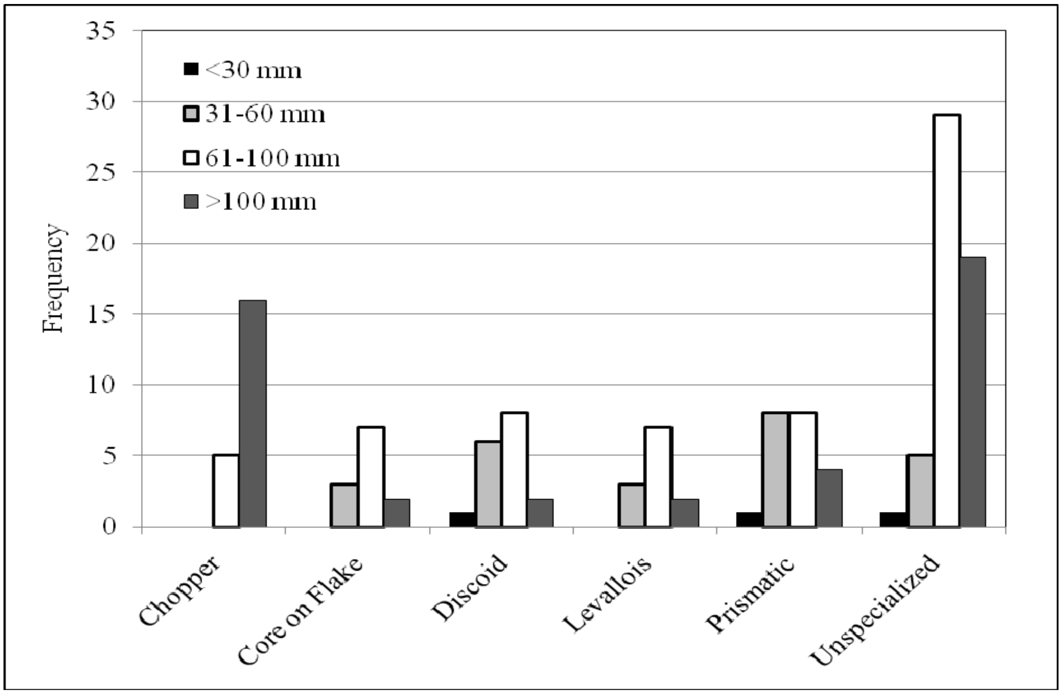
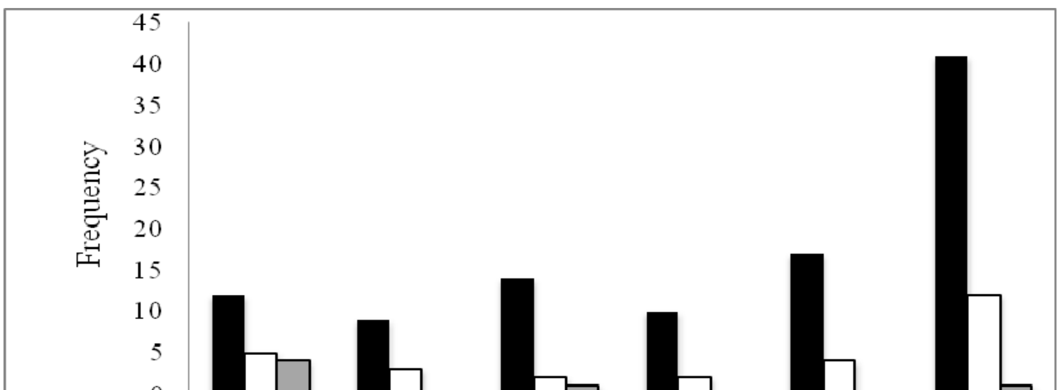


Figure 3.23. Asfet surface core sample, size (length) variability.



Cortex	Chopper	Core on Flake	Discoid	Levallois	Prismatic	Unspecia lized
<33%	12	9	14	10	17	41
33-67%	5	3	2	2	4	12
>67%	4		1			1

Figure 3.24. Asfet surface core sample, cortex variability.

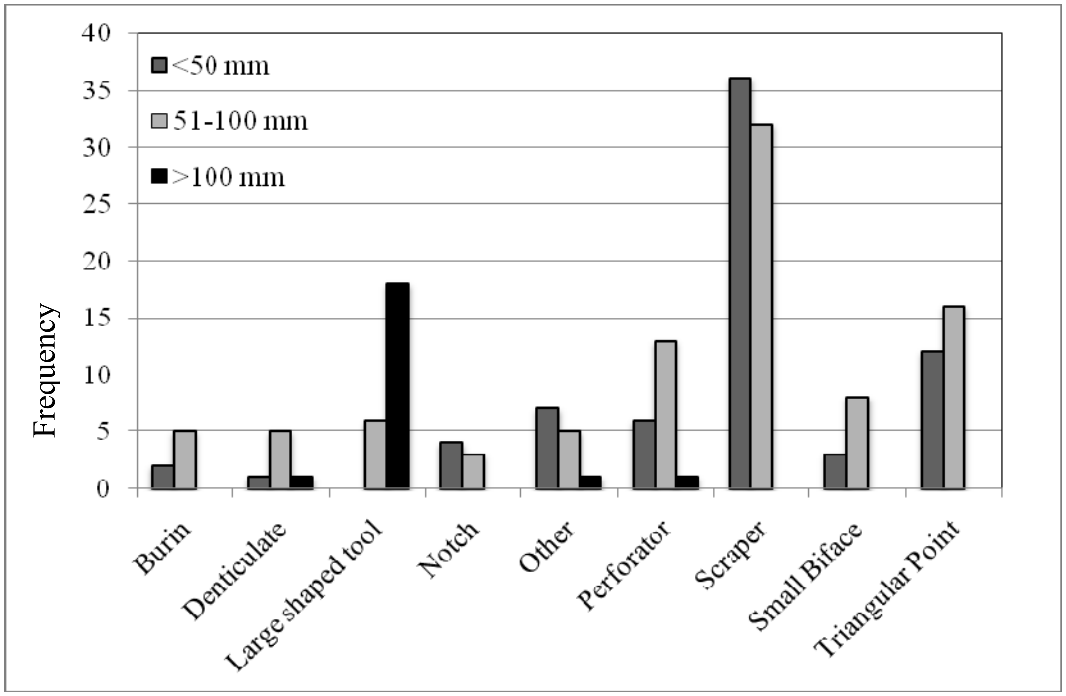


Figure 3.25. Asfet surface tool sample, length variability.

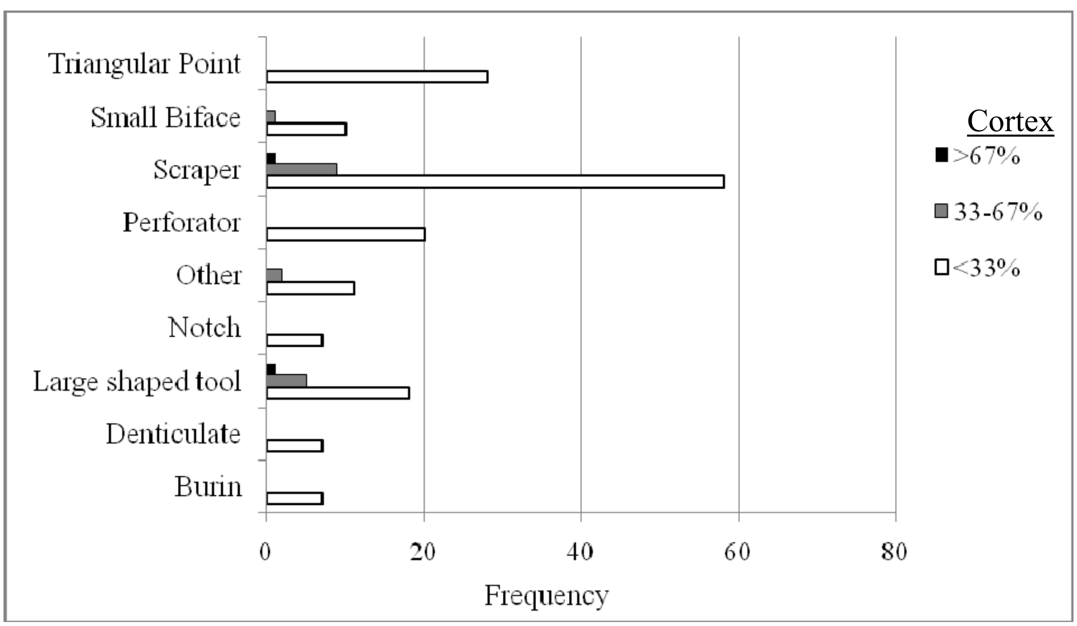


Figure 3.26. Asfet surface tools sample, cortex variability.

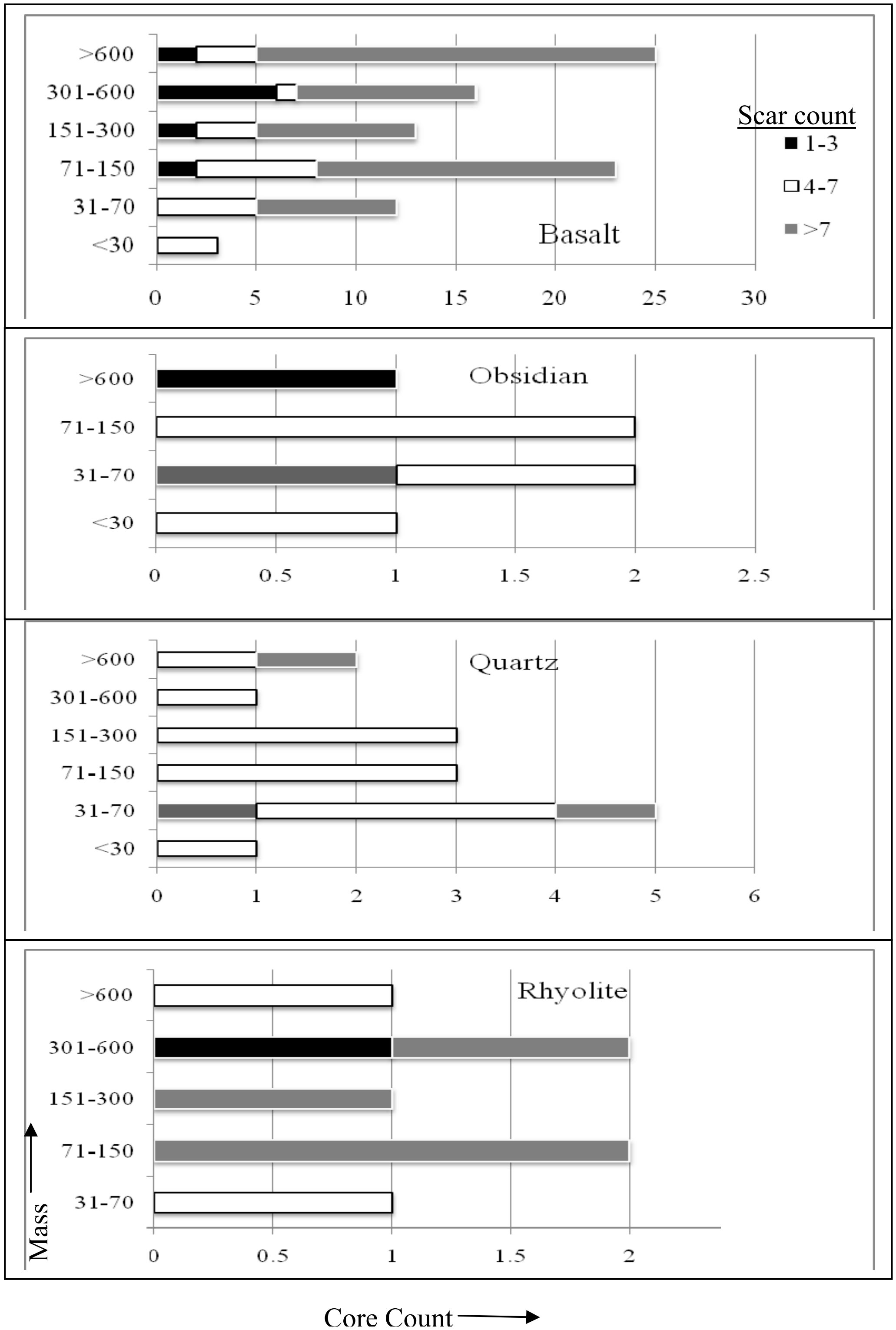


Figure 3.27. Asfet surface core sample, mass vs dorsal scar variability by raw material.

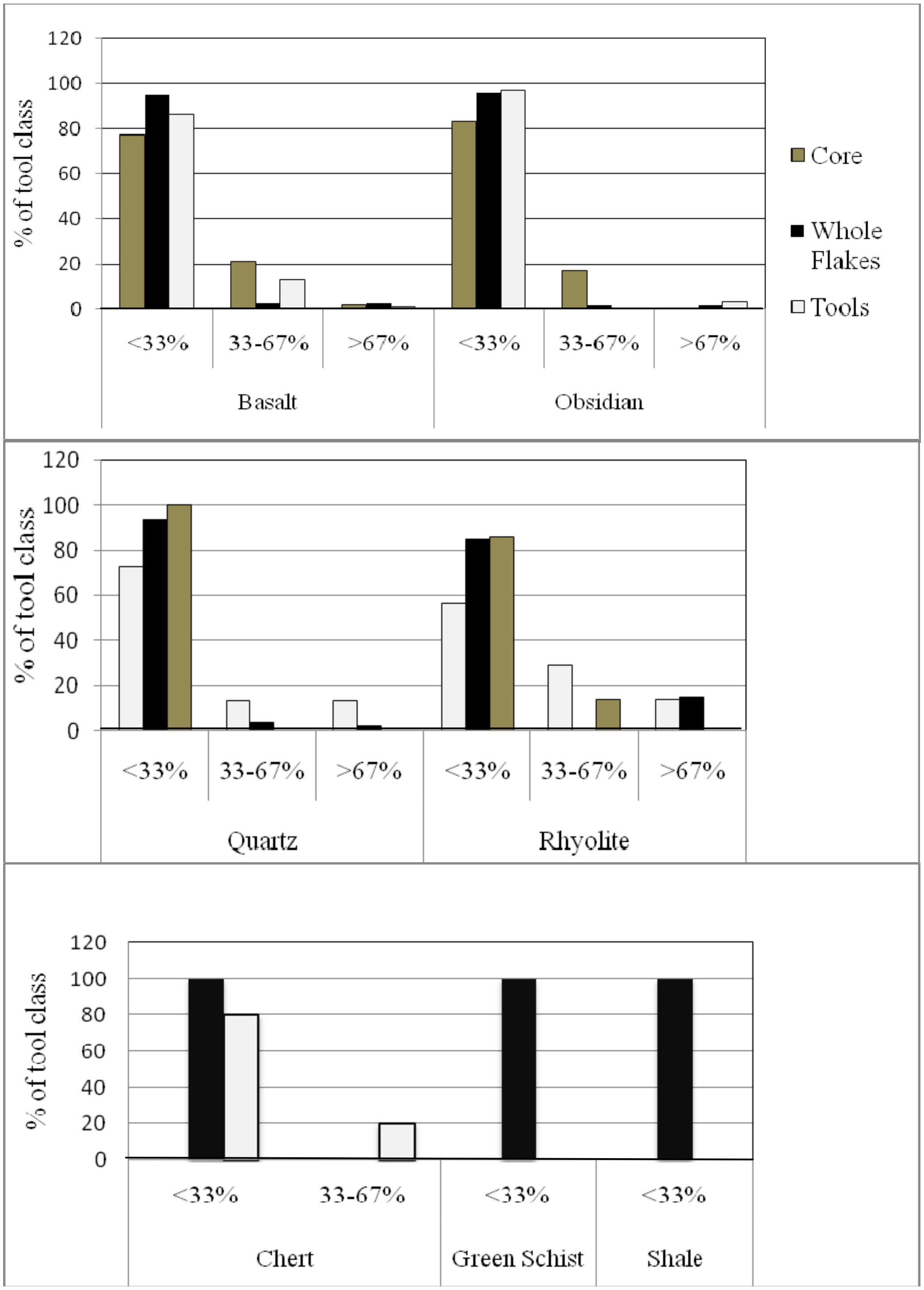


Figure 3.28. Asfet surface shaped tool sample, raw material and cortex relationship.

Lab No.	Section #	Elevation asl (m) or depth (cm)	Texture %			Texture Class	PH	EC MS/ CM
			Sand	Clay	Silt			
586	01	11.5 m asl, Western Ridge	41.7	16.5	41.8	Loam	8.01	6.19
55	01	12.5 m asl, Western Ridge	33.8	27.8	38.4	Clay loam	8.48	4.05
58	01	13.5 m asl, Western Ridge	29	32.9	38.1	Clay loam	8.37	4.4
587	01	15.3 m asl, Western Ridge	29.2	29.4	41.4	Clay loam	8.13	5.69
588	02	8 m asl, Eastern Ridge	60.6	12.3	27.1	Sandy loam	8.38	3.56
589	02	9.5 m asl, Easter Ridge	46.4	18.7	34.9	Loam	7.96	12.4
590	02	12 m asl , Eastern Ridge	36.9	24.4	38.7	Loam	8.08	7.40
56	04	0 -7 cm, below surface, Basin	54.1	26.4	19.5	Sandy clay loam	7.99	5.36
57	04	7-31 cm, Basin	68.1	15.7	16.2	Sandy loam	8.09	4.92
591	04	56 -75 cm , Basin	81.6	5.9	12.5	Loamy sand	8.92	1.35

Table 3.1. Texture, Electrical Conductivity and PH analysis of sediments collected from Asfet (section numbers are indicated in Figure 3.2).

Raw Materials	Core Types						Totals	%
	Choppers	Core on Flakes	Discoid Cores	Levallois Cores	Blade cores	Unspecialized		
Basalt	14	10	13	8	11	38	94	69
Obsidian			1	2	1	1	5	4
Other	2		1	1	5	7	16	11
Quartz	4	1	2		4	4	15	11
Rhyolite	1	1		1		4	7	5
Totals	21	12	17	12	21	54	137	100
%	15	9	12	9	15	39		

Table 3.2. Asfet surface core sample, raw material and artifact inventory.

Core Types	Mass Range (g)						Totals
	<30	31-70	71-150	151-300	301-600	>600	
Choppers			6	1		14	21
Core on Flakes	2	4	3	1	1	1	12
Discoid Cores	1	5	4	3	3	1	17
Levallois Cores		3	5	3	1		12
Blade Cores	1	4	8	2	3	3	21
Unspecialized Cores	1	9	8	10	13	13	54
Totals	5	25	34	20	21	32	137
%	4	18	25	15	15	23	100

Table 3.3. Asfet surface core sample, mass variability.

Mass Range (g)	Raw Material: Basalt	Diorite	Green Schist	Other	Quartz	Totals	%
51-150	2			1	2	5	45.5
301-600					1	1	9
> 600	1	2	1		1	5	45.5
Total	3	2	1	1	4	11	
%	27.3	18	9	9	36.4	100	

Table 3.4. Asfet surface hammerstones, mass and raw material variability.

Statistics	Length	Width	Thickness
Mean	93	68	53
Std. Deviation	25	15	12
Minimum	45	48	33
Maximum	128	92	70
Count	10	10	10

Table 3.5. Asfet surface hammerstones, size mean variability.

Raw Material	Tool Types									Totals	%
	Scrapers	Perforators	Triangular Points	Notches	Denticulates	Burins	Small bifaces	Large shaped tools	Other		
Basalt	20	6	10	3	4	3	5	22	7	80	43
Chert	11	1	3				1			16	9
Obsidian	16	9	6	1	1	1	3		5	42	23
Other	4		1			1	1	2		9	5
Quartz	17	3	7	1		2	1			31	17
Rhyolite		1	1	2	2				1	7	4
Totals	68	20	28	7	7	7	11	24	13	185	
%	37	11	15	4	4	4	6	13	7	100	

Table 3.6. Asfet surface tool sample, raw material and artifact inventory.

Tool Types	Mass Range (g) <20	21-50	51-100	101-300	301-600	>600	Totals
Burins	4	3					7
Denticulates	2	2	2	1			7
Large Shaped Tools			1	7	2	14	24
Notches	4		2	1			7
Others	6	2	2	1		2	13
Perforators	7	8	5				20
Scrapers	22	40	6				68
Small Bifaces	3	2	6				11
Triangular Points	7	17	4				28
Totals	55	74	28	10	2	16	185
%	30	40	15	5	1	9	100

Table 3.7. Asfet surface tool sample, mass variability.

Statistics	Large Shaped Tools			Perforators			Scrapers			Triangular Points		
	Length	Width	Thickness	Length	Width	Thickness	Length	Width	Thickness	Length	Width	Thickness
Mean	129	80	43	61	33	12	53	36	12	57	31	13
Std. Deviation	33	21	15	24	9	4	19	12	5	16	10	12
Minimum	66	40	18	15	19	5	25	13	3	34	15	4
Maximum	190	120	70	110	54	22	120	60	30	92	61	70
Count	28	28	28	20	20	20	68	68	68	29	29	29

Table 3.8. Asfet surface tool sample**,** size mean variability.

Large Shaped tools (n=28)

	Length	Width	Thickness
Length	1		
Width	0.7^{**}	1.0	
Thickness	0.4^{*}	0.4^{*}	1.0

Perforators(n=20)

	Length	Width	Thickness
Length	1		
Width	$0.2^{\#}$	1.0	
Thickness	$0.4^{\#}$	$0.3^{\#}$	1.0

Scrapers (n=68)

	Length	Width	Thickness
Length	1.0		
Width	0.8^{**}	1.0	
Thickness	0.7^{**}	0.7^{**}	1.0

Triangular Points (n=28)

	Length	Width	Thickness
Length	1.0		
Width	0.6^{**}	1.0	
Thickness	$0.2^{\#}$	$0.3^{\#}$	1.0

**correlation is significant at the 0.01 level (2-tailed), P<0.05

*correlation is significant at the 0.05 level (2-tailed), P<0.05

no significant correlation at the 0.01 or 0.05 levels (2-tailed), P>0.05.

Table 3.9. Asfet surface tool sample, bivariate correlation of size attributes.

Tool Types	Flake Scar Range				
	0	1-3	4-7	>7	Totals
Burins	1	6			7
Denticulates		7			7
Large Shaped Tools	1	6	14	3	24
Notches	4	3			7
Others	7	4	2		13
Perforators	6	11	3		20
Scrapers	18	49	1		68
Small Bifaces	3	3	5		11
Triangular Points	8	19	1		28
Totals	48	108	26	3	185

Table 3.10. Asfet surface tool sample, dorsal scar variability
(counted scars all ≥15 mm).

Raw Material	Debitage Types										Totals
	Fully Cortical Flakes	Partially Cortical Flakes	Non-Cortical Flakes	Levallois Flakes	Levallois Points	Levallois Blades	Prismatic Blades	Other Flake Types	Proximal Fragments	Other Fragments	
Basalt	22	96	124	43	14	24	42	55	9	74	503
Chert		8	6	5	1	4	3	5	2	2	36
Green Schist	2	5	8	3	2	1			2	3	26
Obsidian	2	7	91	41	19	11	18	35	19	166	409
Other	3	4	3			1		1		2	14
Quartz	2	13	24	10	10	3	3	4	5	40	114
Rhyolite		2	6		1	1	4	2	3	9	28
Shale	3	5	2	5		1	2	2	1	3	24
Totals	34	140	264	107	47	46	72	104	299	41	1154
%	3	12	23	9	4	4	6	9	26	4	100

Table 3.11. Asfet surface debitage sample, raw material and artifact inventory.

	Mass Range (g)				
Debitage Types	<20	21-50	51-100	>100	Totals
Fully Cortical	7	15	2	10	34
Partially Cortical	17	105	12	6	140
Non-Cortical	85	163	9	7	264
Levallois Blades	5	37	1	3	46
Levallois Flakes	22	79	5	1	107
Levallois Points	12	35			47
Prismatic Blades	30	33	5	3	72
Other Flake Types	36	63	2	3	104
Proximal Fragments	38	3			41
Other Fragments	281	13	2	3	299
Totals	533	546	38	36	1154
%	46	47	3	3	100

Table 3.12. Asfet surface debitage sample, mass variability.

Debitage Types	Length Range (mm) <30	31-60	>60	Totals
Fully Cortical	5	8	21	34
Partially Cortical	4	72	64	140
Non-Cortical	49	157	58	264
Levallois Flakes	7	67	33	107
Levallois Blades		22	24	46
Levallois Points	2	37	8	47
Prismatic Blades	1	33	38	72
Other Flake Types	20	35	49	104
Proximal Fragments	38	3		41
Other Fragments	211	85	3	299
Totals	337	519	298	1154
%	29	45	26	100

Table 3.13. Asfet surface debitage sample, size variability.

Debitage Types	Length: Width Ratio <1	1-1.5	>1.5	Totals
Fully Cortical Flakes	1	17	16	34
Levallois Blades			46	46
Levallois Flakes	3	41	63	107
Levallois Points		7	40	47
Non-Cortical Flakes	17	70	177	264
Partially Cortical Flakes	3	31	106	140
Prismatic Blades			72	72
Totals	24	166	520	710

Table 3.14. Asfet surface debitage, length to width ratio in the complete flakes.

Levallois Flakes	Length	Width	Thickness	SP Width	SP Thickness
Mean	53.3	32.3	9.0	26.6	8.5
Std. Deviation	15.6	10.1	3.9	9.0	4.1
Minimum	16.0	10.0	2.0	11.0	2.0
Maximum	96.0	66.0	23.0	55.0	26.0
Count	154	154	154	154	154
Blades					
Mean	63.0	25.4	8.2	20.7	7.4
Std. Deviation	19.4	8.4	3.5	8.5	3.2
Minimum	15.0	10.0	2.0	1.0	1.0
Maximum	132.0	58.0	19.0	53.0	16.0
Count	118	118	118	118	118
Partially Cortical and Non-Cortical					
Mean	53.4	30.4	9.0	21.7	7.9
Std. Deviation	21.1	12.8	5.3	10.3	4.4
Minimum	10.0	5.0	2.0	4.0	1.0
Maximum	136.0	90.0	70.0	60.0	23.0
Count	404	404	404	404	404

Table 3.15. Asfet surface debitage sample, size means of complete flakes (SP= Striking Platform).

Levallois flakes and points (n=154)	T. Length	T. Width	MP. Thickness	SP. Width	SP. Thickness
T. Length	1.0				
T. Width	0.7**	1.0			
MP Thickness	0.5**	0.5**	1.0		
SP Width	0.5**	0.6**	0.5**	1.0	
SP Thickness	0.5**	0.5**	0.6**	0.6**	1.0
Prismatic and Levallois blades (n=114)					
T. Length	1.0				
T. Width	0.8**	1.0			
MP Thickness	0.6**	0.7**	1.0		
SP Width	0.5**	0.6**	0.5**	1.0	
SP Thickness	0.3**	0.4**	0.6**	0.7**	1.0
Non-Cortical and partially cortical Flakes (n=390)					
T. Length	1.0				
T. Width	0.7**	1.0			
MP Thickness	0.6**	0.6**	1.0		
SP Width	0.5**	0.7**	0.6**	1.0	
SP Thickness	0.6**	0.6**	0.6**	0.8**	1.0

**correlation is significant at the 0.01 level (2-tailed), P<0.00.

Table 3.16. Asfet surface debitage sample, bivariate correlation of size attributes in the complete flakes (T=technological axis, MP= Mid Point, SP=striking platform).

Debitage Types	Striking Platform Types					
	Absent	Cortical	Plain	Facetted	Dihedral	Totals
Fully Cortical	1	3	23	3	1	31
Levallois Blades				40	6	46
Levallois Flakes				96	11	107
Levallois Points				40	6	46
Non-Cortical	5	17	235			257
Other Flake Types	1	6	75	5		87
Partially Cortical	3	25	109			137
Prismatic Blades	1	5	65	1		72
Proximal Fragments		4	24	8	4	40
Totals	11	60	531	193	28	823

Table 3.17. Asfet surface debitage sample, striking platform variability.

Debitage Types	Flake Termination Pattern				Totals
	Feather	Indeterminate	Other	Step	
Fully Cortical	21	1		10	32
Levallois Blades	29	5	1	11	46
Levallois Flakes	74	9	1	23	107
Levallois Points	42	2		3	47
Non-Cortical	175	21		66	262
Partially Cortical	95	10	1	34	140
Prismatic Blades	35	9	3	23	70
Totals	471	57	6	170	704

Table 3.18. Asfet surface debitage sample, flake termination pattern variability.

Raw Material	Cores		Shaped Tools		Debitage		Debitage to Core Ratio
	N	%	N	%	N	%	N/N
Basalt	94	69	80	43	503	44	5.35
Obsidian	5	4	42	23	409	35	81.8
Quartz	15	11	31	17	114	10	7.6
Rhyolite	7	5	7	4	28	2	4
Green Schist	minor	minor	minor	minor	26	2	indeterminate
Chert	minor	minor	16	9	36	3	indeterminate
Shale	minor	minor	minor	minor	24	2	indeterminate

Table 3.19. Summary of raw material frequencies in the Asfet surface tool sample.

Chapter 4
Asfet: Excavation, Chronology and Subsurface Archaeology

Introduction

This chapter deals with subsurface investigation of the Asfet Site Complex. Six test units (A-F) were excavated at different locations of the site (Fig. 4.1). The site was extensively investigated owing to the richness of surface material observed during the survey. However, the majority of the excavated units did not yield any subsurface archaeology. Only one trench (Unit F) produced well preserved lithic and shell remains in close association. The chapter reports the chronology and lithic findings of Test Unit F. It begins with a brief description of the excavated test units.

Description of the Excavated Units

Unit A (1 x 1 m). Located on the mid-section of the sandy area, this was the first test unit to be excavated. Densely scattered shell and lithic remains were recovered from the immediate surface of the unit. The dense cluster of artifacts noted on the surface has initially placed our expectation high for undersurface finds. In addition, the spot is on a convenient location for test investigation. The unit surface is flat, slightly sloping eastward characterized by pale brown, sandy-loam sediment (Munsell: 10YR, 6/3). We collected and mapped over 700 lithic artifacts and shell remains from the immediate 1 x 1 surface boundary (Fig. 3.5). The lithic assemblage is composed of retouched tools, whole flakes and flake fragments. Cores were less abundant. Obsidian and basalt dominate the lithic raw materials. Organic shells were recovered as well, but mostly fragmentary. Initially, the test pit was dug using a 10 cm depth interval for two levels (-20 cm). However, as the upper deposit appeared archaeologically poor, we shifted to 20 cm interval by focusing on a 20x40 cm sounding trench in the middle of the unit. No subsurface material was recovered throughout the exposed levels up to 40 cm below surface. The soil continued to be pale brown and graded to a salt incrusted compact layer beneath Level 1.

Unit B (1 x 1 m). This test unit was located on the southern section of the sandy area along the lower periphery of the western ridge. The surface was characterized by moderately scattered artifacts on a secluded flat section surrounded by basalt rubble. Artifact density was much lower compared to the Unit A surface concentration. The surface material was dominantly lithics with a small quantity of shell fragments. We mapped and collected about 120 lithic artifacts and some shell fragments from the immediate 1 x 1 m surface and the periphery. Blade tools dominate the lithics. The find spot is surrounded by big boulders on the upper side, suggesting that movement by erosion is unlikely. Likewise, the surface artifacts appear to be in a primary context. This section was initially selected for test excavation because it lies at the junction between the flat sandy area and the basalt ridge. By excavating along the base of the basalt ridge, we hoped to determine the source for the dense artifacts on the sandy basin. The excavation did not yield any preserved cultural traces below surface in five levels (50 cm below surface). The soil texture was fine-loose on the upper layers which graded to compact, plagioclase rich deposit towards the lower level.

Unit C (2 x 1 m). This test unit was about 50 m to the southwest of Unit A on a gently sloping surface on the western ridge. We set this test trench outside the sandy area in order to explore the basalt surface for any *in situ* evidence. The surface is covered by gravel and basalt rubble. The distribution of artifacts on the unit surface was sparse, although several heavy-duty cores were encountered interstratified with the gravel heap stretching towards the flat basin. The lithics include cortical flakes on basalt with some sparse quartz and obsidian debitage. A small quantity of shell fragments was recovered from surface. The soil appeared loose, light yellowish brown (Munsell: 2.5Y, 6/3). A few lithic remains were recovered from the upper 8 cm of the excavated deposit. These include a small obsidian flake, chert flake and a quartz flake. Two obsidian flakes possessing lightly modified edges were recovered at -7 and -8 cm respectively. It is not clear whether these pieces signify a primary context or not. They could have rolled into the gravel scree through erosional fissures and been buried afterwards. The surface is tilted and sediments are constantly moving down the slope. The unit was excavated for about five levels (-67 cm). No archaeological remains were discovered from any of the excavated deposits except those few traces discussed above.

Unit D (50 x 50 cm). Located on the lower margin of the eastern basalt ridge, this unit was part of Log 02 (Fig. 3.2) that was initially excavated for sediment analysis. During Log 02 excavation, we uncovered several shell specimens from the lower section of the Log. We excavated the shell bearing section in order to closely examine the nature of shell distribution and association. A 50 x 50 cm area was designated for excavation using a 20 cm arbitrary depth levels. The substrate is sandy loam decomposed from scoriaceous scree and basal rubble. A high concentration of shell remains (mainly bivalves) was exposed in the upper two levels (up to 40 cm deep). Several of the uncovered shells were complete and some even retained closed valves. It appears that the shells were naturally deposited. Unit D is on the periphery of a low alluvium field to the east of the site (less than 5 m asl). A small-scale sea transgression could reach the area depositing the shells on a natural context. The available evidence is not conclusive whether there was any recent sea movement to the area or not. Such events need to be evaluated with additional data from future research. The concentration of shells dropped below 40 cm and the sediments graded to sandy loam rich in plagioclase grains.

Unit E (1 x 1 m). This unit was opened on the eastern slope of a small ridge that protrudes from the base of the western ridge. The unit surface is characterized by basalt gravel dipping about 20^0 eastward. Widely scattered lithic artifacts were noted on surface, including cores, retouched tools and flake fragments made on basalt, quartz and obsidian. A few shell fragments were encountered in association with the lithic scatters. Large shell fragments were noted on isolated spots. A noteworthy find was a piece of flake on green obsidian encountered on the unit surface. Black obsidian dominates in the source areas that we identified around Irafailo. The occurrence of a small quantity of green obsidian at Asfet (another one has been found around Unit F, see below) may signify an exotic source of this type of obsidian. Again, further research on local obsidian sources is needed to test this assumption. The unit was excavated upto five levels at an interval of 10 cm. Artifacts were absent from the entire pit. The lower subsurface turned to unconsolidated sandy-loam.

Unit F excavation

Out of the six test units opened at the Asfet site, only Unit F yielded an archaeological deposit below surface. This unit is situated on a secluded area on top of the western ridge surrounded by basalt boulders. The surface is characterized by a dense concentration of shell fragments and lithic debitage. The sediment bearing area ranges about 8 sq m, while our investigation was limited to 2.9 sq m unit. All archaeological traces on the unit surface were collected prior to excavation. Two diminutive nodules of green obsidian were encountered on surface from the northern periphery of the unit. The archaeological level was restricted to the upper 25 cm deposit (Levels 1 and 2). The unit was initially excavated to 30 cm down (two and half levels) in all sides. Subsequently, a 50 x 100 cm sounding pit was added on the southern section and excavation resumed for another 20 cm. The lower section is characterized by poorly sorted coarse sediments. The arbitrary levels referred to as Levels 1 and 2 do not correspond to any lithological features or true change in artifact style, but were designated so for data control purposes.

Level 1. The level yielded high concentrations of shell remains with lithics. Lithic density was comparatively low. The shell bearing sections were designated as quadrants which included the southeast (SE), northwest (NW) and the southwest (SW) corners. The shells from the SE quadrant were unique because they represent more complete specimens. Shell density continued throughout Level 1 in all corners. Mid-way through this level, a complete obsidian blade has been uncovered from the SW quadrant in a shell cluster. Moreover, several complete flakes, fragmentary debitage and some edge damaged tools were recovered from the southern edge *in situ* and from screening. Obsidian is most common followed by quartz and basalt. A half complete shell with two small obsidian flakes embedded inside was uncovered from the eastern section.

After excavating Level 1, we extended the unit boundary by 20 cm on the eastern margin, 40 cm northward and 50 cm on the southern side. Similarly, a 30 x 60 cm extension was added on the western wall to assess the extent of artifact distribution towards the edge of the ridge (Fig. 4.2). Extending the northern section was justifiable because clusters of shells had been exposed continuously from this side. The added portions were then excavated to Level 1 floor. Dense shell remains were recovered from the upper layer of this level. From the northwestern quadrant of the added portion, a small quartz core was uncovered inside dense shell cluster. The extensions along the northern and eastern walls also revealed dense shell distributions. The southern periphery of the unit produced higher shell and artifact density. From the northern wall, excavators exposed a highly weathered handaxe-like basalt piece. Close examination of the piece suggests that it is naturally modified nodule. One shell sample (A0794) from the mid section of Level 1 (-6 cm) yielded a date ranging 5571-5662 years Cal BP (2-sigma). The concentration of shells and lithic artifacts declined slightly from -8 cm down on the mid section of the unit, and continued in moderate density in the other quadrants.

Level 2. As the concentration of lithics and shells started to decrease on the upper layer of Level 2, we switched to 15 cm level-depth. Shell distribution continued throughout the upper layer of Level 2 in a moderate scale. The association of shells and lithic artifacts varied in different sections of the unit. Several lithic remains were recovered without any shell association. For example, from the southeastern quadrant, a large obsidian flake was encountered several centimeters distant from the shell cluster. Similarly, an isolated large obsidian blank was collected from the northwestern section. The distribution of shells and artifacts started to decline steadily towards the lower stratum of Level 2 (-20 cm). The whole unit turned to completely sterile at -25 cm, ending Level 2 there. Excavation continued for another 20 cm along a 50 x 100 rectangular sounding trench on the southern quadrant, while work has terminated on the rest of the unit after exposing a small section through Level 3 (-30 cm). The extended excavation on the southern section did not produce any archaeological trace.

Asfet Unit F Dating

Table 4.1 below summarizes Unit F dates and the applied methods. Dating sample submission was as follows:

i. One sample from Unit F Level 1 (-6 cm) was submitted to Dr. Hong Wang at the University of Illinois, Urbana-Champaign for sample preparation. It was dated by Atomic Mass Spectrometry (AMS) ^{14}C at the University of California-Irvine.

ii. One sample from the Unit F Level 3 (-21 cm) was submitted to the Geochron Laboratories, Krueger Enterprise (Boston) for AMS ^{14}C dating.

iii. Three samples from Unit F were submitted to Dr. Bonnie Blackwell at Williams College, Massachusetts for Electron Spin Resonance (ESR) dating.

Due to the high discrepancy observed with the ESR dates, only the ^{14}C results are considered in consolidating the age of the site. One occupation phase can be recognized from the radiocarbon dates from Unit F Level 1 and 2. An AMS ^{14}C date of 5385 $\pm$15 years BP from Level 1 has been calibrated to 5586 - 5631 years BP (1-sigma). Another sample from Level 3 was dated to 5350$\pm$ 40 years BP (AMS ^{14}C) which was calibrated to 5553 - 5637 years BP (1-sigma). The slight discrepancy in the ages of the two samples from the lower and upper levels could be a result of different dating labs (preparation technique and instruments). As indicated above, the first sample from Level 1 was dated at the University of California-Irvine, while the second one from Level 3 was dated at the Geochron Laboratories. Another sample from the upper layer of Level 1 yielded a ^{14}C date of 2910 $\pm$ 130 yrs BP using a conventional method. The last sample was suspected to be contaminated and was disregarded, because both AMS samples from above and below it showed similar results. Both the AMS dates from Level 1 and 2 point to a mid-Holocene (6th millennium BP) occupation scenario at Asfet.

The high concentration of marine mollusks with lithic association at the site reflects human exploitation of the shells. Thus, the ages of the shells reflect periods of human occupation and human exploitation of shellfish. The majority of the shell specimens are broken and no signs of burning were noted.

Sample Code	Lab ID	Level	Dating Method	^{14}C and ESR Dates (BP)	Calibrated Age€ (BP)
Asfet01	A0794*	1 (-6 cm)	AMS	5385 ±15	5586-5631 (1σ) 5571-5662 (2σ)
Asfet07	GX - 32978**	2 (-21 cm)	AMS	5350± 40	5553-5637 (1σ) 5475-5672 (2σ)
Asfet02	CM17$	2 (-15 cm)	ESR	8270 ± 908	
Asfet03	CM18$	2 (-14 cm)	ESR	3266 ± 482	
Asfet04	CM18a$	1 (-7 cm)	ESR	5685 ± 586	

Table 4.1. Asfet Unit F calibrated radiocarbon and ESR dates from shell samples. Note to Lab ID symbols: *=University of California-Irvine, **=Geochron Laboratories of Kruger Enterprise, $=Thompson Chemical Laboratory at Williams College, € = Stuiver, et al. 2005 (http://calib.qub.ac.uk/calib/). Radiocarbon dates are ^{13}C corrected.

Unit F stratigraphy

Generally, the stratigraphy of Unit F is characterized by undifferentiated, poorly sorted clay-loam sediments that grade into coarse sandy loam at the lower levels. The deposit lacks any archaeologically distinctive zones. This is not surprising because the site is located on top of unstable basalt ridge where there is less opportunity for sediments to form consolidated and well superimposed strata. Constant wind movement and rain can easily remove sediments from the ridge top.

The Archaeological Level. The archaeological level refers to the section of the unit that yielded shells and lithic remains *in situ*; ranging in vertical depth up to -25 cm.

Two samples from Level 1 and 3 produced close age ranges 5586-5631, and 5553-5637 (1-sigma) years Cal BP respectively. The artifact bearing deposit is clay-loam that lacks soil structure or stratigraphic differentiation (Table 4.2). A dark grayish soil has been exposed from the NW and NE quadrants at -8 cm vertical depth which could reflect biogenic activity. No archaeologically distinctive association was noted around the gray matrix. Plant rootlets (presumably recently grown) have been uncovered from the eastern and northern sides of the unit, diagonally intruding into the archaeological layer. The rootlets display moderate level of weathering with the majority preserving root-sleeves. Dr. Elisabeth Hildebrand of Stony Brook University (a specialist in archaeobotany) assisted with microscopic examination of the root samples in order to determine if there exists any possibility of charcoal. None of the presumed rootlets are carbonized. The lower layer of the archaeological level grades into unconsolidated coarse loam. Soil samples were systematically collected from the excavation layers for texture, PH and Electrical conductivity analysis (see Table 4.2).

The Sterile Level. Excavation continued for about 20 cm on the sterile level on the southern section of the unit in order to further explore the deposit beneath the archaeological level. The deposit here remained sterile throughout the sound trench and sediments continued to be coarser and looser than the overlying sedimetns. Large basalt rubble started to emerge at about -35 cm signifying the layer beneath was indeed natural stratum.

At the end of the fieldwork at Asfet, five spots were selected for Auger test based on artifact concentration and nature of surface substrate (Fig. 4.1). The Auger tests were conducted on a relatively loose substrate and flat surface in the sandy basin along the base of the ridge slopes. However, none of the Auger tests at Asfet yielded cultural remains below surface. Two of the Auger holes were dug up to -30 cm and three up to – 40 cm below surface. In all the trials, the substrate remained sterile. Therefore, future work should focus on the ridge tops.

Asfet Unit F Lithic Assemblage

This section discusses the lithic assemblage recovered from Unit F test excavation. The bulk of the lithic material is fragmentary debitage uncovered in a wide distribution pattern in Level 1. Small quantities of utilized tools and backed microliths were found mainly in Level 1. The lithic material is described in terms of cores, shaped tools and debitage (complete and fragmentary flakes).

Cores

The Unit F cores are few in number and mainly represented by unspecialized (non-blade) pieces (Table 4.3). Obsidian and quartz are the dominant raw materials, constituting 50% and 37% respectively. All of the unspecialized cores weigh below 30 g and measure below 30 mm in maximum length implying that those were extensively reduced. The two prismatic cores are made on obsidian and quartz and exhibit slightly greater mass and length measurements (Tables 4.4 -5). Among the unspecialized cores, there are a few diminutive bipolar cores (Fig. 4.5A, A1002). The mean values for core length, width and thickness are 26, 21, and 12 mm respectively (Table 4.6).

Shaped tools

Backed tools (n=4) and Backed fragments (n=4). Backed tools were generally few at Unit F. Complete backed tools and backed fragments make up 62% together (31% each). The complete backed tools were restricted to Level 1. They all weigh between 1 and 5 g and three-forth of them are less than 20 mm in size (Tables 4.7 and 4.9). Three out of the four backed fragments came from Level 2 (below -15 cm). Only one backed fragment was found in Level 1. Several of the small backed fragments preserve one or two snapped ends (Tables 4.8 -9).

Other retouched tools recovered from Unit F include a few perforators and edge damaged tools. Level 1 and 2 each yielded one edge damaged tool. Both tools are on obsidian and weigh below 5 g. They range between 20 and 40 mm in maximum length. Moreover, two perforators, both made on obsidian were uncovered form Level 1 and 2. While the one from Level 1 weighs below 10 g, the specimen from Level 2 is greater than 10 g (Table 4.8). Both perforators are larger than 40 mm in size.

The mean values for the entire shaped tool class are 25 mm for length, 10 mm for width, and 3 mm for thickness. The large standard deviation for length (13) however implies high variability in length scores. The smaller size of the backed tools may account for much of this variability. The small percentage of shaped tools implies that tool maintenance was less practiced at the site, or otherwise all tools that were modified at the site were discarded elsewhere.

Whole flakes and flake fragments (Debitage)

Compared to the shaped tool and core classes, Unit F yielded a modest quantity of unmodified pieces (n=410). Out of this only 390 were analyzed. The remaining 20 artifacts were recovered during the final excavation, and were not transported to Stony Brook for analysis. Obsidian is the dominant raw material constituting 65% followed by basalt and quartz each representing 17% (Table 4.11). Of the total 390 debitage recovered from the unit, 84% are from Level 1 (0- 10 cm depth) and the rest from Level 2. Rhyolite and chert represented by a few specimens in the first level are completely absent from the second level. Fully cortical flakes mainly on basalt (60%) were recovered from the first level. The presence of cortical flakes indicates primary reduction activity at the site. The few number of cortical flakes on obsidian hints that obsidian cores were decorticated elsewhere, possibly in order to minimize transportation cost.

Partially Cortical (n=15). The majority of partially cortical flakes came from Level 1. This corresponds to the distribution of fully cortical flakes. Only two partially cortical flakes were recovered from Level 2. Most of the partially cortical flakes fall within the mass range of 1-5 g and measure less than 20 mm (Tables 4.12-13).

Non-Cortical flakes (n=101). This is the largest group in the whole flake class comprising 26% of all debitage (21%=Level 1, 5%=Level 2). Obsidian makes up higher percentage in this group (55% in each level) followed by quartz (33% in Level 1 and 20% in Level 2). A large percentage of the non-cortical flakes weigh between 1 and 5 g and measure less than 20 mm in size (Tables 4.12 -13).

Blades (n=24). Level 1 produced the majority of blades (n=21) while Level 2 yielded only 3 specimens. Obsidian is the dominant raw material, and a large number of blades fall within the weight range of 1-5 g (Table 4.12). Likewise, the majority of the blades measure between 20 and 40 mm.

Proximal Fragments (n=32). This group represents a small percentage (8%) of the debitage class. Twenty-six artifacts came from Level 1 and the rest 6 from Level 2. Raw material variability is similar to the other tool classes. The majority is made of obsidian and falls within 1-5 g mass range. Some of the proximal fragments display conjoinable snapped edges suggesting accidental breakage by trampling.

The remaining 4% are other types of complete flakes that do not belong to any of the above classes. Flake fragments that lack proximal landmarks make up more than half (51%) of the debitage class. There is nearly comparable proportion of these elements in the two levels. Most of the fragments fall within the mass range of 1-5 g (Table 4.12).

Technological length, width, thickness and platform size means are shown in Table 4.14. A bivariate correlation test of different size variables shows statistically significant correlation among the size attributes at the 0.01 level (Table 4.15). A strong correlation is noted between platform size and width at mid-point section (r=0.7). What this pattern suggests is that flakes broader at the striking platform are also having broader mid-section. Therefore, striking platform size seems to have great control on the overall flake size.

Summary and Discussion of Asfet Unit F

Unit F produced the first dated evidence for mid-Holocene human adaptation along the southern edge of the Gulf of Zula. Shells and lithics were found throughout the archaeological levels in consistent association. Where there is high density of shells, lithic remains were proportionally abundant. The accumulation of dense shell remains in close association with lithic artifacts suggests human harvesting of mollusks from the nearby coast, but the manner in which the site was used remains unclear and awaits future investigation. Oxygen isotope results are pending for climatic reconstruction. Climatic evidence will clarify the ecological background for human occupation of the region. Lithic and shell distribution along the archaeological levels shows a steady decrease in concentration below -15 cm. A sterile soil was reached at -25 cm. The evidence however does not suggest any culturally or climatically triggered abrupt shift in lithic technology. The technology and subsistence behavior seems invariable throughout the archaeological successions except for the decrease in artifact and shell density towards the lower layers.

A total of 431 lithic artifacts and a dense shell concentration were recovered from the archaeological levels at Asfet Unit F. The bulk of the shell assemblage is fragmentary in nature and a sample of it has been analyzed in the NME (see Appendix I). In general the lithic assemblage from Unit F represents a flake based industry primarily on obsidian. The unit yielded smaller number of shaped tools (n=13) suggesting less emphasis on tool design. The relatively small number of obsidian cores may indicate that humans were not transporting obsidian in the form of core nodules. Instead, humans seem to have been transporting flakes in bulk to the site. The lithic assemblage is dominated by fragmentary debitage. The presence of dense shell remains coupled with the close proximity of the site to the coast suggest Unit F was primarily selected for coastal exploitation. A single ostrich eggshell bead was recovered from Level 2 during from the Southern Quadrant.

Based on raw material and lithic typological variability, the surface evidence and the excavated assemblage represent two different occupations. There is a clear distinction in the techno-typology of the lithic artifacts in the two samples from Asfet. While the surface material shows greater raw material and typological diversity, the Unit F assemblage is strictly a flake based industry mainly produced from obsidian. The surface material appears to be a Middle Stone Age, whereas the Unit F assemblage represents a mid-Holocene (6^{th} millennium BP) Later Stone Age settlement. This difference implies different human groups settled on the Asfet coast at different time periods.

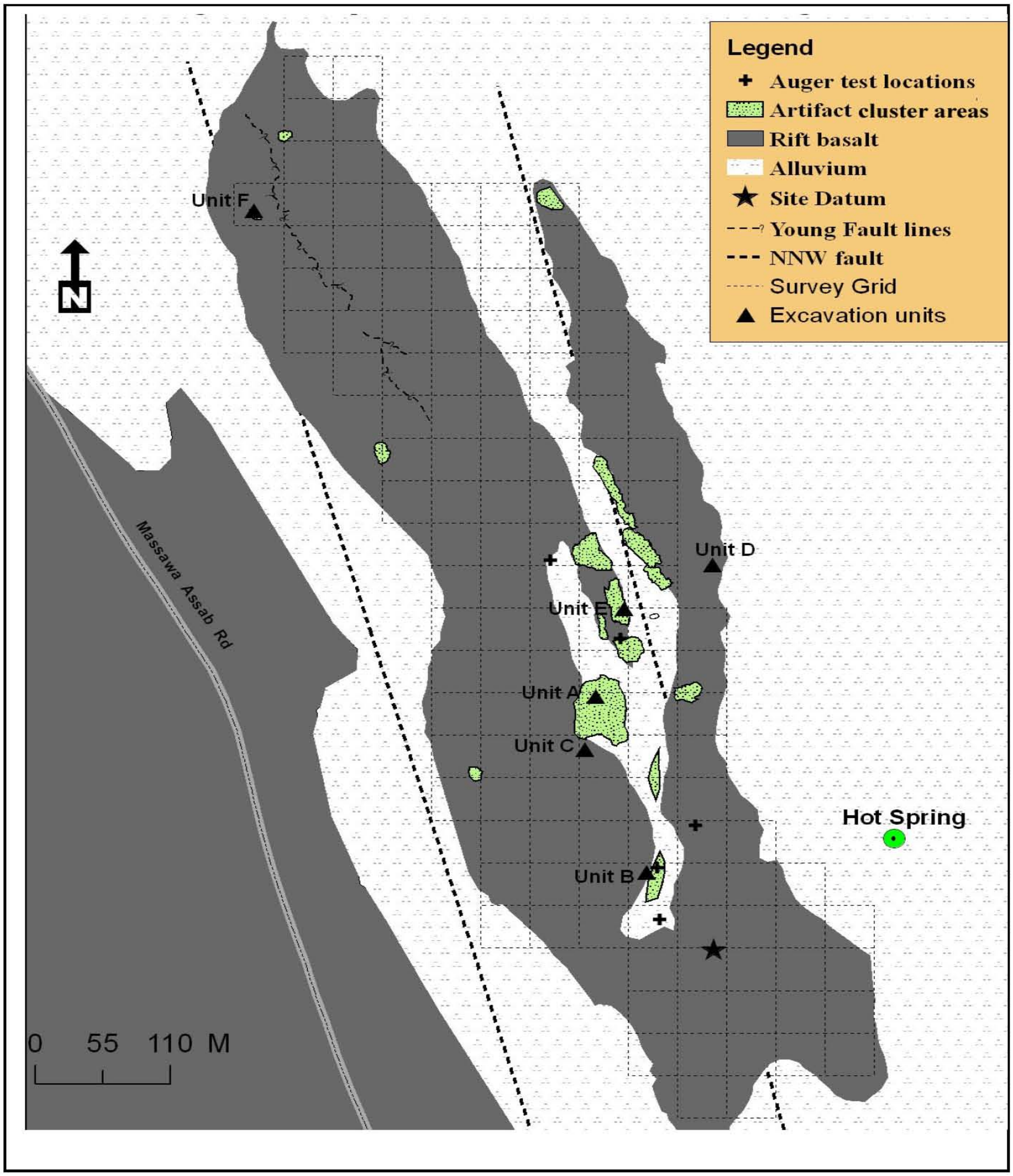


Figure 4.1. Location of Test Units excavated at the Asfet Site Complex.

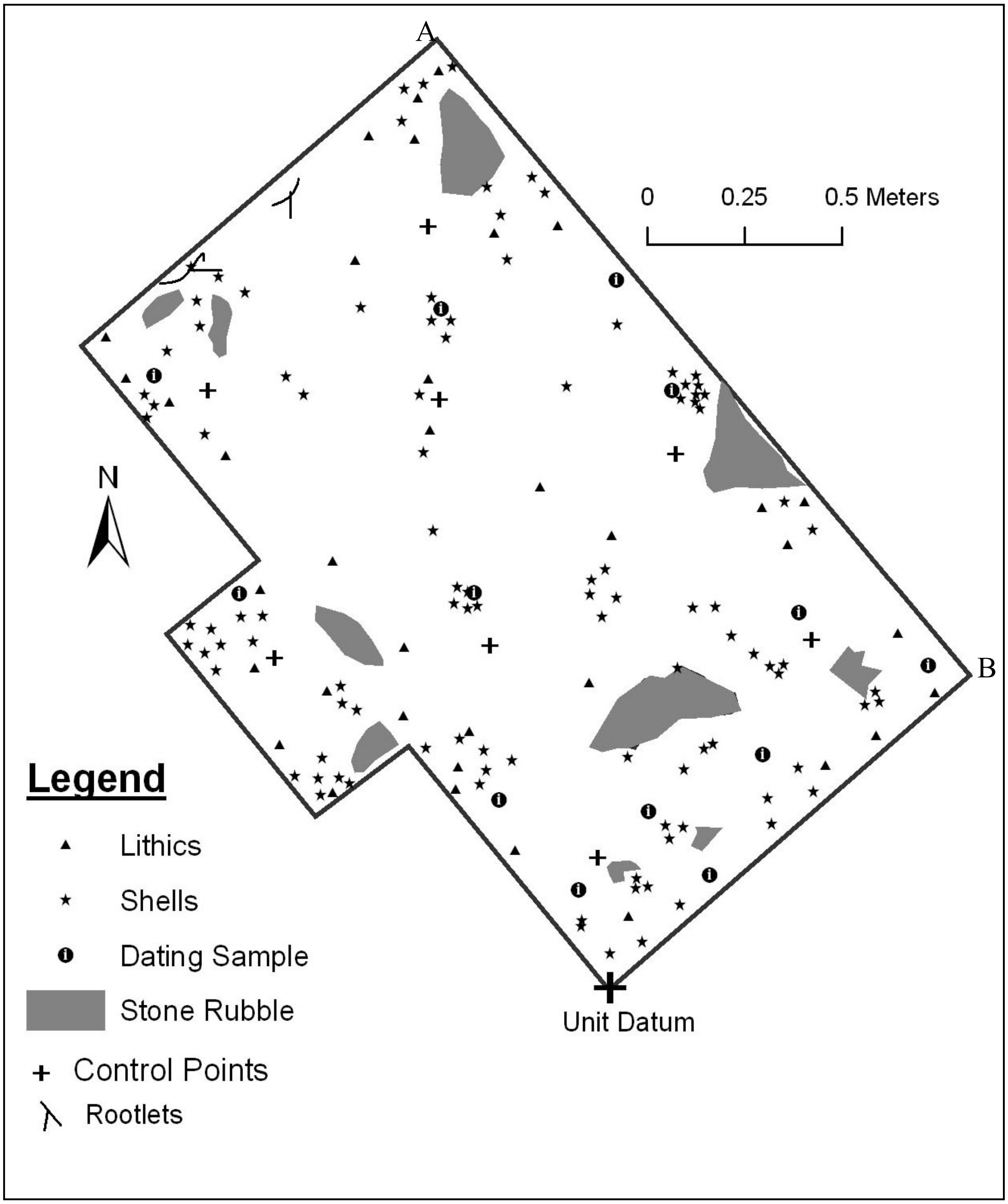


Figure 4.2. Plan view of Unit F Level1 Floor (-10 cm).

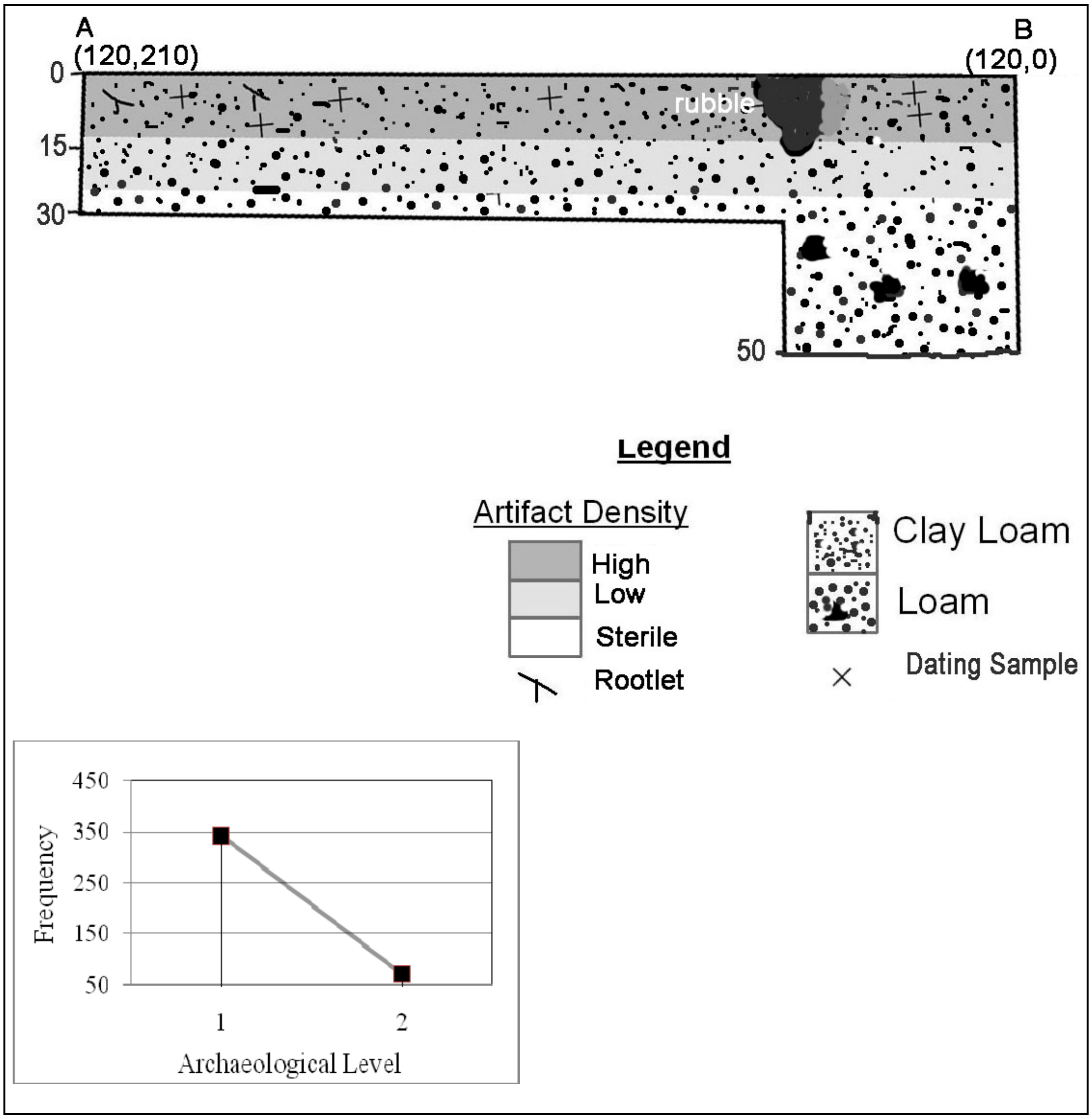


Figure 4.3. Unit F excavation section along A-B axis indicated in Figure 4.2. Lower-left insert shows artifact density in the upper archaeological levels.

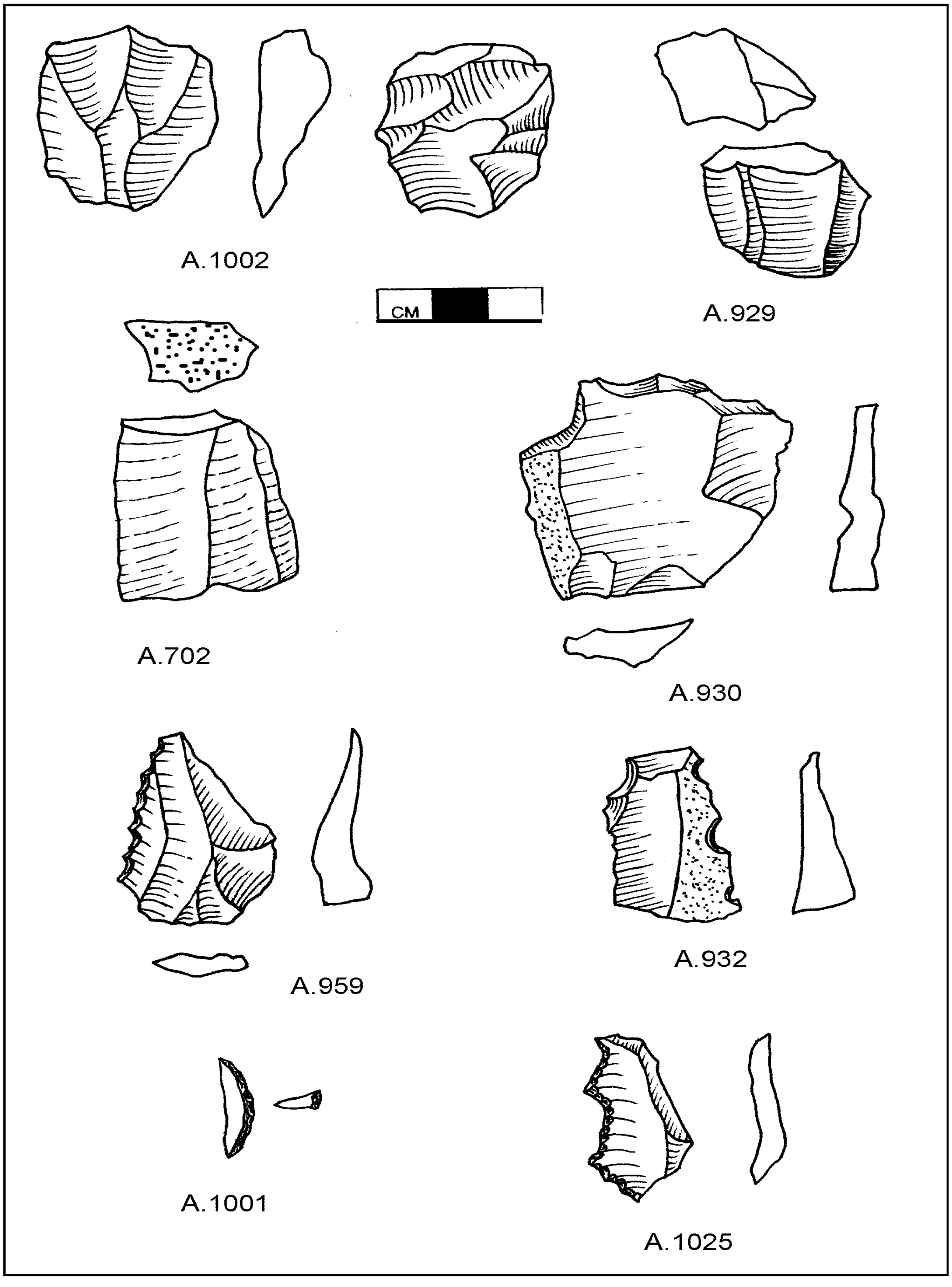


Figure 4.4. Unit F artifacts: Cores -1002 (bipolar on obsidian), 929 (prismatic on obsidian), 702 (bipolar on green schist). A. 930, 959, 932, 1001 and 1025-Various tools all on obsidian.

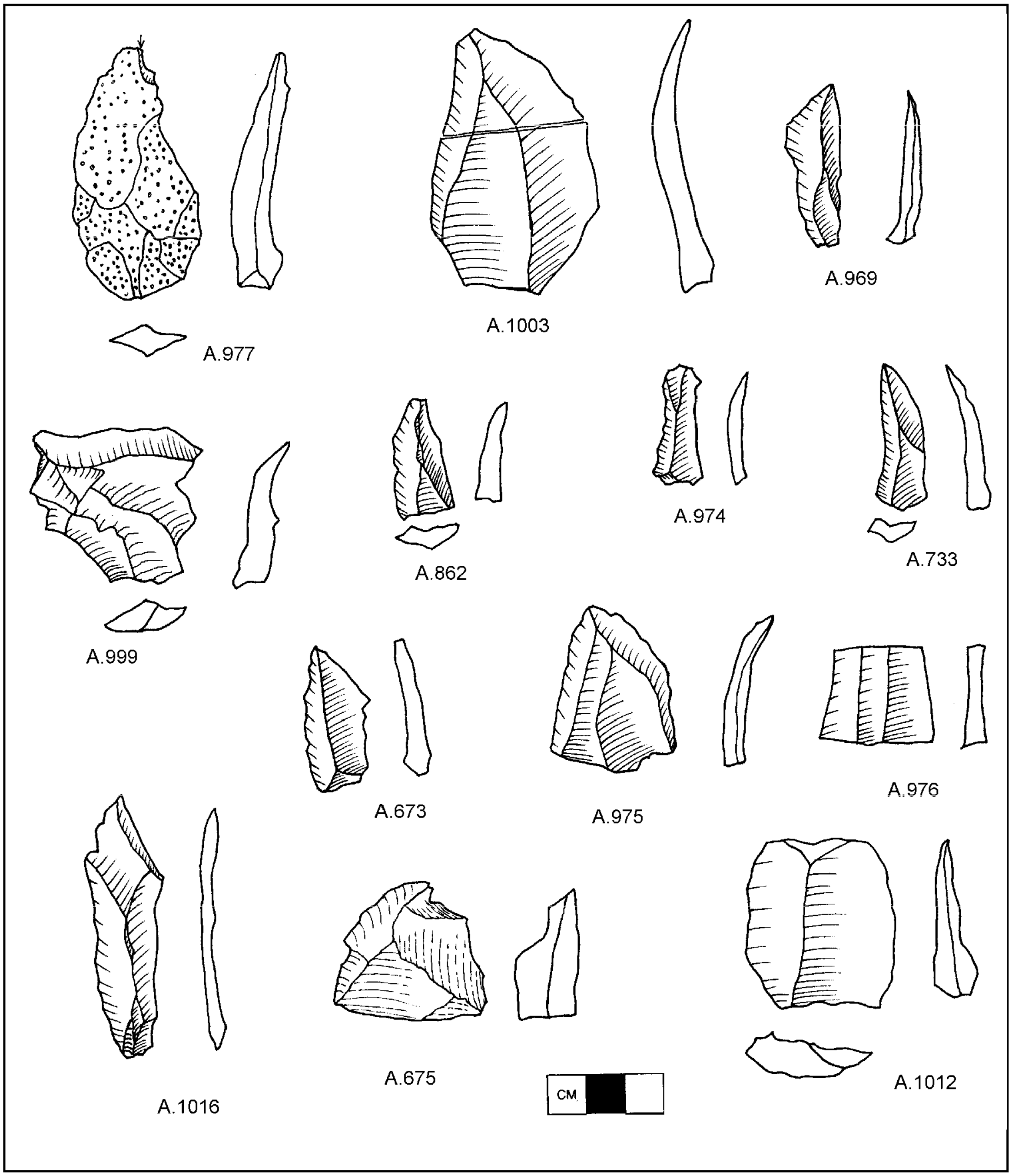


Figure 4.5. Unit F Complete flakes and fragments all on obsidian except A.999 (chert) and A.673 and A.675, both on quartz. Note A.1003 which is conjoined big blank from Level 2.

Lab No.	Sample Provenience	Texture %			Texture Class	PH	EC MS/CM
		Sand	Clay	Silt			
53	Level #1 Southern section 6N, 45W , depth = -7.5 cm	33.9	29.8	36.4	Clay loam	8.21	2.08
594	Level #1, NW Quadrant 40N, 27W, depth= -8 cm	23.6	28.4	48.0	Clay loam	9.26	0.31
595	Level #2 floor, depth = -25 cm	48.5	13.7	37.8	Loam	7.90	3.14
54	Southern Section, depth= -30 to -50 cm	42.4	22.7	34.9	Loam	8.24	2.78

Table 4.2. Texture, PH and EC variability at Asfet Unit F. Although no distinctive stratigraphic horizons were recognized, there is a slight increase in sediment size from top to bottom layers.

	Core Types			
Raw Materials	Prismatic	Unspecialized	Totals	%
Obsidian	1	3	4	50
Quartz	1	2	3	37
Other		1	1	13
Totals	2	6	8	
%	25	75	100	100

Table 4.3. Asfet Unit F core sample, artifact and raw material inventory.

	Mass Range (g)		
Core Types	<30	30-70	Totals
Prismatic	1	1	2
Unspecialized	6		6
Totals	7	1	8

Table 4.4. Asfet Unit F core sample, mass variability.

Core Type	Length Range (mm)		Totals
	<30	30-60	
Prismatic		2	1
Unspecialized	5	1	6
Totals	5	3	8

Table 4.5. Asfet Unit F core sample, size variability.

Statistics	Length	Width	Thickness
Mean	26	21	12
Std. Deviation	9	9	5
Minimum	17	12	6
Maximum	40	35	20
Count	8	8	8

Table 4.6. Asfet Unit F core sample, size mean summary.

	Raw Materials			
Tool Types	Basalt	Obsidian	Totals	%
Level 1	1	6	7	
Complete Backed	1	3	4	57
Backed Fragments		1	1	14
Edge Damaged		1	1	14
Perforators		1	1	14
Level 2		6	6	%
Backed Fragments		3	3	50
Other		1	1	17
Edge Damaged		1	1	17
Perforators		1	1	17
Totals	1	12	13	
%	8	92		100

Table 4.7. Asfet Unit F shaped tool sample, raw material and tool inventory.

Tool Types	Mass Range (g)				
	<1	1-5	5-10	>10	Totals
Level 1 total=n	2	4	1		7
Complete Backed	2	2			4
Backed Fragments		1			1
Edge Damaged		1			1
Perforators			1		1
Level 2 total=n	3	1	1	1	6
Backed Fragments	3				3
Other			1		1
Edge Damaged		1			1
Perforators				1	1
Totals	5	5	2	1	13

Table 4.8. Asfet Unit F shaped tool sample, mass variability.

Tool Types	Length Range (mm)			
	<20	20-40	>40	Totals
Level 1total=n	4	2	1	7
Complete Backed	3	1		4
Backed Fragments	1			1
Edge Damaged		1		1
Perforators			1	1
Level 2 total=n	3	2	1	6
Backed Fragments	3			3
Other		1		1
Edge Damaged		1		1
Perforators			1	1
Totals	7	4	2	13

Table 4.9. Asfet Unit F shaped tool sample, size variability.

Statistics	Length	Width	Thickness
Mean	25	10	3
Std. Deviation	13	7	3
Minimum	10	4	1
Maximum	60	27	10
Count	13	13	13

Table 4.10. Asfet Unit F shaped tool sample, size mean summary.

Dabitage Types	Raw Materials							%
Level 1	Basalt	Obsidian	Other	Quartz	Rhyolite	Chert	Totals	
Total=n (%)	50 (15)	204 (62)	2 (1)	66 (20)	3 (1)	2 (1)	327 (100)	%
Fully Cortical Flakes	3	1		1			5	2
Partially Cortical Flakes	9	1		3			13	4
Non-cortical Flakes	9	45		27			81	25
Prismatic Blades		18		2	1		21	6
Other Flake types	6	6		2			14	4
Proximal Fragments	4	17		4		1	26	8
Other Fragments	19	116	2	27	2	1	167	51
Level 2								
Total=n (%)	11 (17)	41 (65)	-	11 (17)	-	-	63 (100)	%
Non-cortical Flakes	5	11		4			20	32
Prismatic Blades	1	2					3	5
Partially Cortical Flakes	1			1			2	3
Other Fake types	1						1	2
Proximal Fragments	2	2		2			6	10
Other Fragments	1	26		4			31	49
Totals	61	245	1	77	3	2	390	100

Table 4.11. Asfet Unit F debitage sample, raw material and artifact inventory.

Dabitage Types	Mass Range (g) <1	1-5	5-10	>10	Totals
Level 1					
Total=n (%)	50 (15)	223 (68)	36 (11)	18 (6)	327 (100)
Fully Cortical Flakes		2	1	2	5
Non-cortical Flakes	10	57	11	3	81
Other Flake types		11	1	2	14
Other Fragments	33	108	17	9	167
Partially Cortical Flakes		8	3	2	13
Prismatic Blades	3	15	3		21
Proximal Fragments	4	22			26
Level 2					
Total=n (%)	3 (5)	50 (79)	6 (9)	4 (6)	63 (100)
Non-cortical Flakes	1	14	2	3	20
Other Flake types		1			1
Other Fragments	1	26	3	1	31
Partially Cortical Flakes		2			2
Prismatic Blades		3			3
Proximal Fragments	1	4	1		6
Totals	53	273	42	22	390

Table 4.12. Asfet Unit F debitage sample, mass variability.

Dabitage Types	Length Range (mm) <20	20-40	>40	Totals
Level 1				
Total=n (%)	210 (64)	105 (32)	11 (3)	327 (100)
Fully Cortical Flakes	2		3	5
Non-cortical Flakes	54	27		81
Other Flake types	5	8	1	14
Other Fragments	111	52	4	167
Partially Cortical Flakes	9	4		13
Prismatic Blades	4	14	3	21
Proximal Fragments	26			26
Level 2				
Total=n (%)	41 (65)	21 (33)	1 (2)	63 (100)
Non-cortical Flakes	11	8	1	20
Other Flake types	1			1
Other Fragments	21	10		31
Partially Cortical Flakes	2			2
Prismatic Blades		3		3
Proximal Fragments	6			6
Totals	252	126	12	390

Table 4.13. Asfet Unit F debitage sample, size variability.

Statistics	Length	Width	Thickness	SP Width	SP Thickness
Mean	21	15	4	12	4
Std. Deviation	10	7	2	6	2
Minimum	1	4	1	3	0
Maximum	62	39	13	26	11
Count	145	145	145	145	145

Table 4.14. Asfet Unit F debitage sample, size mean summary (SP =Striking Platform).

Attributes	Length	Width	MP Thickness	SP Width	SP Thickness
Length	1				
Width	0.5**	1.0			
MP Thickness	0.4**	0.6**	1.0		
SP Width	0.3**	0.7**	0.5**	1.0	
SP Thickness	0.3**	0.5**	0.7**	0.7**	1

**correlation is significant at the 0.01 level (2-tailed), P<0.00.

Table 4.15. Asfet Unit F complete debitage sample, bivariate correlation of size attributes (SP =Striking Platform).

Chapter 5
The Site of Gelalo NW: Excavation, Chronology and Archaeology

Introduction

This chapter describes the landscape setting, excavation activities, chronology and lithic findings of the Gelalo NW site. The subsurface potential of the site had been established through auger test during the Spring 2006 field season, while site excavations resumed in Fall 2006. Three test units (A, B, C) were excavated in areas of high surface density of lithic remains. The excavations produced a high density of lithics and a modest quantity of shell remains in close association. The chapter focuses on results of lithic techno-typological examination. The result of shell analysis by Dr. Daniella E. Bar-Yosef of Haifa University is presented in Appendix I.

Site setting

The Gelalo NW study area is situated on top of a cone shaped basalt ridge in the Buri Peninsula, about 15 km from the current coastline (Fig. 5.1-2). The Massawa- Assab road leading to Gelalo is to the east of the site. The top of the ridge is about 2280 sq m in area and 65 m asl. It is covered with Neogene basalt flow (Aden series). The substrate on the ridge-top is relatively stable, except on the western margin where sandy sediments are eroding into a saddle shaped depression separating the site from another adjacent ridge on the west (Fig. 5.1). The main site ranges about 665 sq m restricted to the western section of the ridge-top. About 1000 m north of the site are a series of basalt hills ranging 60-70 m asl providing the only vertical relief. Otherwise, extensive low relief alluvium fields dominate the site surroundings. The volcanic ridges appear mostly suitable for prehistoric human habitation, particularly during dry periods. Different forms of massive basalt blocks are eroding from the basalt hills to the alluvium fields. As has been noticed with the Asfet geology, amygdule filled fine grain and scoriacious flows characterize the basalt rocks at Gelalo NW.

The bulk of lithic and shell remains are found on the western section of the ridge top. The site was first discovered during the reconnaissance survey in May 2005 and fieldwork resumed for three weeks in fall 2006. The latter phase involved surface collection and excavation. More time was invested in excavation than survey because the extent of the site and surface distribution was easily discerned.

Survey and Surface Collection

Site survey at Gelalo NW involved GPS-assisted foot survey on the ridge periphery. The site datum was located on the southwestern edge of the ridge top on a stable basalt rock. The boundary of the site was delineated along the ridge margins with minimal artifact distribution. Randomly scattered obsidian artifacts were commonly encountered on the eastern section of the ridge, but they appear to be in secondary context, most likely eroded from the western edge. Two collection grids (2 x 4 m each) were placed on the northwestern edge of the main site (Fig. 5.2). The grids were placed on high density areas. Grid 1 was located towards the northern periphery of the main site. It contained dense surface artifacts on a relatively stable surface (Fig. 5.3). Grid 2 was placed on the western margin of the ridge to rescue the dense artifacts observed on a collapsing substrate. The material on Grid 2 seems to have been brought by wind movement from the center of the site. Over 1200 artifacts (lithics and shell remains) were mapped and collected from both grids.

Circular stone features were noted on top and around the base of the main ridge. According to the local legend of the Afar tribe, these rubble domes mark places where people were violently killed. The bodies were said to be buried in different locations.

Description of the Excavated Units

Unit A (1x1m)

This unit is located on the northern edge of the main concentration area, south of collection Grid 1 (Fig. 5.2). Auger Test 1, which was exposed in the previous season, is to the southwestern corner of the pit. The unit was placed on a flat surface with dense artifact concentration. The surface is covered with unconsolidated basalt scree and battered gravel. The unit was excavated 50 cm below the surface using 10 cm depth intervals. The archaeological layer extends 25 cm below surface with artifact density gradually decreasing. The unit turned sterile below this level.

Level 1. This level covers the upper 10 cm layer from which abundant shell and lithic artifacts were recovered. The substrate is moderately compact, loamy in texture and pale-brown in color. There is no bedding, but rather pseudo-paleosol formation. Three isolated clusters of lithic and shell remains were exposed between -6 and -8 cm at the southeastern quadrant of Level 1. These density spots may represent a dumping episode or accumulation by wind movement. They do not reveal technologically distinct artifact pattern. The southern section of the trench produced higher artifact concentrations relative to the other corners. Several large shell fragments and obsidian flakes (ranging up to 5.5 cm) were recovered from the southern corner at mid-section of the level. Two small ostrich shell beads (about 9 mm maximum diameter) were recovered during screening in sediments that came from about -7 cm on the central section of the unit. The substrate on the bottom layer of the level was less compacted. It was loamy and rich in plagioclase grains. A shell sample from the lower section of the level (-10 cm) has been dated to 8099 - 8364 (1-sigma) years Cal BP (Table 5.1). The shell beads mentioned above were found slightly above the dated layer. A total of 1382 lithic remains were recovered from this level alone.

Level 2. Artifact concentration steadily declined in Level 2. Some clusters of shell and lithic association were exposed on the upper layer of this level. Around the mid-section of the level, we noted moderate association of lithic and shell cluster on the western side. A similar cluster occurred in Level 1 at the same position. The density of shells and lithic artifacts decreased sharply from below the middle section of Level 2 (-15 cm). The soil continued to be loamy and rich in plagioclase grains. A thin scatter of obsidian flakes was encountered at the bottom of the level, around -20 cm. Generally, Level 2 produced fewer lithic and shell remains than Level 1, and their concentration declined sharply below 15 cm. The NW section produced most of the archaeological remains in this level**,** comprising 278 lithics and several shells.

Level 3. Excavation started on the southwestern corner, and a few scattered obsidian flakes were noted from the upper most layers on this section. The other sides remained sterile all the way down to the end of this level. At about -23 cm, the substrate on the northern and western sides turned into loose, dark-brown silty deposit. No distinctive archaeological occurrence was correlated with this change in the soil matrix. The dark brown deposit was 7 cm thick strip, below which the soil turned to light-yellow plagioclase rich loam. One isolated shell fragment was encountered at -25 cm in this layer. The pit turned completely sterile below the dark brown level. Excavation continued for another 30 cm, but it remained largely sterile throughout the lower two levels. This level produced about 36 lithic artifacts.

Unit B (1x1 m)

Unit B was opened on the southern section of the artifact-rich top area. The southeast corner of the unit encompassed Auger test 1 opened in the previous season. The auger test produced artifacts up to -25 cm. Based on this evidence an excavation unit was set up in the vicinity of the Auger test. The surface featured scattered obsidian flakes, mainly around the southwestern corner of the unit. The unit was excavated for four levels and produced artifacts up to -25 cm.

Level 1. The upper layer of Unit B featured a modest concentration of lithic and shell remains, but it was much less compared to Unit A Level 1. The shell distribution was particularly sparse. The southern section of the level shows greater artifact concentration. The obsidian flakes were slightly larger than Unit A finds. A quartz hammerstone, with noticeable pits on one edge was recovered from the upper layer. Another dense lithic scatter was exposed towards the lower section of the level on the NW corner that extended down for about 3 cm. A shell sample from this corner (-8 cm) produced a date of 7195 - 7514 (1-sigma) years Cal BP (Table 5.1). A diagnostic denticulate tool in association with a few large flakes was recovered from the lower part of the level on the SW corner, at about the same level as the dated shell sample. Two basalt rocks were exposed on the western and southern sides covering much of the excavation space. This level produced a total of 984 lithic remains.

Level 2. Scattered lithic remains were exposed on the upper deposit of this level. A shell bead-fragment similar to that uncovered from Unit-A Level 1 was collected from the upper section of the level. Several shell fragments and obsidian flakes were recovered from the mid-section (-14 cm) of the SW corner. The concentration of lithics and shells declined from the middle of Level 2 downward. Scattered artifacts were noted towards the bottom layer of the level. The basalt rocks exposed in Level 1 stretched further down and took up nearly one third of the floor. No indication of fire or any anthropogenic marks were observed on the surface of the rocks. This level yielded 349 lithic remains.

Levels 3 & 4. Artifact traces came to a complete end in the upper layer of Level 3. The substrate in this level turned slightly coarser and less compacted. A few highly scattered lithic remains were recovered. The unit turned completely sterile in the middle of Level 3. The basalt rubble exposed in Level 2 covered more than 75% of the floor. The loose substrate in the central area graded to pale-brown coarse loam. The last archaeological level produced 42 lithic remains. Excavation resumed to Level 4 (-40 cm), but there were no archaeological traces from the last two levels.

Unit C (1 x1m)

A third unit, Unit C was excavated around a high density area between Units A and B. The unit was excavated 5 levels (-50 cm) in a step excavation. For the upper

10 cm the unit was excavated from all corners before it was dividing into southern and northern sections. The substrate was composed of silty-loam sediments; pale-brown in color. The deposit graded to coarser and was less compacted at the bottom.

Level 1. The upper layer of Unit C produced large quantities of shell and lithic remains. One sample from the lower section (-9 cm) of this level produced a date of 8018 - 8407 (1-sigma) years Cal BP (using a conventional method). Two shell bead fragments were recovered from screen-matrix, one from the upper section of the level and another about 6 cm below it. A shell-cluster area featuring a few lithic remains was exposed on the southern corner of the pit. The southeastern corner produced relatively higher density of archaeological remains compared to the other sections in this level. Some randomly distributed shell remains were uncovered from the eastern side on Level 1 floor. This level concluded with rich evidence of lithics (n=1087) and a modes quantity of shell remains in close association. The lithic remains include mainly debitage, but microliths (crescent and segments) were also recovered.

Level 2. At this level, the unit was divided into two equal sections: the northern and southern trenches. The rationale for this strategy was to make thorough investigation of the soil matrix by focusing on one small space at a time. The northern section was the focus of the initial excavation. A step trench was exposed afterwards. The distribution of artifacts on the upper layer of Level 2 followed the pattern in Level 1. Scatters of shells and obsidian tools were recovered from all corners. A small bead similar to those recovered from Units A and B was collected from screen soil. The soil between -13 and -21 cm turned sandy-loam in texture and light gray in color. The concentration of artifacts declined slightly towards the lower section of Level 2 in the northern trench. Subsequent excavation of the southern trench showed a similar artifact distribution pattern to the upper layer of the northern trench. Three cluster areas featuring obsidian tools and a scatter of big shell pieces were exposed on the upper layers of Level 2 in the southern trench. Two of the cluster areas were restricted to -14 cm and one -12 cm respectively. About 35 obsidian artifacts were collected from one of the clusters. From the SW corner of Level 2 (at -14 cm) two circular beads were recovered 30 cm apart. They both resemble those previously collected. A piece of mollusk shell sampled *in situ* from the shell cluster area (-14 cm) produced an AMS date of 7643 - 7710 (1-sigma) years Cal BP (Table 5.1). The area around the bead find-spots was thoroughly inspected to look for additional evidence, but only a scattered association of shells and debitage was noted. Artifact and shell densities declined from the middle section (-15 cm) of the level downward on the southern sector. The bottom layer of Level 2 produced a small quantity of artifacts. The substrate in this section turned slightly coarser, incorporating plagioclase grains and basalt rubbles. Overall, both the southern and northern sectors yielded rich archaeological evidence in Level 2, but less dense compared to Level 1. A total of 721 lithic remains were recovered from this level. This level produced the highest concentration of artifacts compared to the second level in Units A and B.

Level 3 and below. Level 3 was exposed in two phases, whereas the northern section has directly followed Level 2 northern-trench, the southern trench was excavated later after exposing the last level of the northern sector. The northern trench was excavated to -50 cm and the southern one to -30 cm. Except for a few obsidian flakes and fragments, artifact concentration decreased sharply below middle section of Level 3. The southern trench that produced several artifact clusters in the previous levels became almost sterile at about -25 cm. From the lower NW corner of Level 5 (-48 cm), two isolated obsidian flakes were uncovered a few centimeters apart. No additional archaeological traces were encountered below the finding spots of the two flakes. Gravel and unconsolidated coarse-loam dominate the lower substrate of Level 3 through Level 5. Only 7 flakes were recovered from this layer.

In all the exposed units at Gelalo NW, the archaeological levels were limited to the upper 25 cm deposit. The artifact-bearing substrate is soft, poorly consolidated loam, lacking any stratigraphic configuration. For this, it was not possible to determine any episodic sedimentation events corresponding to the archaeological formation. The sterile layers beneath those cultural levels tend to be coarse sandy-loam, rich in plagioclase grains and gravel. The absence of artifact remains below 25 cm in the majority of the excavated units at Gelalo NW is consistent with the pattern at Asfet Unit F (chapter 4) and with that of Misse East (Chapter 6). The cultural layers are shallow in all the investigated units so far. It is worth noting here that all the sites are located on hill-tops where deflation is high, hindering soil sedimentation process. A swift wind movement over the hill slops constantly removes fine and loose sediments. The lack of discrete stratigraphic layers and the relatively thin nature of the archaeological deposits reflect arid environments. Laboratory analysis of three soil samples shows higher EC value (Table 5.2). The implication of this higher EC is unclear, but it could be due to constant losing of soil moisture.

Gelalo NW Dating

As was the case with the Asfet excavation, neither charcoal nor any other organic remains were preserved, and mollusk shell was the only material suitable for ^{14}C dating. Several shell samples were collected from the respective excavated units and submitted to dating laboratories in the USA. Table 5.1 summarizes the dating results and associated methods.

i. One sample from Unit C-Level 2 (-14 cm) was submitted to Dr. Hong Wang at the University of Illinois, Urbana-Champaign for sample preparation. The sample was dated by AMS technique at the University of California-Irvine.
ii. Three samples from Units A, B, and C were submitted to the Geochron Laboratories for conventional ^{14}C dating.
iii. Three samples from Unit C were submitted to Dr. Bonnie Blackwell at Williams College for Electron Spin Resonance dating.

Due to the high discrepancy observed with the ESR dates, only ^{14}C results are considered in consolidating the age of the site. The radiocarbon dates from the three units roughly cluster between 7200 and 8400 years Cal BP (1-sigma) or 5200 to 6400 BC (1-sigma). Of all the analyzed samples, Unit C produced the oldest date (8018 - 8407 BP, 1-sigma) while the youngest date comes from Unit B (7195 - 7514 BP, 1-sigma). A shell-sample (GNW07) from Unit C Level 1 produced slightly older age than another one 5 cm below it (GNW01). Soil disturbance due to deflation or human activity may have caused this discrepancy. It is also possible that the application of two different techniques; AMS for the upper sample and conventional method for the lower one caused the noted discrepancy. At this point only the AMS date is considered in defining the date for Unit C. Generally, the three radiocarbon results from Units A, B and C firmly place the age of the site in the early mid-Holocene time span (8th millennium BP). The observed age distribution hints at sporadic occupation pattern of the area. It is not clear whether the young age from Unit B represents an occupation gap or technical anomalies with the dating processes. The archaeological levels do not show clear a diachronic change in lithic technology or stratigraphic configuration.

Sample Codes	Lab ID #	Unit Depth (cm)	Dating Method	^{14}C and ESR Dates (BP)	Calibrated Age[€] (BP)
GNW 01	A0797*	C (-14)	AMS	7345 ± 20	7643-7710 (1σ) 7611-7749 (2σ)
GNW 05	GX-32910**	A (-10)	Conventional	7890 ± 130	8099-8364 (1σ) 7953-8478 (2σ)
GNW 06	GX-32911**	B (-8)	Conventional	6970 ± 170	7195-7514 (1σ) 6982-7658 (2σ)
GNW 07	GX-32913**	C (-9)	Conventional	7900 ± 190	8018-8407 (1σ) 7826-8651 (2σ)
GNW 02	CM19[$]	C (-6.5)	ESR	7812 ± 830	
GNW 03	CM20[$]	C (-9)	ESR	6312 ± 659	
GNW 04	CM21[$]	C (-17)	ESR	5381 ± 490	

Table 5.1. Gelalo NW calibrated radiocarbon and ESR dates from shell samples. Note to Lab ID symbols: *=University of California-Irvine, **=Geochron Laboratories of Kruger Enterprise, $=Thompson Chemical Laboratory at Williams College, € = Stuiver, et al.2005 (http://calib.qub.ac.uk/calib/). Radiocarbon dates are ^{13}C corrected.

Shell Beads

Six complete and two small fragments of circular beads were recovered from excavation at Gelalo NW (Fig. 5.5). They all appear to be made of ostrich egg-shells. Another interesting group of finds were four modified mollusk shells, identified during shell analysis by Dr. Bar-Yosef Mayer. They all exhibit intentionally perforated parts on the mid-section. Table 5.3 summarizes the context and major attributes of the shell beads. Shell beads have commonly been found in association with LSA assemblages in the Horn of Africa (Brandt 1982; Clark 1954). This demonstrates strong cultural connections among the Horn of African communities, possibly through trade interactions.

Gelalo NW Lithic Assemblage

The three excavated units produced lithic assemblages in varying quantities (Table 5.4). Lithic artifacts were recovered in higher density from the upper 10 cm in each unit. Although there is a slight difference in the dates, the lithic materials from each unit do not show any major techno-typological differences. For this reason, the excavated lithic assemblages from the three units were treated together in this analysis. The assemblages from Gelalo NW and Misse East were analyzed at Stony Brook University and in somewhat greater detail than for Asfet.

Cores

Cores were the least abundant group (n=58) of the excavated assemblage from the three units (Table 5.5). Unit A yielded a total of 30 cores, of which 77 % (n=23) came from Level 1 alone. Level 2 produced the remaining seven cores (23%). No cores were recovered from the lower levels. Prismatic and bipolar cores dominate the core class constituting 23% and 20% respectively. More than two parallel-running flake scars and usually one striking platform surface distinguish the prismatic cores, whereas the bipolar types exhibit step terminating, short *ad hoc* scars from opposite platforms. Anvil impact marks commonly occur along the platform edges on the bipolar pieces. Core fragments, cores-on-flakes and core tools are present in small proportions. Several miscellaneous pieces such as cores lacking any diagnostic features are treated as a separate class and represented 30% of the core sample in Level 1. The specialized cores (prismatic/laminar and bipolar) display some variation in form and size. A notable pattern in the present sample is that a large proportion of the cores (53%) weigh less than 10 g. Bipolar cores, core fragments and miscellaneous types account for much of the low mass range (Table 5.6). Five out of the six bipolar cores and all of the core fragments weigh below 10 g. In contrast, three out of the seven prismatic cores weigh above 20 g and the rest three between 10 and 20 g. About 73% of the cores from Unit A fall within the size range of 20-30 mm (Table 5.7). All of the bipolar pieces and five prismatic cores measure between 20 and 30 mm. The nature of cores recovered from the upper and lower levels is similar, except the decrease in number towards the lower layers.

Unit B produced fewer cores compared to Unit A, with a total of 18 specimens from the three levels (Table 5.5). Level 2 Unit B yielded greater number of cores (n=9) compared to the other two levels (Level 1, n= 6; Level 3, n =3). The prismatic/laminar group is the most dominant in this excavation unit (39%). Bipolar and core-on-flakes make up 28% together. As indicated above, elongated parallel-running flake scars and a single striking platform surface distinguish the prismatic cores, whereas opposing scars and crushed edges along the periphery of the platform characterize the bipolar types. A few miscellaneous pieces and core fragments were identified, mainly from Level 2. A large proportion of the cores (50%) weigh less than 10 g. Thirty-three percent of this group are bipolar cores (Table 5.6). The majority of the prismatic cores fall between 10-20 g. This is consistent with the pattern in Unit A. In metric aspects, all of the bipolar pieces and 67% of the prismatic cores measure between 20 and 30 mm (Table 5.7). A few prismatic pieces are longer than 30 mm. Overall, the typological and metric variability seen in Unit B core class is consistent with that of Unit A.

Cores constitute a small proportion of the lithic assemblage from Unit C (n=10). Level 1 produced four and Level 2 six artifacts (Table 5.5). Unit C exhibits a large quantity of debitage, but few shaped tools and cores. Prismatic and bipolar cores are the dominant types constituting 40% each (Table 5.5). All of the bipolar cores weigh less than 10 g and range 20-30 mm in size (Tables 5.6-7). Prismatic specimens show slight variability in mass and size with two specimens weighing below 10 g and falling below 20 mm in size. The remaining two pieces weigh between 10 and 20 g and measure greater than 30 mm in size.

The number of flake scars preserved on core surfaces and the directionality of flake removals were recorded to assess the nature of core treatment. Quantifying flake scars enables one to assess the intensity of flake removal and level of curation. Likewise, scar orientation is intended to explore flake removal strategy, such as whether the core was struck from one platform or multiple platforms. In the investigated sample, the majority of cores (59%) contain four to seven scars (only scars greater than 15 mm were counted). In general, cores with greater number of scars appear to correlate with bidirectional and multidirectional removal patterns (Table 5.8). This suggests that the more the core is reduced the removal direction can shift from one orientation to another. A high proportion of the cores contains less than 33% cortical surface, implying that cores were highly reduced prior to discard (Table 5.9). Descriptive statistics for metric variables for cores are presented in Table 5.10.

Shaped tools

Shaped tools are the second abundant group recovered from excavation at Gelalo NW Site. A total of 242 tools comprising eight major types were identified (Table 5.11). The major types include straight backed blades, backed fragments (segments), burins, denticulates, edge damaged, geometric microliths, notches and scrapers. Unit A yielded more shaped tools (n=107), followed by Unit B (n=73) and

Unit C (n=62). In all the test units, the majority of the shaped tools were recovered from the upper 15 cm.

Non-geometric Backed Tools (n=9). This artifact category includes backed blades and flakes lacking any geometric form (as opposed to geometric microliths that display a standard shape). Most of the tools included in this group exhibit straight backed edge, but the overall shape varies from parallel sided blade type to irregular form. Non-geometric backed tools represent 4% of the shaped class in Unit A, 3% in Unit B and 4% in Unit C (Table 5.11). Unit A produced a higher proportion of non-geometric microliths, accounting for 44% followed by Unit C (33%) and Unit B (22 %). The majority of the artifacts in this class weight below 5 g and range between 20 and 30 mm in length (Tables 5.12-13). Most of the non-geometric microliths preserve one backed margin covering 33-67 % of the lateral edge (Table 5.15).

Backed Fragments (n=33). This class comprises all incomplete backed pieces derived from geometric and non-geometric implements. They exhibit one or two snapped ends and usually one backed edge. Unit A produced 13 backed fragments (39%), and Unit B and C produced the remaining 9 (27%) and 11 (33%) respectively. Although Unit A has produced higher quantity of backed fragments, the same group in Unit C represents larger proportion (18%) with respect to the total number of shaped tools in that unit. All of the backed fragments from the three units weight below 2 g (Table 5.12). Most of the Unit A segments range below 20 mm in length, whereas those of Units B and C represent slightly longer backed fragments, up to 30 mm. In the majority of the segments, the modified edge covers 33-67% of the entire tool margin (Table 5.15).

Geometric Microlithis (n=40). Crescents (lunates) displaying plano-convex outline dominate the geometric tools. The margin opposite to the backed edge is usually straight and sharp. The highest number of geometric microliths was recovered from Unit A (n=18) followed by B (n=12) and C (n=10) (Table 5.11). Ninety percent of the geometric microliths weighs below 2 g, and 73% range between 20 and 30 mm in length (Tables 5.12-13). The scale of morphological and mass variability in the geometric class is similar among the different units. A slight distinction in size has been noted however between Unit B specimens and the other two groups. For instance, 28% of specimens from Unit A are below 20 mm in length, whereas most of Unit B specimens (92%) are above 20 mm. The average length, width and maximum thickness at the backed side range 25, 8 and 2 mm respectively (Table 5.14). Geometric microliths vary from narrow to elongated form and are usually pointed on both ends. Length to width ratio (Table 5.14) suggests that the majority of the geometric microliths were made on elongated blanks (ratio greater than 2). The maximum width usually occurs around the mid-point of the tool. The retouch design suggests that bipolar technique was used to craft the backed edge. In most cases, the backing retouch runs in opposite directions. The majority of the geometric microliths display one fully backed lateral edge. From a macroscopic observation, the tools appear in fresh condition. It seems that they were not extensively utilized.

Burins (n=20). Burins occur in similar proportion in all the excavated units (Table 5.11). Almost all of the identified burins weigh below 5 g, except two specimens from Unit A which are greater than 5 g. One noticeable pattern here is that Unit A and B artifacts seem larger in size than Unit C ones (Tables 5.12-13). Retouched edge extent varies among the different groups with nearly half of the sample preserving a modified edge covering less than 33% and the rest between 33% and 67% (Table 5.15). The modified portion in this class is expected to be restricted, because burination usually takes only small portion of the edge.

Denticulates (n=11). Unit A produced the majority of denticulates (n=6) and almost all these artifacts were recovered from the upper layers, except in Unit C where the only two artifacts from that unit came from Level 2 (Table 5.11). The serrated edges in denticulates show some variation, while some are deeply grooved other exhibit shallow and dispersed notches. The majority of denticulates fall within the range of 2-5 g and a few specimens from Unit A are below 2 g (Table 5.12). The denticulates from Unit B are greater than 30 mm in length, while most of the artifacts from Unit A and C fall within the rage of 20-30 mm (Table 5.13). The modified edge covers 33-67% of the lateral sides in the majority of the denticulate class.

Edge Damaged (n=85). This is by far the most abundant group in the shaped tool class, and the quantity varies among the excavated units. Unit A produced the largest percentage (53%) followed by Unit B (28%) (Table 5.11). This class incorporates tools with a wide range of modified edge morphology. The major tool types included in this category are flakes and fragments preserving utilized or casually modified edges (scars usually less than 2 mm). Edge damaged tools do not show any significant variation in mass when compared to other categories in the shaped tool class. The majority of edge damaged tools fall either below 2 g or between 2 and 5 g range (Table 5.12). Only one artifact from Unit A weighs over 5 g. The size of edge damaged tools from each unit shows slight variation. As can be seen in Table 5.13, 62% of Unit B tools fall in the size range of 20-30 mm, whereas only 42% of Unit A and 50 % of Unit B edge damaged tools fall in this range. Overall, the majority (49%) of edge damaged tools falls between 20 and 30 mm size range. In general, most edge damaged tools preserve a modified portion that extend less than 33% of the lateral margin, and the retouch usually occurs either along the lateral margins (42%) or slightly towards the dorsal face (38%) (Tables 5.15-16). A few artifacts preserve damage or retouch on the ventral face.

Notches (n=27). Characterized by a single concavity, notches represent 11% of the shaped tool class. Unit B yielded the majority (44 %) followed by Unit A (33%), and Unit C produced the rest 23% (Table 5.11). Due to the fact that the notching occurs along a restricted part on the lateral side/s, it has less effect on the length, but it could certainly affect the mass. A large percentage of notches weigh below 5 g, but there is notable variation in length (Tables 5.12-13). As can be seen in Table 5.13, while the majority of the denticulates fall within the size range of 20-30 mm, several notches are either greater than 30 mm or below 20 mm in length. The retouch that produced the notches was usually applied towards the dorsal face and the notched edge extends less than 33% of the total margin (Table 5.15).

Scrapers (n=17). This class represents tools exhibiting continuous retouch longer than 2 mm on either the dorsal or ventral faces. Unit C yielded the highest number of scrapers (n=7). Retouch scars are usually shallow and display scalar and shallow pattern. Scrapers vary enormously in shape. Some are on blade blanks, while others lack consistent form. There is a noticeable variation in mass, where 8/17 specimens weigh between 2 and 5 g and the rest fall either above 5 g or below 2 g mass ranges (Table 5.12). Of all the shaped tools discussed above, the greatest number of tools that weigh above 5 g occurs in the scraper class. A large percentage of scrapers fall in the length range of 20-30 mm (Table 5.13). The modified edge extends less than 33% in more than half of the scrapers and the retouched portion usually occurs on the dorsal surface. Relatively, few scrapers were recovered from Gelalo NW.

Whole flakes and flake fragments (Debitage)

Whole flakes and flake fragments form the largest group in the lithic assemblage recovered from Gelalo NW. A total of 4,583 pieces of debitage were uncovered from the three test units. Unit C produced the largest number of debitage (38%), followed by Unit A (34%) and Unit B (28%) (Table 5.17). Four types of complete flakes were identified: blades, non-cortical flakes, fully cortical flakes and partially cortical flakes. Such division was desired to examine the nature of core reduction and blank variability. Lithic analysts follow different approaches to debitage analysis depending on the nature of their research questions. Commonly, debitage is analyzed in order to : i) explore core design, ii) assess raw material economy and iii) infer prehistoric human activity (Rasic and Andrefsky 2003; Sullivan and Rozen 1985). These concepts are briefly addressed; although the main objective of debitage analysis here is to describe artifact variability. Traditionally, lithic analysts tended to classify debitage based on the scale of cortex coverage and they use cortex to discriminate between reduction stages (Odell 1989). However, such an approach faces some critiques, mainly due to lack of consistency in the scale of cortex measurement by different researchers (Sullivan and Rozen 1985). Moreover, it is unclear to what extent cortex could address technological variability or reduction stages. Assessing the validity of these arguments is beyond the scope of this research and variation in cortex coverage is used here just to infer whether nodules were transported as original blocks or in reduced form. In this regard, fully cortical debitage would signify core transportation without much prior treatment.

Blades (n=239). This class includes all flakes with length to width ratio greater than or equal to 2. The majority of debitage classified as blades exhibit either pointed or parallel lateral margins. Generally, parallel flake scars characterize the dorsal surface indicating unidirectional flake removal pattern, but a significant number also display opposing and transverse scar arrangement. Some debitage that exhibit blade geometry were excluded because they preserve irregular dorsal surface and jagged lateral margins (classified as miscellaneous flakes). Unit A yielded the highest number of blade blanks (50%), most of which came from Level 1 (Table 5.17). The occurrence of higher proportion of blades in Unit A corresponds to the abundant numbers of geometric microliths and cores recovered from the same unit. It appears that Unit A was associated with more tool preparation activities. This pattern hints differential use of space within the site frontiers. Most of the blades (74%) weigh below 2 g and the remaining 25% weigh between 2 and 5 g (Table 5.18). More than half of the blade class falls between 20 and 30 mm in size, and 24% measures over 30 mm in maximum length (Table 5.19). The average length of blades ranges 26 mm (Table 5.20). There is higher proportion of blades over 30 mm in Unit B than in the other units. This agrees with the previous observation that most of the shaped tools from Unit B are larger in size as well. As can be seen in Table 5.20, 69% of the blades display length to width ratio greater than 2 implying greatly elongated shape.

Fully Cortical Flakes (n=36). This group represents a small percentage of the debitage class (~1%) with the majority recovered from Unit A Level 1 (Table 5.17). Cortical flakes are commonly treated as primary preparation stage removals (Sullivan and Rozen 1985). Thus, greater proportion of fully cortical flakes could imply that greater numbers of cores were transported to the site as natural nodules. As noted earlier, Unit B sample comprises slightly heavier specimens. As such, specimens weighing between 2 and 5 g dominate the cortical sample in Unit B (Table 5.18). About 42% of the fully cortical flakes fall below the size range of 20 mm. Most fully cortical flakes exhibit cortical platform and convergent lateral edges (Tables 5.21-22). The low number of cortical flakes in the assemblage suggests that either a few nodules were brought to the site or cores were decorticated elsewhere prior to their transportation to the site.

Partially Cortical Flakes (n=106) and Non-Cortical Flakes (n=308). Both debitage types can be considered as a continuum of core reduction process. Such a distinction between non-cortical and partially cortical flakes is meant to assess the distribution of cortex. In the analyzed sample, Unit A produced greater number of non-cortical flakes (47%), whereas partially cortical flakes were recovered from all the units in similar proportions (Table 5.17). Although Unit C has the highest number of debitage, the majority of it is fragmentary (see below). The majority of the non-cortical flakes from Units A and B weigh below 2 g, whereas Unit C yielded slightly heavier flakes in this group. The partially cortical flakes from all the test units appear to be slightly heavier than the non-cortical ones. As such the majority (nearly 50% in each unit) fall in the weight range of 2-5 g. Unit C in particular produced heavier partially cortical flakes compared to the other units (Table 5.18). As shown in Table 5.19, non-cortical and partially cortical flakes exhibit slight difference in size. While most non-cortical flakes measure below 20 mm, a large proportion of partially cortical flakes fall between 20 and 30 mm size range. Likewise, partially cortical flakes show higher length mean than non-cortical flakes (Table 5.20). This is evident since partially cortical flakes are produced at earlier phase of the reduction process. The key implication of this pattern is that partially cortical flakes reflect original nodules that may have arrived in large size. Length to width ratio shows similar pattern in both classes. Plain and beveled platform dorsal edge morphologies are common among the debitage class. Lateral margin varies slightly between non-cortical and partially cortical specimens. While high number of non-cortical flakes exhibit either parallel or convergent margins, the majority of partially cortical flakes display curved and expanding lateral margins (Table 5.22). This implies less regulated reduction strategy when removing partially cortical flakes than when removing non-cortical ones.

Other Flakes (n=49). This class includes all miscellaneous complete flakes that lack standardized shape and even lateral edge thickness. Flakes with irregular shape and jagged edge margins characterize this group. A few core trimming flakes are included in this class.

Incomplete Fragments (n=3845). Broken fragments are by far the most dominant group in the debitage class constituting 79% of the total lithic assemblage. Proximal fragments constitute about 27% of the fragment class. Unit C produced a higher percentage of fragments, but relatively fewer complete flakes. While it is possible that post-depositional movement may have caused the apparent high density of fragments, human activity could have played a role as well. Because obsidian is a very brittle rock, breakage could easily have occurred during manufacturing process, by trampling and/or by surface movement. The high density of fragmentary debitage suggests repeated human activity in the site. The original context of the fragments may vary as aeolian movement could have gathered only the light specimens to the vicinities of the excavated spots or vice versa.

Because the platform area is the only diagnostic part that can be measured on the proximal fragments, metric measurements were recorded on a proximal sample from Unit A and compared with the complete class. Student's t-test of mean difference (Table 5.24) shows that there is no significant difference in platform width means between the complete and proximal sample ($t=0.4$, $p<0.3$). This implies that the majority of proximal fragments represent broken parts of complete flakes as a result of accidental breakage by trampling or human use.

Debitage attributes recorded for the complete flake class include striking platform dorsal morphology, mid-point cross section, striking platform surface morphology, lateral margin and termination pattern (Tables 5.21-23). Striking platform dorsal edge morphology has been recorded in the debitage class in order to assess the extent of core preparation (Holdaway and Stern 2004). Most blades and non-cortical flakes preserve preparatory removals on the dorsal margin of the proximal end, dominantly beveled and facetted scars suggesting regular trimming of the core margin before knocking of the potential blank (Table 5.21). Beveled scar pattern on the flake dorsal margin is considered to be a result of bipolar core reduction (ibid.). This suggests that bipolar technique was commonly used to reduce small cores. Comparison of lateral margin morphology shows that about 47% of blades display parallel margin and 37% convergent (Table 5.22). Moreover, mid-point cross section has been recorded for the complete flaks in order to assess the distribution of mass at the mid-point section of the flakes. In general, the majority of the debitage class displays symmetrical cross section (Table 5.23), meaning that the thickest part occurs around the mid-section of the flakes. A large percentage of the complete flakes preserve feathered termination and plain striking platform, except blade blanks which show higher percentage of crushed proximal ends.

Surface collection

Table 5.25 presents the inventory and mass range of lithics and shell remains collected from the two adjacent collection grids on the northwestern side of the site. A total of 1264 lithic artifacts and 121 shell fragments were collected from the grids. The distribution pattern on the surface ranges 90 artifacts per m^2. The surface material has not been subjected to thorough analysis due to lack of secured context and presence of extensive post-depositional breakage on the artifacts. Fresh and discontinuous damages were noted on almost every artifact which made it difficult to differential intentional human modification from those accidentally accumulated damage signs. This is particularly a problem because the entire assemblage is on obsidian which is brittle rock and surface movement by wind can easily break the tool margins. Hence, metric measurement and typological classification cannot be reliable on the surface assemblage. As can be seen from the inventory table, more artifacts were recovered from Grid 1 than Grid 2. Moreover, the total mass of Grid 1 assemblage is slightly higher than that of Grid 2 which is not surprising because there is greater number of artifacts in Grid 1 (Table 5.25). Fragments dominate the surface collection in both grids. In Grid 1, the percentage of complete flakes is slightly greater than proximal fragments. In contrast, the proportion of proximal fragments to complete flakes is higher in Grid 2 (32% to 26%). Higher quantities of shaped tools were recovered from Grid 1 compared to Grid 2. Overall, the surface assemblage in the site appears to be in secondary context. Wind is the principal disturbing agent for artifact context on the ridge top. This is particularly true because the site is located on top of a high relief where wind energy can easily move artifacts.

Summary of Gelalo NW Findings

The site of Gelalo NW offered the first evidence of human settlement on the Buri Peninsula by the 8th millennium BP. Before this discovery, Stone Age sites dating to early Holocene time period were only known from the interior of the Horn of Africa (Brandt 1986; Finneran 2007). Lithic artifacts were the major findings from the site, both from surface and subsurface contexts. The lithic analysis has focused on the excavated assemblage only because the surface material was collected from an unstable context, and is highly modified by post-depositional processes. The entire assemblage is on obsidian, which is locally available within 10 to 15 km distance. Generally, the lithic assemblage displays little variability among the excavated units. Prismatic core reduction and microlithic production were the major features. The predominance of prismatic blade cores and the corresponding higher percentage of blade debitage suggest that blade technology was the principal mode of reduction. The micolithic class encompasses geometric and no-geometric forms. Lunates (crescents) dominate the geometric class. Edge damaged tools are present in large percentages. The occurrence of microliths and prismatic cores suggest a Later Stone Age cultural affinity.

The large percentage of edge damaged elements in the lithic sample suggests that trampling and surface movement has transformed the artifact morphologies. During the analysis, distinguishing accidental edge damage from those produced by intentional human activity was problematical, unless the retouch was fresh; in which case it implies recent breakage by trampling or mechanical weathering. An experimental study (McBrearty, et al. 1998) has shown that on a hard substrate, artifact trampling would produce edge damage that resemble intentional retouch. The cited study identified notches and denticulate-looking tools to be commonly produced from trampling activities on a hard substrate. The Gelalo NW site is indeed on a hard volcanic substrate. Because the material is entirely on highly brittle raw material, it is possible that trampling and surface movement of artifacts produced the notches and edge damages observed on the tools.

The presence of fewer cores but a large quantity of debitage suggests that cores were vital for the dwellers that they may have taken them to other settlements when they abandoned the site. Alternatively, it could imply that mostly blanks were transported to the site. The core data is inconclusive about the nature (size) of the original nodules being transported to the site. The debitage metric data was applied to assess the size of the original core arrived at the site. It is argued here that the maximum size score noted in the debitage or the tool class could give one a rough estimation of the size of the original core. The assumption is that at least one, if not several flakes from the entire assemblage have traversed parallel to the longest axis of the core representing the longest dimension of the core. This means that, in an assemblage where debitage preservation is high, at least one flake should provide a size score closer to the longest axis of the core. This is likely true if we have abundant prismatic cores on high quality raw materials, such as obsidian; because there is less obstruction to the force of propagation given the cryptocrystalline nature of the rock. An experimental study by Rasic and Andresky (2003) shows that blade cores produce blanks that have closer length range as the cores themselves. Obviously, this assumption needs to be tested through more experimental and refitting studies. By looking at the mean length of the debitage class (Table 5.19) most of the cores reduced at Gelalo NW seem to have an optimal size between 20 and 30 mm. This is because a large percentage of the debitage class falls in this size range. The highest size scores in the debitage and tool classes range about 55 mm. Based on this score, we can approximate the size of the largest nodules brought to the site in the range of 55-60 mm. By this standard, the tool makers at Gelalo NW do not seem to have transported large nodules to the site.

The discovery of marine mollusks in association with lithics reflects human use of the shells for food. Some perforated specimens (Fig. 5.5) were identified among the mollusk shells implying human use of mollusk shells for symbolic purposes as well. The shell assemblage is fragmentary and no sign of burning has been noted. The site is located about 15 km from the present coast line. The occurrence of shells on the hill-top, distant location from the seashore signifies the importance of shellfish to human subsistence. This might have entailed what anthropologists refer to as collectors mode of mobility pattern (Binford 1980). Collectors mobility strategy involves bringing resources to residential camps which are usually positioned near a stable primary dietary source (Binford 1978). According to this model, foragers usually shift to broad-spectrum, low-rank resources upon the decline of stable resources. No other fauna other than mollusk shells were recovered from the site, but from the location of the site further inland, it is highly the case that the Gelalo NW site was primarily selected for terrestrial resource exploitation. It is possible that humans were exploiting marine mollusk when terrestrial resources were scarce, on seasonal basis. Remains of terrestrial fauna have not been recovered from the site. This could be due to excavation or preservation biases. The location of the site on a steeply rolling hill-top makes it less convenient for rapid sedimentation due to swift wind movement. The discovery of abundant lithic artifacts (especially microliths) suggests human hunting activity. Otherwise, it is less likely the case that all the stone tools were desired for mollusk exploitation. The presence of shell remains hints at intermittent human visits to the coast. The people who lived at Gelalo NW may have been exploiting shellfish and other coastal resources whose remains are not preserved.

Water is a scarce resource in the lava strewn-barren fields near Gelalo. There is no major drainage in the area today except the ephemeral floodplan to the west (near Bordeli), and the Buri Lake to the north, which is a temporary reservoir of brackish water. Ceramics and other water carrying devices must have been needed for water transportation, but their remains have not been discovered yet. The attractiveness of the site may lie in its strategic location to monitor game movement. The vast flatland of the Peninsula is home to various medium size wild game (gazelle, hare), ostrich and wild ass. These animals can be hunted in group or on a solitary pursuit, specifically near water sources such as the Buri Lake and along the floodplains to the west of the site. Moreover, the site may have provided protection from intensive sandstorms during dry periods.

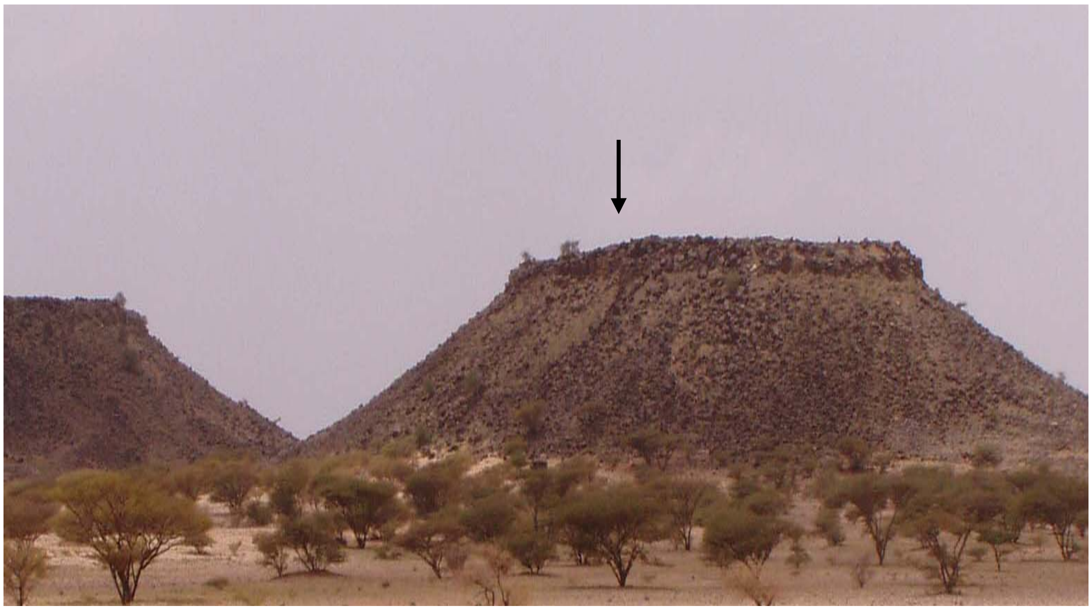


Figure 5.1. Gelalo NW site on top of a steep basalt ridge (south view).

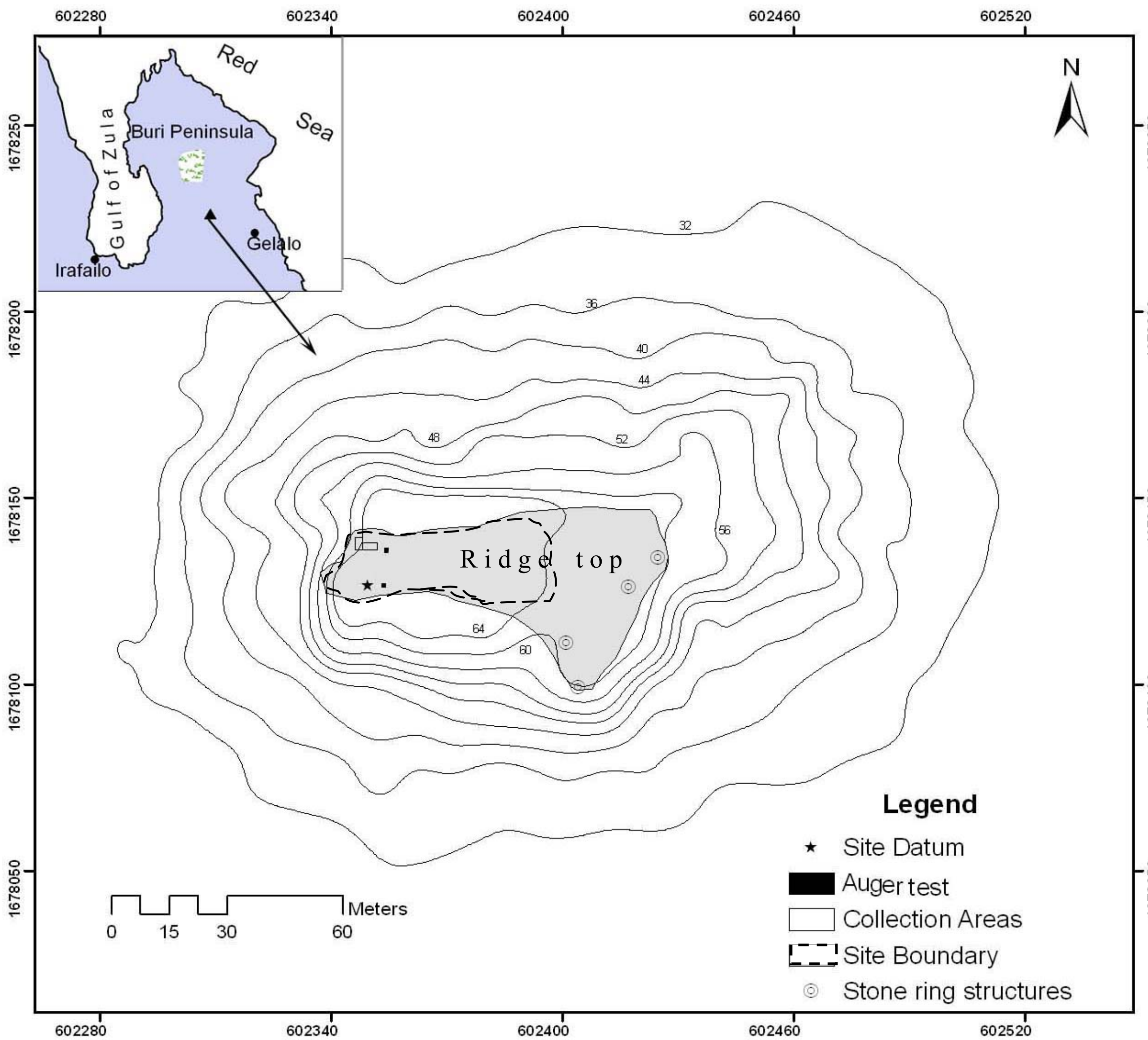


Figure 5.2. Map of Gelalo NW Site showing excavation units and auger test-pits.

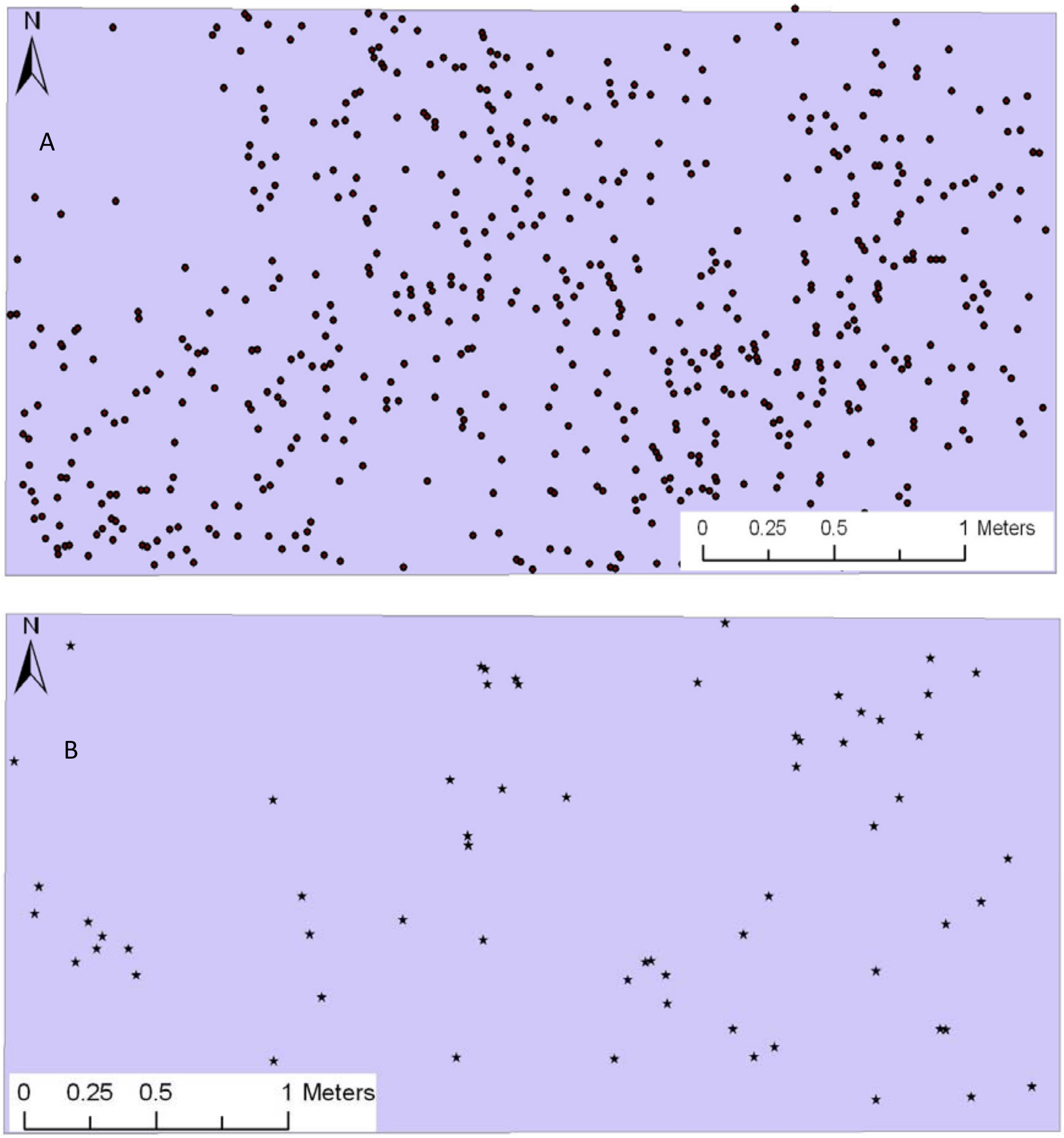


Figure 5.3. Artifact distribution in Collection Grid 1, Gelalo NW site: A) Lithic remains, B) Shell remains. Note the high surface density of lithic artifacts.

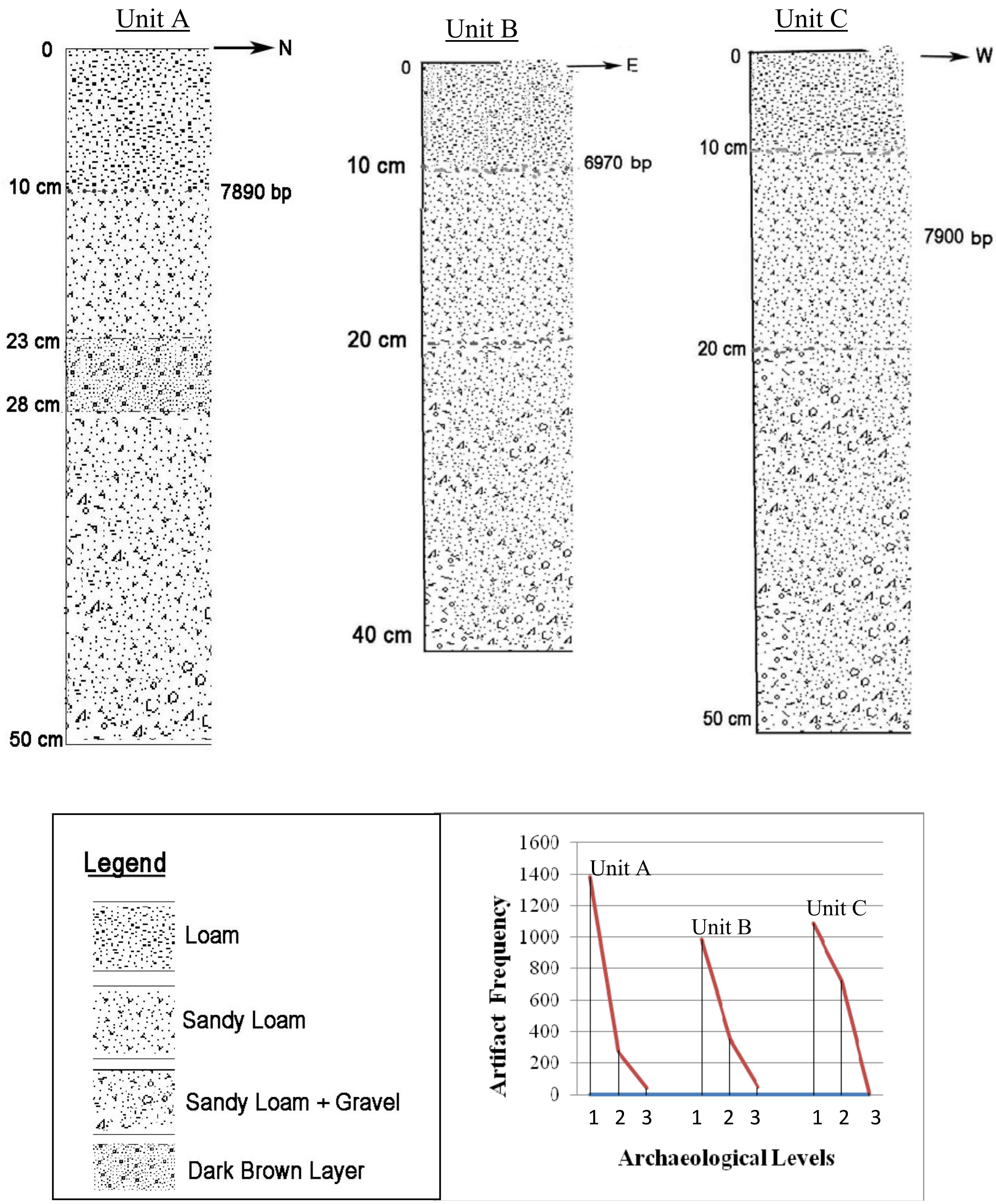


Figure 5.4. Lithostratigraphy and selected ^{14}C dates for the excavated units at Gelalo NW site. Lower right insert depicts artifact distribution by excavation levels.

a)

b)

Figure 5.5. Beads recovered from Gelalo NW Site: a) ostrich eggshell, b) perforated mollusk shells.

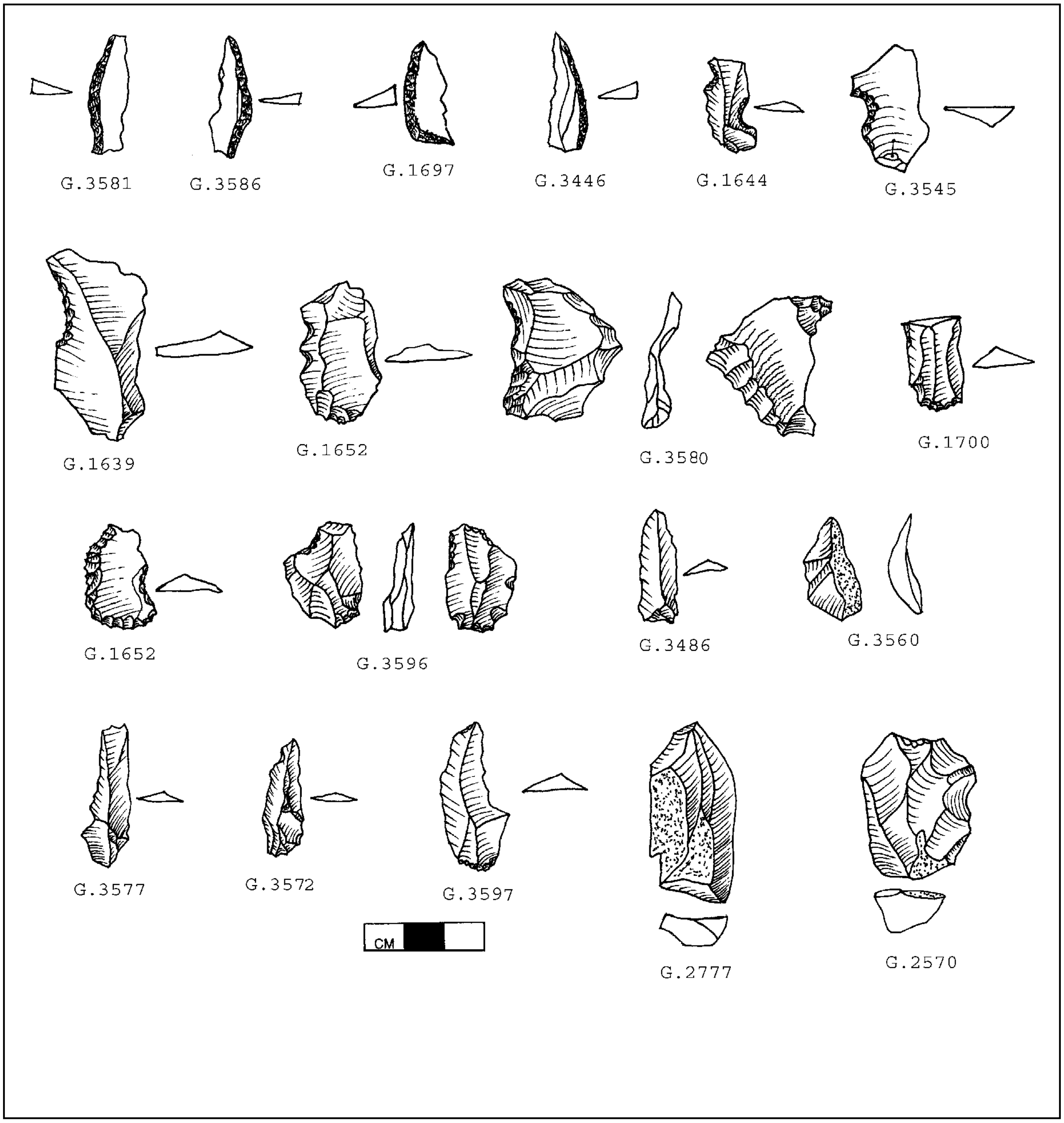


Figure 5.6. Surface lithic findings from Gelalo NW: Backed tools (3581, 3586, 1697, 3446), Notches (1644, 3545, 1639), Denticulate (1652), Scrapers (3580, 1700, 1652), edge damaged tool (3596), Blades/bladelets(3560, 3577, 3572, 3592), Cores (2777, 2570). The alphabet (G) stands for Gelalo.

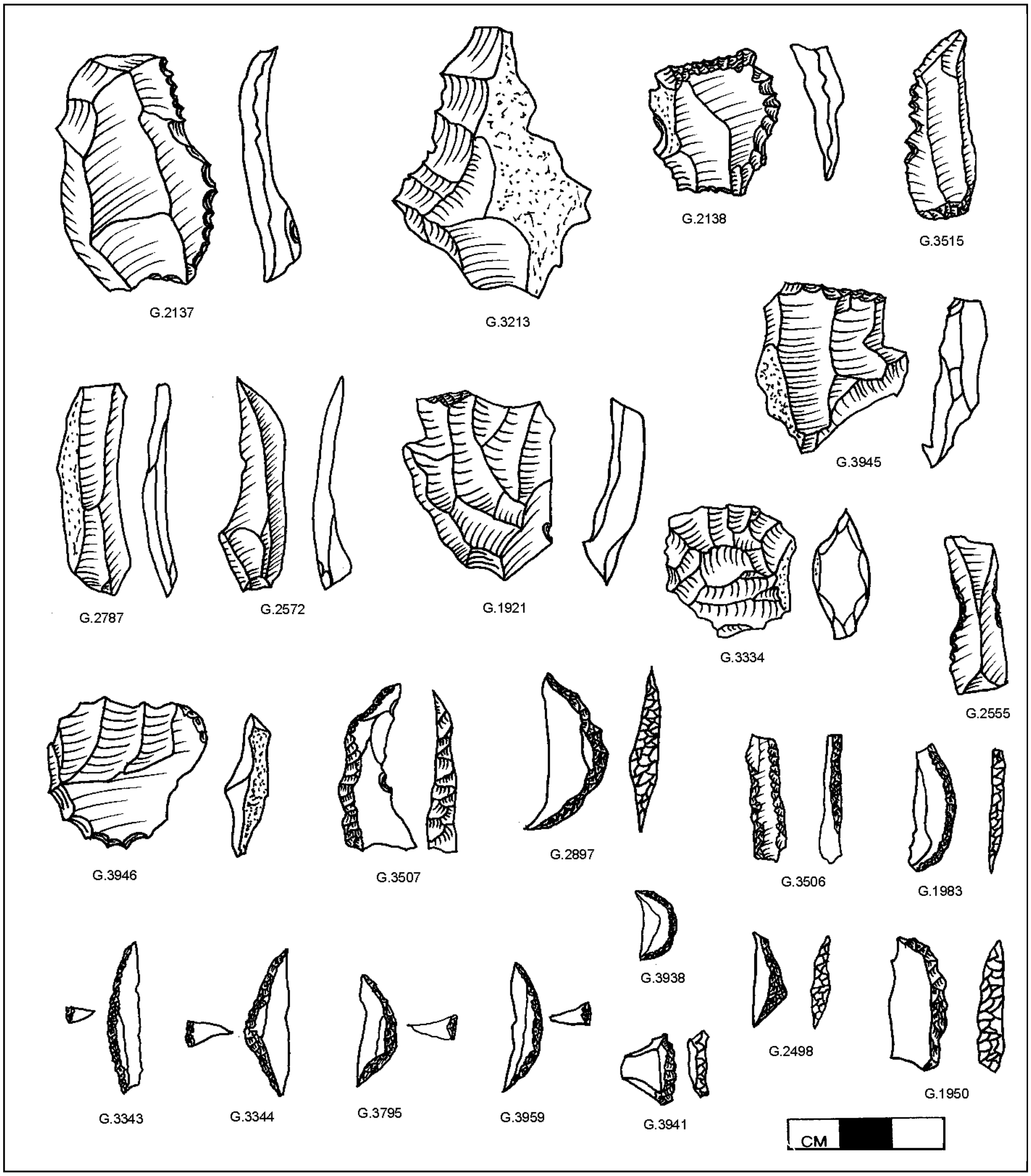


Figure 5.7. Excavated lithic artifacts from Gelalo NW: Scrapers (G.2137, 3213, 2138), Denticulate (G.3515), Cores (G.3945, 1921, 3334, 3946), Blades (G.2787, 2572), Edge damaged (G.2555), Backed tools (G.3507, 2897, 3506, 1983, 3938, 2498, 1950, 3343, 3344, 3795, 3959, 3941).

Lab No.	Sample Provenience	Texture %			Texture Class	PH	EC MS/ CM
		Sand	Clay	Silt			
51	Unit A (-8 cm)	42	22	36	Loam	7.84	7.31
49	Unit A (-25 cm)	64	14	22	Sandy loam	7 .55	16.93
596	Auger Test#1 (30-38 cm)	67	15	18	Sandy Loam	8.5	0.82

Table 5.2. Gelalo NW sediment analysis results: texture, PH and EC variability in Unit A and Auger Test1 sediments. Although no distinctive stratigraphic horizons were discerned, there is a slight increase in sediment size from the upper to the lower layer in Unit A.

Catalogue #	Specimen	Unit	Level	Provenience	Depth (cm)	Max. Body Diameter (mm)	Max. hole Diameter (mm)	Max. Thickness (mm)	Mass (g)	Source
G.1	Complete	A	1	Screen		9	2	1	<1	OES
G.2	Complete	A	1	Screen		5	2	<1	<1	OES
G.3	Fractured	A	2	*In Situ*	-13	16	4		<1	MS
G.4	Complete	B	2	Screen		6	1.5	<1	<1	OES
G.5	Half Disc	C	1	Screen					<1	OES
G.6	Half Disc	C	1	Screen					<1	OES
G.7	Complete	C	2	Screen		5	1.5	<1	<1	OES
G.8	Complete	C	2	*In Situ*	-14	9.5	3	1.8	<1	OES
G.9	Complete	C	2	*In Situ*	-14	□□3	3	1.5	<1	OES
G.10	Complete	C	2	*In Situ*	15	15	6	8	1	MS
G.11	complete	C	2	*In Situ*	15	13	4	8	1	MS
G.12	Complete	C	2	*In Situ*	15	12	3	7	<1	MS
G.13	Complete	C	2	*In Situ*	15	9	1	5	<1	MS

Table 5.3. Context and major attribute of shell beads recovered from Gelalo NW. Key to Source: OES= Ostrich Egg-Shell, MS= Mollusk Shell.

Tool Classes	Count	Mass (g)
Unit A		
Cores	30	326
Shaped Tools	107	175
Complete Debitage	322	599
Proximal Fragments	310	331
Other Fragments	927	733
Totals	1696	2164
Unit B		
Cores	18	191
Shaped Tools	73	127
Complete Debitage	211	353
Proximal Fragments	310	332
Other Fragments	761	760
Totals	1373	1763
Unit C		
Cores	10	81
Shaped Tools	62	99
Complete Debitage	206	489
Proximal Fragments	431	540
Other Fragments	1106	898
Totals	1815	2107

Table 5.4. Inventory of excavated lithic assemblage from Gelalo NW site.

Excavation Unit	Excavation Level	Core Types							
		Bipolar	Core Fragments	Core on Flakes	Core Tools	Discoids	Others	Prismatic/Laminar	Totals
A	1	4	3	1	2	1	7	5	23
	2	2		1			2	2	7
A Total									
n		6	3	2	2	1	9	7	30
%		20	10	7	7	3	30	23	
B	1	1		1				3	5
	2	1	1		1	1	2	3	9
	3	1					1	1	3
	Surface			1					1
B Total									
n		3	1	2	1	1	3	7	18
%		17	5	11	5	6	17	39	
C	1	1						1	2
	2	2					1	3	6
	Surface	1					1		2
C Total									
n		4					2	4	10
%		40					20	40	
Totals		13	4	4	3	2	14	18	58

Table 5.5. Gelalo NW excavated core sample, core inventory by excavation level and unit.

Excavation Unit	Mass Range (g)	Core Types							
		Bipolar	Core Fragments	Core on Flakes	Core Tools	Discoids	Others	Prismatic/Laminar	Totals
A	<10	5	3	1			6	1	16
	10-20	1			1	1	3	3	9
	>20			1	1			3	5
A Total		6	3	2	2	1	9	7	30
B	<10	3	1	1	1		2	1	9
	10-20			1		1	1	4	7
	>20							2	2
B Total		3	1	2	1	1	3	7	18
C	<10	4					1	2	7
	10-20							2	2
	>20						1		1
C Total		4					2	4	10
Totals		13	4	4	3	2	14	18	58

Table 5.6. Gelalo NW excavated core sample, mass variability by excavation unit.

Excavation Unit	Length Range (mm)	Core Types							Totals
		Bipolar	Core Fragments	Core on Flakes	Core Tools	Discoids	Others	Prismatic/Laminar	
A	<20		1				2		3
	20-30	6	2	1	1		7	5	22
	>30			1	1	1		2	5
A Total		6	3	2	2	1	9	7	30
B	<20		1				1		2
	20-30	3		1	1	1	2	4	12
	>30			1				3	4
B Total		3	1	2	1	1	3	7	18
C	<20							2	2
	20-30	4					1		5
	>30						1	2	3
C Total		4					2	4	10
Totals		13	4	4	3	2	14	18	58

Table 5.7. Gelalo NW excavated core sample, length variability.

Number of Flake Scars	Flake Removal Pattern	Core Types							Totals
		Bipolar	Core Fragments	Core on Flakes	Core Tools	Discoids	Others	Prismatic/Laminar	
1-3	Bidirectional	2						1	3
	Multidirectional						2		2
	Unidirectional	1	1	4			2	3	11
1-3 Scar Total		3	1	4			4	4	16
4-7	Bidirectional	8					3	2	13
	Multidirectional	1	3		2		3	2	11
	Unidirectional				1		1	8	10
4-7 scar Total		9	3		3		7	12	34
>7	Bidirectional						1	1	2
	Multidirectional	拠				2	1	1	5
	Unidirectional						1		1
>7 Scar Total		1				2	3	2	8
Totals		13	4	4	3	2	14	18	58

Table 5.8. Gelalo NW excavated core sample, flake removal pattern.

Excavation Unit	Cortex Scale	Core Types							Totals
		Bipolar	Core Fragments	Core on Flakes	Core Tools	Discoids	Others	Prismatic/Laminar	
A	>67%			1				1	2
	0-33%	6	3	1	2	1	7	6	26
	33-67%						2		2
A Total		6	3	2	2	1	9	7	30
B	>67%						1		1
	0-33%	2	1	1			2	6	12
	33-67%	1		1	1	1		1	5
B Total		3	1	2	1	1	3	7	18
C	>67%						1	1	2
	0-33%	4					1	3	8
C Total		4					2	4	10
Totals		13	4	4	3	2	14	18	58

Table 5.9. Gelalo NW excavated core sample, cortex variability by excavation unit.

Statistics	Length (mm)	Width (mm)	Thickness (mm)
Mean	26	22	11
Std. Deviation	7	7	5
Minimum	13	10	3
Maximum	46	39	24
Count	58	58	58

Table 5.10. Gelalo NW excavated core sample, summary of size means.

Excavation Unit	Level	Tool Types									
		Backed Blade/Flakes	Backed Fragments	Burins	Denticulates	Edges Damaged	Geometric Microliths	Notches	Scrapers	Totals	%
A	1	3	10	6	6	37	15	7	3	87	81
	2	1	3	1		8	3	2	2	20	19
A Total = n		4	13	7	6	45	18	9	5	107	
%		4	12	6	6	42	17	8	5		100
B	1	2	7	5	3	21	5	9	4	56	77
	2		2	1		3	7	3	1	17	23
B Total = n		2	9	6	3	24	12	12	5	73	
%		3	13	8	4	33	16	16	7		100
C	1	2	7	5		11	5	5	6	41	66
	2	1	4	2	2	5	5	1	1	21	34
C Total = n		3	11	7	2	16	10	6	7	62	
%		5	18	11	3	26	16	10	11		100
Totals		9	33	20	11	85	40	27	17	242	

Table 5.11. Gelalo NW, inventory of tool sample by excavation unit and level.

Excavation Unit	Mass Range (g)	Tool Types								Totals	%
		Backed Blade/Flakes	Backed Fragments	Burins	Denticulates	Edges Damaged	Geometric Microliths	Notches	Scrapers		
A	<2	2	13	1	3	24	17	4	1	65	59
	>5			2	1	1			2	6	6
	2-5	2		4	2	20	2	5	2	37	35
A Total		4	13	7	6	45	19	9	5	108	100
B	<2	1	9	3		9	9	7	2	40	56
	>5						1	1		2	3
	2-5	1		3	3	15	1	4	3	30	41
B Total		2	9	6	3	24	11	12	5	72	100
C	<2	3	11	5		6	10	2	2	39	63
	>5								2	2	3
	2-5			2	2	10		4	3	21	34
C Total		3	11	7	2	16	10	6	7	62	100
Totals		9	33	20	11	85	40	27	17	242	

Table 5.12. Gelalo NW excavated tool sample, mass variability.

Excavation Unit	Length Range (mm)	Tool Types									
		Backed Blade/Flakes	Backed Fragments	Burins	Denticulates	Edges Damaged	Geometric Microliths	Notches	Scrapers	Totals	%
A	<20	0	11			12	6	2	2	33	31
	>30			4	2	14	1	3	1	25	23
	20-30	3	2	3	4	19	12	4	2	49	46
A Total		3	13	7	6	45	19	9	5	107	100
B	<20	1	2			4	1	3		11	15
	>30	1		3	3	5	3	2	1	18	25
	20-30	1	7	3		15	7	7	4	43	60
B Total		3	9	6	3	24	11	12	5	73	100
C	<20		5	1	1	4	1		2	14	23
	>30				1	4		3	2	10	16
	20-30	3	6	6		8	9	3	3	38	61
C Total		3	11	7	2	16	10	6	7	62	100
Totals		9	33	20	11	85	40	27	17	242	

Table 5.13. Gelalo NW excavated tool sample, size variability.

Statistics	Length	Width	Max. Backed edge Thickness	Length to Width Ratio	
Mean	25	8	2	Range	Count
Std. Deviation	6	2	1	1-2	9
Minimum	6	5	0	2-4	25
Maximum	37	14	4	>4	6
Count	40	40	40		

Table 5.14. Gelalo NW, size means for complete geometric microliths.

Tool Types	Retouched Edge Extent			
	<33%	>67%	33-67%	Totals
Backed blade/Flakes	5		4	9
Backed Fragments	2	1	30	33
Burins	9	2	9	20
Denticulates	4	1	6	11
Edges damaged	42	7	36	85
Geometric Microliths	4	1	35	40
Notches	25		2	27
Scrapers	9		8	17
Totals	100	12	130	242

Table 5.15. Gelalo NW excavated tool sample, retouched edge extent variability.

Tool Types	Retouch Position Dorsal	Ventral	Alternating	Edge Margin	Totals
Backed blanks				9	9
Backed Fragments				33	33
Burins	1		1	18	20
Denticulates	6		1	4	11
Edges damaged	29	8	13	35	85
Geometric Microliths	1			39	40
Notches	13	9		5	27
Scrapers	13		2	2	17
Totals					
n	63	17	17	145	242
%	26	7	7	60	100

Table 5.16. Gelalo NW excavated tool sample, retouch position variability.

Excavation Unit	Level	Blades	Fully Cortical Flakes	Non Cortical Flakes	Others	Partially Cortical Flakes	Proximal Fragments	Other Fragments	Totals	%
A	1	96	13	136	6	28	258	734	1271	82
	2	24	3	9	3	3	52	157	251	16
	3							36	36	2
A Total=n %		120 8	16 1	145 9	9 1	31 2	310 20	927 59	1558	 100
B	1	55	8	59	13	18	228	541	922	72
	2	17	3	11		18	72	201	322	25
	3	4		3	2		10	19	38	3
B Total=n %		76 6	11 1	73 6	15 1	36 3	310 24	761 59	1282	 100
C	1	24	6	51	16	26	284	635	1042	60
	2	19	3	39	9	13	144	467	694	39
	3						3	4	7	1
C Total=n %		43 2	9 1	90 5	25 1	39 2	431 25	1106 64	1743	 100
Totals		239	36	308	49	106	1051	2794	4583	

Table 5.17. Gelalo NW excavated debitage sample, tool inventory by unit and level.

Excavation Unit	Mass Range (g)	Blades	Fully Cortical Flakes	Non Cortical Flakes	Others Flakes	Partially Cortical Flakes	Totals	%
A	<2	91	4	90	2	13	200	62
	2-5	27	7	50	5	12	101	31
	>5	2	5	5	2	6	20	7
A Total		120	16	145	9	31	321	100
B	<2	56	4	52	8	15	135	64
	2-5	19	6	20	6	16	67	32
	>5	1	1	1	1	5	9	4
B Total		76	11	73	15	36	211	100
C	<2	29	2	46	13	10	100	49
	2-5	14	5	40	8	23	90	43
	>5		2	4	4	6	16	8
C Total		43	9	90	25	39	206	100
Totals		239	36	308	49	106	738	

Table 5.18. Gelalo NW excavated debitage sample, mass variability.

Excavation Unit	Length Range (mm)	Blades	Fully Cortical Flakes	Non Cortical Flakes	Others	Partially Cortical Flakes	Totals	%
A	<20	29	8	65	2	11	115	36
	20-30	65	4	65	2	12	148	46
	>30	26	4	15	5	8	58	18
A Total		120	16	145	9	31	321	100
B	<20	13	4	45	4	9	75	35
	20-30	47	4	26	6	22	105	50
	>30	16	3	2	5	5	31	15
B Total		76	11	73	15	36	211	100
C	<20	6	3	46	6	9	70	34
	20-30	22	4	39	14	23	102	50
	>30	15	2	5	5	7	34	16
C Total		43	9	90	25	39	206	100
Totals		239	36	308	49	106	738	

Table 5.19. Gelalo NW excavated debitage sample, size variability.

Tool Types	Length: Width Ratio				Length Mean	Totals
	<1	1-2	2-3	>3		
Blades	3	6	166	64	26	239
Fully Cortical Flakes	9	21	6		24	36
Non Cortical Flakes	36	253	19		20	308
Other		5	36	8	28	49
Partially Cortical Flakes	7	88	9	2	24	106
Totals	55	373	236	74		738

Table 5.20. Gelalo NW excavated debitage sample, length: mid-Point width ratio.

Tool Types	Striking Platform Dorsal Edge Morphology			
	Crushed/ Beveled	Facetted	Plain/ Cortical	Totals
Blades	91	49	99	239
Fully Cortical Flakes	4		32	36
Non Cortical Flakes	111	61	136	308
Other Flakes	10	12	27	49
Partially Cortical Flakes	21	17	68	106
Totals	237	139	362	738

Table 5.21. Gelalo NW excavated debitage sample, striking platform dorsal edge variability.

	Lateral Margin Morphology				
Tool Types	Convergent	Curved	Expanding	Parallel	Totals
Blades	88	27	11	113	239
Fully Cortical Flakes	13	11	9	3	36
Non Cortical Flakes	83	73	65	87	308
Other Flakes	23	8	5	13	49
Partially Cortical Flakes	20	38	23	25	106
Total	227	157	113	241	738

Table 5.22. Gelalo NW excavated debitage sample, lateral margin variability.

	Mid-point Cross Section			
Tool Types	Skewing left	Skewing right	Symmetrical	Count
Blades	11	16	212	239
Fully Cortical Flakes	1		35	36
Non-Cortical Flakes	14	19	275	308
Other Flakes	9	5	35	49
Partially Cortical Flakes	11	13	82	106
Grand Total	46	53	639	738

Table 5.23. Gelalo NW excavated debitage sample, mid-point cross section variability.

	Complete Flakes	Proximal Fragments
	Platform width	Platform width
Mean	7.7	7.8
t Stat	-0.4	
P(T<=t) one-tail	0.3	
Observations	652	238
	Platform Thickness	Platform Thickness
Mean	1.8	2.2
t Stat	-3.4	
P(T<=t) one-tail	0.0003	
Observations	652	238

Table 5.24. Gelalo NW excavated debitage sample, t-test results of platform size attributes.

Tool Classes	Grid 1		Grid 2	
	Frequency	Mass	Frequency	Mass
Shaped Tools	70	192	20	48
Complete Flakes	178	495	158	494
Proximal	132	306	195	481
Other Fragments	264	709	208	561
Cores	17	122	22	224
Lithics total	661	1824	603	1808
Shell remains	65		56	

Table 5.25. Gelalo NW inventory of lithic and shell assemblage from surface.

Chapter 6

The Sit of Misse East: Excavation, Chronology and Archaeology

Introduction

Misse East was the final excavated site of this project. This chapter reports site context, excavation activities, chronology and results of lithic analysis. Following surface survey and augur test investigations in the previous season, a 1 x 1 m unit (Unit A) was selected for excavation on a high density area. Three out of the five auger tests produced lithic and shell remains up to 30 cm deep. The excavated unit was placed south of the richest auger test-pit on the eastern side of the limestone ridge. Both the lithic and shell collections were subjected to detailed analysis at Stony Brook University. The results of shell analysis are presented in Appendix I.

Site setting and survey

The site of Misse East is located on top of a level section of a limestone ridge on the western margin of the Buri Peninsula (Figs. 6.1-2). The site is about 4 km inland from the coast overlooking the Misse River that flows into the Gulf of Zula. The landscape is rugged featuring undulating flat ridges covered by heavily weathered limestone bedrock and isolated Neogene lava flows. Scoriacious scree and fine grained boulders characterize the volcanic flows. The eastern part of the ridge top forms a steep slope descending into a narrow river channel formed by a NNW trending fault. The fault leads the eastern channel into the Misse River to the south. Scattered limestone boulders cover the ridge slopes on the eastern and southern slopes. There is a small hill on the southern periphery. The western periphery of the site is a strip of limestone that gently descends to the Misse River. Lava flows dissected by small channels characterize the lower margin of the western slope around the river banks supporting patches of acacia trees. A series of flat hills define the northern periphery of the site.

As with Gelalo NW, survey was limited to GPS-assisted pedestrian walking. The overall extent of the site has been properly discerned during the pilot fieldwork. The main site ranges 968 sq m in size confined to the southeastern edge of the ridge (Fig. 6.2). The site datum was established on the southern edge of the main ridge top. Following its initial discovery in 2005, the site was visited for a short time in Spring 2006 when an auger test was conducted on three spots to verify the subsurface potential of the site. The three pits revealed lithic artifacts and shell remains up to 30 cm below surface. The auger results affirmed the potential of the site for later investigation. Controlled surface collection and excavation resumed in Fall 2006.

Dense clusters of lithic artifacts and shell remains characterize the surface of the main site. One, 1 x 1 m collection grid was placed on the southern side of the site on a spot where high artifact density was observed. Excavation of a 1x1 m square continued at the same spot.

Description of Unit A

The surface of Misse East is covered by eroded limestone scree and unconsolidated windblown silt deposit. The site preserves a shallow deposit, but one that has rich archaeological remains, especially mollusk shells. Throughout the excavated layers, the substrate of Unit A remained clay-loam, loose in texture and dark brown in color. The position of the site on a high ridge may have contributed to the shallow nature of the sediment deposit. There is low rate of soil deposition on those high ridges due to the swift wind movement and hard bedrock surface, which promote soil erosion.

All archaeological traces were carefully removed from the immediate surface of the unit before excavation. Excavation began on the northern section of the unit. The eastern side of the unit yielded higher density of archaeological remains relative to the other sections in the upper layer. A dense cluster of lithic and shell remains was exposed on a small secluded spot at -3 cm on the southeastern corner. The shell assemblage was dominated by bivalves, and a number of them preserve complete valves, but split into respective halves. Shell samples for dating were systematically collected from the density areas. Similarly, soil samples were collected from each layer for texture analysis. Towards the end of Level 1(-9 cm), artifact density started to decline on the western side of the pit. Shell distribution was relatively homogeneous throughout the first level, especially on the eastern section. At -7 cm, a small shell cluster was exposed on the eastern side. The shell remains in the cluster area include some large specimens in addition to the small bivalves that dominate the molluskan fauna at the site. A small, highly weathered bone-looking fragment was recovered within the large shell cluster in the eastern section. Identification of the bone was not possible due to its deformed and weathered nature. A circular bead was collected from screen soil that came from the lower layer of Level 1. Artifact density started to decrease towards the lower stratum of Level 1 (-10 cm). Excavation continued to Level 2, but artifact density, especially lithic traces turned extremely low below Level 1. The soil turned slightly loamy below Level 1. The unit was excavated for two and half levels and reached sterile layer at about -20 cm. The substrate turned to complete limestone bedrock at about -25 cm. Some vesicular pockets filled with loose deposits were exposed on the northern side of the pit from where a few obsidian flakes were recovered.

Misse East Dating

As with Asfet and Gelalo NW, no other organic remains suitable for dating were recovered *in situ* except shells. Two samples were collected from Level 1, and submitted for radiocarbon dating - one to the University of California-Irvine and another to the Geochron Laboratories. The sample that was submitted to the University of Irvine (A0796) was dated using AMS, whereas a conventional method was applied to the one submitted to the Geochron Lab (GX-32914). The two samples gave an age bracket of 7485-7857 years Cal BP (1-sigma). The ages confirm a mid-8th millennium BP Holocene settlement on the eastern coast of the Gulf of Zula. Based on the close range of the dates, only one occupation phase can be recognized at Unit A. The Misse East dates closely match that of Gelalo NW Units B and C suggesting Misse East and Gelalo NW were broadly contemporaneous settlements.

Sample Code	Lab ID	Level	Dating Method	^{14}C Dates (BP)	Calibrated Age€ (BP)
Misse01	A0796*	(-6 cm)	AMS	7145± 20	7485-7545 (1σ) 7452-7564 (2σ)
Misse02	GX-32911**	(-5 cm)	Conventional	7330 ± 190	7504-7857 (1σ) 7323-8039 (2σ)

Table 6.1. Misse East calibrated radiocarbon dates from shell samples. Note to Lab ID symbols: *=University of California-Irvine, **=Geochron Laboratories of Kruger Enterprise, €= Stuiver, et al.2005 (http://calib.qub.ac.uk/calib/). Radiocarbon dates ^{13}C corrected.

Misse East Lithic Assemblage

Misse East Unit A produced a total of 739 lithic remains, all on obsidian. The upper layer of the unit, which includes the surface boundary and up to -10 cm deposit preserved the highest density of lithic and shell remains. The lithic findings from surface and the subsurface layers show strong techno-typological affinity, dominated by fragmentary debitage. For this reason, they are described together. Illustrations of representative classes are presented (Figs. 6.5-6).

Cores

A few cores (n=8), mainly prismatic type were recovered from Misse East accounting for about1% of the lithic assemblage (Table 6.2). The majority of the cores were collected from surface. Two of the bipolar forms and two specimens from the prismatic class weigh below 2 g (Table 6.3). The remaining artifacts weigh between 2 and 5 g (n=2) or more than 5 g (n=2). Size means are 33 mm for length, 22 mm for width and 12 mm for thickness (Table 6.4). The maximum length reaches 55 mm on one core scraper. The maximum core length and length of the longest scar on the core are close in dimension. The scars usually originate from the platform and run straight along the longest axis. This results in long scars that traverse the longest axis of the core. Given the high quality of raw materials used (obsidian), long flakes can be easily produced from prismatic cores. Although it is not possible to make any generalization about the core variability due to small number of the analyzed sample, the pattern suggests that cores were transported to the site in the form of small nodules. The maximum length score on the debitage class was 60 mm (see below). This indicates that the larger core nodules were approximately 60 mm (or slightly larger) in maximum length when first brought to the site. Relatively, however, the Misse East cores appear slightly larger than those from Gelalo NW.

Shaped tools

Shaped tools represent the second most abundant group in the Misse East assemblage. Although limited in number (only 54 artifacts), shaped tools display considerable variation in size and form. The dominant types in the Misse East assemblage include backed microliths (complete and segments), scrapers, and edge damaged tools (Table 6.5).

Complete Backed Tools (n=17). This class includes all complete backed tools (geometric and non-geometric backed blades). Lunates (crescents) dominate the geometric class. The non-geometric group is represented by straight backed blades and constitutes fewer specimens relative to the geometric sample (Table 7.5). The majority of the geometric forms weigh less than 2 g and measure between 20 and 30 mm (Tables 6.6-7). Size means for the backed sample are 32 mm for length, 9 mm for width and 3 mm for thickness (Table 6.8). As can be attested from the length to width ratio (Table 6.8), the majority of the backed tools exhibit true blade geometry (length to width ratio greater than two). The backed edge extends between 33 and 67%, usually along one margin (Tables 6.9-10). Although the backed tool class is represented by small sample size, it shows a distinct pattern with respect to size in that backing was selectively applied to long and narrow blanks. Those blanks offer greater cutting edge per unit of mass.

Backed Fragments (n=14). These are incomplete backed fragments that exhibit one or two snapped ends. The majority weigh less than 2 g and measure between 20-30 mm (Tables 6.6-7). Retouched edge extends between 33 and 66% mm along one margin. Some of them appear to be intentionally modified at the end for hafting purposes, but several also show snapped ends.

Scrapers (n=8) and Notches (n=3). A few notches and scrapers were identified. Side scrapers dominate the scraper class. Most of the scrapers weigh more than 5 g and measure greater than 30 mm in maximum length (Tables 6.6-7). The retouched edge extends less than 33% limited to the dorsal surface (Tables 6.9-10). Scrapers vary in shape from parallel sided blade geometry to irregular forms.

Notches preserve one or more small concavities along the edge, which appear to be formed by repeated retouch removals extending towards the dorsal surface. Due to small sample size, further characterization of the notches is skipped here. No denticulate specimens were identified in the analyzed sample.

Edge Damaged (n=8). This group comprises tools displaying small, continuous or semi-continuous scars along the edge. The edge damage on these tools vary in intensity and distribution pattern; some exhibit patterned distribution suggesting intentional modification, while others preserve randomly distributed scars along one or more edges which could be a result of trampling or use damages. Half of the edge damaged specimens weigh more than 5 g and the rest between 2 and 5 g

(Table 6.6). The majority measure greater than 30 mm and do not seem to have lost a large portion of their original size (Table 6.7). Thus, the weight and length measurements may reflect the original size of the flakes. The extent of the damage varies from a few traces along one edge (<33%) to 66% on one or two sides. Damage marks occur along the edge margins, as well as on the dorsal and ventral surfaces.

Tools that could not be classified into any of the above categories were noted as "miscellaneous." These are specimens that preserve edges obliterated by recent retouch (displaying extensive recent scar marks). There were not many of this type from Misse East Unit A (only 4). The majority were from surface and the entire sample fall in the mass range of 2-5 g (Table 6.6). The retouched edge covers 33-67%; and some of the tools exhibit bifacial retouches as well (Table 6.10).

Flakes and flake fragments (Debitage)

Flakes and flake fragments are the most abundant group in the Misse East assemblage. Non-cortical flakes and blade blanks dominate the complete flakes, while fragments are by far the most abundant class. For analytical purposes, the Misse East debitage sample was classified into three complete classes: blades, non-cortical and partially cortical and miscellaneous flakes.

<u>Blades (n=36)</u>. Blades constitute 30% of the complete flake debitage and the majority were recovered from Level 1 (Table 6.11). Twenty- one blades weigh below 2 g and 10/36 between 2 and 5 g (Table 6.12). A greater percentage of blade blanks are greater than 30 mm, with mean score of 33 mm (Table 6.13). As can be seen in Table 6.14, a greater proportion (52%) of the blade blanks is narrow or elongated in shape with length to width ratio ranging more than 3. The bulk of the prismatic blades preserve either beveled or plain proximal dorsal edge (Table 6.15). Although the majority display parallel lateral margins, several blades show convergent tip and a few others retain curved distal end (Table 6.16). Many of the blades preserve long dorsal scars that surpass the mid-point.

Non-cortical and Partially Cortical (n=63). Both non-cortical and partially cortical flakes together form the largest group (57%) in the complete debitage class (Table 6.11). Although their major distinction was based on the presence/absence of cortical surface, they also vary slightly in mass and length (Tables 6.12-14). While a large number of the non-cortical flakes weigh less than 2 gm, 9/16 of the partially cortical flakes weigh between 2-5 g. Similarly, while the majority of partially cortical flakes measure greater than 30 mm (mean=31), a large percentage of the non-cortical flakes falls within the size range of 20-30 mm (mean=23). The observation that many of the partially cortical flakes are heavier and larger in size reflects that the cortical flakes were produced during earlier stages of core reduction.

Miscellaneous (n=19). This group includes core trimming flakes and miscellaneous complete debitage that could not be attributed to any of the above classes. Long flakes with uneven lateral edge and irregular dorsal surface predominate in this group. The majority weighs below 2 g and measure more than 30 mm in length (mean=43) (Tables 6.12-13). As can be seen in Table 6.14, length to width ratio exceeds 2 in the majority of the complete debitage implying elongated shape. Several of the specimens in this group display curved lateral margins and facetted proximo-dorsal edge. In general, the miscellaneous class displays similar size and morphological variability to the other complete flakes.

Proximal and Indeterminate Fragments (n=559). Fragments by far dominate the Misse East assemblage. They include both proximal and indeterminate fragments for which only mass was recorded. The total mass of the counted fragments ranges 1079 g (Table 6.17). More fragments were recovered from surface and Level 1 of Unit A. This is consistent with the overall artifact distribution pattern.

Other findings

A few bone fragments and two teeth remains were recovered from the unit boundary on surface. However, it was not possible to determine the association of the specimens due to the unstable nature of the surface. Identification of the teeth specimens is pending, but the bone remains are too fragmentary for analysis.

Three shell beads resembling those found at Gelalo NW were also recovered (two from surface and one from excavation). The beads are thin, preserving circular rings at the center, presumably for the insertion of string/fiber. The discovery of symbolic remains that resemble finds from the site of Gelalo NW suggests that both sites were settled by groups with similar tradition of personal adornment.

Summary of Misse East Findings

Misse East produced well preserved lithic artifacts and dense shell remains in a close association. All the analyzed material came from Unit A, the only excavated unit at the site. The archaeological occurrence in Unit A was mainly restricted to the upper 15 cm deposit. A completely sterile bedrock layer was reached at -25 cm. The lithic assemblage represents a LSA industry; one consisting of blade cores and backed implements (geometric and non-geometric). Obsidian is the dominant raw material. The nearest source of obsidian is within 5-10 km on the volcanic hills to the southwest of the site (see Appendix II for raw material analysis report). The backed edge of the microliths display refined retouching design resulting from bipolar hammering and possibly pressure technique. The Misse East backed implements are longer and narrower than the Gelalo sample. Crescents are the dominant type in the geometric-microlithic class. The apparent dominance of long crescents suggests that the Misse East knappers were engaged in modifying long blanks into microliths. Those implements offer greater cutting edge per unit mass. Based on the close association of small backed segments and large debitage with shell remains, the material appears in primary context.

The results of surface collection and test excavation from the site of Misse East confirm the presence of 8^{th} millennium BP human settlement in the Buri Peninsula. The Misse East finding joins the previously described evidence from the site of Gelalo NW. Both sites contain similar material culture and represent contemporaneous settlements. Mollusk shells and backed tools were discovered form both sites. Although the Misse East and Gelalo NW lithic evidence shows strong affinity, the Misse East assemblage is dominated by slightly larger artifacts, both debitage and microliths. The discovery of shell remains at both sites suggests similar subsistence economy that involved human exploitation of coastal resources, most likely on seasonal basis. The dominant shell species from Misse East differs from what was discovered at Gelalo NW. Misse East was dominated by *Atactodea glabrata*, a small bivalve that dwells in sandy-intertidal zone, while Gelalo NW contains mainly *Terebralia palustris*, a large gastropod living among mangroves (Appendix I). This variability in shell preferences suggests cultural and/or ecological variation.

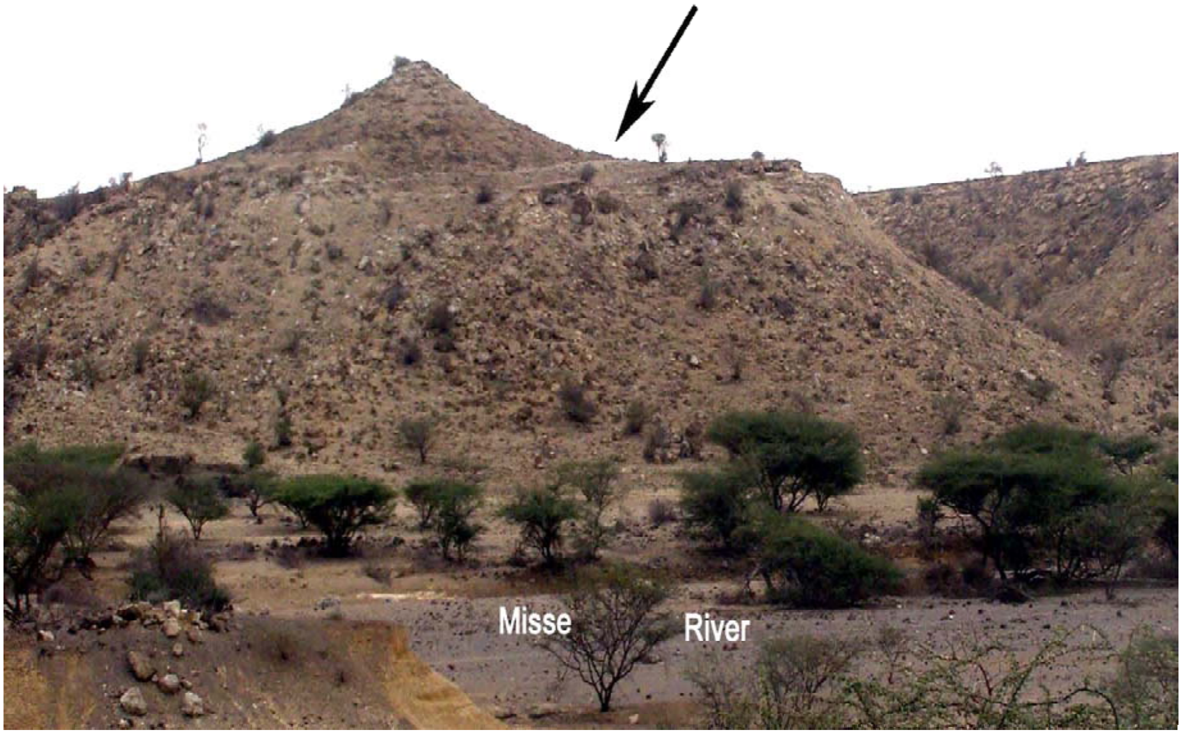


Figure 6.1. Misse East Site, southwest aerial view.

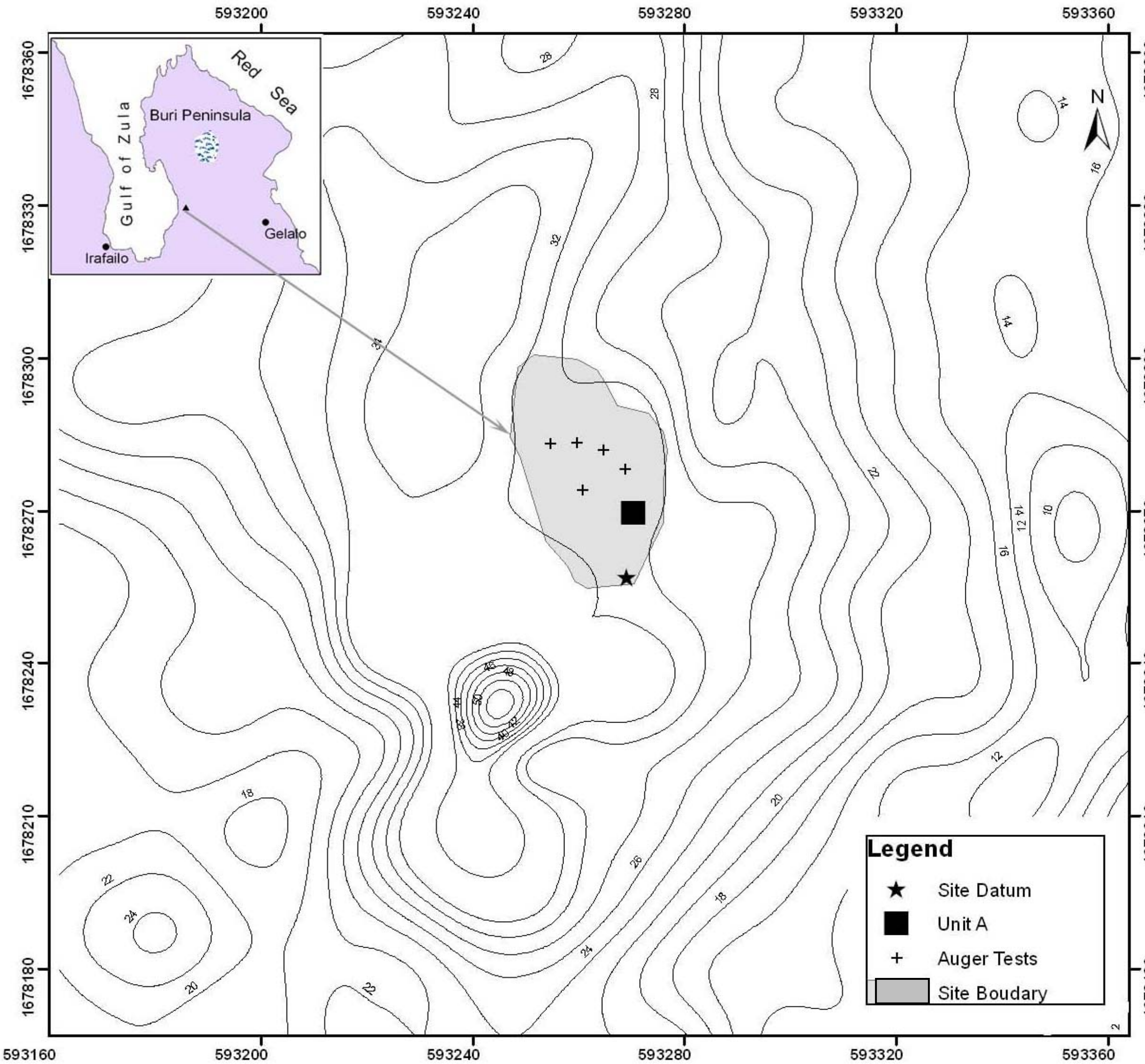


Figure 6.2. Map showing the location, topographic setting and major activity areas at the Misse East Site.

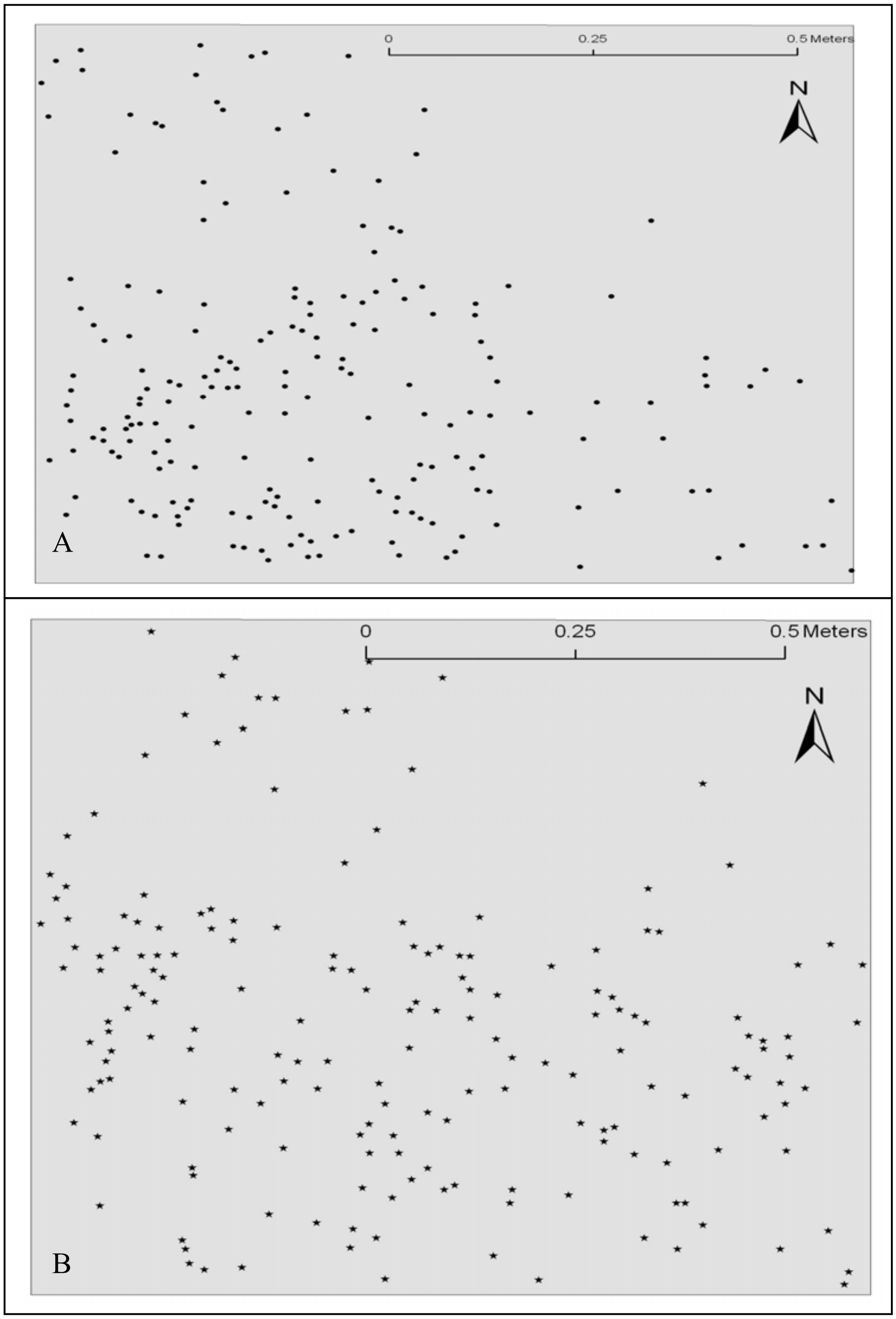


Figure 6.3. Surface artifact distribution in the designated Collection Grid at Misse East Site. A: Lithic remains, B: Shell remains. Note the similar distribution pattern.

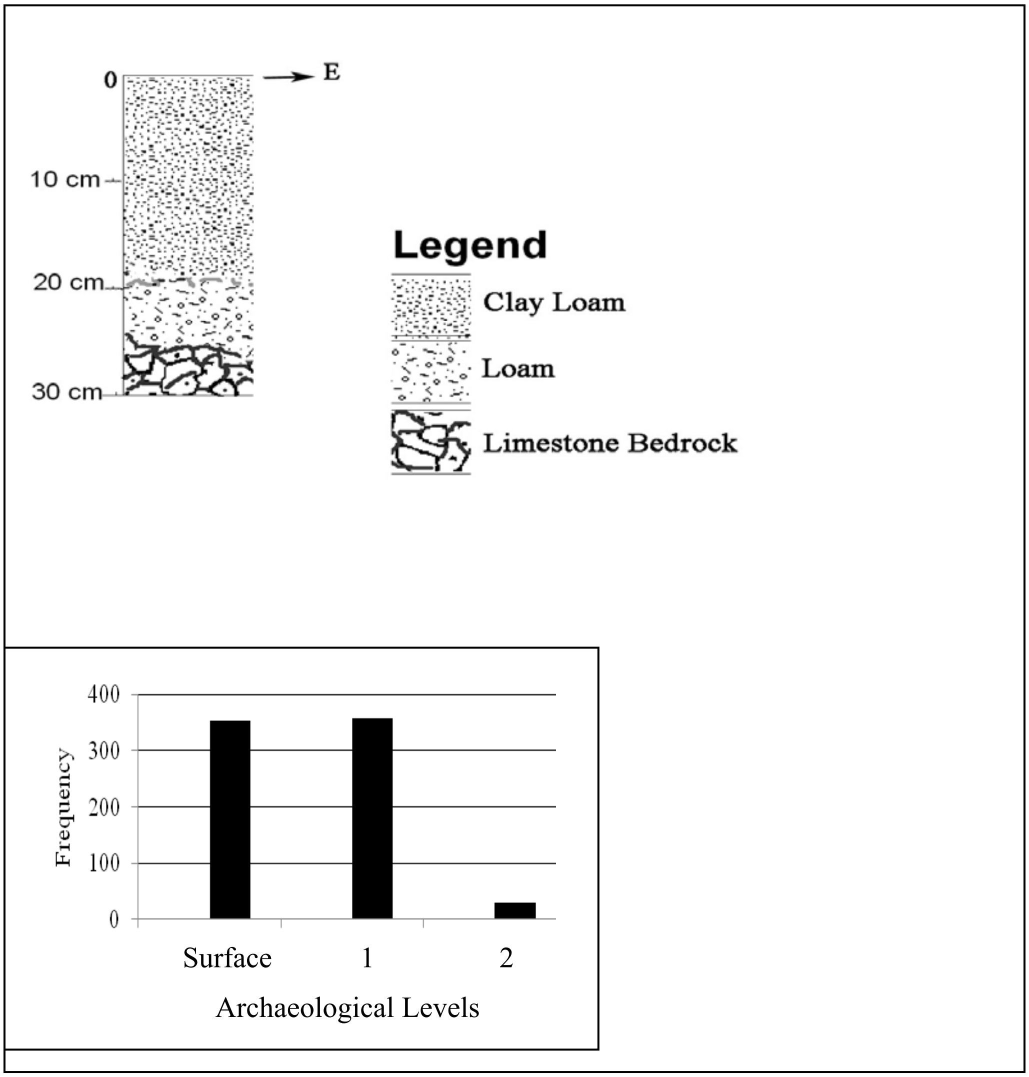


Figure 6.4. Stratigraphy of Misse East Unit A. A histogram on the lower insert shows artifact distribution pattern in Unit A.

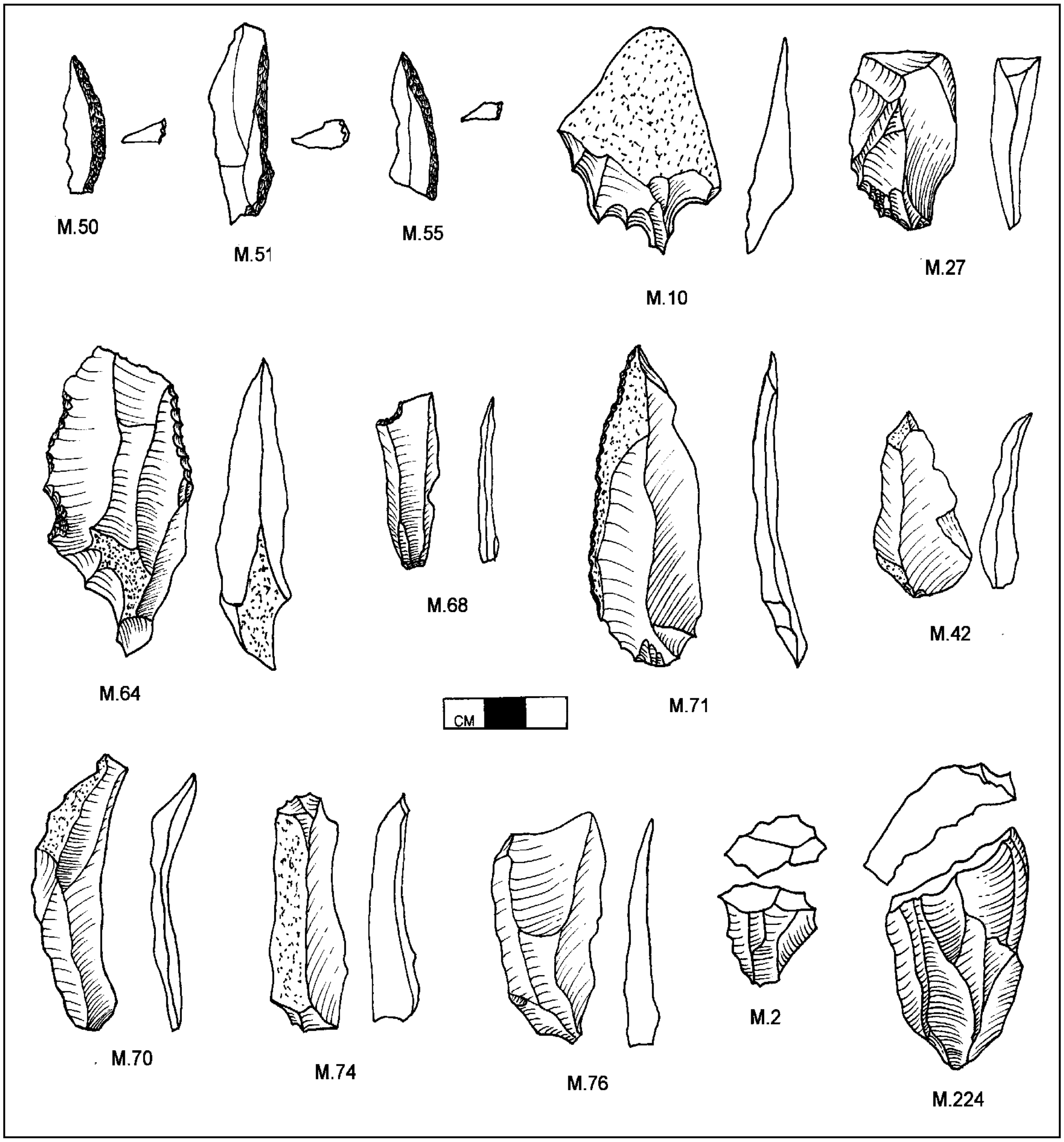


Figure 6.5. Misse East surface lithic findings: backed tools (50, 51, 55), scrapers (10, 27,64,), edge damaged tools (68, 71), blades (42,70,74,76), prismatic cores (2,224). The Prefix "M" before artifact numbers stands for Misse East.

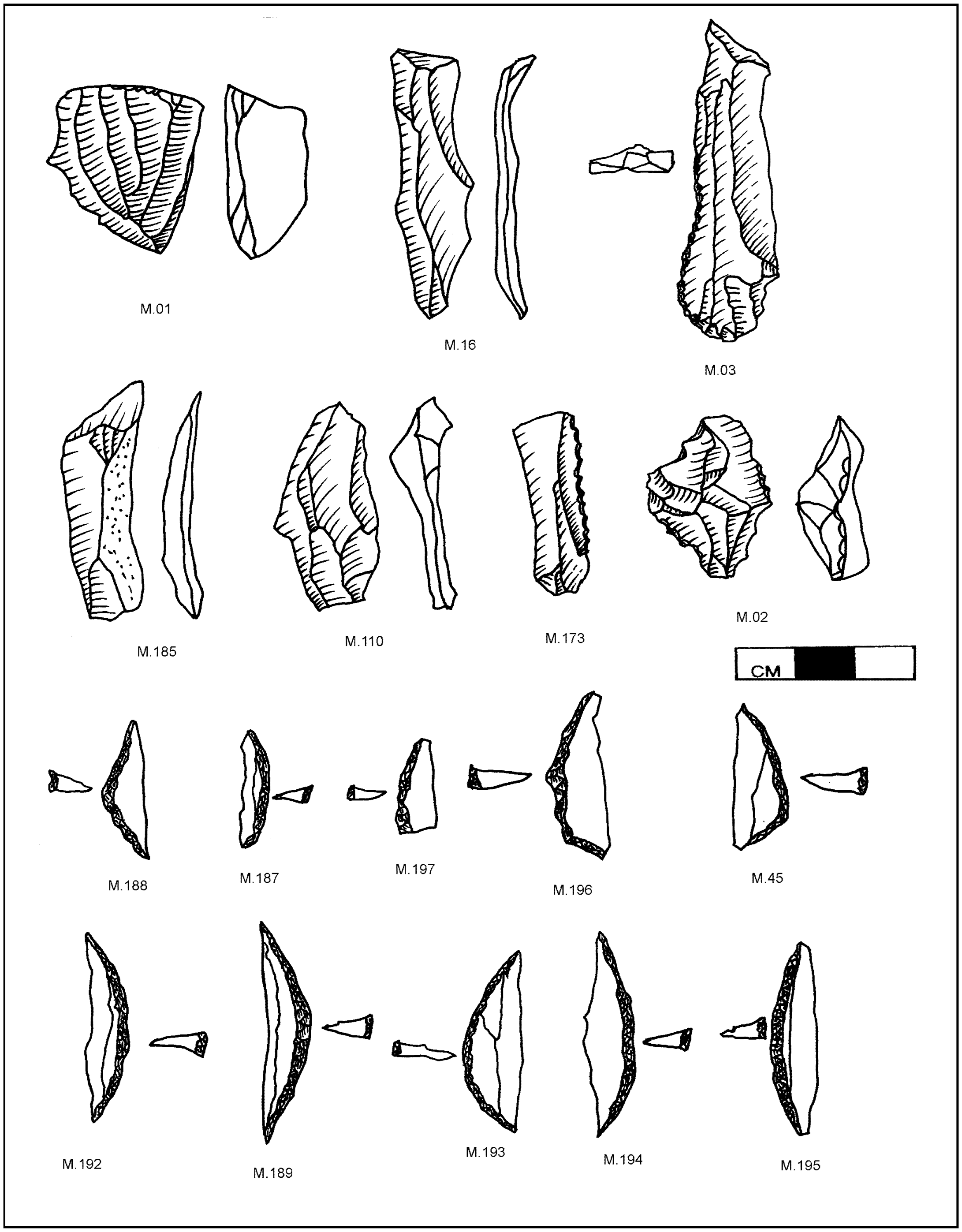


Figure 6.6. Excavated lithic artifacts from Misse East: Blades (M.16, 185, 110), Edge damaged blades (M.03, 173), Core (M.02, 01-surface find), Backed tools (M. 188, 187,197, 196, 45, 192, 189, 193, 194, 195).

Core type	Level		
	S	1	Totals
Bipolar	2		2
Core on Flake		1	1
Other		1	1
Prismatic	4		4
Totals	6	2	8

Table 6.2. Misse East excavated core sample, general inventory.

	Mass Range (g)			
Core types	< 2	2-5	> 5	Totals
Bipolar	2			2
Core on Flake		1		1
Other			1	1
Prismatic	2	1	1	4
Totals	4	2	2	8

Table 6.3. Misse East excavated core sample, mass variability.

Statistics	Length (mm)	Width (mm)	Thickness (mm)
Mean	33	22	12
Std. Deviation	13	7	3
Range	38	15	10
Minimum	17	16	7
Maximum	55	31	17
Count	8	8	8

Table 6.4. Misse East excavated core sample, size means.

	Levels			
Tool Types	S	1	Totals	%
Geometric Microliths	5	7	12	22
Backed Flakes	4	1	5	9
Backed Fragments	9	5	14	26
Denticulates	1	1	2	4
Edge damaged	6	2	8	15
Miscellaneous	2		2	4
Notches	2	1	3	5
Scrapers	7	1	8	15
Totals	36	18	54	100

Table 6.5. Misse East excavated shaped tool sample, artifact inventory.

Tool Types	Mass Range (g) <2	2-5	> 5	Totals
Geometric Microliths	9	3		12
Backed Flakes	3	2		5
Backed Fragments	13	1		14
Edge damaged		4	4	8
Denticulates		2		2
Miscellaneous		2		2
Notches		2	1	3
Scrapers		2	6	8
Totals	25	18	11	54
%	46	33	20	

Table 6.6. Misse East excavated shaped tool sample, mass variability.

Tool Types	Length Range (mm) <20	20-30	>30	Totals
Geometric Microliths	1	6	5	12
Backed Flakes		2	3	5
Backed Fragments	3	10	1	14
Edge Damaged		2	6	8
Denticulates		1	1	2
Miscellaneous		1	1	2
Notches		1	2	3
Scrapers			8	8
Totals	4	23	27	54
%	7	43	50	

Table 6.7. Misse East excavated shaped tool sample, size variability.

Statistics	Length	Width	Maximum Backed Edge thickness	Length To Width Ratio	
Mean	32	9	3	Range	Count
Std. Deviation	9	2	1	2 - 2.9	8
Minimum	15	5	1	3 - 4	3
Maximum	48	12	4	>4	6
Count	17	17	17		

Table 6.8. Misse East excavated geometric and non-geometric tools, size means.

Row Labels	Retouch Position				Totals
	>50% Ventral	>50% Dorsal	Bifacial	Edge Margin	
Geometric Microliths				12	12
Backed Flakes				5	5
Backed Fragments		1		13	14
Edge Damaged		4		4	8
Denticulates			1	1	2
Miscellaneous			1	1	2
Notches	1	1		1	3
Scrapers		8			8
Totals	1	14	2	37	54

Table 6.9. Misse East excavated shaped tool sample, retouch position.

Tool Types	Retouch Extent			Totals
	<33%	>67%	33-67%	
Geometric Microliths	2		10	12
Backed Flakes	1		4	5
Backed Fragments	1	1	12	14
Edge Damaged	4		4	8
Denticulates			2	2
Miscellaneous		1	1	2
Notches	3			3
Scrapers	6		2	8
Totals	17	2	35	54

Table 6.10. Misse East excavated shaped tool sample, variability in retouched edge extent.

Tool Type	Level		Totals	%
	S	1		
Core trimming flakes		3	3	2
Non Cortical flakes	28	19	47	40
Other	7	9	16	14
Partially cortical flakes	13	3	16	14
Prismatic blades	15	21	36	30
Totals	63	55	118	

Table 6.11. Misse East excavated dabitage sample, artifact inventory.

Tool Type	Mass Range (g)			Totals
	<2	2-5	>5	
Core trimming flakes	2		1	3
Non Cortical flakes	28	16	3	47
Other	7	4	5	16
Partially cortical flakes	2	9	5	16
Prismatic blades	21	10	5	36
Totals	60	39	19	118

Table 6.12. Misse East excavated dabitage sample, mass variability.

Tool Type	Length Range (mm)				
	<20	20-30	>30	Mean	Totals
Core trimming flakes		1	2	34	3
Non Cortical flakes	19	22	6	23	47
Other	2	4	10	43	16
Partially cortical flakes		6	10	31	16
Prismatic blades	7	6	23	33	36
Totals	28	39	51		118

Table 6.13. Misse East excavated dabitage sample, size variability.

Tool Type	Length :Width ratio Range 1- 2	2- 3	>3	Totals
Core trimming flakes	1	1	1	3
Non-cortical flakes	43	1		47
Other	2	11	3	16
Partially cortical flakes	16			16
Prismatic blades	2	15	19	36
Totals	64	28	23	118

Table 6.14. Misse East excavated complete dabitage sample, length: width ratio.

Tool Type	Proximal edge dorsal morphology			
	Crushed/Beveled	Facetted	Plain/Cortical	Totals
Core trimming flakes	1		2	3
Non-cortical flakes	20	9	18	47
Other	5	9	2	16
Partially cortical flakes	2	3	11	16
Prismatic blades	12	10	14	36
Totals	40	31	47	118

Table 6.15. Misse East excavated dabitage sample, proximal edge dorsal morphology.

Tool Type	Lateral Margin Morphology				
	Convergent	Curved	Expanding	Parallel	Totals
Core trimming flakes	1			2	3
Non-cortical flakes	10	14	12	11	47
Other	4	6	2	4	16
Partially cortical	4	5	5	2	16
Prismatic blades	10	6	1	19	36
Totals	29	31	20	38	118

Table 6.16. Misse East excavated dabitage sample, lateral margin variability.

Tool Types	Level	Count	Mass
	S	36	94
	1	18	35
Shaped Tools	Tool total	54	129
	S	6	64
	1	2	38
Cores	Core total	8	102
	S	63	255
	1	55	127
Complete Flakes	Complete flakes total	118	382
	S	88	263
	1	97	201
	2	12	12
Proximal Fragments	Proximal total	197	476
	S	160	409
	1	185	184
	2	17	10
Other Fragments	Fragments total	362	603
Grand Total		739	1692

Table 6.17. Summary of lithic findings from Misse East Unit A.

Chapter 7
Inter-site Lithic Comparison

Introduction

Whereas the chronological backgrounds of the Later Stone Age sites from the Eritrean Red Sea Coast have been clearly established, their cultural affinities have not been described in detail. This chapter compares the lithic assemblages from the three excavated LSA sites using key techno-typological attributes. Gelalo NW and Misse East are early mid-Holocene LSA settlements dating to the 8th millennium BP. The excavated assemblage from the Asfet site has been dated to the 6th millennium BP, while the surface material from that site lacks an absolute date. The inter-site lithic comparison aims to:

i. Assess the nature of lithic technological relationship among the three LSA sites excavated on the Buri Peninsula and Gulf of Zula
ii. Compare lithic variability in the study area with neighboring regions.
iii. Relate lithic variability to settlement patterns on the Red Sea Coast.

The inter-site lithic comparison is a key step in establishing the Holocene culture history of the Red Sea Coast (chapter 8).

The surface material from Asfet which represents a MSA tradition is broadly compared with Late Pleistocene assemblages from the Ethiopian Afar Rift.

Comparative Approaches

Cores, shaped tools and debitage from the three assemblages, Asfet Unit F, Gelalo and Misse were compared using selected techno- typological attributes. The main comparative variables are as follows:

Raw Material. Raw material composition was compared among the three sites in order to assess variation in technological organization and land use (Barut 1994).

Mass. Mass was compared as a means of investigating variation in the volume of raw materials transported or reduced at the sites. In order to evaluate mass variability, artifact types were first grouped into arbitrary mass ranges.

Metric Measurements. Length, width and thickness were compared in order to investigate variation in artifact size among the site-assemblages. Artifact types were first grouped into arbitrary length ranges.

Retouch Aspects. Retouch distribution, extent and position were compared among the shaped tool classes from each site in order to investigate variation in tool maintenance and design strategies.

Debitage Morphology. Striking platform surface, lateral margin and termination pattern were compared among the debitage classes from each site in order to assess hammering technique and core preparation strategies (Kelly 1996).

Mean values of Flake Surface Area/Flake Thickness ratio (FSA/T) and Striking Platform Width/Striking Platform Thickness ratio (PW/PT) were computed to assess variability in cutting edge production efficiency (Davis 2000; Dibble 1997).

Microlithic Attributes. Geometric microliths are considered crucial elements in drawing cultural affinities. Length, width and thickness were compared among the microlithic classes (mainly crescents) from the respective sites. Geometric microliths were recovered in moderate quantities from Gelalo and Misse.

Stone tool style and size have commonly been used to assess cultural variability within and among widely located archaeological sites (Barut 1994; Gang 2001; Kelly 1996). As such, lithic variation can reveal differences in technological processes (raw material procurement, core design, tool resharpening and discard), site function as well as symbolic and/or stylistic behavior (Sackett 1973).

Core comparison

The main variables used in the core comparison were artifact composition, raw material type, and mass and size ranges. Tables 7.1-2 summarize core type composition and raw material variability among the focal sites. The core sample from

Asfet and Misse is represented by fewer specimens, whereas the sample from Gelalo is relatively larger. Hence the core comparison is based on highly disproportional sample size. Cores were first classified into three arbitrary mass and length ranges. Figures 7.1-2 depict the patterns observed from mass and size comparisons.

Core type comparison shows that the Asfet Unit F sample is dominated by expedient cores, whereas the Gelalo and Misse samples display greater percentages of prismatic and bipolar types. The occurrence of more formal cores (prismatic) at Gelalo and Misse and fewer in the Asfet Unit F collection implies differences in reduction strategy. Raw material comparison of core samples among the three sites shows somehow a contrasting pattern. While the Asfet Unit F core sample displays relatively greater diversity of raw materials, the Gelalo and Misse collections are entirely on obsidian. As is shown in Table 7.2, obsidian and quartz make up 37.5% each in the Asfet group, but they are both absent in the Gelalo and Misse collection. This pattern corresponds to the variability observed in the tool and debitage classes, where obsidian is the principal raw material at Gelalo and Misse.

In assessing core variability using mass, the most notable pattern is that about 50% of the specimens from the three assemblages fall below 10 g. The Misse East sample represents a modest proportion of artifacts above 20 g (Fig. 7.1).

Length varies most among the core samples. While there are more specimens from Asfet that fall below 20 mm and above 30 mm respectively, there are fewer artifacts from Gelalo and Misse in this size range (Fig. 7.2). More than 65% of the Gelalo sample falls between 20 and 30 mm, while that of Misse are equally split in the two size ranges, below 20 mm (40%) and between 20 and 30 mm (40%).

Tool comparison

The following patterns were noted in the tool comparison: i) small number of retouched tools at Asfet, ii) more backed fragments at Missse than Gelalo, iii) higher percentage of edge damaged tools at Gelalo than Misse, iv) higher percentage of scrapers at Misse than Gelalo (Table 7.3). The Gelalo assemblage is dominated by edge damaged tools (35%), while the Misse assemblage contains relatively higher proportion of microliths (geometric and fragmentary backed segments). Complete crescents and backed segments comprise 14/54 and 12/54 respectively at Misse East. The rest of the Misse sample is dominated by scrapers and miscellaneous tools. In light of these differences, it appears that the Asfet, Misse and Gelalo inhabitants slightly differed in tool maintenance strategies. The presence of a significant number of designed tools at Misse and Gelalo suggests curated technology (Kuhn 1994).

Geometric microliths are fairly represented in the Gelalo collection (n=40, 17%), but less compared to the relative proportion at Misse (n=12, 22%). Only 13 shaped tools were identified in the entire Asfet Unit F collection. Out of which 4/13 (31%) are backed fragments and the rest comprises small quantities of scrapers, triangular points, complete crescents (n=2) and a backed blade. A few notches and burins were recovered from Gelalo. Denticulates are present in the Gelalo and Misse assemblages in low frequencies. The comparison clearly demonstrates less tool maintenance activity at Asfet, and the material there shows less artifact diversity. In contrast, the tools from Gelalo and Misse show greater diversity and contain higher percentages of designed tools.

Mass variability among the tool samples is shown in Figure 7.3. There are more tools from Gelalo that fall below 2 g range, while several of the Misse and Asfet tools appear to be greater than 2 g. There are more tools from Misse that weigh more than 5 g. The majority of the Gelalo tools fall in the size range of 20-30 mm, while a large portion of Misse measures above 30 mm (Fig. 7.4). The pattern with the Misse material is particularly interesting in that more than 90% of the tools from the site are greater than 20 mm in length, and about 50% of this exceeds 30 mm. In contrast, the majority of the Asfet material measures below 20 mm. Only about 20% of the Gelalo and Asfet tools measure above 30 mm. Overall, the Misse artifacts are longer compared to the other two assemblages.

Microlithic size variability (length, width and maximum thickness) is shown by boxplots in Figure 7.5. A boxplot depicts variability of numerical measures and symmetry of the score distribution (Ott and Longnecker 2001). The lower and upper limits of the closed box represent the 25^{th} and 75^{th} percentile values of the scores after being arranged. A straight line (left-right) inside the box depicts the median of the scores, and its position with respect to the upper and lower quintiles determines the degree of skewness (degree of deviation from the line of symmetry). The mean length reaches 20, 24 and 33 mm for Asfet, Gelalo and Misse respectively (Fig. 7.5). The length scores appears to be highly skewed in the three assemblages as is indicated by the high deviation of the middle line towards the lower and upper quartile margins. The Asfet microlithic sample is so small (n=4) that the mean scores are insignificant. In general, the Misse material is dominated by longer geometric tools than the Gelalo and Asfet samples. The other notable difference between the two microlithic groups is in backed-edge thickness. The Gelalo microliths have thinner backed edge than that of Misse (Fig. 7.5). The Misse and Gelalo microlithic tools, however display similar microlithic width, and both exhibit bidirectional backing retouch.

Chi-square significance tests were performed to investigate technological relationship between shaped tool samples from Misse and Gelalo. Seven out of 13 variables (technological and typological) revealed statistically significant difference (Table 7.4). The two groups display significant difference (x^2=19.5, $p<0.007$) in tool composition to which three variables seem to have contributed most, i) the presence of more backed fragments in Misse than Gelalo, ii) higher percentage of edge damaged tools at Gelalo than Misse, iii) higher percentage of scrapers at Misse than Gelalo. Moreover, microlithic length and mass from the two sites vary significantly; x^2=13, P=0.001 and x^2=17.8, p=0.000 respectively. With respect to mass, the Gelalo sample contains a slightly higher percentage of microliths weighing below 2 g (90%) compared to 75% at Misse. A larger percentage of the Misse microliths fall in the mass range of 2-5 g (25%) compared to 10% at Gelalo. In terms of length, the Misse assemblage contains a greater percentage of microliths exceeding 30 mm while the Gelalo group is dominated by shorter specimens (below 20 mm). Likewise, a Chi-square test of length to width ratio shows significant difference between the two assemblages (x^2=7.8, p=0.02). A statistically significant difference has also been noted between the two groups in retouch morphology and retouch size; p^2=18.4, p=0.001 and x^2=34.5, p=000 respectively. In this regard, the Misse group has higher percentage of backed class, whereas the Gelalo assemblage contains more edge damaged tools (retouches less than 2 mm). Another notable difference between Misse and Gelalo is in the size of backed fragments (x^2=6, P=0.036). While the majority of the Gelalo backed fragments are below 20 mm, the Misse group fall in the range of 20-30 mm. Overall, the Misse segments are longer, suggesting that they were derived from longer blanks. All the backed segments from Misse and Gelalo weigh below 2 g.

Debitage comparison

The most notable variation in the debitage sample is that the Asfet material contains a low percentage of prismatic flakes (15%) compared to Gelalo and Misse, where blade flakes represent 32 and 30 % respectively (Table 7.5). Another notable difference in the debitage class is the absence of cortical flakes in the Misse collection, while a small percentage of cortical specimens are represented in the Asfet and Gelalo collections. The absence of cortical flakes from the Misse collection suggests that cores were decorticated elsewhere. By decorticating cores off-site, the Misse knappers utilized cores more efficiently. Inter-site comparisons of debitage mass and size have shown interesting patterns as well. In terms of mass, the Gelalo collection falls mainly below 5 g, while a fair percentage of the Misse and Asfet artifacts weigh over 5 g (Fig. 7.6). In general, however, there is less contrast in mass among the three assemblages. The percentage of debitage artifacts decreases proportionally in the three samples across lower to higher mass ranges. Length comparison shows somehow contrasting pattern. While the Asfet sample mainly clusters below 20 mm, the majority of the Gelalo and Misse groups fall within 20-30 mm and greater than 30 mm respectively (Fig. 7.7).

Striking Platform was compared among the debitage collection in order to assess variability in core design (Fig. 7.8). Generally, plain platform morphology appears to be the dominant feature in the Asfet, Galalo and Misse assemblages. While plain platform is the most dominant (75%) in the Asfet collection, a significant number of the Misse and Gelalo debitage preserve crushed morphology. The occurrence of crushed platforms at Misse and Gelalo suggests that cores were regularly roughed-out and punch technique may have been used during knapping (Brandt 1982).

Another approach to assess variability among the debitage groups was using mean plots of Flake Surface Area/ Mid-point Thickness (FSA/T) against Platform Width/Platform Thickness (PW/PT). These are proxy measurements of technological "cost" and "benefit" that have been recently introduced to the lithic analytic routines (Davis 2000; Dibble 1997; Shea, et al. 2007). In brief, these parameters measure lithic production efficiency or cutting edge recovery rate per a given volume of core. In the first case (FSA/T) a flake with larger surface area (technological length x width at mid-point of length) relative to its thickness would yield more benefit in terms of potential cutting edge than a flake with smaller area and thicker at the mid-point. The second concept entailing cost-benefit comparison is the ratio of flake striking platform to its thickness (PW/PT). In this case, flakes with broader striking platform can quickly deplete the core-platform surface, which is that part of the core where striking force initiates. By removing a large portion of the core-platform, flakes with wider and thicker striking platform would limit the removal of additional flakes from the core. Hence, wider platform accrues greater cost to the tool maker.

Using the above analytic concepts, it was possible to discriminate the debitage assemblages. It is necessary to note here that cost and benefit comparisons are valid on complete flakes only. As can be seen from Figure 7.9, the mean FSA/T value for Misse sits higher on the Y-axis, which signifies more efficient flake recovery rate per a given volume of core. This means that the Misse collection contains higher percentage of narrow and thin flakes. In contrast, the Asfet assemblage sits lower on the Y-axis suggesting lower benefit. The Asfet assemblage is dominated by broad and thick flakes. Gelalo NW lingers below Misse, but higher than Asfet on the FSA/T axis (Y-axis). The Gelalo sample is plotted on the extreme right-side on the X-axis (SPW/SPT), implying higher cost than Asfet and Misse. The above relationship among the debitage classes is further elucidated using boxplot graphs (Fig. 7.10). The Asfet collection displays the lowest length mean, higher width mean and the highest striking platform width mean. There is similar degree of skewness between Asfet and Misse length measurements are skewed in similar direction with the maIn contrast, the Misse debitage shows the highest length and width means, but lower striking platform width mean. Based on this observation, the Asfet assemblage provides lower efficiency of flake recovery rate because it is dominated by broader and shorter flakes. In contrast, the Misse collection is dominated by long and thin flakes and demonstrates higher flake recovery efficiency. The Gelalo material falls in between the efficiency index of Asfet and Misse.

A multivariate discriminant approach was used to assess debitage size variability. Accordingly, striking platform thickness contributes the most size variation (84.7%) among the debitage samples from the three sites (Fig. 7.11). This means that there is high variability in striking platform thickness than any other attribute in the debitage samples. Length explains the remaining 15.3% of the variation among the assemblages. A multivariate analysis of group covariance, which assesses measured dispersion ranked Asfet with greater intra-group variation followed by Misse (Table 7.6). This means that flake production was less regulated at Asfet, whereas consistent knapping strategy seems to have been employed at Gelalo.

Comparison with Other LSA Sites

Background to regional comparison

In order to set out a regional interpretation for the LSA evidence from the Eritrean Coastal lowlands, selected LSA lithic assemblages from the Horn of Africa and Kenya were briefly compared using lithic measurement data. Comparative sites were drawn from dry land and lacustrine contexts in order to assess variability among diverse habitats. Six sites were selected for this purpose based on their geographic proximity, age similarity and lithic composition. These are Gobedra, Baati Nebiat, and Danie Kawlos all from northern Ethiopia (around Aksum); Lake Besaka in eastern central Ethiopia, Lothagam on the west side of Lake Turkana, and Enkapune Ya Muto (GtJi12) and Marula rockshelter (GsJj24) both from Central Rift of Kenya (Table 7.7). Size attributes: length, width and thickness on geometric-crescents and whole flakes were compared. Microliths are considered hallmarks of the LSA tradition in Sub-Saharan Africa (Clark 1985; Phillipson 1982), and they bear design aspects upon which one can draw technological relationship and cultural affinities.

The distribution of microlithic industries in eastern Africa became more widespread towards the beginning of the Holocene epoch (Ambrose 1984; Phillipson 1982). Many LSA sites were discovered from coastal and interior districts of Somalia, and highland and central rift of Ethiopia suggesting human expansion after the onset of early Holocene wet phase (Clark 1954; Phillipson 1982). The LSA findings from the central rift (Lake Besaka) and northern Ethiopia (Aksum sites) offer strong evidence for early Holocene human occupation of the highlands of Tigray/Eritrea, some of which might have been related to the recently discovered settlements along the Eritrean Coast. To assess technological affinities, lithic size attributes from Lake Besaka, Danie Kawlos, Gobedra and Baati Nebiat were compared with that of Asfet, Gelalo and Misse data. Upon identifying technological similarities, prediction is made about inter-site cultural relationships. Although requests were made for primary metric data, none of the researchers who studied the sites were able to provide any. Only published artifact size means for microliths and whole flakes were used to pursue the comparison with the Besakan and northern Ethiopian assemblages.

The Central Rift Valley and Lake Turkana regions of Kenya contain rich records of early Holocene cultural developments (Ambrose 1984; Robbins 2006). Numerous shell middens and rock shelters excavated from the region produced a wide range of evidence concerning hunter-gathers subsistence and settlement pattern in the early and mid-Holocene (ibid.). At some point, the widespread fishing settlements around Lake Turkana were referred to as “Aquatic Civilization of Middle Africa”(Sutton 1974). Lately, the widespread lacustrine settlements were interpreted as local developments in response to the availability of aquatic resources with onset of the early Holocene wet phase (Stewart 1989). These fishing settlements preserve some of the earliest evidence for decorated pottery, rock art engravings, burial practices and grinding stones indicative of greater cultural complexity. Located on a Holocene beach deposit, the site of Lothagam produced numerous barbed bone points (harpoons), microlithic industry, undecorated pottery, abundance fish bones and fragmentary human skeletal remains (ibid.). As noted by (Robbins 2006:75), "Lothagam was one of the first major Later Stone Age fishing settlements discovered in Kenya, and as such it was very important in historical sense because it focused attention on Lake Turkana in several major theoretical contexts in African archaeology." The site dates to about 6,000-7,000 BP (Robbins and Lynch 1978). A microlithic data from a 1965 excavation of Lothagam was generously provided by Dr. Larry Robbins.

Early and mid-Holocene settlements from the Central Rift Valley of Kenya are collectively referred to as the "Eburran" cultures (formerly known as Kenyan Capsian) under which several entities were recognized based on artifactual remains, ecozonal context and chronological placement (Ambrose 1984). The Eburran cultures represent expanded settlements around the rift valley in response to the humid climate of early Holocene. The earliest Eburran sites (phases 1-4) date between 12 and 6 Ka BP, and feature high densities of faunal and artifactual remains. Microliths (mostly crescents) on obsidian raw material dominate the Eburran lithic assemblages. Among the well researched Eburran sites in the Kenyan Rift Valley are Enkapune Ya Muto (GtJi12) and Marula (GsJj24) rockshelters (ibid.). Microlith samples from Enkapune Ya Muto (EYM) and Marula Rock Shelter (MRS) were included in this comparison. While the EYM material represents Eburran Phase 4/5 (~6 ka BP), the MRS sample represents Eburran 3 (~8 ka BP). Hard copies of the Enkapune Ya Muto and Marula Rock shelter microlithic data were kindly provided by Dr. Stanley Ambrose.

The comparison

The first batch to be compared with the Eritrean coastal sites consists of Baati Nebiat, Danie Kawlos, Gobedra and Lake Besaka. Three groups can be identified based on the whole flake size mean-plot (Fig. 7.12A): i) Lake Besaka with length mean below 20 mm, ii) Asfet, Danie Kawlos, Gobedra Unit IV and Gelalo, length mean between 21-23 mm, and iii) Misse and Baati Nebiat, with length mean exceeding 27 mm. Generally, the whole flake data shows strong lithic size similarity with the hinterland counterparts. The apparent differences between the three contiguous coastal sites correlates with the differences observed among the highland assemblages. In both cases, the older sites contain longer flakes, while the younger ones are characterized by shorter artifacts. The Besakan assemblage from FeJx2 appears distinct from the other sites in that shorter flakes dominate it. Whether this difference emanates from raw material variation or core design strategy is unclear. The Besakan sample was the largest in the compared groups and obsidian is the dominant raw material (Brandt 1982). Likewise, obsidian is the most common raw material in the coastal sites, while chert (Danie Kawlos), quartz and mudstone (Baati Nebiat), and chalcedony and jasper (Gobedra) dominate the highland assemblages in varying proportions. Thus, the observed variability in debitage morphology can be attributed to a combination of factors; raw material sources, core design and mobility pattern. The magnitude of statistical differences among the assemblages could not be verified due to lack of raw metric data.

The inter-site comparison of microlithic size among the coastal and highland sites has produced slightly different patterns than the debitage data. On the basis of microlithic size pattern, three groups can be distinguished (Fig. 7.12B): i) Danie Kawlos and Gobedra IIb with mean scores below 20 mm, ii) Gelalo and Lake Besaka between 24 and 25 mm, and iii) Misse exceeding 30 mm. Gobedra Stratum IV, Baati Nebiat and Asfet did not produce ample microlithic remains and were omitted from the comparison. The similarity in microlithic technology between the two highland sites (Gobedra and Danie Kawlos), which are separated by several millennia in age suggests that the LSA tradition in the highlands had persistently focused on smaller microliths, while the coastal and the Besakan inhabitants seem to have utilized larger backed tools relative to the highlands. As with the debitage data, these differences can be attributed to raw material variability and functional requirements of microliths. Whereas the coastal and the Besakan assemblages are entirely on obsidian (local source), the highland sites feature a variety of sources (see above), most of which are of lower quality than obsidian. The other notable aspect is the absence of microliths in the earlier deposits of Gobedra, which implies that microlithic technology evolved later during the Holocene in the region. Overall, according to the microlithic data, the coastal sites show closer technological affinity with Lake Besaka. Both the coastal and Besakan inhabitants depended on black obsidian, and both exploited aquatic resources. The observed technological affinity may reflect similar adaptive behavior.

Inter-site comparison with the Kenyan sites (Lothagam, Enkapune Ya Muto and Marula Rock Shelter) was performed using microlithic data (Fig. 7.13). Of the two coastal sites, the Misse sample shows greater technological affinity with MRS, EYM and Lothagam respectively. Table 7.8 reports results of t-test among microlithic size data. There is no statistically significant difference in microlithic length ($t=-0.95$, $P=0.34$), width ($t=-0.08$, $P=0.94$), and thickness ($t=1.3$, $P=0.2$) between Misse and MRS sites, while there is a significant difference in mean length between Misse and EYM ($t=6.8$, $P=0.00$). Although the Gelalo mean score tends to be comparable with the EYM, there is however statistically significant difference in the majority of microlithic attributes between Gelalo and the three compared samples from EYM, MRS and Lothagam (Table 7.8). The only attribute where the Gelalo sample does not show statistically significant size difference is in microlithic width with the MRS sample ($t=1.9$, $p=0.3$). The Gelalo and MRS samples show statistically significant difference in both microlithic length and thickness; $t=2.47$, $p=0.01$ and $t=-9.3$, $p=0.00$ respectively. The Lothagam sample contrasts with all other samples in microlithic width and thickness except with Misse. The Lothagam microliths tend to be twice wider and thicker than the coastal and Eburran artifacts. In general, the Misse microliths suggest stronger relationship with Lothagam and the two Eburran sites (EYM and MRS). The Gelalo microlithic sample shows a weak relationship with the Lothagam and the Eburran sites.

Summary of Inter-Site Comparisons

According to the results of core comparison, the Asfet group shows a distinct pattern in that unspecialized cores dominate the assemblage there. In contrast, the Gelalo and Misse assemblages represent relatively higher proportion of prismatic and bipolar cores. This suggests that cores were exploited in an expedient manner at

Asfet, while knappers at Misse and Gelalo seem to have been engaged in designing formal cores. Moreover, the Asfet material shows higher raw material diversity than the other two groups. Obsidian is dominant at Misse and Gelalo, whereas the Asfet collection incorporates much quartz and basalt in addition to obsidian.

The Asfet collection represents low frequency of shaped tools and the assemblage is less diverse. In contrast, the Gelalo and Misse samples show greater artifact diversity and contain higher percentages of designed tools, such as geometric microliths. While the Gelalo assemblage is dominated by high number of edge damaged tools, the Misse assemblage contains relatively higher percentage of microliths in the tools class. Such variability in tool composition signifies differences in technological organization, mobility pattern and the kinds of resources exploited at the respective sites. Comparison of debitage composition revealed a low percentage of blade-flakes at Asfet (15%), whereas blades represent 32% at Gelalo and 30 % at Misse. Another clear difference in the debitage composition is that cortical flakes are absent from the Misse collection, whereas small percentages of this class are present in the Asfet and Gelalo collections. The absence of fully cortical flakes in the Misse collection indicates that cores were decorticated elsewhere. This reflects more efficient use of raw material at Misse. In grouping the assemblages according to metric attributes, it has been shown that flake length and striking platform morphology discriminate the three assemblages better. Putting the debitage information together, the two older sites (Gelalo and Misse) represent higher proportion of blade technology compared to Asfet Unit F. The inter-site comparison among the Eritrean coastal sites shows directional change with time in core technology, tool design and raw material utilization. Gelalo and Misse show more curated technology than Asfet in containing more backed tools and prismatic blade cores. The Asfet Unit F shows somehow greater raw material diversity. While the Gelalo and Misse collections are entirely on obsidian, the Asfet assemblage contains a modest quantity of quartz and basalt in addition to obsidian. This variation implies differences in raw material access or technological choices associated with different mobility strategies. The limited inter-site comparison has shown some technological affinities between the coastal sites and hinterland settlements in Ethiopia and Kenya.

A general comparison with the Tigrayan sites has shown some patterns. Flake size mean comparison shows strong relationship between Gelalo and Gobedra IIb, both sites dating to the 8th millennium BP, but this relationship does not hold true with respect to the microlithic data. Irrespective of the whole flake data, Gelalo shows closer affinity with Lake Besaka in microlithic size. While the highland inhabitants had exploited a variety of rocks, such as chert, mudstone and quartz, obsidian dominates the Besakan and the coastal assemblages. Though limited in scope to length-mean, the Besakan assemblage shows stronger relationship with the coastal sites in the present review. In both cases, geometric crescents are common entities of the shaped tool class and obsidian was the preferred raw material.

Microlithic size comparison with Lothagam and the two Eburran sites has presented interesting results from which to infer adaptive similarities with the focal sites. In the first place, Misse exhibits closer similarity in microlithic size attributes with the two Eburran sites and Lothagam. Gelalo is weakly related to the hinterland sites in microlithic length, width and thickness. The observed pattern can be attributed to raw material variability, core reduction strategy and microlithic function. While the majority of the Eburran artifacts were reduced form obsidian, basalt dominates the Lothagam assemblage. The mechanical property of basalt could have caused the production of large microliths at Lothagam. Basalt is low quality rock compared to obsidian and large striking platform is required in order to remove useful blanks in such circumstances. Large striking platform in turn promotes the production of long and broad blanks. The Lothagam sample contrasts with all the compared samples in having broader and longer artifacts. Generally, microlithic style correlates with raw material sources. While the affinity of the coastal assemblages with the Eburran sites has been clearly demonstrated using microlithic size data, a thorough investigation of the relationship between the Eburran and Besakan has not been pursued. In this regard, it may merit citing David Phillipson's brief comment;

> "a backed industry, predating the eleventh millennium BC, has been recovered near Lake Besaka in the southern Afar Rift, the tool types which include microlithic forms, appear to resemble those of the Eburran. In a subsequent phase the makers of this industry may be shown to have been in contact with the Red Sea coastal regions" (Phillipson 1982:434).

This study demonstrates technological (adaptive) affinities among the Eritrean Coast, the Eburran and Besakan sites. Although, it is unclear to which particular region of the Red Sea Coast Phillipson was referring, his remarks agree with the present findings. In conclusion, the study has shown that the nature of lithic relationship among the sites varies independent of site location and age range. There is no pattern in the nature of lithic size variability that corresponds to the geographic location and age of the sites. Nonetheless, placing the coastal evidence in the broader context of LSA adaptations in eastern Africa requires detailed comparison using larger samples and additional techno-typological attributes.

Comparing the Asfet Surface Evidence

Although direct comparison of the Asfet evidence with specific sites in the Horn could not be achieved at the moment, it is worth discussing the overall affinity of the assemblage with known MSA occurrences in the Afar Rift of Ethiopia. For this, the sites of K'one, Aduma and Ala Kanasa are the closest samples. The K'one site produced well developed Levallois and Nubian reduction techniques for the production of partibifacial and unifacial points, and blades (Kurashina 1978). Based on depositional context, the MSA sequence at K'one falls within the early stage of OIS-4 dry period (ibid.). The lithic remains from K'one show some affinity with the Asfet surface assemblage in containing Nubian core types. The recently described MSA assemblage from Aduma (Middle Awash basin) features foliate points, Levallois and blade technologies attributed to a regional "Aduma entity" based on the dominance of small shaped tools (Yellen, et al. 2005). While small proportions of Nubian and discoidal cores were recovered from Aduma, the material lacks handaxes and cleavers. At an assemblage level, the finding shows strong technological similarity with the Asfet material in preserving points, and Nubian and prepared cores. Aduma represents riverine settlement dating to between 80-100 Ka BP (ibd.) from which later dry-period settlements on the Afar Rift could have been derived. Ala Kanasa is another MSA site in the Middle Awash with comparable lithic evidence. Levallois, and bifacial and unifacial points reduced from non-local chert, rhyolite, shale and obsidian characterize the assemblage (Clark 1988). While their chrono-stratigraphic relationship remains unknown, the MSA occurrences in the Afar Rift and that of Asfet in the Gulf of Zula show some affinity in raw material composition and techo-typological diversity. It is important to note that, the majority of Late Pleistocene sites on the Afar Rift have been discovered from low altitude arid settings similar to Asfet. In explaining the absence of Late Pleistocene MSA sites in southeastern plateau of Ethiopia, Desmond Clark once noted;

> ”at the height of cold episodes synchronous with glacial condition in the high latitudes, it is probable that the high plains would have been windy and unfavorable habitats and this may be the reason why it seems, on the basis of site distribution as presently known, that at such times the population was concentrated at lower altitudes” (Clark 1988:266).

If this assumption holds true, the Asfet settlement represents a northern extension of the Late Pleistocene (MIS 4, cold period) adaptations along the Afar Rift. Presumably, such adaptations must have been restricted to riverine, lacustring and coastal settings. In the mean time, hominins may have seasonally moved between the interior and coastal lowland habitats in response to any unfavorable conditions.

The presence of distinctive Nubian cores most common in southern Egypt and northern Sudanese MP Sites (Van Peer 1998) signifies adaptive similarity between the Zula and the Nile Valley settlements. Nubian settlements along the Nile Valley are thought to have been associated with hunting activities and were widespread during cold (dry) episodes. Likewise, the Asfet assemblage reflects similar adaptive strategy, although terrestrial faunal evidence is so far scarce. The Asfet evidence also shows broad affinity with the recently described MP assemblages from southern Arabia (Rose 2006) in presenting a variety of MP/MSA bifacial tools, prepared cores, large cutting tools and blade technology.

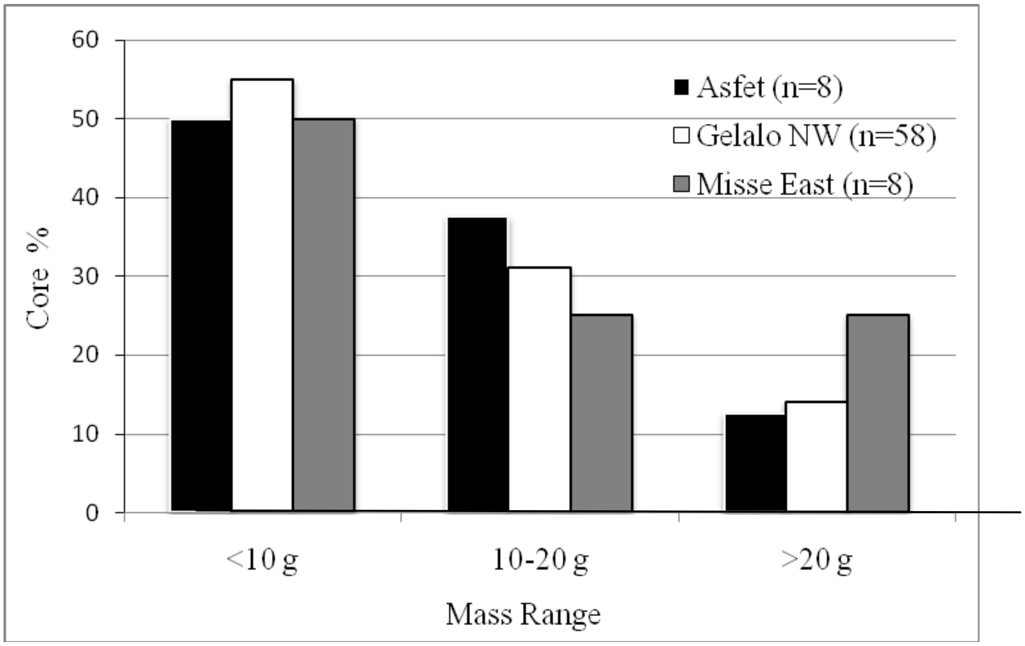


Figure 7.1. Mass variability in the core class at Asfet, Gelalo and Misse.

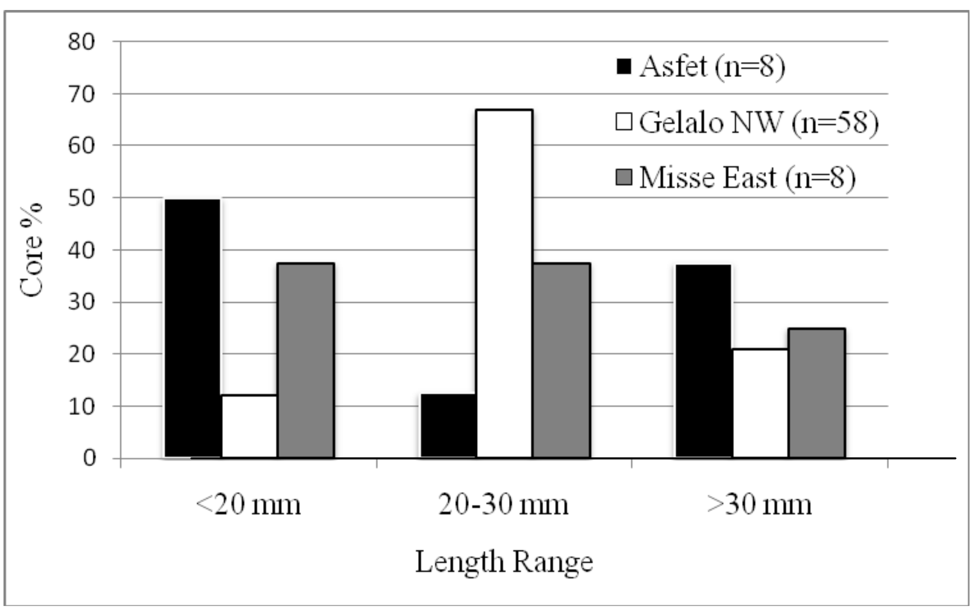


Figure 7.2. Length variability in the core class at Asfet, Gelalo and Misse.

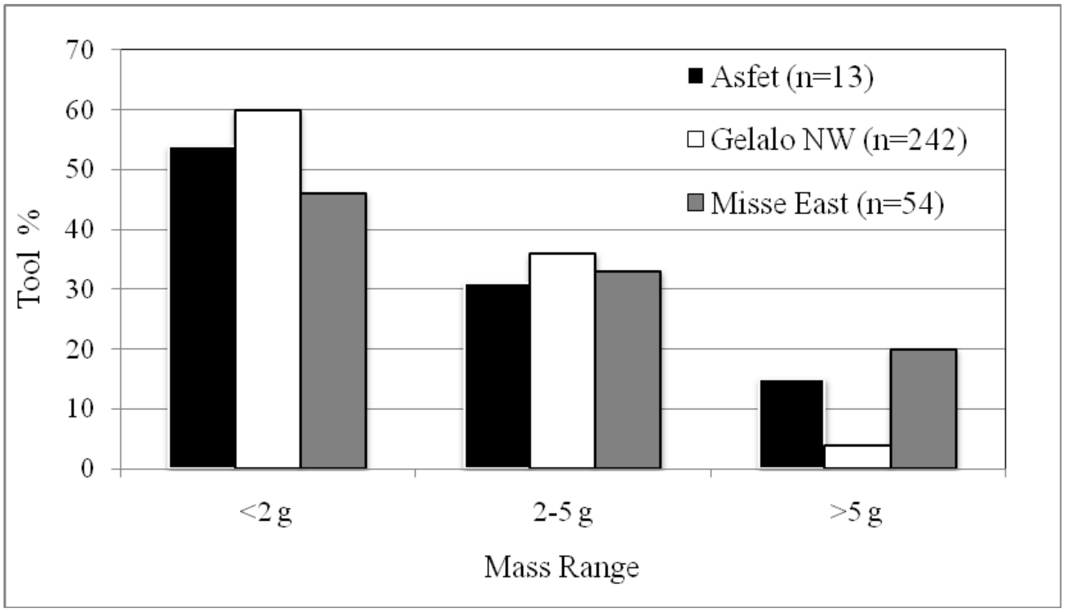


Figure 7.3. Mass variability in the shaped tool class at Asfet, Gelalo and Misse.

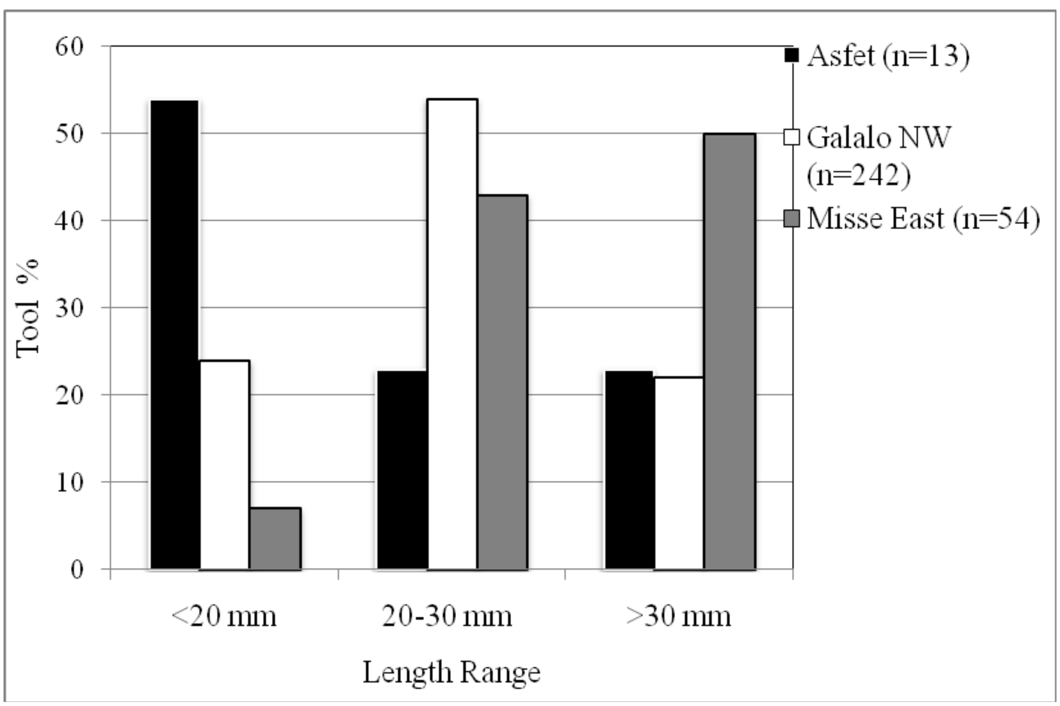


Figure 7.4. Size variability in the tool class at Asfet, Gelalo and Misse.

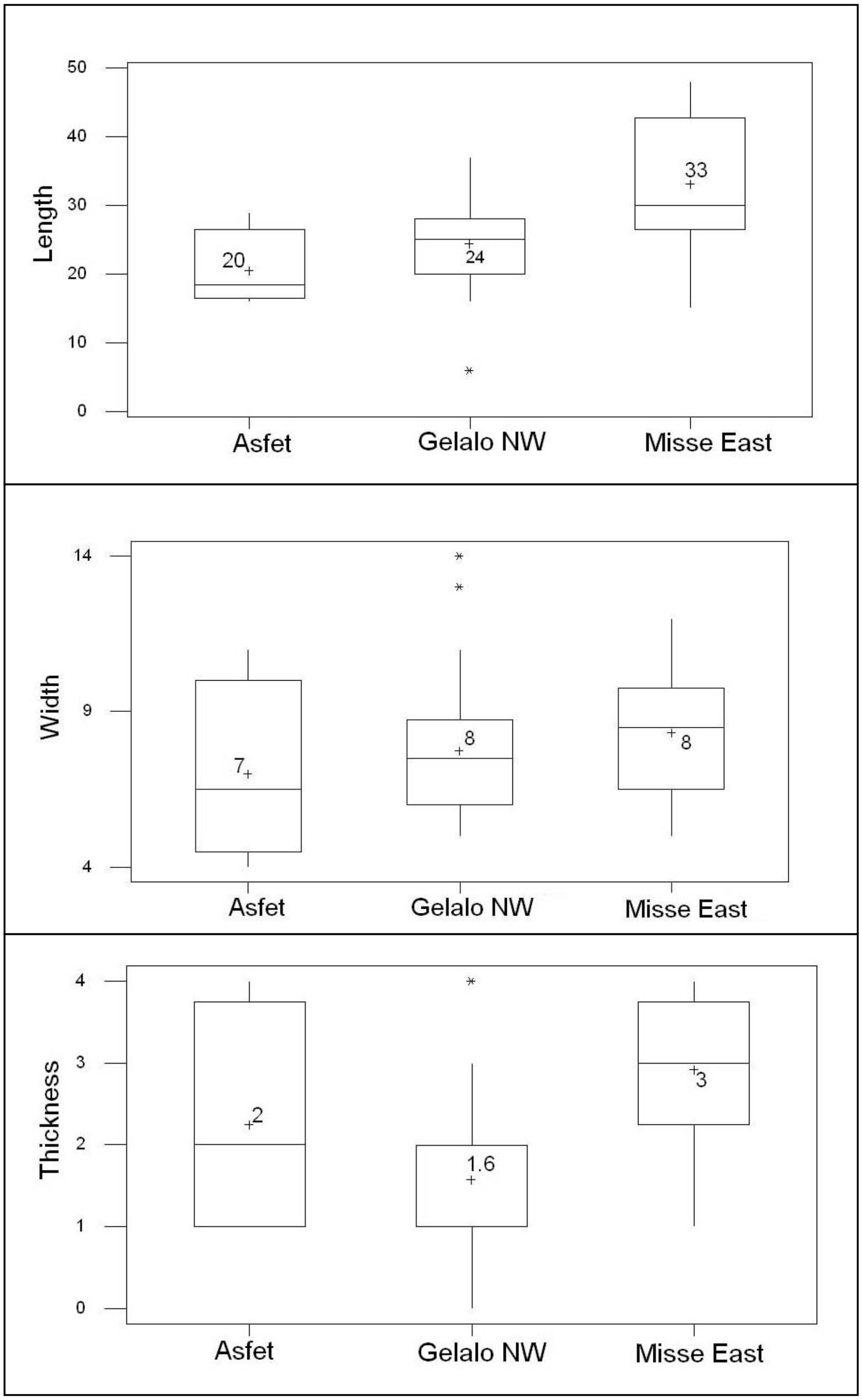


Figure 7.5. Box plots showing microlithic size relationship among Asfet, Gelalo and Misse sites. Numbered cross signs represent mean values.

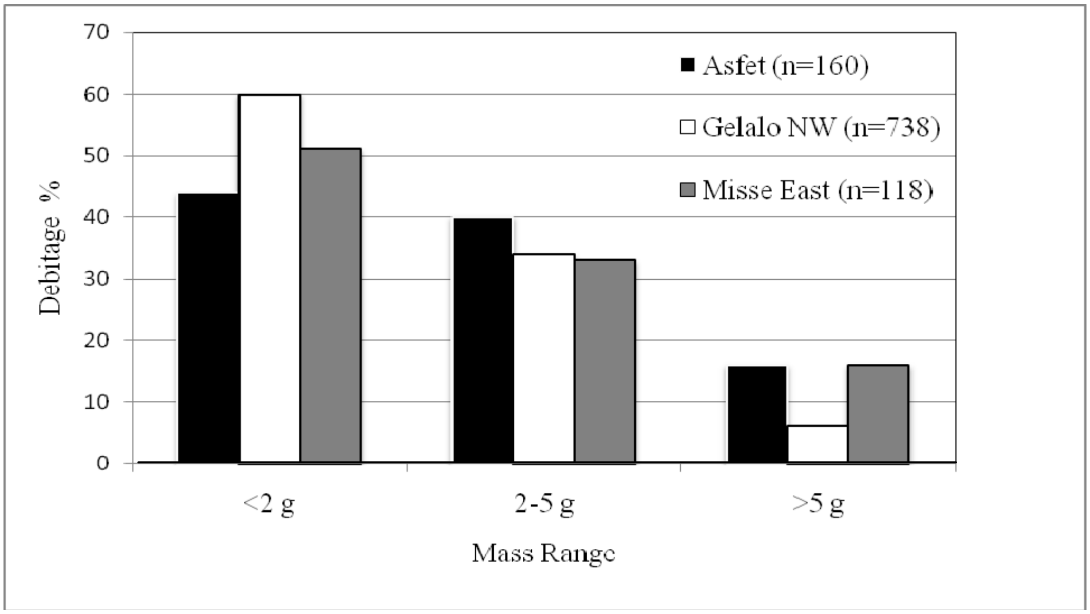


Figure 7.6. Mass variability in the debitage class at Asfet, Gelalo and Misse.

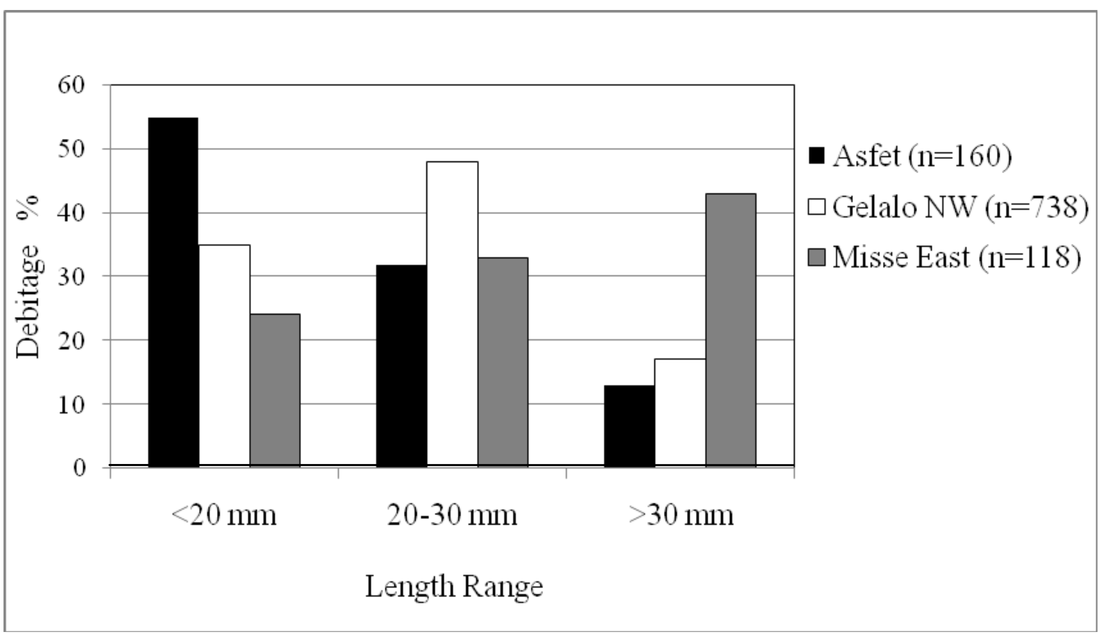


Figure 7.7. Length variability in the debitage class at Asfet, Gelalo and Misse.

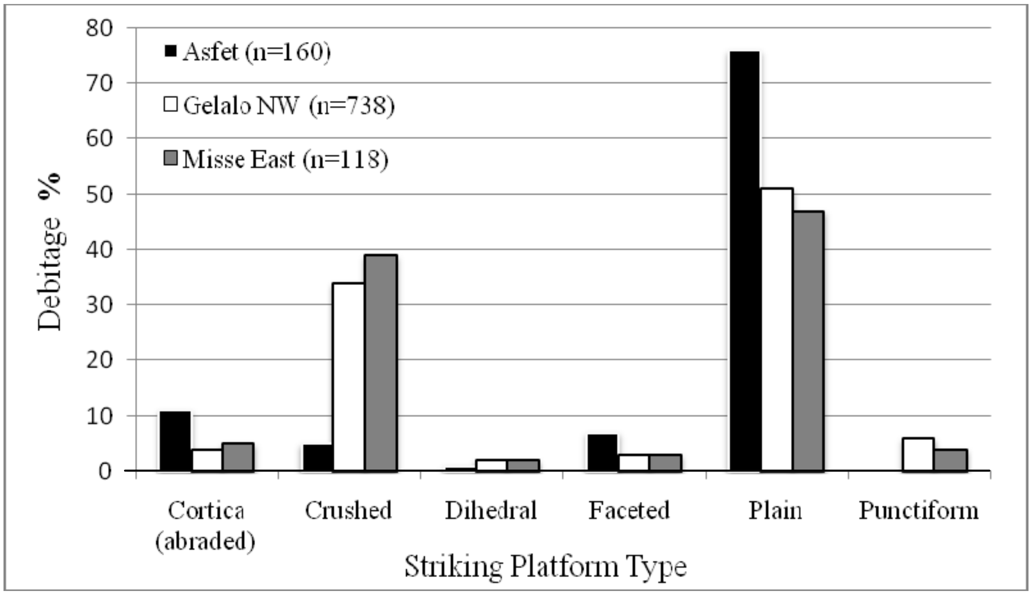


Figure 7.8. Debitage striking platform variability at Asfet, Gelalo and Misse.

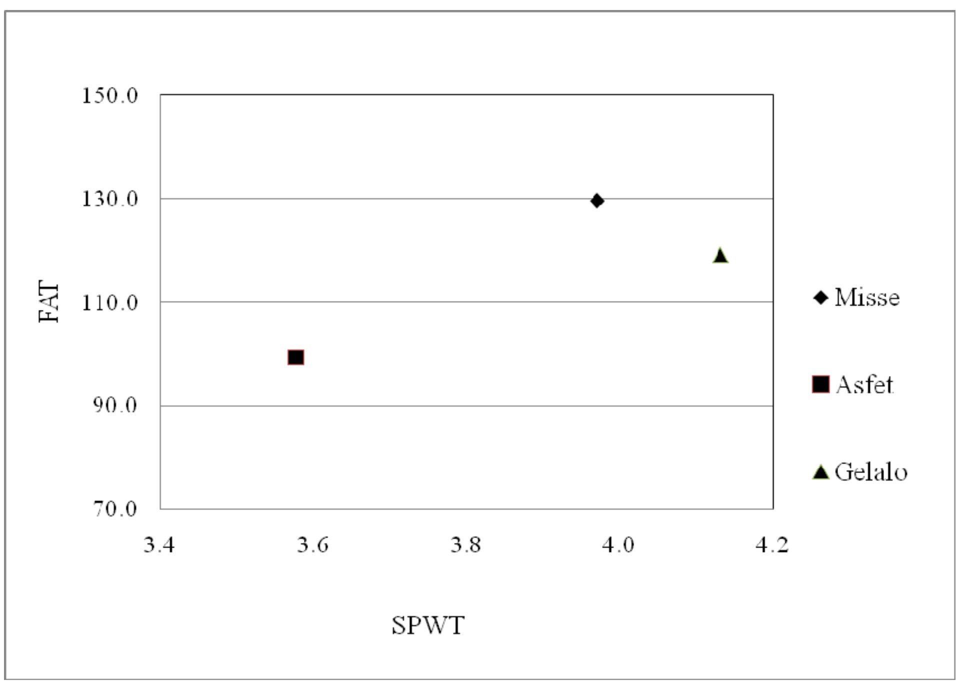


Figure 7.9. Mean plots of Flake Area/Mid-Point Thickness (FAT) against Striking Platform Width/ Thickness (SPWT) for the complete flakes from the focal sites.

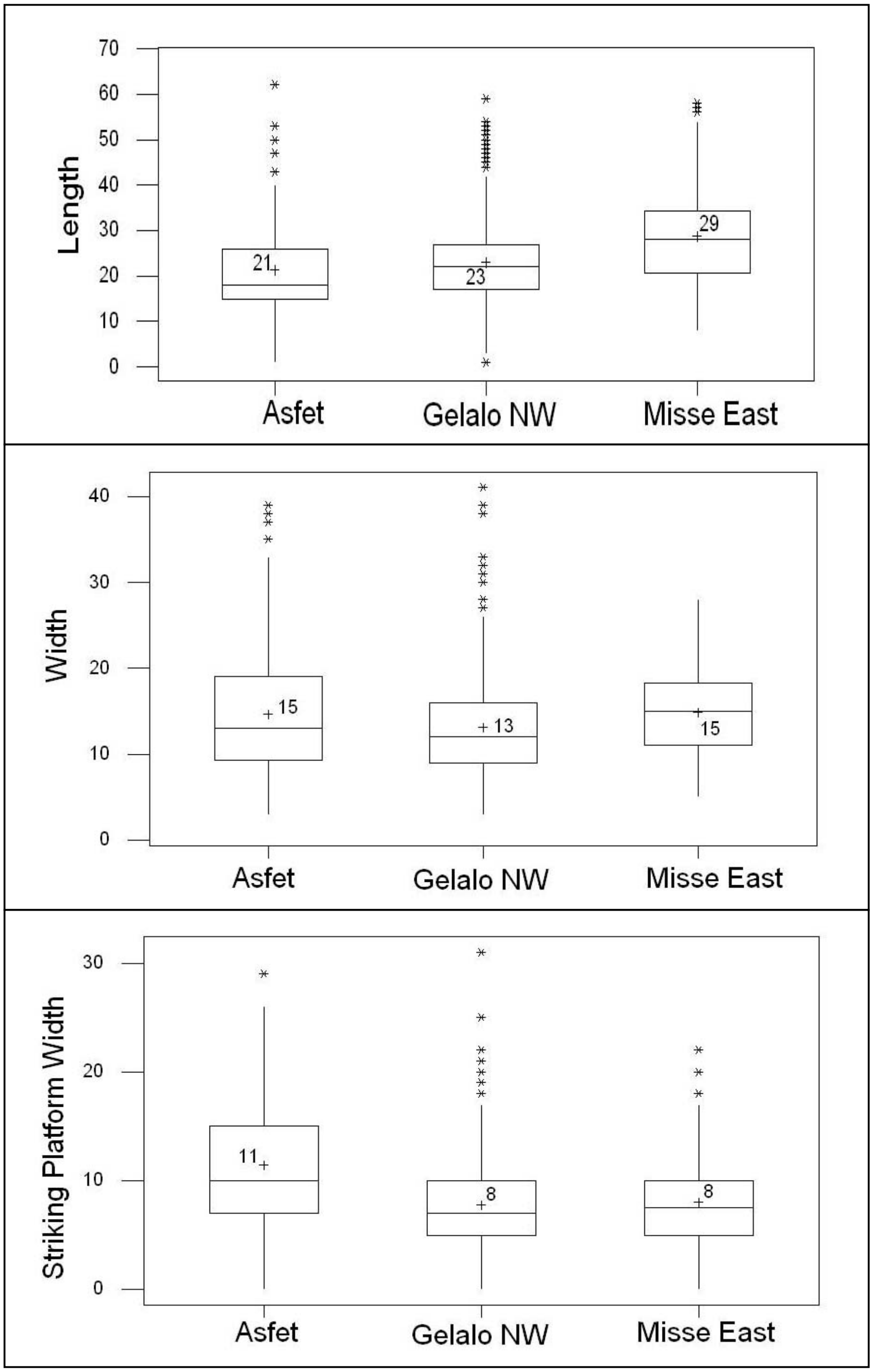


Figure 7.10. Box plots showing debitage size relationship among the focal sites. Note that the Asfet assemblage is represented by broader (greater striking platform width) and shorter artifacts (mean length smaller than the other two sites).

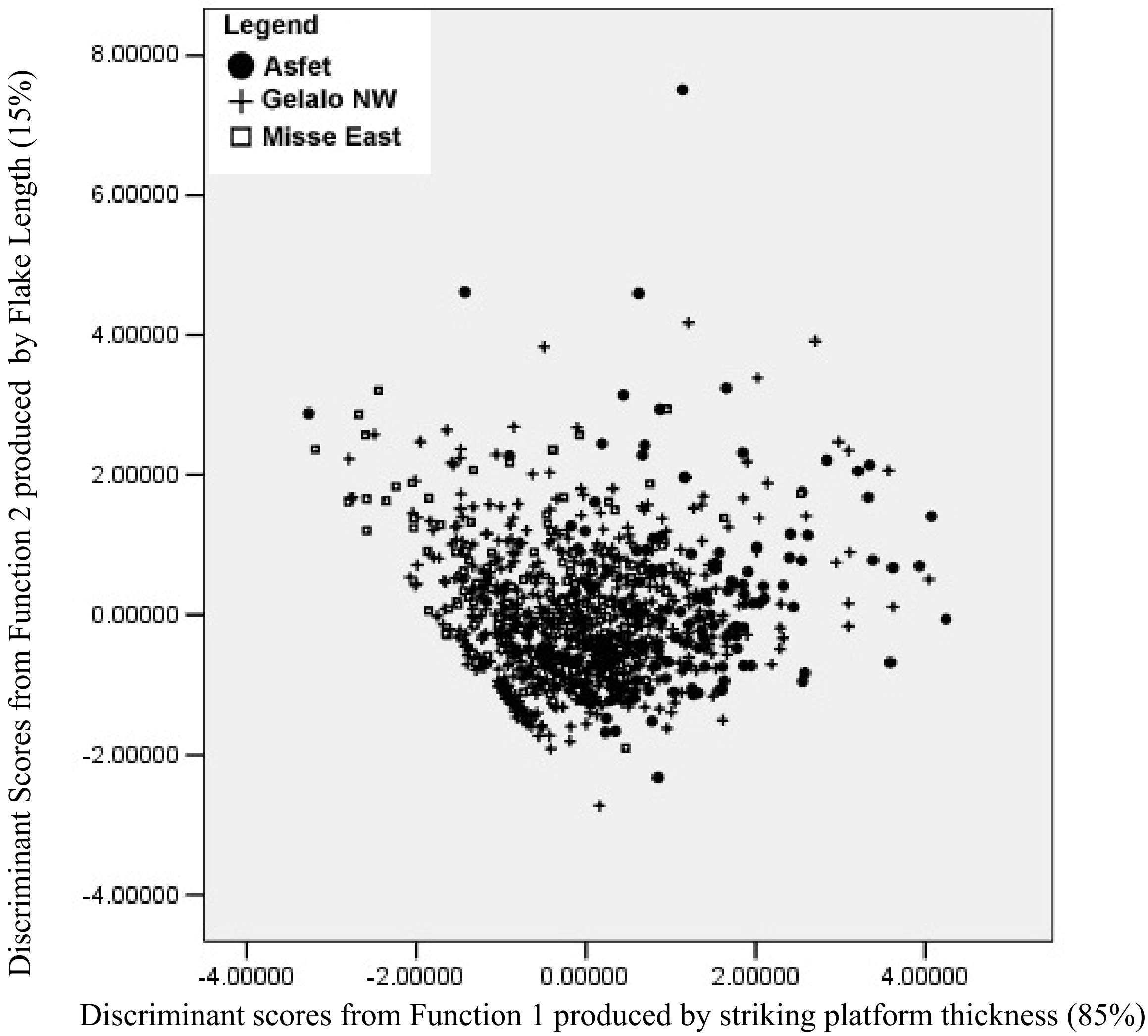


Figure 7.11. A plot of discriminant scores showing the pattern of debitage data in relation to flake length (Function 1) and Striking Platform Thickness (Function 2) among the Coastal Sites. See Table 7.6 for log determinants associated with the measured dispersions among the size attributes.

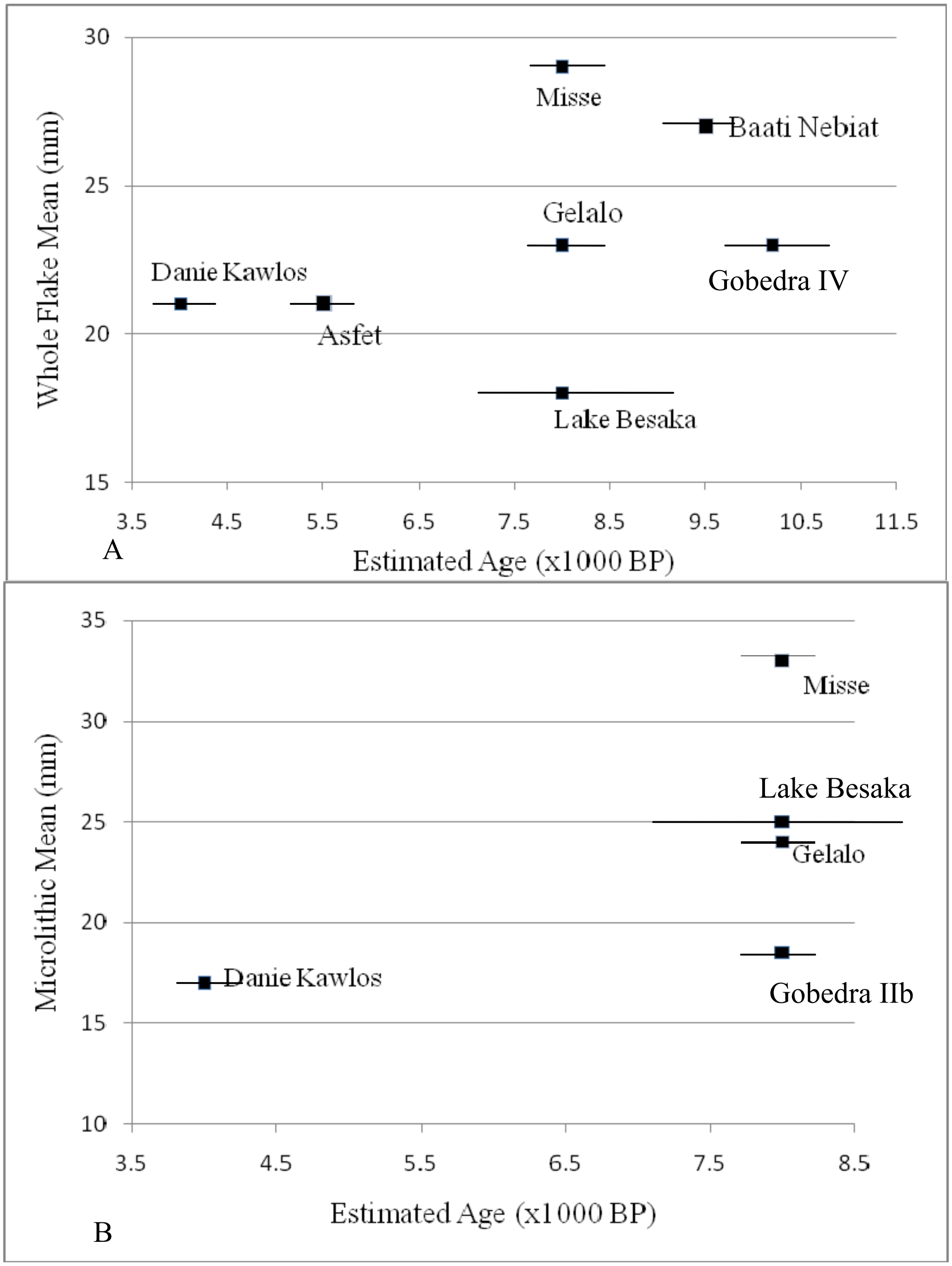


Figure 7.12. Plot of size means for the focal sites, and comparative sites from Tigray (northern Ethiopia) and Lake Besaka; a) whole flakes, b) microliths. Horizontal lines indicate approximate age range.

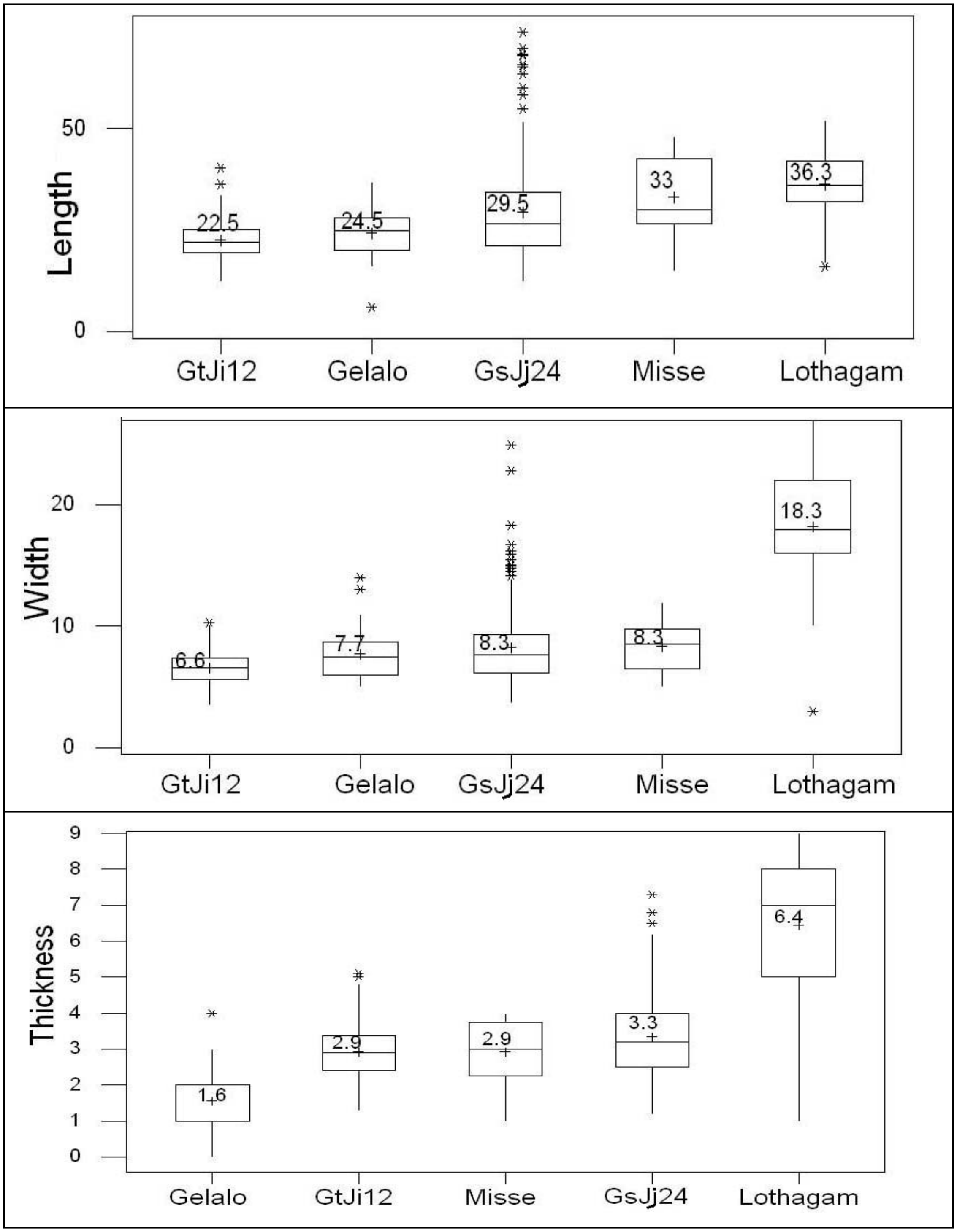


Figure 7.13. Box Plot showing microlithic size relationship among the comparative sites from the Eritrean Coast and other regions.

Core Class	Sites		
	Asfet n (%)	Gelalo NW n (%)	Misse East n (%)
Core on Flake	1 (12.5)	4 (7)	1 (12.5)
Prismatic	1 (12.5)	18 (31)	4 (50)
Bipolar		13 (22)	2 (25)
Core Fragment		4 (7)	
Core Tool		3 (5)	
Discoid		2 (3)	
Other/ Unspecialized	6 (75)	14 (24)	1(12.5)
Total Count	8	58	8

Table 7.1. Variability in core composition at Asfet, Gelalo and Misse.

Raw Material	Sites		
	Asfet n (%)	Gelalo NW n (%)	Misse East n (%)
Obsidian	3 (37.5)	58 (100)	8 (100)
Other	2 (25)		
Quartz	3 (37.5)		
Total Count	8	58	8

Table 7.2. Raw material variability in the core class at Asfet, Gelalo and Misse.

Tool Type	Sites		
	Asfet n (%)	Gelalo NW n (%)	Misse East n (%)
Backed blade/Flake	2(15)	9(4)	5(9)
Backed Fragments	4 (31)	33	14(26)
Burins		20(8)	
Denticulate		11(5)	4 (7)
Edge damaged/other	1(8)	85(35)	8(14)
Geometric Microliths	2(15)	40(17)	12(22)
Notches		27(11)	3(6)
Scrapers	2(15)	17(7)	8(15)
Triangular Points	2(15)		
Totals	13	242	54

Table 7.3. Variability in shaped tool composition at Asfet, Gelalo and Misse.

Attributes	Chi-Square	df	P-value
Tool composition (artifact classes represented in respective assemblages)	19.5 #	7	0.007
Length (complete microliths)	13 #	2	0.001
Mass (complete microliths)	17.8 #	2	0.000
Retouch position	3.2 *	3	0.35
Cortex	1.6 *	2	0.400
Retouch morphology	18.4 #	7	0.000
Retouch distribution	1.2 *	2	0.500
Retouch size	34.5 #	3	0.000
Retouch extent	2.2 *	2	0.332
Edge form	9 *	5	0.140
Shape	4.8 *	8	0.400
Length/width (complete microliths)	7.8 #	3	0.020
Shape (backed fragments)	5.4*	3	0.500
Length (backed fragments)	6#	2	0.036

#=significant difference at 0.05 level
*= no significant difference at 0.05 level

Table 7.4. Chi-square significance test for microlithic techno-typological variables between Gelalo NW and Misse East.

Tool Type	Sites		
	Asfet n (%)	Gelalo NW n (%)	Misse East n (%)
Fully cortical	5(3)	36(5)	0
Non-cortical	101(63)	308(42)	47(40)
Other flake type	15(9)	49(7)	19(16)
Partially cortical	15(9)	106(14)	16(14)
Prismatic	24(15)	239 (32)	36(30)
Total Count	160	738	118

Table 7.5. Variability in complete debitage composition at Asfet, Gelalo and Misse.

Asfet	13.312	1
Gelalo	11.744	3
Misse	12.205	2
Pooled variance within groups	12.153	2

Table 7.6. Log determinants and multivariate measured dispersion (variation) among Asfet, Gelalo and Misse sites.

Site	Context	Age (x1000) BP	Microlith Length (mm)		Whole Flake Length (mm)	
			N	Mean	N	Mean
Asfet	Levels 1-2	< 6			160	21
Gelalo NW	Levels 1-2	~8	40	24	738	23
Miss East	Levels 1-2	~7.5	12	33	118	29
Baati Nebiat[#]	Context 5	~9.5			83	27
Danie Kawlos*	Layers 4-5	<4	9	17	539	21
Gobedra[+]	Stratum I, IIa, IIb, III	<7.7	87	18.5	304	23
	Stratum IV	~10.2			125	23
Lake Besaka[$]	FeJx2, Unit 1	~7	619	25	11714	18
Enkapune Ya Muto (GtJi12)[@]	RBL1, 2.1, 2.2 and 2.3	<6	155	22.5		
Marula Rock shelter (GsJj24)[@]	E 6-7, E 7-8, E 8-9	~8	228	29.5		
Lothagam[€]	Square IV, VI, VII	~7	30	36.3		

Table 7.7. Age, context and mean of selected early and mid-Holocene lithic assemblages from the Horn and Kenya. Key to data sources: [#]Finneran 2000; *Negash 2001; [+]Phillipson 1977; [$]Brandt 1982; [@]Stanley Ambrose personal data; [€]Larry Robbins personal data.

Sites	Attributes	Mean	Misse East Length	Misse East Width	Misse East Thickness	Gelalo NW Length	Gelalo NW Width	Gelalo NW Thickness
GtJi12	Length	22.5	t=6.8# P=0.00			t=-2.2# P=0.03		
	Width	6.6		t=-4.9# P=0.00			t=-4.2# P=0.00	
	Thickness	2.9			t=0.03* P=0.97			t=10.4# p=0.00
GsJj24	Length	29.5	t=-0.95* P=0.34			t=2.47# P=0.01		
	Width	8.3		t=-0.08* P=0.94			t=1.94* P=0.3	
	Thickness	3.4			t=1.3* P=0.2			t=9.3# P=0.00
Lothagam	Length	36.3	t=1.1* P=0.32			t=6.6# P=0.00		
	Width	18.3		t=6# P=0.00			t=11# P=0.00	
	Thickness	6.5			t=7* P=0.00			T=16# P=0.00

#= significant difference at 0.05 level
*=no significant difference at 0.05 level

Table 7.8. T-test significance test results for microliths from the Red Sea and Kenya.

Chapter 8

Discussion and Conclusions

Human adaptation on the Eritrean Coast: a summary

The archaeological work along the Red Sea Coast of Eritrea produced evidence for Middle and Later Stone Age human occupations. This chapter presents the general synthesis of field and laboratory research. Since this is a pioneer work on an area that has been little explored, there are practical limitations underlying the present interpretation. The Gelalo NW, Misse East and Asfet Unit F sites all produced mollusk shells suggesting human interest in coastal economy (a report on shell analysis is included in Appendix I). Gelalo and Misse were both dated to the 8th millennium BP, but characterized by different mollusk species. Whereas Misse was dominated by *Atactodea glabrata*- a small bivalve found buried in the sand of the intertidal zone, *Terebralia palustris* - a large gastropod that dwells among humid mangrove shades dominates the Gelalo shell assemblage. Gelalo also produced a relatively large number of shell beads (mollusk and ostrich egg-shell). Asfet Unit F, dated to the 6th millennium BP, produced the highest density of shell remains dominated by *Terebralia palustris*. More than eight other mollusk species were identified in the three assemblages, most of them in small proportions. The scale of human reliance on shellfish harvesting appears to be greater at Asfet Unit F and Misse compared to Gelalo (shell density is relatively low at Gelalo).

The evidence suggests exploitation of different types of mollusk species, seemingly from a variety of coastal habitats. Such an emphasis on specific mollusk species at different sites implies different choices by human groups at correspondingly different time periods. Faunal remains other than mollusk shells were absent. It is unclear whether the absence of terrestrial fauna is due to preservation bias or if those species were not consumed at all. Under normal situations, bones decay slowly in alkaline setting, particularly above 8.1 PH range (Berna, et al. 2004). PH analysis of soil samples from the excavated pits shows more of alkaline context (>7). Furthermore, the presence of shells in an excellent preservation condition suggests that the soil was alkaline. Therefore, soil chemistry seems to have little impact on bone decomposition at the sites. If terrestrial animals were consumed their remains may have been discarded in different location than the excavated spots. The presence of abundant stone tools at the sites is tempting to conclude that terrestrial fauna were indeed exploited, but their remains were not recovered for taphonomic reasons or excavation bias. As such, the sites can be better viewed as products of a mixed economic activity involving terrestrial and coastal resource exploitation depending on the prevailing ecological circumstances.

Site locations from the current coastline vary from less than 1 km at Asfet to about 15 km at Gelalo. Although some of the sites may have been much closer to the coast during their occupation, the inland location of some sites such as Gelalo implies that shells were transported for a long distance to base camps. Presumably, stable resources, including fresh water must have been available in the interior fields of the Buri Peninsula - closer to the Buri Lake where base camps were positioned. Importantly, the ephemeral lake in the Buri Peninsula may have supported fauna and flora that could be regularly exploited by humans. When conditions were less hospitable in the hinterlands, foragers would have to increase their diet breadth, and incorporate mollusks to offset the decrease in the densities of high ranked resources (Kelly 1995). Thus, shellfish gathering may have been scheduled in relation to the availability of other terrestrial resources in the hinterlands. There is no clue about plant or animal domestication as organic remains other than mollusk were not found.

The lithic assemblages from both surface and subsurface contexts of the three focal sites (Asfet, Gelalo and Misse) have been the focus of this dissertation. The analyzed assemblages fall broadly into two distinct traditions: i) MSA *sensu lato*, which is exclusively known from surface context at Asfet, and ii) radiometrically dated LSA assemblages excavated from Asfet Unit F, Gelalo and Misse. Two types of LSA assemblages are recognized: i) Gelalo and Misse, ii) Asfet subsurface. Sites were assigned to the MSA if they feature core preparation (Levallois) technology.

Prismatic blade core and backed microlithic technologies are generally seen as hallmarks of LSA Industry in Sub-Saharan Africa, although some early MSA sites in eastern Africa have shown conclusively prismatic blade production (Leakey, et al. 1969; McBrearty and Tryon 2006). When the evidence is viewed along a temporal line, there is directional change in core technology, tool design and raw material utilization among Asfet surface, the two older LSA sites (Gelalo and Misse) and the Asfet subsurface evidence. The Asfet surface assemblage represents distinct MSA Industry characterized by prepared cores, triangular points, small bifaces and blades on a variety of raw materials. In the case of the LSA settlements, specialized blade cores have been recovered from Gelalo and Misse, whereas more expedient cores characterize the Asfet subsurface collection. Moreover, the Gelalo and Misse assemblages feature microlithic technology entirely on obsidian, while the Asfet subsurface assemblage incorporates quartz and basalt in addition to obsidian. Blade blanks are present in both the LSA groups (from the Buri Peninsula and Asfet).

One potential obsidian source area has been identified during our survey near the Kusrale Basin (at the southeastern margin of the Gulf of Zula). Obsidian samples were collected from Kusrale and subjected to X-ray and Neutron Activation Analysis (Glascock, et al. 2008). See Appendix II for obsidian source analysis. X-ray and Neutron Activation Analysis provide means of identifying the geological source of obsidian samples by comparing the chemical concentration of specific elements in obsidian such as Rabidium, Iron, Zirconium, Manganese and others (Glascock, et al. 1998). According to the results of the X-ray analysis, the Gelalo sample clusters closer to the reference sample from Kusrale, whereas the Misse and Asfet specimens do not show any distinctive pattern with respect to the reference sample. Using Neutron Activation Analysis, three clusters were recognized based on iron and rubidium concentrations, indicating three potential source areas. The region is rich in volcanic flows and obsidian may have been procured from a variety of sources. The observed raw material variability among the LSA sites signifies differences in raw material accessibility or it may indicate technological choices associated with different mobility strategies.

Variability in core technology is thought to be an important technological proxy to explain differences in mobility pattern among prehistoric human groups. By examining numerous assemblages in North American Late Prehistoric sites, Parry and Kelly (1987) found a close relationship between decreased mobility and increased emphasis on expedient cores. According to this model, humans in sedentary settlements knap opportunistically and casually, investing less time in making formal cores. This is because sedentary groups often use tools at the base camp where other organic substitutes are available. In contrast, highly mobile foragers rely more on formal cores and designed tools because these tools provide higher efficiency during unanticipated needs in the course of foraging movement. There is always a trade off in choosing expedient over formal cores; the two determinant variables being higher raw material cost for expedient technology and higher manufacturing time cost for formal ones (ibid.). The model offers a useful framework to explain the observed patterns in core technology among Asfet, Gelalo and Misse sites. In this respect, the higher frequency of formal cores and designed tools at Misse and Gelalo suggests that early Holocene sites around the Buri Peninsula represent settlements by more mobile human groups. Notably, the absence of less portable material remains such as ceramics and grinding stones together suggests that the Eritrean sites were occupied by mobile groups. The shallow nature of the archaeological deposits further suggests short occupation spans.

Culture Historical Sequence of the Red Sea Coast

Later Pleistocene MSA Settlement

The evidence for this settlement scenario is restricted to the Asfet surface occurrence. The assemblage features prepared core and blade technologies on a variety of raw materials. The commonly utilized rocks include basalt, obsidian, quartz, chert, green schist, shale and rhyolite. Several of the raw materials utilized were from local source, particularly those on hard volcanic rocks and quartz. A few others, however, lack definite provenance such as chert, obsidian and shale. The shaped tools are comprised of scrapers, points, perforators and bifaces (small and large handaxes). The discovery of points (triangular flakes and perforators), small bifaces, prepared core products and abundant blades place the Asfet occurrence within the range of Modes 3 and 4 traditions of the Later Pleistocene period in the Sub-Saharan Africa (Clark and Kleindienst 2001). The small number of handaxes is characteristic of Mode 2 Industry, but they do not necessarily represent the Acheulian culture *per se* due to their small quantity. The rest of the blank artifacts are predominantly flakes comprising non-cortical, partially cortical and fragmentary debitage. The raw material and typological diversity suggests varieties of technological steps taking place at the site involving raw material transportation, core reduction and tool shaping. Artifact context at Asfet varies from rolling basalt slopes on the western ridge to loose sandy deposits on the N-S stretching shallow basin. Site formation history and directional change over time within the Asfet surface assemblage could not be firmly established due to lack of secured chronological context and deflated nature of the substrate. Therefore, although the typological characteristics of the Asfet assemblage broadly signify a MSA occupation, it is possible that more than one cultural entity is represented at the site. Complete understanding of the cultural variability at the site will require examining assemblages recovered from primary subsurface context.

Whether the Asfet settlement originated from preexisting hominin adaptations around the region such as the Middle Pleistocene *Homo erectus* of Buia (Abbate, et al. 1998), or from new inhabitants from the other parts is unclear. The Abdur site on the eastern side of the Gulf of Zula, located about 20 km distant from Asfet, is the nearest prehistoric locality with which the Asfet evidence could be compared. Unfortunately, the Abdur cultural evidence has not been subjected to any formal investigation and there are controversies over the geological context of the artifacts from the site (Bailey and Flemming 2008). Except for a few specimens collected for museum display, inadequate lithic samples have been recovered from Abdur to allow techo-typological assessment. The Asfet and Abdur sites seem to differ in a number of important aspects. While the Abdur context represents limestone (coral reef) formation belonging to the Last Interglacial period, the Asfet assemblage occurs on an open basalt landscape. Thus, the geological context at Asfet does not represent any specific event, while the Abdur evidence does. There are also questions about the association between the cultural remains and the coral reef at Abdur. It is unclear whether the artifacts were embedded into the reef by natural processes or through human activities. During a brief visit to the site, the author noted the lithic distribution there to be rather sparse and disturbed, although the few exposed artifacts seem to be manmade. Hence, due to the absence of detailed information about the Abdur lithic evidence, and lack of absolute date for the Asfet site, it was not possible to establish firm cultural relationship between Abdur and Asfet sites.

Early Mid - Holocene LSA Settlement

This settlement scenario is best represented at the two excavated LSA sites in the Buri Peninsula (Gelalo and Misse). The Gelalo Site produced dates ranging between 7000 and 8400 years Cal BP (2-sigma). The Misse site produced closely overlapping dates in the mid- eighth millennium BP, and it seems to represent shorter occupation phase than Gelalo. There is no cultural difference between the two sites, except that Gelalo reflects broader age span than Misse. This could be because Gelalo was extensively investigated than Misse and more samples were dated from that site. Gelalo and Misse produced similar LSA artifacts featuring backed tools, blades and abundant non-cortical and fragmentary debitage. The observed pattern from core, tool and debitage data in the course of lithic investigation attests that both Gelalo and Misse assemblages represent similar adaptive strategy (technological behavior).

Crescents are the most diagnostic geometric tools at Gelalo and Misse. In terms of size, the Misse collection contains longer geometric backed tools suggesting that the knappers at Misse were modifying larger blanks. Furthermore, the presence of longer microlithic tools at Misse and shorter ones at Gelalo implies varying core preparation and transportation strategies. The Gelalo knappers may have been reducing smaller nodules while those of Misse had access to larger ones. Microliths are light and they offer greater advantages over heavy tools for mobile human groups (Shott 1986). In Sub-Saharan Africa, the emergence of microlithic technology dates back to the MSA, although their widespread use became more apparent during the LSA, particularly since the onset of the Holocene period (Ambrose 2002). Some researchers view their widespread occurrence throughout the LSA and Neolithic in an evolutionary context, and argue that microliths offered selective advantages for human survival under certain environmental circumstances (Neeley 2002). Variables that confer higher selective rank to microliths include their functional versatility as inserts for composite tools and cutting implements, low cost of manufacture from a variety of blank forms, and low cost of transportation due to their light weight (ibid.). Although microlithic technology is commonly associated with mobile hunter - gatherers, there was no specific geographic area or cultural context for their early invention (Kuhn and Elston 2002). They evolved in a wide range of geographic and social contexts (agriculturalist and mobile foragers) (ibid.). The presence of microliths at Gelalo and Misse sites may indicate hunting economy with a possible use of the microlithic implements as inserts for hunting tools. In this respect, human adaptation of the Buri Peninsula seems to have involved terrestrial game exploitation.

Mid-Holocene LSA settlement

The subsurface evidence from the Asfet Unit F represents this settlement scenario dating to the 6th millennium BP. Lithic artifacts continue to be the major cultural evidence. The subsurface assemblage at Asfet Unit F differs from those two older Holocene sites on the Buri Peninsula in raw material and tool diversity. The Asfet assemblage reveals higher raw material diversity compared to the obsidian dominated assemblages from Gelalo and Misse. Quartz and basalt were exploited at Asfet in addition to obsidian. Moreover, the percentage of backed tools is very low at Asfet Unit F compared to Gelalo and Misse. The lack of more designed tools at Asfet could be tentatively explained in relation to mobility pattern. Assuming that standardized tools are common in highly mobile groups (Shott 1986), an assemblage characterized by a lower frequency of designed tools can be correlated with more sedentary settlements (Parry and Kelley 1987). *Terebralia palustris*, which is a common mollusk in the nearby coast today, is the dominant species in the shell assemblage excavated from Unit F. This indicates that the Asfet Unit F settlement represents broadly similar climatic or ecological conditions to the present times. Nowadays, the Asfet coast preserves mangrove vegetation, salinity resistant plants that create favorable habitat for shell reproduction and herbivore forage. Such plants could have offered sustainable niche to the terrestrial fauna in the past upon which prehistoric humans could have subsisted. The site is convenient for harvesting other aquatic resources as well, such as fish, but their remains have not been discovered due to excavation bias or taphonomic reasons.

The available evidence is inconclusive over whether the LSA sites represent a continuation of preexisted cultures in the region or newly established settlements in the Holocene. There is no clear association between the Asfet surface material (presumably a Late Pleistocene settlement) and the Holocene occurrences to assume that the Holocene settlements evolved locally. If the LSA sites represent newly established settlements, the Afar Rift to the south would be the likely source of human groups who occupied the coast during the early mid-Holocene times. The broad technological and chronological affinities between Lake Besaka and Gelalo corroborate this assumption. Alternatively, the coastal settlements might have branched from the highland occupations documented around Aksum such as Gobedra and Baati Nebiat. Some LSA sites in the Afar Rift and interior highlands represent older dates (10-9 ka BP) with continuous occupations till later Holocene (Finneran 2007). Human groups might have dispersed to the coast from one or both regions as a result of climatic aridity or niche broadening during humid episodes.

It is important to note that several other sites representing LSA and MSA lithic assemblages were recorded near the Buri Lake shore and along the southern peripheries of the Gulf of Zula during the reconnaissance survey (Beyin and Shea 2007). The Irafailo study area (on the southern tip of the Gulf of Zula) was the most intensively visited area during the survey and with the highest landscape diversity. Eight sites (Asfet, Asadaf East, Asadaf North 1, 2, 3, and Kusrale 1, 2, 3), spanning

Neolithic to MSA cultural context have been documented here. The Meka Enile area was the next target after exploring the Irafailo basin. This study area combines coastal margins and inland ridges around the Meka Enile Village. Three sites (Jasper Quarry, Triple Ridges, Harerti) were documented here. The Dagat study area encompasses the southeastern portion of the Buri Lake (Dagat) located at the center of the Peninsula and a small portion on the northwest of the town of Gelalo. This is the lowest of the study areas with a minimum elevation recorded –8 m at the southern shore of the Lake. Four sites, mainly LSA (Gelalo NW, Gelalo AH, Buri Lake Ridge, Buri Lake Shore) were documented there during the initial survey. The last surveyed locality was the Ingel area, located at the northern edge of the Buri Peninsula and northeast of the Ingel-Village. Two sites (Ingel 3 and Ingel Hill Site) were documented from this survey area. Based on the lithic composition, mainly the dominance of blade tools in most sites, LSA sites seem better represented (Beyin and Shea 2007). Typically MSA artifacts were documented at three sites: Asfet, Kusrale 3 and Asadaf East while LSA (Fig. 1.2). Obsidian is the commonly reduced raw material in most sites. No pattern was observed with regards to the surface distribution of artifacts on the inland sites versus near coastal ones. Similar raw material variability and lithic production techniques were noted in both near coastal and inland sites. Traces of ceramics were noted during the initial survey around the Irafailo Basin and the Buri Lake peripheries. However, it was not possible to make more specific typological identification due to the fragmentary nature of the specimens. The wide distribution of sites along the Buri-Zula terrain implies that humans exploited diverse landscapes. The coastal shores and the Buri Lake could have offered prehistoric humans great advantage as stable resources of water and other resources.

Climatic context of the LSA Settlements

Intermittent dry periods characterize the early mid-Holocene period regionally (Hassan 1997; Umer, et al. 2004). One particular region with an extensive record of Holocene climate is the Ethiopian/Afar Rift region (Gasse 1977; Gasse, et al. 1980).

A number of studies on the Rift Lakes (see summary in Umer, et al. 2004) recorded recurrent dry events marked by decline in lake level hydrology towards the mid-Holocene. For instance, dry events were recorded at Lakes Ziway and Abhe between 8700 - 8100, at 6700 and between 5700 - 5100 years Cal BP (ibid.). Similarly, sporadic arid phases had prevailed in the eastern Sahara during early mid- Holocene, such as 7500, 6500 and 4500–3000 radiocarbon years BP (Hassan 1997; Marshall and Hildebrand 2002). Hassan (1997:213) recognizes six major drought events in the monsoon dominated areas of Africa following the Terminal Pleistocene: 12,000-11,500, 8500, 7500, 4500, 4000-3700 and 2000 uncalibrated radiocarbon years BP. The dates for Gelalo and Misse occupations fall in wet episode in relation to the climatic record from Lake Abhe in the Afar Rift, but the earlier dates for Gelalo fall in an arid phase in relation to the late 9th millennium hydrological record of Ziway-Shala (Gasse 2000) (Fig. 8.3). The mid-Holocene site of Asfet (Unit F) broadly coincides with wet conditions witnessed at Lake Abhe, but also represent partially dry episode when seen with respect to the hydrological record of Lakes Ziway-Shala (Fig. 8.3). In general, the Eritrean sites seem to represent humid phases with dry periods hitting the region either at the terminal or initial phases of these settlements.

In explaining early Holocene subsistence patterns in the Horn, Brandt (1986:72) states," even though the archaeological record of the early Holocene in the Horn is scanty, the one adaptive strategy for which we have adequate data is hunter/gatherer utilization of the rich and varied resources of the Ethiopian and Afar lakes." The current evidence from the Buri Peninsula and Gulf of Zula corroborates the above assertion in showing early mid-Holocene human aquatic exploitation. The coastal areas may have been attractive during wet and arid conditions due to the presence of freshwater and predictable resources along the shorelines. Human movement due to climate would have resulted in widespread and stable occupations, because an entire population would move to the coast in search of resources critical to everyone's survival, whereas smaller groups may have moved to the coast during humid periods resulting in restricted or short-term settlements. Freshwater is a critical resource in the coastal region, which has an important implication in human settlement structure. The area is extremely hot throughout the year and any sustainable human settlement can only exist close to freshwater. At present, the sites are variably located between 1- 5 km distant from potential water sources. In the past, freshwater must have been present at a much closer distance to the sites, assuming there was limited access to water containers (ceramic, gourd). Future studies focusing on landscape archaeology, drainage pattern and tufa deposits may further clarify settlement configuration with respect to water sources in the area.

Figure 8.4 presents a generalized model of settlement dynamics on the Eritrean Red Sea Coast. Accordingly, it is hypothesized that, the presence of broad coastal plains and hyrostatic springs could create optimal conditions for human coastal settlements during glacial (dry) periods. However, site visibility at present is low for occupations formed during glacial events due to inundation by sea water. Alternatively, increased size of the aquatic habitat (sea water) during interglacial could have attracted human settlements on the near shore landscapes, for which we can find ample evidence, since the impact of sea level increase would be minimal. According to Yesner (1980: 729-30) “coastal settlements tend to favor: i) complex coastlines where protective and productive bays are found, ii) areas associated with streams or lakes serving as additional habitat for waterfowl and fish as well as a source of fresh water, iii) areas close to upwelling zones, iv) strandflat zones where shellfish and other invertebrates are available and v) good areas for beaching boats.” Most of these conditions co-occur in the study area. It seems reasonable to infer that humans continuously settled on the Buri-Zula littoral taking advantage of these provisions as climatic conditions required.

Regional Implication of the Evidence

Current archaeological studies suggest intensified human settlements around riverine and lacustrine habitats in Sub-Saharan Africa with the onset of the Late Pleistocene to Middle Holocene African Humid Period (Arkell 1949; Garcin, et al. 2009; Robbins 2006; Stewart 1989).The Sahara Desert which lies closer to the Horn Africa in geographic latitude is a better researched region from which to draw some comparisons. Kuper and Kröpelin (2006:803) recently reported four major occupation phases spanning early to Late Holocene period (Table 8.1). The first episode referred to as Early-Holocene Reoccupation Period (8500 to 7000 BCE) transpired with the rapid arrival of monsoon rains turning the Sahara into habitable environment. The second phase - the Mid-Holocene Formation Period (7000-5300 BCE) was characterized by extended human settlements and domestication of cattle, sheep and goats in the eastern Sahara. This was followed by the Mid-Holocene Regionalization Period (5300-3500 BCE) which coincided with the desiccation of the Egyptian Sahara, forcing human groups to concentrate along the Nile Valley and some highland refugia. This period is also known for regional differentiation and beginning of population expansion to the better watered Sudanese plains. The last phase or Late-Holocene Marginalization Period (3500-1500 BCE) was characterized by further desiccation of the desert, and only transient human activities resumed in the Egyptian Sahara. Main settlements remained concentrated around northern Sudan and NE Egypt setting the initial stage for the Pharaonic Civilization. The Gelalo and Misse dates represent early 6th millennium BC settlements, and broadly correlate with the Mid-Holocene Formation Period (7000-5300 BCE). The Asfet subsurface evidence clearly coincides with the Mid-Holocene Regionalization Period (5300-3500 BCE) characterized by retreat of populations to ecological refugia. The Red Sea coast seems to have been an important refugium for human occupation during humid and dry episodes in early Mid-Holocene. It is not clear whether settlements continued along the coast throughout the later millennia or if humans abandoned the coast in the later periods in favor of the interior. Late Holocene human expansion eastward from the Nile Basin is witnessed by widespread Neolithic occupations of the fertile Gash Delta on the Eritrea-Sudanese boarder (Arkell 1954). However, the nature of human interaction along the eastern coastal lowlands of Eritrea has yet to be explored.

Saharan-Nile Valley Occupation Phases *		Eritrean Red Sea Coast settlements
Period	Date (BCE)	
Early Holocene Reoccupation	8500 -7000	?
Mid-Holocene Formation	7000-5300	Gelalo and Misse
Mid-Holocene Regionalization	5300-3500	Asfet Unit F
Late Holocene Marginalization	3500-1500	?

Table 8.1. Relationship between the eastern Sahara (Nile Valley) and the Eritrean Red Sea Coast settlement patterns in the mid-Holocene. * = Kuper and Kropline 2006.

The evidence from the Eritrean Coast parallels early mid-Holocene human adaptations on the Arabian side of the Red Sea. Several Holocene shell middens have been recorded from the Wadi Surdud -Tihamah region of southwestern Yemen dating to the 8^{th} - 6^{th} millennia BP (Tosi 1986). *Terebralia palustris* (a common species at Asfet and Gelalo) dominates the Tihamah shell midden sites. Moreover, an ongoing research at the Farasan Islands, off the western coast of Saudi Arabia has discovered abundant midden sites dated to the 8^{th} millennium BP (Bailey, et al. 2007). Similarly, a shell mound-site named El Gouna has recently been reported from the Egyptian Red Sea of Hurghada region (Vermeersch, et al. 2005). The site dates to 5800 BP (uncalibrated radiocarbon years) with a remarkably similar shell composition (*Terebralia palustris)* to that of Asfet Unit F.

Overall, the LSA evidence from the Red Sea Coast of Eritrea seems to represent early mid-Holocene regional phenomena of population expansion, economic diversification and aquatic exploitation (Kuper and Kröpelin 2006; Marshall and Hildebrand 2002; Stewart 1989).

Conclusions

Following the discovery of the Abdur coastal site along the Gulf of Zula, the first systematic archaeological survey on the Eritrean coast took place in 2005. The research began as an ambitious mission to explore the archaeology of the Buri Peninsula and Gulf of Zula. The primary goals of the project were to document archaeological sites, and to describe the geological, cultural and chronological context of the findings. The project was successful in documenting several prehistoric sites associated with coastal economy from near coastal and inland landscapes. Based on the current radiometric dates and lithic composition (Figs. 8. 1-2), three settlement scenarios can be distinguished on the study area: i) Later Pleistocene MSA settlement represented at Asfet, ii) early mid-Holocene LSA settlements at Gelalo and Misse, iii) mid-Holocene LSA settlement at Asfet Unit F. Gelalo and Misse are dated the 8th millennium BP (7000 - 8400 Cal. years). Both settlements contain similar lithic assemblages associated with blade and microlithic technology. The excavated site from Asfet (Unit F) is dated to the 6th millennium BP, 5475-5670 Cal. years. The Holocene sites broadly coincide with wet phases, although shorter spans of dry phases seem to have occurred. The three excavated sites produced evidence for shellfish exploitation. The surface evidence from Asfet demonstrates Late Pleistocene MSA occupation, but due to lack of secured date, its age and climatic context could not be defined. The Asfet surface assemblage differs in lithic technology from the LSA assemblages at Unit F, and the two LSA occurrences on the Buri Peninsula, i.e. Gelalo and Misse. It appears that there were intermittent human occupations of the Buri Peninsula and Gulf of Zula coasts by MSA and LSA hunter-gatherers. The study did not discover any evidence for domestication or agricultural innovations.

A plausible explanation for the existence of prehistoric settlements on the Eritrean Coast is that humans were attracted to the coastal habitats due to the availability of freshwater and predictable coastal resources. Other potential cause for human settlement on the Buri-Zula littoral could be population pressure in the interior highlands forcing humans to migrate to the coastal lowlands to avoid ethnic confrontations and competition for key resources. From the available evidence, we can postulate that the coastal region, the interior of the Afar Rift and the highland plateaus triggered “push and pull” settlement cycles during the early mid-Holocene period. As the climate after mid-Holocene continued to be dry (although stable); the highlands may have been better suited for permanent human settlements, agricultural innovations and domestication. In the meantime, transhumance movement might have resumed between the coast and the highlands in response to climatic and/or population dynamics.

The archaeological sites from the Buri Peninsula and Gulf of Zula are important as the first systematically documented traces of human presence on the Eritrean Coast during early mid-Holocene. Many coastal environments have served as stable refugia for human habitation in the Late Pleistocene and Holocene (Erlandson 2001). The Red Sea littoral may have been a major refugium for hunter-gatherers dispersing from the interior of East Africa by following confined ecological patches such as river margins and high escarpments. The present research expands our knowledge of prehistoric human adaptations on the Horn of African side of the Red Sea in the Late Pleistocene and Holocene. The Eritrean coastal region remained archaeologically *terra incognita* until very recently. Most archaeological explorations in the past were focused on the highland plateaus. Only recently were archaeological investigations initiated on the Gulf of Zula coast. A geological survey along the eastern margin of the Gulf of Zula has identified Paleolithic artifacts embedded in the Reef Limestone Complex at Abdur dating to the Last Interglacial, 125 ka BP (Walter, et al. 2000). Holocene Stone Age sites were not known from the Eritrean Coast prior to this work. Thus, this thesis represents an original archaeological contribution to the prehistoric heritage of Eritrea and the Horn of Africa. The findings suggest intermittent human occupation of the Buri-Zula littoral during Late Pleistocene and early mid-Holocene times. Prehistoric foragers that lived along the Eritrean coast would have been well positioned to exploit coastal and terrestrial resources by dispersing into the interior of Buri Peninsula, the Danakil Depression and highland plateaus of Eritrea/Tigray depending on the prevailing ecological conditions.

Future research is desirable in order to advance the present evidence in spatial and chronological extent. In order to expand the present archaeological record of the Eritrean Coast, further survey and excavations should continue in the nearby coastal margins. Similarly, more evidence is needed from elsewhere in the Red Sea Basin in order to assess adaptive variability of prehistoric settlements in the region.

The economic background of human adaptation on the Eritrean Coast needs to be further investigated. Shells were recovered in close association with lithic artifacts at the three excavated sites. It is unclear, however, whether humans primarily depended on coastal or terrestrial resources. The presence of lithic remains hints at human interest in terrestrial game, but their remains have not been recovered so far. Future research will shed more light on the subsistence behavior and site use strategies by engaging in extensive survey and excavation programs from inland and near-coastal areas. With the excavation of several sites from multiple localities, it would be possible to assess the range of resources humans exploited. Moreover, an ethnographic study of coastal dwellers on the African and Arabian sides is necessary in order to assess the economic role of mollusks to prehistoric humans.

Sites were discovered from inland and near-coastal landscapes, but we know little about the link between the development of human settlements and ecological history of the region. Reconstruction of Holocene climate using isotope data and coastal stratigraphy is needed in order to understand human cultural ecology.

Although the present study was partly stimulated by the COM, the project did not discover archaeological evidence directly associated with coastal springs of glacial episodes. The COM assumes that the presence of freshwater springs along the coast during sea level lowering would create suitable environments for human survival when the interior land was relatively dry. However, such sites are vulnerable to inundations following sea level rise in the Holocene interglacial. Thus, it is possible that sites formed during decreased sea levels (glacial times) near the coast could be found underwater today. Therefore underwater survey should be employed in order to test the COM for underwater potential of the study region. Although many of the springs formed during glacial times could be underwater now, geological survey for paleo-channels and tufa deposits along the coastal plains can help map prehistoric water sources and reconstruct ancient settlement structure.

Early Holocene settlements were present on the highlands of northern Ethiopia, near Aksum and in the interior Afar Rift such as Lake Besaka, but the nature of human interaction between the inland and coastal landscapes is less clear at present. A regional survey focusing on the inland escarpments is desirable in order to investigate prehistoric connections between coastal and interior -highland settlements. With the discovery of more sites from the intermediary settings, it will be easier to infer mobility pattern and demographic structure of prehistoric groups.

The connection between the African and Arabian sides of the Red Sea needs to be examined using adequate archaeological sources (raw material and ethno-linguistic distribution). The presence of early mid-Holocene sites from the Tihamah littoral and the Farasan Islands hints at contemporaneous human occupation of the eastern and western coastal margins of the Red Sea, but the cultural relationship of those populations has not been explored thus far. Similarly, the Holocene period witnessed a proliferation of lacustrine adaption in the interior of Eastern Africa (Nile Valley, Lake Turkana…etc). The present evidence from the Eritrean coast parallels these regional phenomena, but the relationship between analogous inland lacustrine and coastal adaptations has yet to be investigated.

The fact that archaeological sites were discovered from the Red Sea Coast proves that humans lived there. However, the demographic background of the inhabitants could not be discerned from the archaeological remains alone. Cushitic speaking Saho and Afar ethnic groups dwell on the coastal peripheries today. A large part of the highland plateaus, on the other hand, is occupied by Semitic speaking Tigrigna communities. Both the Cushitic and Semitic groups belong to the Afro-Asiatic language cluster. The root of the Afro-Asiatic languages in the region is highly controversial (Ehret 1974). How far back in time the present map of Afro-Asiatic speakers emerged in the region is an important issue. Future research focusing on ethno-linguistic and bioarchaeological or genetic studies (if human remains are recovered) are crucial in order to clarify the demographic backgrounds of the Eritrean and Ethiopian populations.

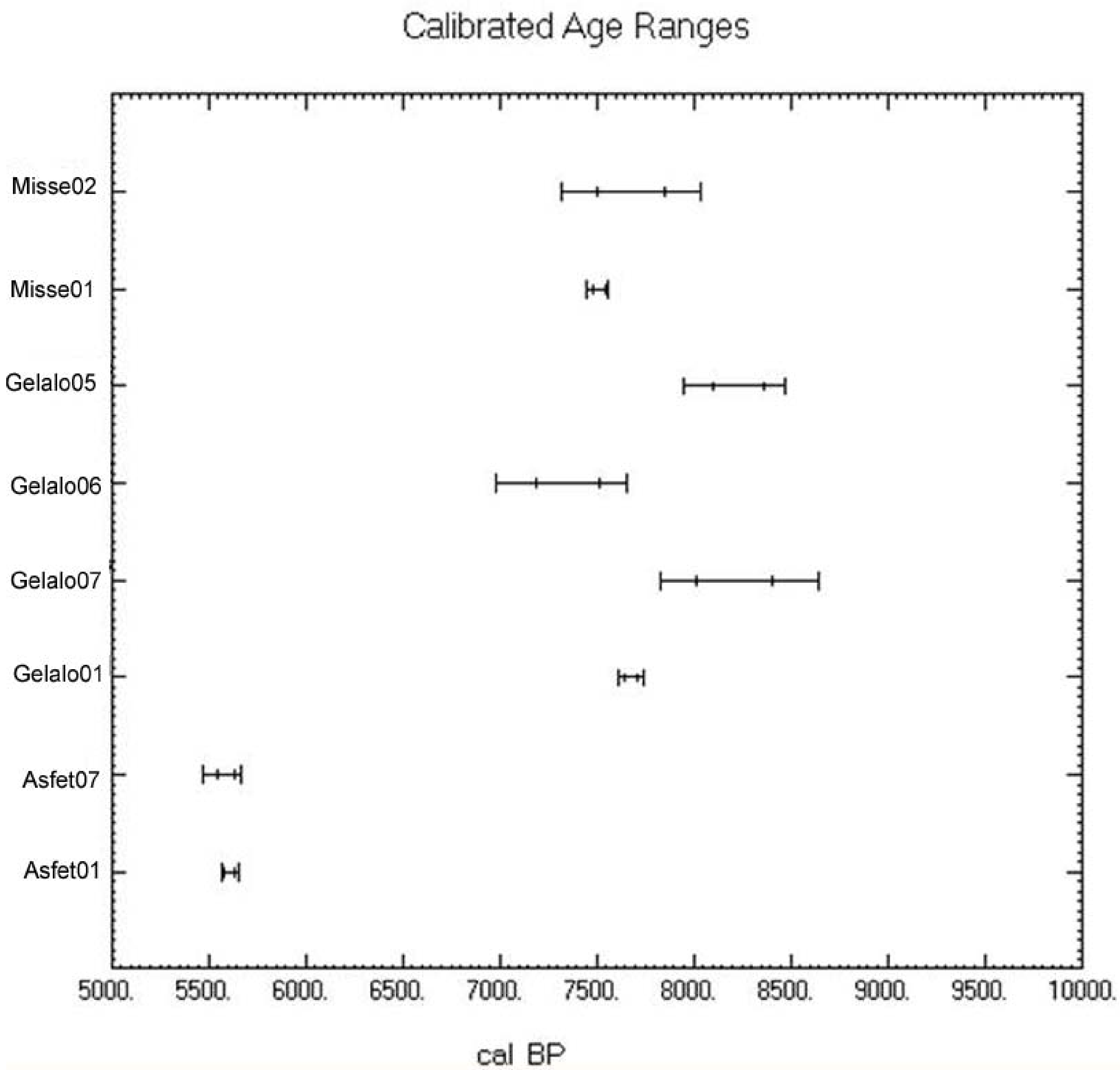


Figure 8.1. Bar-Plot showing the calibrated age ranges (BP) for the Red Coastal Latter Stone Age sites at one and two sigma levels.

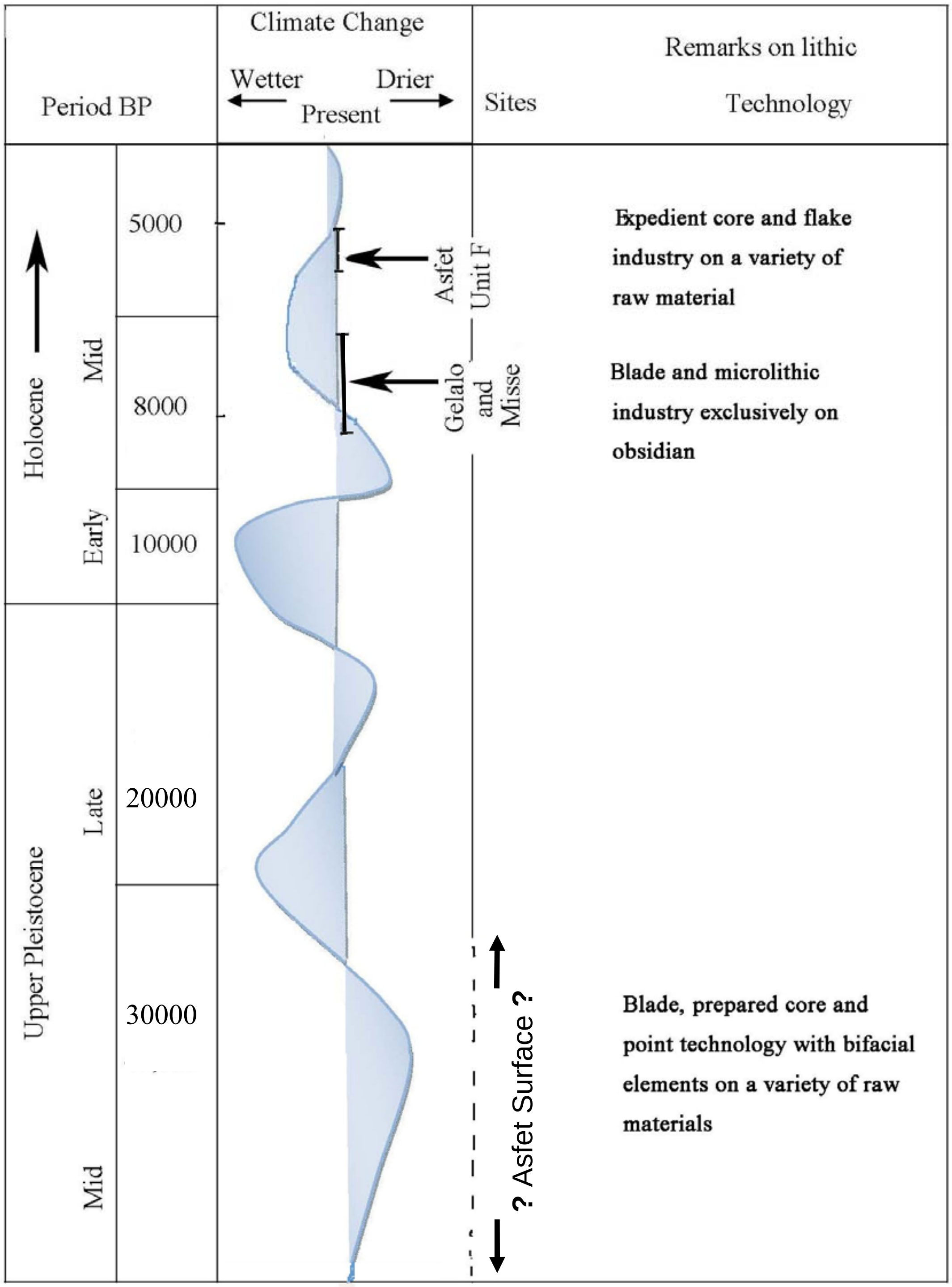


Figure 8.2. Schematic summary of culture history of the Red Sea Coast of Eritrea in relation to past African climatic patterns from lake level fluctuations (Gasse 2000).

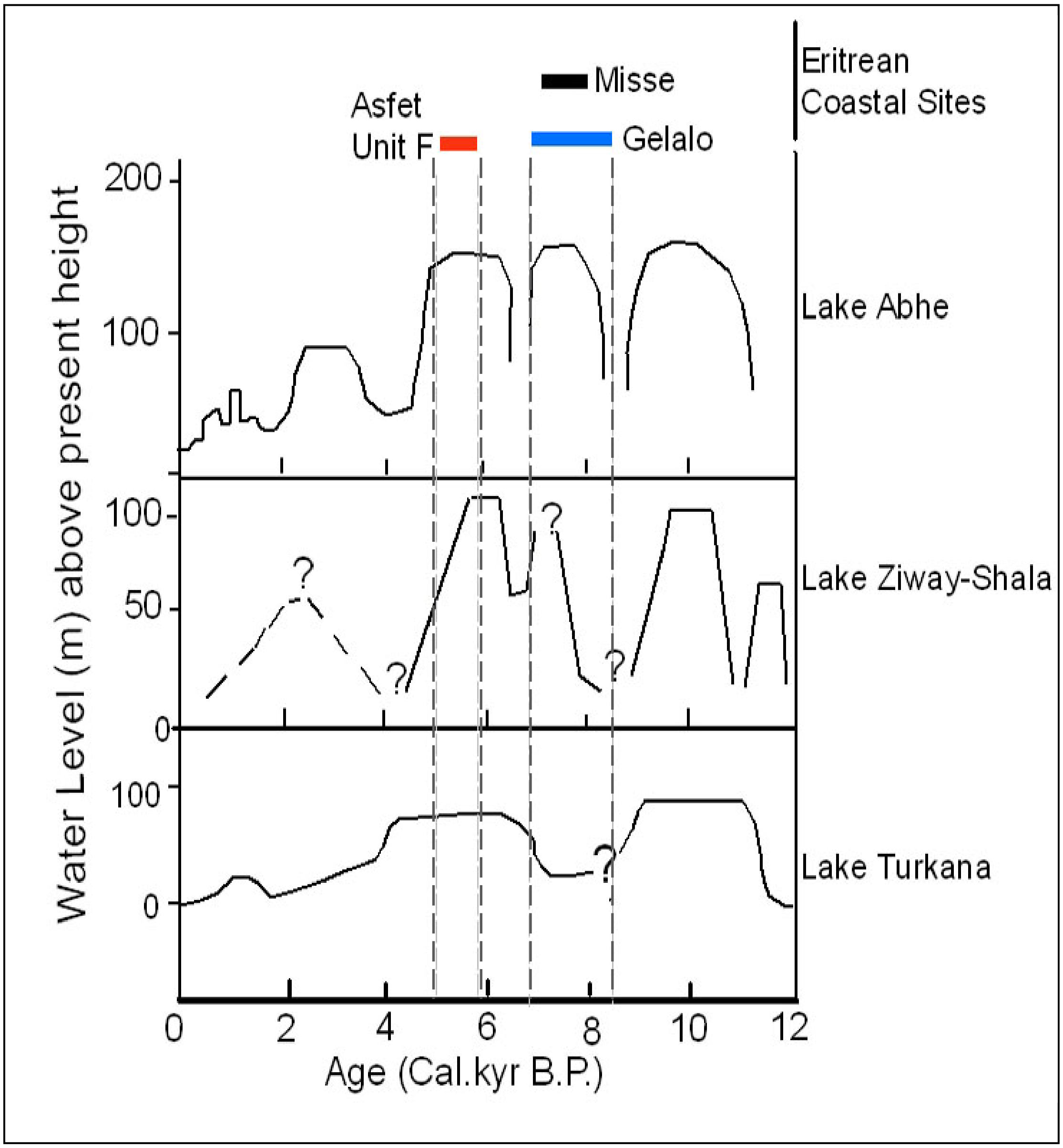


Figure 8.3. Climatic context of the Later Stone Age sites from the Eritrean Red Sea Coast with respect to Holocene hydrological record of the Ethiopian Rift Lakes and Turkana Basin. Lake Abhe (Gasse 1977), Lake Ziway-Shala(Street 1979; Umer, et al. 2004), Lake Turkana (Gasse 2000; Johnson 1996)

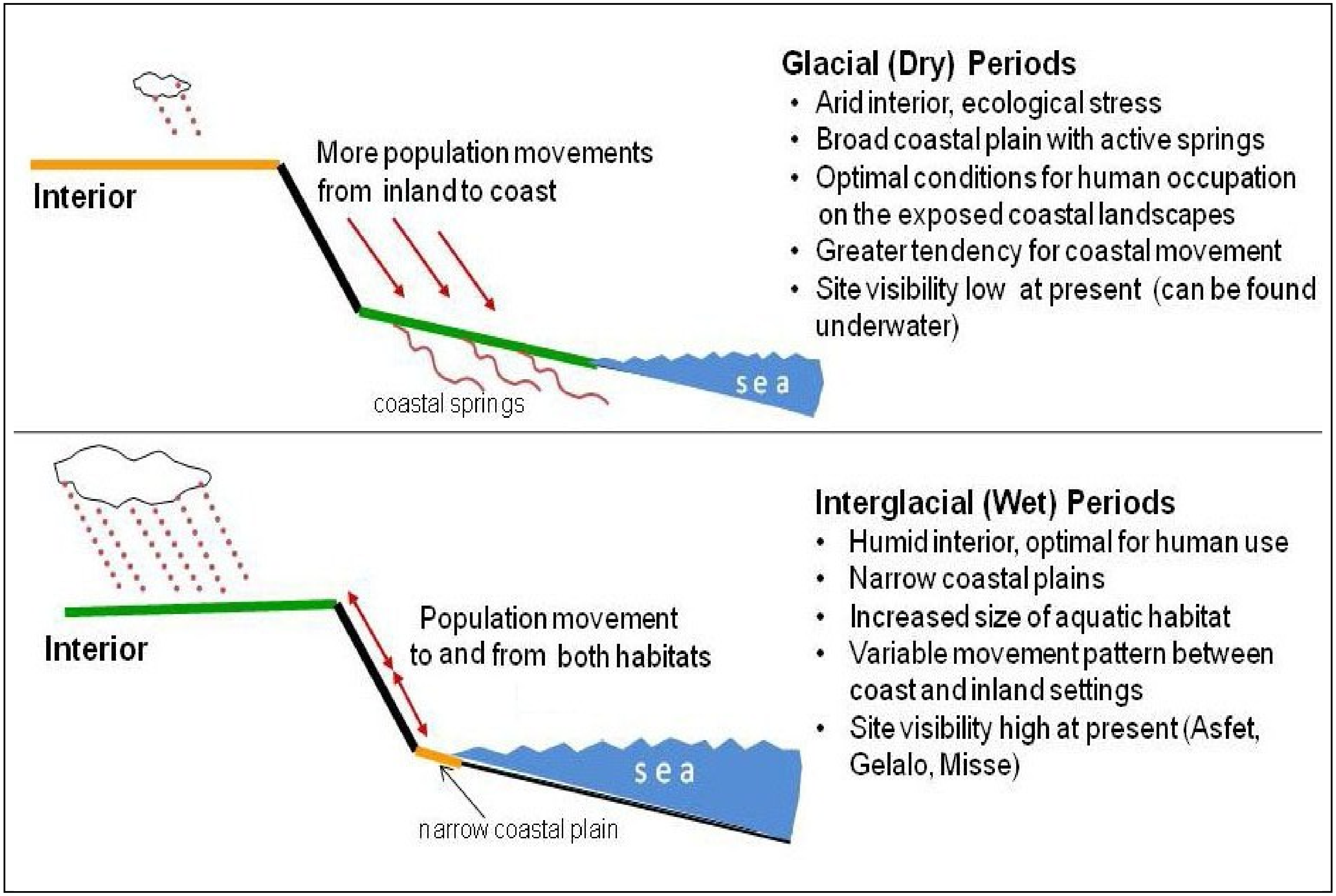


Figure 8.4. A generalized model of settlement dynamics on the Eritrean Red Sea Coast.

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Appendix I

A Report on the Molluscan Fauna of Gelalo Northwest, Misse East and Asfet, Red Sea Coast of Eritrea

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1. Introduction

The antiquity of mollusk exploitation by humans, like many other aspects of aquatic adaptations has been debated (Erlandson 2001, McBrearty and Brooks 2000). Relatively few Lower, Middle and Upper Palaeolithic sites can be considered as shell middens in which shell is the dominant find, and most known shell middens date to the Holocene (Waselkov 1987). Whether this is a result of older ones being submerged under rising sea levels during the end of the Pleistocene, or as a result of humans' preference, is not always possible to determine (but see Bailey and Craighead 2003, Bailey et al. 2007). There are several categories of shell middens (Claassen 1991:252) but here we refer to "shell bearing midden sites", i.e., sites in which there are traces of various activities, including shell assemblages in large numbers. Typically in these sites there are one or two dominant species, this being a strong indication that specific species were targeted as food.

The geographic position of Eritrea with a long strech of coastal landscape makes it a unique place for testing hypotheses of human coastal adaptations along the Red Sea. To date, very little reserch activities were committed to this region and known archaeological sites from the Red Sea coast are scarce. This report deals with Later Stone Age and Neolithic cultural phases. The sites of Gelalo Northwest, Misse East and Asfet are some of the Later Stone Age sites that have been excavated during recent field investigations (Beyin and Shea 2007). Here the preliminary shell findings from the sites are present and the implications of this evidence to early Holocene human adaptations along the Red Sea coast of the Horn of Africa are discussed.

2. Methods

Most shells were studied at the National Museum of Eritrea in October 2006, and a small portion was also investigated at Stony Brook University in April 2007. In the absence of a local comparative collection, species identification was based on Sharabati (1984) and Bosch, et al. (1995). Each shell was recorded in a database, and large concentrations of shell fragments were also weighed. The length and width of complete valves of bivalves were measured. In order to be able to present the large amounts of shell fragments as MNI (minimum number of individuals) it was necessary to determine the criteria for counting each shell species as representing one individual animal. For the most commonly encountered species, *Terebralia palustris*, it was decided to use the base of the shell (the siphonal canal) as MNI indicator. A field trip to the site and its vicinity – the mangroves where *T. palustris* are abound, revealed that in some specimens the apex of their shell erodes *in vivo*, and therefore cannot be used for counting shells. In the case of other gastropod shells such as *Chicoreus ramosus* the apex was used to determine MNI, but in the absence of apex of *Tibia insualaechorab* we resorted to counting the spire, and in the case of *Nerita polita*, the presence of a complete aperture indicated a minimum of one. MNI for the bivalve *Anadara antiquata* was based on the number of complete left valves, while that of *Barbatia decussata* was determined based on complete right valves. In the case of *Atactodea striata* (Gmelin 1791; previously known as *A. glabrata*) however, due to constraints regarding their study at a later time in the U.S., it was impossible to separate between right and left valves, and we counted MNI based on the total number of specimens containing the umbones, divided by two. Measurements were taken of the complete valves using a digital caliper.

3. Results

3.a. Gelalo Northwest

This site is the oldest of the sites studied with C-14 dates spanning from 7900±190 BP to 6970±170 BP thus dating to the 8th millennium BP (Bar-Yosef Mayer and Beyin 2009). It is the smallest shell assemblage, represented by 200 specimens, presented in Table 1.

At Gelalo only 8 fragments contained the siphon that provides indication for MNI of *T. palustris* and the assemblage as a whole is very fragmented. At this site the *Nerita, Engina, Persicula* and the disc beads were all perforated and used as ornaments. About 40% of the shells were used as ornaments, however, the small sample size hinders us from reaching definite conclusions on this topic.

3.b. Misse East

The dates of Misse East are also from the second half of the 8th millennium BP (Bar-Yosef Mayer and Beyin 2009). A sample of 323 shells was studied from the excavation of unit A at Misse East.

Following are a few comments on this assemblage:

Because this is only a sample that was gathered in a fairly small excavation unit, the actual number of shells is insignificant. What is significant is the dominance of one particular species, *Atactodea striata*, that forms about 82% of the number of shells. These represent 133 actual bivalves thus forming about 94% of the assemblage. With the exception of *Atactodea striata*, all species were also encountered at Asfet, however, the dominance of this species here changes the character of the midden. In addition one should note that surface collection on the site yielded *Terebralia palustris* and *Chicoreus virgineus* as well.

3.c. Asfet

Asfet differs from the previous two sites in its much younger age of the 6th millennium BP, with two AMS dates of 5350±40 and 5385±15 BP. A younger age of ca. 2910 BP is considered intrusive (Bar-Yosef Mayer and Beyin 2009).

All the mollusc shell remains from Asfet are Red Sea species. Following are a few comments that may help in interpreting this assemblage.

Chiton – Only one small fragment was found, and it could not be identified beyond genus level.

Nerita sp.– One of the complete specimens was a *N. sanguinolenta*, while the other two complete shells belong to *N. polita*. In addition, there were two complete apertures of *N. polita* and seven fragments.

Tibia insulaechorab – This large gastropod may reach 150 mm (Bosch et al. 1995). Of the 17 fragments, there were only three that formed most of the spire.

Terebralia paslustris – This shell was represented by a total of 3018 shells, most of them fragments. There were no complete shells, there were 162 apex or spire fragments, 456 fragments of the columella, and 616 parts containing siphon, some of them include the entire aperture (Fig. 3). The latter form the basis for determining MNI of this species. The rest were other body fragments.

Chicoreus ramosus – A gastropod related to the Muricidae family, was represented by nine fragments, one broken shell, and one shell that seems to have been artificially perforated with a hole in the body whorl opposite the aperture, but its lip was missing.

Barbatia decussata – This bivalve is represented by 7 left valves, and 9 right valves.

Anadara antiquata – Is represented by four left valves, three right valves and the rest are fragments.

Ostreidae – One shell fragment belonging to this family could be that of could be *Saccostrea cuccullata*.

A shell of the family Cardiidae was also recognized. One of the three unidentifiable bivalve fragments might belong to a *Tridacna* sp.

Unidentifiable shells: These include three gastropod fragments, three bivalve fragments, and four shell fragments that were not assigned to any class. (Because they could belong to any of the identified shells, their MNI is listed as 0 in Table 1).

In addition to the shells described above, a disc bead made of shell was recovered. It was impossible to identify what species it was made of. The bead measures 7.67 mm in outer diameter, 2.24 mm is the diameter of its hole, and it was 1.83 mm thick.

The shell midden of Asfet is dominated by the presence of *Terebralia paslustris* (Fig. 4). Being the most common molluscan species found nearest to the site at the mangrove forest, that is today about a half an hours walk from the site (and would have been slightly further away during the time of the sites occupation in the sixth millennium BP, its presence is not surprising. This is a fairly large mollusc, with shells reaching 90 mm (Bosch, et al. 1995), they can easily be picked off the ground during low tide (Fig. 5; de Boer, et al. 2000) and can provide a fair amount of calories, and moreover, proteins and dietary supplements, as is the case with most edible molluscs (e.g., Claassen 1998:184-5).

The inhabitants of Asfet collected shells not only in the nearby mangroves, but also at other locations along the coast, both in muddy and sandy environments, and on rocky shores (Table 1). This is evident by the presence of other relatively large shells, that may have served as a food source: *Tibia insulaechorab, Chiton, Anadara* *antiquata, Barbatia decussata*. While the paucity of these species does not allow us to conclude with certainty that they served as food, the fact that none of them were worked in any way reinforces this notion. The only shell that was artificially perforated is one *Chicoreus ramosus* with a hole in its body whorl, but two *Nerita polita* with naturally abraded apertures (i.e. the apertures are complete while the rest of the shell is missing) may have also served as beads. The latter is a common bead type in Neolithic sites in Sinai (Bar-Yosef Mayer 1997).

4. Discussion

Among the newly discovered sites in the Horn of Africa reported here, several shell middens suggest coastal adaptations of humans during the mid-Holocene. The rich Indo-Pacific fauna of the Red Sea, includes approximately 1200 species (Dekker and Orlin 2002), however, in the sites described above only very few species were selected, implying specific adaptations.

All three sites are clearly shell middens, in which specific mollusc species are targeted, *Terebralia palustris* and *Atactodea striata*, respectively. *Terebralia* is a large gastropod living on mangrove beds, and *Atactodea* a relatively small bivalve that buries itself in the sand in the intertidal zone. Both would be easily collected during low tide (on mollusc gathering practices see Meehan 1982).

In Gelalo northwest a large component of the shells were used as decoration, but the large number of fragments of *T. palustris* suggests that those were consumed nonetheless. The high fragmentation could have been caused by the consumers of the molluscs. An ethnographically documented cased from Australia reports that *T. palustris* are hammered against each other to extract the flesh (Meehan 1982:109). To date very few Late Stone Age sites have been discovered along the western coasts of the Red Sea. Misse East, and Gelalo Northwest are both dated to the end of the 8th millennium B.P. Currently no other sites of this age are known from the Red Sea. A few "strandloopers" sites near the coast of Somalia that contained mussel shells (Clark 1954) do not have absolute dates. It is worth mentioning, however, that at the end of the 8th millennium BP the Red Sea was about 20 meters below its current level (Siddall et al. 2003). This implies that the seashore would have been further away from these sites, and that other sites, not yet discovered, might be underwater. Sites that appear to be underwater shell middens were identified by Bailey, et al. (2007) in the region of the Farasan islands off the Saudi Arabian coast, that are in fact almost "opposite" the Eritrean coast, and much closer to the Dahlak archipelago that is off the Eritrean coast.

By about 6000 b.p. the Red Sea's sea-level is almost at its current position (Siddall, et al. 2003), and this undoubtedly had an impact on the populations residing in the area. Asfet, dated to the 6th millennium BP represents the period that follows the rise in sea level. In recent years two other projects report the presence of shell middens in this region: One is El Gouna in Egypt (Vermeersch, et al. 2005), the other is Dankalelo in Djibouti (Poisblaud, et al. 2002). The fauna of El-Gouna, dated to 5800 BP (uncalibrated) is remarkably similar in species composition to that of Asfet. While it is impossible to draw an immediate connection between the two sites, both because of the ca. 400 years that separate them and the geographic distance between them, they may point to a specific adaptation along the Red Sea coast during the 6th millennium BP. What is string in all three sites is the complete absence of bone, which suggests that molluscs were the only animal food consumed (for discussion of bone preservation see Berna, et al., 2004; Bar-Yosef Mayer and Beyin 2009). The lack of other food remains in the sites, and the current limited knowledge of the archaeology of this region hinders us from further exploring the circumstances of shellfish consumption, whether it was famine food or food of choice, whether it was consumed year round, seasonally, or during occasional (ceremonial?) events. Sites dating to the 6th millennium onwards on the eastern coasts of the Red Sea (Bailey, et al. 2007, Rougeulle 1999) that are under investigation, as well as future research in Eritrea may provide more explanations.

By contrast, the site of Denkalelo in Djibouti where 99% of the assemblage is composed of oysters reflects a different type of adaptation dated to the 3rd millennium B.C. (5th millennium BP; Poisblaud, et al. 2002) and therefore cannot serve for comparison with the sites discussed here. This site provides further information on the potential information that future explorations will provide us.

Climatic changes that occurred in the beginning of the Holocene had a major effect on human adaptation to the Sahara desert (Kuper and Kröpelin 2006). The Sahara desert which is within the same geographic latitudes as the Horn of Africa has been researched more widely, therefore we draw much information from there. The eastern Sahara during the Holocene had alternating dry and humid phases that caused fluctuations in human occupation, with the earliest evidence for sedentism during the eighth-ninth millennium BP (Arz, et al. 2003, Garcea 2008). It is associated in southern Egypt with a transition from foraging to pastoralism as a strategy for the exploitation of a broad spectrum of wild resources (Garcea 2008). This strategy that allowed humans to cope with irregular precipitation and to manage drier periods of reduced rainfall, may account for the shell middens of the Red Sea coast.

Pastoralism and farming developed at the Fayum in the Egyptian Sahara at around 5300 BCE (7300 BP; Kuper and Kröpelin 2006:805 and see Marshall and Hildebrand 2002) and the formation of shell middens in the lowlands also appears to begin in the eighth millennium BP. Although in the Horn of Africa, to date, the earliest evidence for cattle herding dates to the fourth millennium BP, this might be simply due to lack of evidence. At the same time, one should note, pastoral societies in Africa typically co-exist with hunter-gatherers (Marshall and Hildebrand 2002:121) so that at this point we cannot be certain as to the main economic strategy of the inhabitants of the eighth millennium BP in this region. What is more evident is that the coastal settlement seems to be a response to significantly hotter and drier conditions. This is seen not only in the Sahara (Kuper and Kröpelin 2006) but is also expressed in the lowering of water-level of Lakes Ziway-Shalla and Abhé on the Ethiopian plateau that culminates between 7800 and 7200 BP (Umer, et al. 2004). As a result, once resources in the hinterland of the Afar depression deteriorated, humans could not bear the hostile environment and moved to better-watered areas. This notion is supported by Faure, et al.'s (2002) study of freshwater sources along coastal areas. While in Egypt this trend is expressed in the intensification of settlements along the Nile, in Eritrea those would have been either on the coast or on other parts of the highlands. This is also supported by recent archaeological investigations in the Tigray region (northern Ethiopia) (Finneran 2001, Negash, 2001), and by settlement in the Gash Delta near Kassala close to the Sudan/Eritrea frontier (Phillipson 2005:205).

5. Conclusions

The shell middens of Eritrea discussed here are undoubtedly representations of food debris. While some Red Sea species are obviously not easily accessible to humans, and others are not desired, but the fact that only about 14 different species are represented in the three sites discussed here point to a clear choice of species. The shells were collected from a variety of habitats, especially rocky and sandy shores, as well as mangroves. Some species were collected as food and others as raw material for making beads, or as ready-to-use beads as in the case of the *Nerita* apertures, pointing to the importance of marine resources in the lives of the inhabitants of the region during the Later Stone Age.

The choice of a limited number of species marks a cultural trait that typifies certain human groups, and is possibly characteristic of specific time periods. While there are many possible reasons for shell accumulations (e.g., Erlandson and Moss 2001), there is no doubt that in Eritrea, the association of shells with lithic artifacts is a result of human activity. Future research may help us identify the underlying reason for having one midden dominated by *Terebralia* and another dominated by *Atactodea*, both reflecting coastal adaptations. Additional research may also reveal the impact that changes of sea level during the Holocene may have had on these coastal societies.

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Class	Genus/species	Habitat	NISP	MNI
Polyplacophora	*Chiton*	On or under rocks	1	1
Gastropoda	*Nerita sanguinolenta*	Intertidal on rocks	1	1
	Terebralia palustris	Mud among mangroves	188	8
	Engina mendicaria		3	3
	Persicula terveriana		1	1
Bivalvia	*Barbatia decussata*	Under rocks, upper shore	1	1
	Atactodea striata	Intertidal in sand	1	1
	Unidentifiable bivalve		1	1
unknown	Shell disc bead		3	3
	Total		200	20

Table 1. The shells of Gelalo Northwest.

Class	Genus/species	Habitat	NISP	MNI
Polyplacophora	*Chiton*	On or under rocks	2	1
Gastropoda	*Nerita* sp.	Intertidal on rocks	8	3
	Unidentifiable gastropods		10	0
Bivalvia	Ostreidae	Usually attached to rocks	21	1
	Anadara antiquata	Muddy sand, intertidal and off-shore	3	1
	Barbatia decussata	Under rocks, upper shore	10	1
	Cardiidae	variable	1	1
	Atactodea striata	Intertidal in sand	267	133
unknown	Shell disc bead		1	1
	Total		323	142

Table 2. The shells of Misse East.

Class	Genus/species	Habitat	NISP	MNI
Polyplacophora	*Chiton*	On or under rocks	1	1
Gastropoda	*Nerita* spp.	Intertidal on rocks	12	5
	Chicoreus ramosus	Intertidal rocks and coral	9	1
	Tibia insulaechorab	Intertidal on sand	17	3
	Terebralia palustris	Mud among mangroves	3018	616
	Unidentifiable gastropods		3	0
Bivalvia	Ostreidae	Usually attached to rocks	1	1
	Anadara antiquata	Muddy sand, intertidal and off-shore	22	4
	Barbatia decussata	Under rocks, upper shore	34	9
	Cardiidae	variable	3	1
	Unidentifiable bivalves		3	0
unknown	Shell disc bead		1	1
	Total		3124	642

Table 3. The shells of Asfet.

Appendix II

X-ray Fluorescence and Neutron Activation Analysis of Obsidian Artifacts and Source Samples from the Red Sea Coast of Eritrea

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Introduction

Ninety three (93) artifacts of obsidian from sites along the Red Sea Coast of Eritrea and three source specimens from the Kusrale volcanic source were submitted to the Archaeometry Laboratory at MURR by Mr. Amanuel Beyin, graduate student at SUNY-Stony Brook for chemical analysis and source determination. The samples were assigned analytical IDs as follows: artifact ANIDs = AB001 thru AB093 and the Kusrale source sample ANIDs = KRE001 thru KRE003. All of the artifacts and source samples were analyzed by non-destructive energy dispersive X-ray fluorescence (ED-XRF). Subsequently, twenty (20) of the artifacts and all source specimens were analyzed by neutron activation analysis (NAA). This report presents the data and an interpretation of the possible geochemical subgroups. We suggest that this is a preliminary study that could be enhanced by analyzing additional source samples with known geographic coordinates.

Background

The prehistoric archaeology of Eritrea and the Horn of Africa during Middle and Late Stone Age are important to studying the origin of modern humans and dispersal history. An investigation of lithic materials from the coastal sites of Asfet, Gelalo, and Misse East and the nearby obsidian source at Kusrale uncovered thousands of obsidian artifacts of which a subset were submitted for for chemical analysis. To the best of our knowledge, no previous research on the geochemical analysis of obsidian from Eritrea has been reported. Recent work in Ethiopia has been reported by Negash and colleagues (Negash, et al. 2006[2], 2007).

Analytical methods for obsidian provenance

Although a variety of physical, chemical, and isotopic methods have been employed for obsidian provenance research (Tykot 2004), the analytical methods most frequently in use today are neutron activation analysis (INAA), X-ray fluorescence (XRF), and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS). Each analytical method has specific advantages and disadvantages when applied to the characterization of obsidian. For example, INAA offers excellent sensitivity, precision and accuracy for a large number of elements, and as a bulk technique it can be used analyze both large and small samples. However, INAA requires that the analytical sample portion be destroyed and made radioactive. The availability of NAA is somewhat limited and time-consuming due to the requirement that samples undergo decay. XRF offers good sensitivity and satisfactory accuracy for a limited number of elements important for discriminating between obsidian sources. XRF can be performed non-destructively, and it is both a rapid and inexpensive method. However, XRF has size limitations making analysis of small, thin, and irregularly-shaped artifacts difficult or impossible. LA-ICP-MS is a sensitive analytical technique and can measure a large number of elements in a relatively short period of time. However, analytical samples generally have to be removed from artifacts in order to make the analytical procedures more efficient. And, LA-ICP-MS has serious limitations with respect to absolute standardization and instability of the torch during sample runs. In this study, XRF and NAA were the only techniques used.

The history of obsidian provenance research at MURR

The Archaeometry Lab at MURR has been actively involved in obsidian provenance research for more than 25 years. The early work began in Mesoamerica but gradually expanded to include the western US, South America, the Mediterranean, and Russian Far East. During this time, thousands of source samples and artifacts have been analyzed to establish a comprehensive obsidian source database. Using this data base, the Archaeometry Laboratory at MURR has used INAA and more recently XRF to determine the provenance of more 20,000 obsidian artifacts from around the world (Burger and Glascock 2007; Cobean, et al. 1991; Glascock 2002; Kuzmin, et al. 2002; Santley, et al. 2001; Yacobaccio, et al. 2004).

Recently, the Archaeometry Laboratory at MURR acquired a table-top ED-XRF spectrometer allowing the possibility of a rapid, non-destructive analysis of obsidian artifacts. The XRF spectrometer is light-weight and offers the possibility of *in situ* analysis of artifacts at archaeological sites, museums, etc.

Analytical Methods

X-ray Fluorescence

An Elva-X energy dispersive X-ray fluorescence spectrometer was employed in this study. The spectrometer is equipped with an air-cooled rhodium target anode X-ray tube with 140 micron Be window and a thermoelectrically cooled Si-PIN diode detector. The beam dimensions are 3 x 4 mm and the detector has a resolution of 180 eV for the 5.9 keV from iron. In order to measure the eleven elements reported in this study (K, Ti, Mn, Fe, Zn, Ga, Rb, Sr, Y, Zr, and Nb), the X-ray tube was operated at 35 kV using a tube current of 45 μA. Measurement times were 400 seconds on all samples. Peak deconvolution and element concentrations were accomplished using the ElvaX spectral analysis package. The instrument was calibrated using data from a series of well-characterized source samples in the MURR reference collection, including eleven Mesoamerican sources (El Chayal, Ixtepeque, San Martin Jilotepeque, Guadalupe Victoria, Pico de Orizaba, Otumba, Paredon, Sierra de Pachuca, Ucareo, Zaragoza, and Zacualtipan) and three Peruvian sources (Alca, Chivay, and Quispisisa). Artifacts larger than 0.8 cm across with an appoximately a flat surface area are typically suitable for XRF. Smaller samples should be analyzed by NAA.

Instrumental Neutron Activation Analysis

Neutron activation analysis of obsidian at MURR consists of a single irradiation for five seconds of a sample weighing about 100 mg encapsulated in a polyethylene vial using a thermal neutron flux of $8x10^{13}$ n cm^{-2} s^{-1}. The short irradiation was followed a 25–minute decay and 12–minute count enabling measurement of seven short-lived elements (i.e., Al, Ba, Cl, Dy, K, Mn, and Na). Portions of the obsidian samples weighing about 200 mg were encapsulated inside high-purity quartz vials and subjected to one long irradiation of 70 hours using a thermal neutron flux of 5×10^{13} n cm^{-2} s^{-1}. The long irradiation was followed by two counts on each sample. The first count occurred between seven and eight days after the end of irradiation, using a sample changer to measure each sample for 30 minutes. This first count enabled determination of seven medium-lived elements (i.e., Ba, La, Lu, Nd, Sm, U, and Yb). The second count took place about four weeks after the end of irradiation, again using the sample changer to measure sample for 3 hours each. This latter measurement facilitated measurement of fifteen long-lived elements (i.e., Ce, Co, Cs, Eu, Fe, Hf, Rb, Sb, Sc, Sr, Ta, Tb, Th, Zn, and Zr). When the long irradiation is performed, the barium concentration from measurement of the medium-lived isotope (i.e., ^{133}Ba) is considered superior, and it is preferred over the concentration obtained from the short-irradiation and measurement which relies on the less sensitive isotope ^{139}Ba.

Results

Table I lists the XRF results for the artifacts and source samples analyzed in this study. In particular, it is noted that the concentrations for Fe cover a relatively broad range from about 15000 to 34000 ppm (or 1.5 to 3.4 %) suggesting possible subdivision. The source samples from Kusrale are grouped rather tightly with Fe concentrations of around 2.0%. A plot of Fe and Rb is shown in Figure 1 for the Kusrale source samples and with the obsidian artifacts plotted according to their archaeological site.

In order to investigate the possibility of subgroups within samples as suggested by XRF, the NAA results listed in Table II were carefully examined. Bivariate plots of the 20 artifacts and three sources samples using Fe with Th and Fe with Rb in Figures 2 and 3, respectively, suggest that there are three subgroups containing four or more samples each and that five other samples appear to be outliers on most of the elements. Group #1 consists of nine obsidian artifacts with no particular regard for archaeological site having the highest Fe concentrations of about 2.7% and lowest Ba concentrations (i.e., values of 0.0 indicate that the element was below detection in the sample). Group #2 consists of two obsidian artifacts and the three source samples from Kusrale. The Fe concentrations for Group #2 as determined by NAA are about 2.2% and again the Ba concentrations are below detection. Group #3 consists of four obsidian artifacts with an average Fe concentration of about 1.9% and a high average Ba concentration of nearly 900 ppm.

The information obtained from the NAA measurements was used to establish possible subdivisions among the entire collection of artifacts and source samples measured by XRF. A plot of the samples subdivided according to Groups 1 thru 3 is presented in Figure 4. The outlier samples identified by the NAA results are not shown on this XRF plot.

Conclusions

XRF and NAA measurements on obsidian artifacts and source samples from the Red Sea Coast of Eritrea suggest the presence of at least three geochemical groups. The groups are similar on most elements which would seem to suggest a single source. However, variation and possible subgroups are suggested by the elements Fe, Mn, Sc, Ba, and Zr. There does not appear to be any significant correlation between archaeological site and geochemical group. The Kusrale samples provided match with one of the three groups (Group #2). Due to the limited geochemical data for the Kusrale source, we are cautious with regard to the claim that we have provenanced the artifacts in this study other than a suggestion that the Kusrale source may have several subsources and all three were being exploited by the people from the different archaeological sites with no particular preference.

We strongly recommend the collection of additional sources samples by Mr. Beyin and colleagues and submission to XRF and NAA.

Acknowledgements

We acknowledge a grant from the National Science Foundation to the Archaeometry Laboratory at MURR which made this work possible (NSF grant #0504015).

Figures

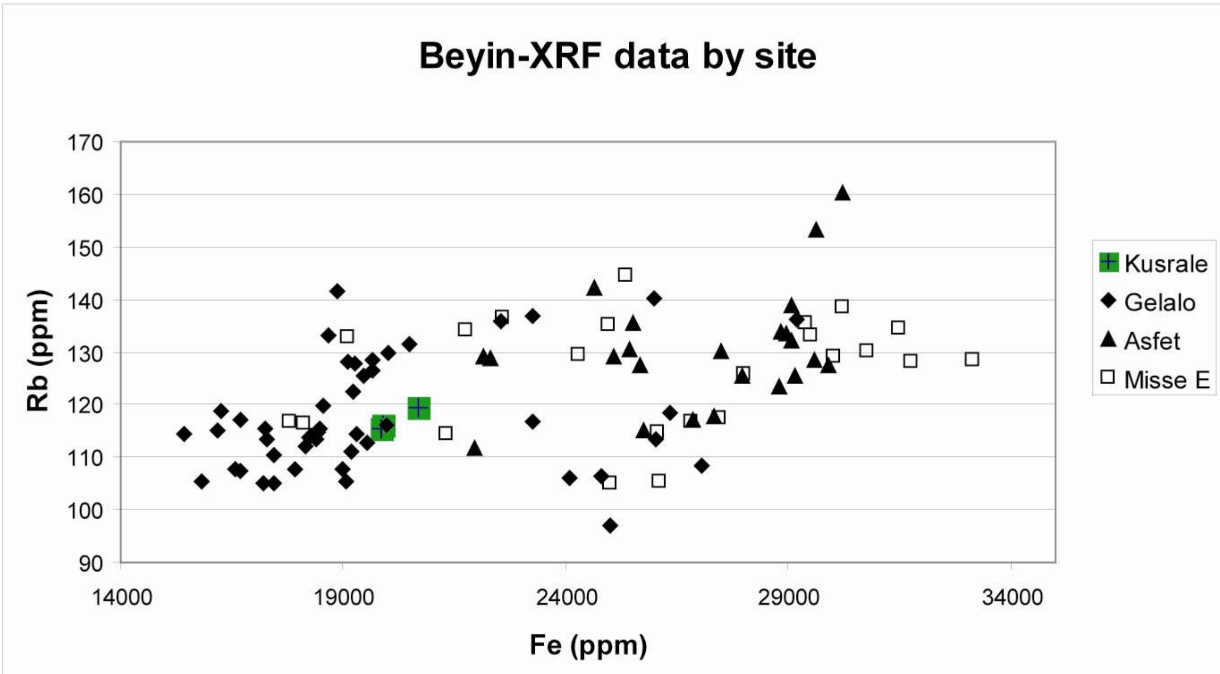

Figure 1. Bivariate plot of Fe and Rb using XRF data for obsidian artifacts and source samples from the Red Sea Coast of Eritrea plotted according to archaeological site.

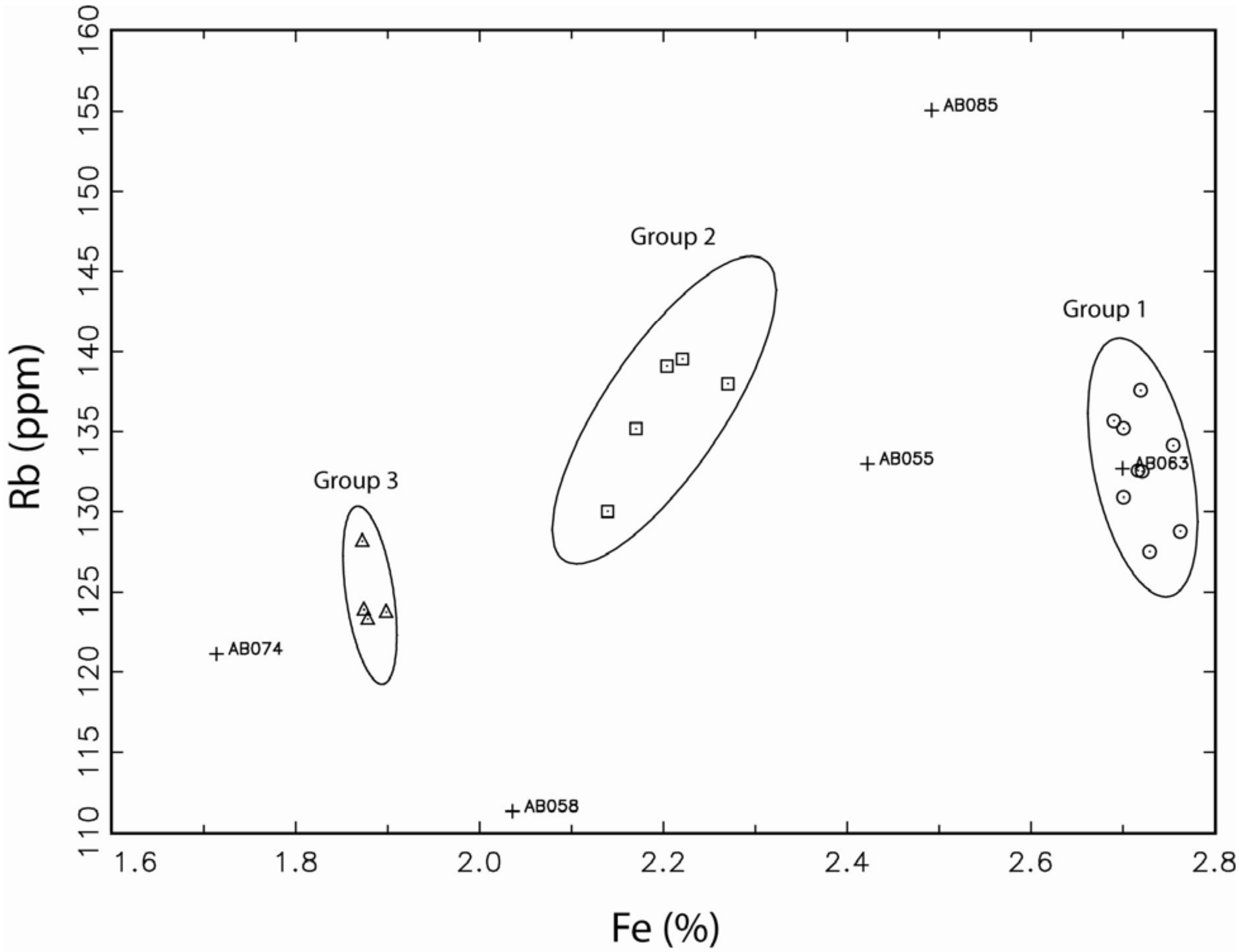

Figure 2. Bivariate plot of Fe and Rb using NAA data for obsidian artifacts and source samples from the Red Sea Coast of Eritrea plotted according to suggested groups with five outlier samples.

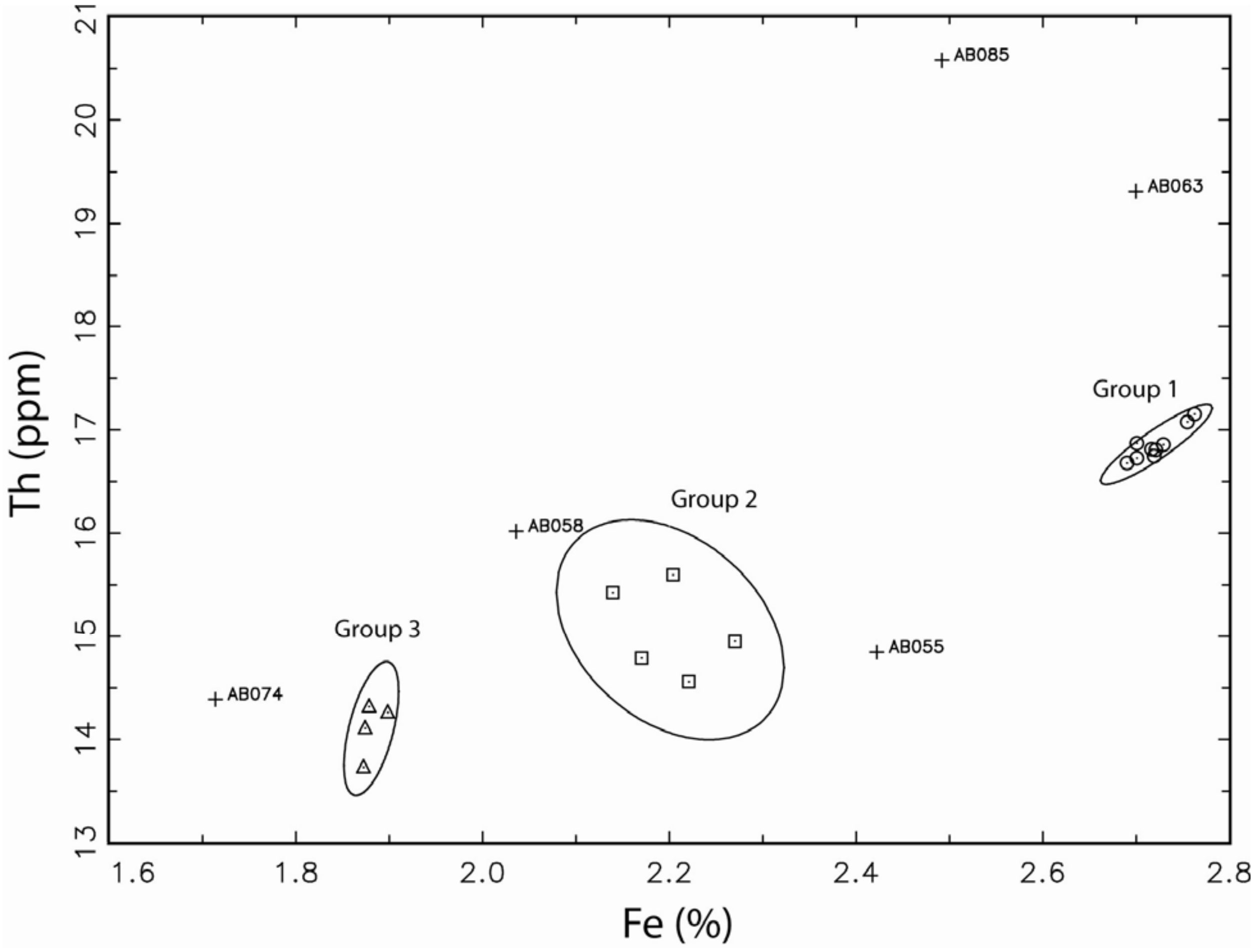

Figure 3. Bivariate plot of Fe and Th using NAA data for obsidian artifacts and source samples from the Red Sea Coast of Eritrea plotted according to suggested groups with five outlier samples.

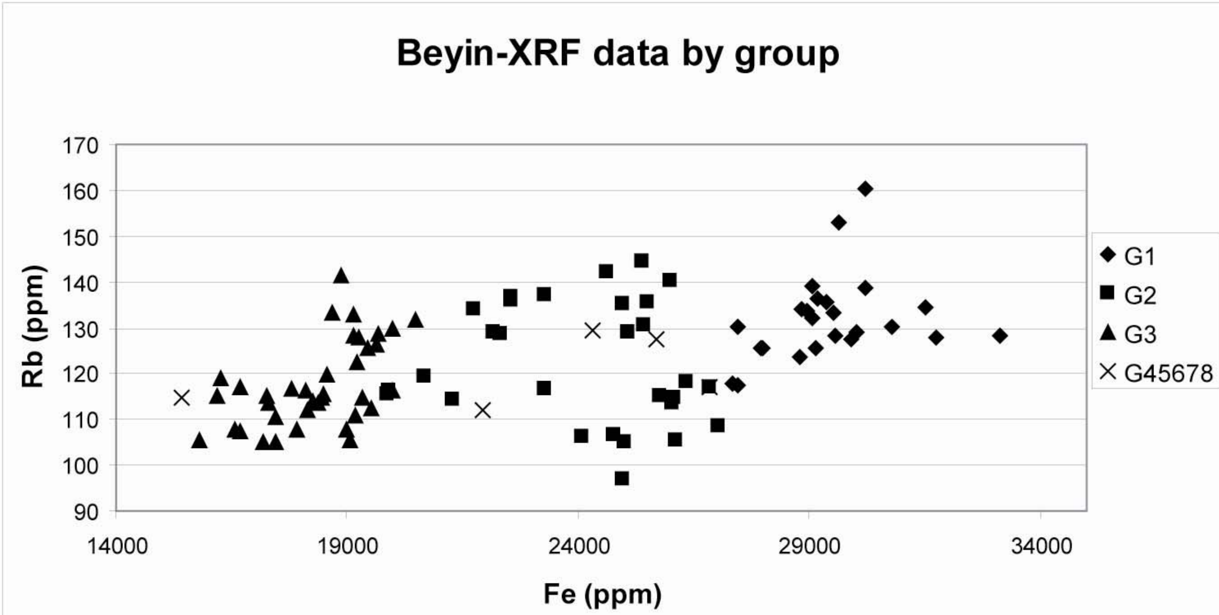

Figure 4. Bivariate plot of Fe and Rb using XRF data for obsidian artifacts and source samples from the Red Sea Coast of Eritrea plotted according to groups suggest by the NAA data.

Table I. XRF Results for Obsidian from Eritrea listed in ppm.

anid	K	Ti	Mn	Fe	Zn	Ga	Rb	Sr	Y	Zr	Nb
KRE001	38980.3	1188.6	767.3	19909.2	143.7	9.6	116.1	0.0	72.9	453.0	54.0
KRE002	39287.5	1150.6	804.5	19872.2	139.1	12.1	115.6	0.0	71.4	452.9	53.2
KRE003	40880.3	1183.6	812.2	20686.1	132.0	10.6	119.5	0.0	80.7	484.6	56.2
AB001	40710.7	2082.4	682.9	18881.4	156.7	12.3	141.5	115.9	79.0	555.1	49.2
AB002	40753.4	2014.8	621.7	20492.4	165.1	7.1	131.6	125.4	91.0	578.1	57.1
AB003	39455.3	2005.9	542.6	19264.2	167.3	7.8	127.8	107.1	83.1	516.0	47.9
AB004	39643.5	1607.3	614.0	19205.4	148.1	5.5	122.4	84.2	85.0	497.7	54.0
AB005	35338.7	1481.0	647.2	17437.7	157.9	0.0	105.1	81.5	71.1	384.6	45.4
AB006	37687.1	1853.3	729.9	19975.8	173.4	1.9	116.1	93.5	81.2	469.1	47.6
AB007	35675.8	1617.8	576.7	17287.6	160.7	6.1	113.4	81.1	69.6	416.6	45.4
AB008	39930.3	1567.0	1062.0	26336.5	201.8	0.0	118.4	0.0	95.6	530.6	62.2
AB009	36770.2	1803.4	650.4	18473.9	168.2	4.3	115.4	106.4	79.2	448.4	48.1
AB010	31944.1	1963.4	1401.2	19525.9	217.3	0.3	112.6	65.9	76.7	416.1	47.0
AB011	38820.2	1470.6	1046.5	26030.2	208.2	0.0	113.4	0.0	96.3	492.8	62.1
AB012	40072.7	1752.7	1203.0	24977.6	252.3	9.8	97.1	0.0	72.6	619.4	86.0
AB013	38944.2	1799.2	707.5	19171.3	162.8	2.1	111.0	115.2	73.3	484.1	51.7
AB014	37652.5	2238.5	954.3	23256.0	238.2	8.5	116.8	94.5	66.4	589.3	66.4
AB015	37347.6	1735.1	626.1	16695.6	150.3	9.4	117.0	91.8	61.7	426.7	43.1
AB016	35808.2	1721.3	546.7	16179.1	177.1	11.2	115.1	115.1	59.7	453.2	53.9
AB017	37433.5	1683.4	634.5	17253.2	143.1	7.9	115.3	99.2	67.0	425.7	43.1
AB018	37971.6	1524.3	638.4	18253.7	158.2	5.3	114.1	74.2	73.4	454.0	54.2
AB019	34664.8	1753.0	632.3	19057.0	187.6	4.1	105.5	65.8	70.8	410.9	45.8
AB020	36177.4	1357.0	583.7	16570.8	144.1	8.6	107.8	53.8	67.7	388.2	45.7
AB021	37704.2	1544.9	1000.3	27032.1	241.0	0.0	108.4	0.0	92.5	485.5	62.7
AB022	36471.5	1538.0	674.2	17902.7	153.4	5.9	107.6	76.1	69.8	410.2	46.7
AB023	35961.0	1510.1	558.2	16686.3	170.1	9.7	107.4	64.0	65.5	413.3	52.3
AB024	34137.7	1932.5	626.1	18243.9	189.2	5.2	113.9	79.7	70.1	412.0	42.3
AB025	33948.7	1645.1	545.9	15804.2	153.1	3.3	105.5	94.9	57.6	354.6	37.5
AB026	37065.6	1448.3	948.2	24780.1	210.6	0.0	106.5	0.0	84.1	453.0	58.6
AB027	35963.0	1425.1	1002.7	24068.1	215.9	0.0	106.2	0.0	79.4	434.4	58.6
AB028	40852.1	1436.5	845.3	22303.1	164.5	2.4	128.8	0.0	80.6	521.9	60.0
AB029	39628.0	1722.4	918.3	30222.8	278.3	5.5	160.4	0.0	134.0	791.0	96.3
AB030	41846.8	1787.7	1108.4	27954.4	225.7	0.0	125.6	0.0	111.6	666.7	75.8
AB031	41128.9	1357.6	753.5	22162.7	157.2	7.1	129.1	0.0	84.6	538.9	61.4
AB032	41563.2	1660.6	863.6	27469.1	213.3	0.0	130.3	0.0	116.5	647.9	75.9
AB033	43546.7	1561.1	791.7	24619.2	166.5	4.0	142.2	0.0	103.8	639.7	68.4

Table I. XRF Results for Obsidian from Eritrea listed in ppm.

anid	K	Ti	Mn	Fe	Zn	Ga	Rb	Sr	Y	Zr	Nb
AB034	40926.8	2410.3	909.4	25428.8	197.8	4.9	130.5	114.7	82.0	604.4	52.5
AB035	41902.4	1775.5	955.5	29071.9	232.0	0.0	132.2	0.0	112.1	616.5	70.2
AB036	39972.7	2444.1	912.9	25070.5	207.3	0.0	129.0	123.2	80.2	587.5	50.7
AB037	42992.7	1752.2	921.7	28936.0	211.0	1.6	133.5	0.0	111.7	654.1	71.8
AB038	37671.6	2224.2	1058.2	29134.6	328.2	0.0	125.6	0.0	106.2	566.1	67.2
AB039	40408.3	1858.5	1206.8	28777.9	241.1	0.0	123.5	0.0	105.9	588.9	68.4
AB040	37028.6	1511.5	971.6	25751.6	238.2	0.0	115.2	0.0	94.6	475.9	62.4
AB041	39697.5	1817.3	568.1	19117.7	154.2	12.4	133.0	98.6	87.0	533.0	53.9
AB042	42807.9	1781.9	1003.0	29515.9	220.8	0.0	133.2	0.0	116.0	656.1	73.0
AB043	41105.0	1898.9	932.2	30019.0	256.0	0.0	129.2	0.0	113.5	614.3	68.7
AB044	41381.0	1715.6	1053.8	28004.6	213.6	0.0	125.7	0.0	108.4	588.5	68.0
AB045	40390.4	1501.7	1027.9	25365.9	191.7	0.0	144.6	2.2	104.5	619.4	77.7
AB046	38050.9	1540.9	1016.0	26056.5	224.9	0.0	114.7	0.0	95.2	499.7	63.1
AB047	39098.4	1486.8	1186.2	24970.3	207.7	0.0	135.1	0.0	101.9	563.5	73.0
AB048	38066.6	1571.0	711.7	18095.6	135.3	9.0	116.3	105.2	74.4	455.7	47.9
AB049	40378.6	1337.6	887.8	21298.3	153.0	5.3	114.5	0.0	73.8	475.7	55.8
AB050	37187.9	1477.6	1064.1	24997.0	213.7	0.0	105.1	0.0	81.4	450.8	56.9
AB051	36200.1	1814.5	1169.5	26121.3	267.0	0.0	105.5	0.0	81.9	445.2	56.0
AB052	37305.4	1474.0	702.4	17794.0	148.9	5.3	116.7	78.1	77.1	436.8	50.9
AB053	38446.3	1628.2	1084.1	26820.7	231.2	0.0	116.9	0.0	97.7	504.8	63.3
AB054	40373.8	1675.7	879.6	28820.1	233.5	0.0	133.9	0.0	118.0	611.1	72.8
AB055	39454.1	2569.7	812.7	25686.2	223.2	0.2	127.6	127.3	82.3	598.1	50.6
AB056	40525.7	1874.2	917.6	29913.3	263.9	0.0	127.5	0.0	116.9	598.5	69.6
AB057	42819.7	1895.8	885.4	29077.4	215.6	0.0	139.0	16.6	124.1	726.6	80.2
AB058	38516.3	1673.5	788.1	21948.3	194.6	5.7	111.9	5.3	84.7	533.3	58.4
AB059	43291.0	2497.4	998.0	25514.0	192.5	4.4	135.5	114.3	83.0	651.0	54.0
AB060	43637.8	1820.1	1043.9	29563.7	210.6	0.0	128.4	0.0	112.5	653.6	72.4
AB061	41669.3	1674.6	1134.5	29637.4	238.1	0.0	153.1	0.0	124.8	777.9	91.0
AB062	41570.5	1652.7	1069.5	27333.9	202.2	0.0	117.7	2.4	109.8	626.6	72.2
AB063	39598.1	1688.4	1047.8	26841.1	219.7	0.0	117.0	0.0	107.3	577.7	68.3
AB064	41978.8	1292.2	666.2	22537.8	149.6	14.0	136.0	0.0	89.7	579.8	67.9
AB065	44259.1	2598.5	915.1	25987.2	181.1	7.1	140.2	148.9	84.5	699.4	55.1
AB066	42290.4	1727.0	892.4	29178.5	215.6	0.0	136.2	0.0	115.5	639.6	72.6
AB067	41979.9	1710.2	570.8	19994.2	144.0	12.0	129.8	71.1	95.0	566.5	57.5
AB068	43412.2	1384.1	776.3	23255.3	141.5	8.6	137.0	0.0	94.4	608.8	67.4
AB069	39448.4	1921.4	533.6	18662.7	157.9	9.8	133.1	119.0	81.1	523.9	51.4

Table I. XRF Results for Obsidian from Eritrea listed in ppm.

anid	K	Ti	Mn	Fe	Zn	Ga	Rb	Sr	Y	Zr	Nb
AB070	40053.9	1897.9	630.0	19652.9	167.5	9.8	128.6	91.9	88.8	541.4	56.6
AB071	40112.3	1987.1	550.5	19118.7	157.0	7.9	128.1	121.2	75.7	530.2	48.1
AB072	39425.7	1615.5	593.2	19453.5	157.0	4.7	125.5	74.2	86.2	499.8	55.6
AB073	39761.0	1761.4	624.0	19647.3	159.1	7.1	126.4	76.0	83.2	506.3	52.9
AB074	38803.0	1745.1	465.3	15405.9	149.7	14.9	114.6	87.7	51.7	460.1	47.7
AB075	38717.1	1737.5	725.9	18549.9	152.1	8.1	119.7	87.6	77.6	470.9	48.5
AB076	40312.9	1780.2	520.0	16262.4	113.8	13.1	118.8	119.6	56.3	451.8	32.6
AB077	39313.6	1678.6	701.7	18444.6	146.4	5.9	114.9	84.7	75.5	466.8	47.2
AB078	37059.8	1781.3	750.6	18374.3	172.3	2.4	113.5	114.7	71.3	467.2	51.7
AB079	34369.0	1883.6	890.1	18986.4	215.4	5.3	107.7	62.7	76.4	439.2	51.6
AB080	39190.0	1776.6	766.9	19311.2	151.5	2.2	114.6	121.8	75.1	482.5	50.1
AB081	35425.5	1274.0	638.0	17194.4	148.9	1.9	105.1	72.9	70.5	379.5	48.6
AB082	38546.4	1539.5	628.6	18145.5	160.5	10.0	112.1	55.9	72.9	465.1	55.3
AB083	37618.1	1363.1	646.8	17456.0	132.8	7.7	110.4	68.9	70.4	419.1	47.0
AB084	40670.6	1682.8	1158.1	27454.9	217.4	0.0	117.4	0.0	98.0	537.8	63.0
AB085	38545.9	1433.4	1027.5	24299.0	197.9	0.0	129.6	0.0	89.8	544.9	71.3
AB086	40263.1	1269.1	710.8	22563.4	153.7	10.9	136.6	0.0	89.3	551.9	63.7
AB087	42927.0	1757.3	959.9	30217.1	224.6	0.0	138.7	0.0	121.7	677.6	76.9
AB088	41912.1	1953.8	961.8	31494.0	284.9	0.0	134.5	0.0	127.2	641.5	73.1
AB089	41242.5	1866.1	1037.4	29365.4	249.4	0.0	135.6	0.0	113.7	628.5	72.4
AB090	43137.6	2023.1	658.3	21755.0	149.8	7.5	134.2	128.1	101.8	622.2	61.0
AB091	44943.5	1949.5	1078.7	30780.5	215.2	0.0	130.1	0.0	121.0	697.9	73.5
AB092	42931.2	2082.4	962.7	31759.4	261.8	0.0	128.0	0.0	125.8	682.6	74.5
AB093	41064.3	2197.8	1203.8	33129.7	321.9	0.0	128.4	0.0	127.0	641.6	70.2

Table II NAA Results for Obsidian from Eritrea

anid	Ba	La	Lu	Nd	Sm	U	Yb	Ce	Co	Cs	Eu	Fe
AB007	908	69.62	1.30	48.46	9.56	6.20	8.34	129.07	0.624	1.65	1.53	18739
AB008	0	90.81	1.23	66.82	11.34	7.43	7.87	160.90	0.000	1.29	0.55	27164
AB038	0	91.97	1.31	65.60	11.54	6.02	7.90	164.15	0.000	1.12	0.79	27549
AB039	0	91.06	1.25	63.99	11.36	6.37	7.97	163.67	0.000	1.25	0.67	27290
AB040	0	90.96	1.25	63.43	11.36	6.13	7.86	162.11	0.000	1.36	0.65	26900
AB052	898	71.67	1.37	49.90	10.06	5.28	8.98	133.18	0.000	1.56	1.47	18724
AB053	54	91.66	1.25	60.62	11.34	6.76	7.87	165.01	0.000	1.27	0.77	27209
AB055	484	78.81	1.02	51.26	9.07	6.17	6.38	141.84	0.440	1.52	1.12	24220
AB058	766	89.83	1.18	67.83	11.73	6.73	7.40	164.67	0.000	1.17	1.80	20358
AB060	0	91.65	1.27	68.24	11.49	7.05	7.87	166.82	0.000	1.45	0.70	27626
AB063	18	107.24	1.39	72.34	12.76	8.31	8.59	194.42	0.519	1.13	0.94	26998
AB064	46	89.35	1.12	64.56	10.92	6.38	6.98	159.37	0.000	1.39	0.51	21394
AB068	0	90.69	1.11	65.06	11.00	6.17	7.13	159.94	0.000	1.38	0.65	22039
AB074	742	63.89	1.05	42.11	8.19	5.94	6.37	115.95	1.575	1.47	0.88	17136
AB077	877	69.83	1.25	51.53	9.78	6.15	8.63	129.31	0.838	1.56	1.62	18982
AB081	890	71.50	1.29	50.60	10.09	6.40	8.72	133.47	0.367	1.47	1.44	18782
AB085	38	114.72	1.43	76.72	12.65	8.77	8.87	202.95	0.000	1.47	0.55	24918
AB088	0	90.77	1.25	67.72	11.50	7.04	7.89	162.30	0.000	1.42	0.66	27194
AB091	0	91.50	1.28	64.52	11.59	7.25	7.96	169.72	0.000	1.30	0.68	27006
AB092	0	90.36	1.29	63.18	11.80	6.39	7.89	170.89	0.000	1.08	0.65	27006
KRE001	0	93.63	1.27	62.26	11.48	5.96	7.45	172.22	0.058	1.64	0.71	22702
KRE002	0	90.79	1.22	61.42	11.21	5.73	7.51	166.72	0.000	1.62	0.68	22205
KRE003	0	93.04	1.24	61.51	11.57	6.01	7.46	170.96	0.035	1.68	0.67	21703

Table II NAA Results for Obsidian from Eritrea

anid	Hf	Rb	Sb	Sc	Sr	Ta	Tb	Th	Zn	Zr	Al	Cl
AB007	10.87	123.90	0.00	2.490	0.0	5.81	1.67	14.11	116.9	420.7	65338	1302
AB008	11.80	132.57	0.00	0.205	0.0	7.84	1.86	16.81	160.1	389.9	62671	1419
AB038	11.97	134.14	0.00	0.214	0.0	7.75	1.95	17.08	135.9	368.1	63128	1351
AB039	11.60	127.51	0.00	0.203	0.0	7.57	1.89	16.86	160.8	355.0	63101	1352
AB040	12.07	135.67	0.00	0.220	0.0	7.69	1.79	16.68	136.0	395.7	59923	1400
AB052	11.77	128.17	0.00	2.232	0.0	6.19	1.73	13.73	119.2	368.4	62845	1355
AB053	11.76	132.52	0.00	0.238	0.0	7.88	1.81	16.81	127.9	376.6	62154	1421
AB055	10.25	132.99	0.00	3.429	0.0	6.79	1.33	14.84	112.7	339.6	69071	1370
AB058	11.76	111.33	0.00	1.180	0.0	7.14	1.77	16.02	134.3	367.8	60909	1536
AB060	11.74	128.77	0.26	0.210	0.0	7.72	1.88	17.15	148.3	345.4	59446	1377
AB063	13.35	132.70	0.00	0.343	0.0	9.60	2.01	19.31	164.4	407.2	61835	1586
AB064	11.73	130.03	0.00	0.509	0.0	7.06	1.72	15.42	128.7	407.4	60113	1426
AB068	11.96	139.07	0.00	0.503	0.0	7.17	1.70	15.60	144.6	424.0	66399	1360
AB074	10.95	121.11	0.35	2.983	0.0	4.49	1.26	14.39	72.1	358.3	69200	1145
AB077	11.17	123.76	0.00	2.497	0.0	5.90	1.69	14.26	119.5	358.1	66221	1203
AB081	11.31	123.32	0.00	2.250	0.0	6.07	1.85	14.32	124.0	350.0	63779	1219
AB085	14.22	155.06	0.00	0.596	0.0	10.51	2.09	20.58	131.2	498.1	53598	1882
AB088	11.87	137.57	0.00	0.205	0.0	7.73	1.87	16.74	144.5	351.9	66516	1450
AB091	12.20	135.20	0.00	0.224	0.0	7.83	1.87	16.87	138.1	335.7	56745	1442
AB092	11.81	130.90	0.00	0.220	0.0	7.64	1.93	16.73	144.7	398.7	62328	1501
KRE001	12.72	137.98	0.25	0.541	0.0	8.03	1.80	14.95	154.9	488.5	65274	1380
KRE002	12.38	139.52	0.24	0.511	0.0	7.94	1.81	14.56	156.8	445.3	65652	1347
KRE003	12.78	135.18	0.20	0.508	0.0	7.13	1.77	14.79	152.0	458.3	61359	1377

Table II NAA Results for Obsidian from Eritrea

anid	Dy	K	Mn	Na
AB007	12.83	41162	587.7	33218
AB008	11.91	39694	810.4	39470
AB038	12.82	40598	816.5	39960
AB039	13.34	42231	815.4	39600
AB040	12.06	44001	816.5	39644
AB052	13.75	39289	613.7	33755
AB053	12.79	40694	813.7	39550
AB055	9.47	40928	811.2	38309
AB058	12.18	37594	731.3	36571
AB060	13.36	38466	820.2	39883
AB063	14.75	42342	746.7	39614
AB064	11.70	39955	697.5	39727
AB068	12.33	40643	687.9	39218
AB074	9.33	43090	465.0	33668
AB077	12.96	39155	591.1	33185
AB081	12.89	42856	604.3	33351
AB085	12.68	35990	793.4	38259
AB088	12.48	38979	823.6	39796
AB091	11.14	39885	791.3	38798
AB092	12.12	41660	810.3	39437
KRE001	11.88	41319	685.8	39018
KRE002	11.45	40352	685.9	38712
KRE003	11.88	40405	681.4	38800

Appendix III

Microwear Study of Lithic Artifacts

Amanuel Beyin

Introduction

The fact that the archaeological sites discovered along the Red Sea Coast contain lithic implements implies that some activities requiring stone tools were performed at the sites. Direct evidence of the nature of those activities is unknown at this time. The faunal association, which is entirely dominated by mollusk shells, does not offer ample evidence whether or not the stone tools were solely required for the exploitation of mollusks. In order to understand the role of the stone tools recovered from the focal sites, a microwear study of selected artifacts was conducted.

As noted by Odell (1981:197), "stone tools that were utilized in prehistoric times often afford ample evidence of their use through the damage they sustained while being used." Archaeologists commonly employ microwear analysis to infer tool function from the damage signatures left on tool edge in the form of breakage, striations and polish. Using microwear information, it is possible to investigate the link between artifact style, tool function and human activities (ibid.). As such, microwear investigation offers a unique opportunity to understand the subsistence behavior of prehistoric groups when the physical remains of the resources being exploited are not preserved (Crombé, et al. 2001; Lombard 2005).

Material and Methods

The lithic samples selected for microwear analysis were from Gelalo and Misse only. Since the majority of the Asfet material was not transported to the USA, it was not included in the analysis. Seventy-three (Gelalo=57, Misse =16) judgmentally selected artifacts were subjected to macroscopic and microscopic examination for use-wear evidence. The analyzed sample includes microliths, edge damaged tools and blanks. Analytic steps employed in Shea (1991, 2007) were followed in designing the laboratory work. Tools were examined under Olympus zoom stereomicroscope (SZ4060) at a magnification level less than10x. Such low magnification approach was preferred because the majority of the artifacts were made of obsidian, which produces flakes with delicate edges where accidental damages could greatly mimic use-wear at a micro-level. In order for a damage to be recognized as possible use-wear, it had to extend more than 10 mm along a continuous portion of the tool edge. Accidental damages were designated so by the lack of pattern and/or erratic distribution and presence of fresh broken surface shine. All the tools were washed prior to analysis, and were cautiously handled during transportation to prevent any damage due to collision. Two major microwear phenomena, fractures and striations were recorded on an analytic chart specifically designed for this study. Obsidian does not form polish; hence it was not recorded in the course of this study. Within each microwear aspect, type, location and extent were regularly noted. A list of analytic attributes employed in this study is shown in Table 1. Because some tools may feature multiple damage types, the analytic chart was set up to accommodate overlapping features.

Interpretation of microwear variability and possible tool function were guided by published resources, and Shea's reference collection (artifact replica and teaching manual) housed in the Department of Anthropology at Stony Brook University, USA.

Damage Characterization and Interpretative Framework

Microwear analysis tries to discover the worn parts of a tool, and interpretation of tool function relies on the damage characteristics preserved on the worked edge (Shea 1992). Thus, it is necessary to describe some of the common damage features resulting from intentional use and/or taphonomic activities. The common microwear phenomena include striation and macro/microfracture. Variability in damage mechanisms and associated agents are discussed under each microwear category.

Striations: are linear impressions formed when a tool slides over a hard particle or once suspended between two surfaces (Shea 1992). Striations are aligned parallel to the plane of tool motion; and the orientation and extent of the grooves depend on the nature of the worked surface, depth of the contact area and the material the tool is made from. Cutting hard material leaves horizontal striations, while edge traversing motions, such as scraping or adzing produce striations perpendicular to the cutting edge (ibid.:144). Processing soft substance such as meat and hide results in oblique striations on the contact surface (ibid.).

Edge Fractures: are microscopic or macroscopic concavities formed by bending and shear fracture along the worked edge of a stone tool (Odell 1981; Shea 1992). The extent and manner of fracture depends on the magnitude of loading (force), resistance of the worked material and the direction of motion. Generally, hard contact surface produces larger edge fractures. Likewise, "harder contact materials cause edge damage characterized by a higher incidence of hinge and step fracture" (Odell 1981:200), while soft substances often result in feather terminated fractures (Fischer, et al. 1984; Shea 1991). Cutting produces alternating fractures on both sides of the worked edge, whereas shaving and scraping produce fractures on one side of the utilized area (assuming that we are assessing a single generation of fractures). Large scars of feather termination suggest the line of force was directed into the body of the tool. Fischer et al (1984: 22-23) identify two types of fractures related to projectile points: i) cone fracture which result from force applied over a relatively small area and the fracture initiates in the immediate vicinity of the contact area, ii) bending fracture where the force is distributed over a relatively large surface and where the fracture does not necessarily initiate at the contact area. Bending fracture from impact use can sometimes initiate a small conical fracture from the ventral surface called spin-off (ibid.).

Edge damage can be caused by various agents including cultural and natural activities (McBrearty, et al. 1998; Shea and Klenck 1993; Tringham, et al. 1974). Intentionally produced retouch can often be confused with accidental damages such as trampling, weathering and erosion. This is especially common with obsidian due its brittle and cryptocrystalline nature. Researchers employ different parameters to distinguish accidental damages from intentional ones. For instance, Shea and Klenck (1993) found unevenly distributed broad, less elongated flake scars to be associated with trampling activities. Likewise, Tringham, et al. (1974) argue that accidental damages occur on one side of the tool, while McBrearty, et al. (1998) note that trampling damages resemble intentional retouch/use-wear in a number of aspects. According to McBrearty, et al. (1998) trampling on hard substrate results in accidental edge damages dominated by notches. An image based recent microwear study by Bird et, al. (2007) showed more patterned edge damages to be associated with intentional human modification. These researchers advocate for an assemblage level interpretation as opposed to artifact based inference of edge damage or use-wear origins. Accordingly, non-random edge damage or retouch pattern at an assemblage level implies intentional behavior, whereas inconsistent edge damage locations could be a result of accidental processes.

Analysis Results

A large percentage of the analyzed sample preserves use-wear traces. The observed damage frequencies and associated patterns are shown in Tables 2-7. The proportion of tool classes represented in the analyzed sample varies slightly between the two sites. While miscellaneous tools are the most dominant class in the Gelalo sample (39%), geometric microliths were the largest group in the Misse sample (56%). Together, geometric microliths make up the largest class in the analyzed sample followed by miscellaneous tools and backed fragments. About 77% of the artifacts exhibit a variety of damage traces, some with a single damage type, while the majorities preserve multiple damage types. In this study, the presence of multiple damage types on a single edge has been interpreted as a strong evidence of use-wear. This does not mean that a single damage type is not reliable, but multiple traces add much confidence to our interpretation.

The first evidence for use-wear comes from edge fracture and abrasion, which together were noted in the majority of the examined tools. The most notable patterns are that 43% of the analyzed sample displays edge fracture and abrasion, 18% fracture only, and 12% a combination of edge fracture, striation and abrasion (Table 2). The samples from the two sites represent similar proportion (44%) of tools with edge fracture and abrasion on the functional edge (Table 2). It must be noted however that a smaller sample was analyzed from Misse compared to Gelalo. Almost equal proportions of artifacts display fracture alone, while abrasion alone was noted in the Misse sample only. Twenty-three percent (n =17) of the analyzed artifacts lack any discernible evidence of edge damage below 10 x magnifications level. Out of these, 13 are from the Gelalo sample and 4 from Misse. As noted earlier, any damage evidence observed above 10 x magnification level can be easily confused with damages caused by weathering, winnowing or other accidental agents. This is particularly true considering the delicate nature of obsidian raw material. Besides, obsidian does not form distinct polish/gloss, thus there is limitation in terms of discerning evidence of plant processing by obsidian.

Assessment of damage pattern by tool type indicates that geometric microliths display the weakest evidence of microwear traces. Out of the 27 geometric microliths, 11 specimens (8=Gelalo, 3=Misse) do not preserve any discernible edge damage. Moreover, 6 implements (5=Gelalo, 1=Misse) of the same class display only edge fracture. Backed fragments represent the second class to display weak evidence of edge damage. Of the 18 total number of backed fragments, 6 (5=Gelalo, 1=Misse) display indeterminate damage, and 5 segments from Gelalo exhibit edge fracture only. The Misse and Gelalo microliths (complete and fragments) display comparable frequency of damage pattern with the exception of abrasion, which occurs more in the Misse sample. Multiple forms of edge damage were regularly noted in the miscellaneous tool class (long blades and various retouched flakes). Edge fracture and abrasion occur frequently together in the majority of the miscellaneous tools suggesting intentional use for cutting soft to medium substance.

Variability in fracture formation along the damaged edges has been systematically described with the aim of finding some pattern in damage types. In this regard, bending snap and hinge fractures dominate the analyzed sample (Table 3). Tools with snap and hinge fracture constitutes 65% of the entire sample from both sites. The snap fracture usually produces dulled edge and is restricted to the longitudinal margins. The miscellaneous class displays greater percentage of snap and hinge fracture, while the majority of the backed tools (complete geometrics and segments) display indeterminate fracture. The backed tools frequently preserve abraded edges. Assessment of damage position on the tool body shows that the majority of macro and micro-damages are distributed along the margin (Table 4). About 70% of the analyzed sample from the two sites displays edge damage on the margin in the form of fracture and abrasion. Of this, 30% display only marginal damage while the remaining 40% preserve multiple fracture scars in the form of feather and/or hinge on the ventral and dorsal surfaces. Snap damage was mostly noted along the margin, while hinge and feather scars usually occur on the dorsal and ventral surfaces.

The nature of backing was assessed for the complete and incomplete microliths to infer the technique used to design backed implements. Several of the backed tools (26/49), including geometric and non-geometric elements display unidirectional backing orientating from ventral to dorsal by hard-hammer abrasion (Table 5). A limited experimental test by the author demonstrates that obsidian flakes can be easily backed by hard-hammer abrasion and the edge where the hard-hammer makes initial contact preserves dense abrasion. The analyzed sample shows consistent pattern with this observation. Occasionally, the backed microliths display bidirectional removals (mainly at the proximal and distal ends). Modest proportions (15/49) of the microliths preserve multiple scars on the backed edge, such as bipolar, bidirectional and hard-hammer abrasion. Such a combination of backing feature appears more common with the geometric class. Tool use was inferred from the nature of edge damage noted on each artifact. Static cutting motion was inferred from the observed damage patterns on several microliths. As can be seen in Table 6, 75% of the artifacts preserve edge damages, seemingly as a result of deliberate use. Based on the observation that the majority of the edge-damages are restricted to the margin, the tools seem to have been used for cutting soft to medium resistance substances. Notably, the microlithic class represents the largest group among those displaying weak evidence of edge damage. As noted earlier, the majority of this class exhibits randomly distributed traces of fracture and abrasion. The implication of this is important in explaining site formation process and discard behavior of prehistoric people. In this respect, the used microliths may not have returned to the site and those recovered at the site were fresh-made tools.

All the specimens subjected to microwear analysis were visually inspected for macro-fracture traces before examining under the microscope. Such an approach is aimed at verifying the frequency of artifacts that bear microwear traces that could not be determined without the aid of a microscope, and to assess how much information could be discerned with the naked eye alone. As can be seen in Table 7, the majority of the analyzed artifacts preserve macro-damages characterized by fracture and abrasion. In this regard, about 67% of the Gelalo and 56% of Misse artifacts exhibit edge fracture identifiable without the aid of a microscope. Only 21% of the Gelalo and 31% of Misse specimens lack macroscopic traces. This is in fact very close figure to the proportion of artifacts without discernible damage evidence at all (Table 2). Among the artifacts that display indeterminate macrofracture, geometric microliths are by far dominant. A large number of the miscellaneous class displays macrofractures discernible with the naked eye. In general, the study found that the majority of the damage traces can be discerned with the naked eye, but microscopic examination would be desirable to identify fracture types.

Discussion and Conclusions of Microwear Study

Microwear analysis of LSA artifacts from the Red Sea Coast using a low magnification stereomicroscope revealed evidence for edge damage on the majority of the analyzed sample (Figs. 1-2). The major findings of the study can be summarized as follows:

i) Edge fracture and abrasion are the two most common damage types noted in the Gelalo and Misse collections.
ii) Edge snap and hinge fracture characterize the damage patterns.
iii) Long blades display more evidence for use-wear, whereas microliths (geometric and non-geometric) preserve weak evidence of use.
iv) Edge damage (snap and abrasion) commonly occurs on the lateral margins of long blades, backed microliths and other tools.

A considerable number of the tools seem to have been used for cutting soft to medium substances. Thus, in addition to tool manufacturing, a variety of subsistence activities seem to have taken place at the sites. While the study was successful in providing evidence for intentional use, the precise nature of the activities/function performed by the tools could not be discerned. Where there is no other evidence for subsistence sources except mollusk shells, it is likely that some of the tools were used to process marine shells. However, the study is inconclusive as to what extent the tools might have been desired for shell processing. It is not clear whether the tools were primarily manufactured for shell processing or for other purposes.

Since the samples were pooled from nearly contemporaneous sites, it was not possible to address any chronological trend in microwear variability. It is unclear to what extent tool function may have changed through time because the assemblage from the younger site of Asfet, with which comparison would have been ideal, was not subjected to microwear study. The relationship between form/shape and function is a highly debated issue among researchers. While some scholars, example (Binford 1986; Close 1978) suggest that stylistic traits are independent of function, Sackett (1973) argues style and function complement each other and that, both play a role in bringing assemblage-level variation. In this study, although microwear evidence occurs mostly on long blades, there is no strict correlation between tool function and shape or form *per se*. All the tools that bear edge damage seem to have been used in similar ways with snap, hinge and abrasion usually co-occurring along the lateral edges. Such broadly shared feature at an assemblage level implies intentional cause for the noted damage pattern (Bird, et al. 2007). The lack of much edge damage evidence on the microlithic class is tempting to find alternative explanation as to what the role of these implements might have been.

The commonly held opinion about microlithic function in Africa and Eurasia is that they were primarily used as inserts for arrows, barbs, and to some extent as sickle blades for cutting grass (Becker and Wendorf 1993; Clark 1985; Clark and Prince 1978; Crombé, et al. 2001). Microwear studies in different regions suggest multiple use of microlithic tools. Clark and Prince (1978) found close similarity in edge damage between prehistoric microliths from Laga Oda (southeast plateau of Ethiopia) and experimental replicas tested on plant processing. The occupation span of the Laga Oda site ranges from 15 ka to 325 bp with a probable occupation haitus between 10.3 ka and 3.5 ka bp (ibid.:102). According to this study, microliths used for shredding leaves and cutting *Equisetum* plants display polish and gloss along the worked edge similar to what they noticed on the actual artifacts recovered from Laga Oda site (ibid. 105). Cutting *Equisetum* also produces micro-flake scars in addition to the gloss and polish. Similarly, microwear study by Becker and Wendorf (1993) of a Terminal Pleistocene assemblage (14.5-12 ka bp) from the site of Qadan in southern Egypt identified multiple use of lunates, such as for hide-scraping and meat-cutting. This study found weak correlation between typological difference and function.

Another study by Crombé, et al. (2001) on an Early Mesolithic collection from the site of Verrebroek (Belgium) dating to about ca.10.5 ka bp found exclusive evidence for the use of microliths as barbs rather than as arrow heads. In light of the evidence from these case studies, it appears that geometric microliths could have had varieties of uses in prehistoric cultures, although there is a strong inclination to regard them as composite tools (Clark 1985; Phillipson 1977). If they were exclusively used as composite tools for hunting, it is tempting to assume that there is less chance for the used implements to return to base camp. Thus, what archaeologists find in the sites could be those implements discarded before hafting. Therefore, it is expected many of the microlithic tools to show weak macro/micro-damage if they were not used for activities that produce edge damage. In addressing the evolution of microliths, Ambrose (2002) attributes the invention of microlithic technology to increased human mobility and raw material scarcity towards the end of the Pleistocene and early Holocene. Although the available evidence from the Red Sea Coast is not conclusive about the specific role of microliths, it is apparent that subsistence needs associated with hunting activities might have stimulated the technology there.

One of the main aims of the microwear study was to determine whether the tools recovered from the two LSA sites (Gelalo and Misse) preserve evidence for use-wear. The analysis presented evidence suggesting that several of the tools were intentionally used. Yet, the evidence is too limited for generalization about the specific activities being performed at the sites.

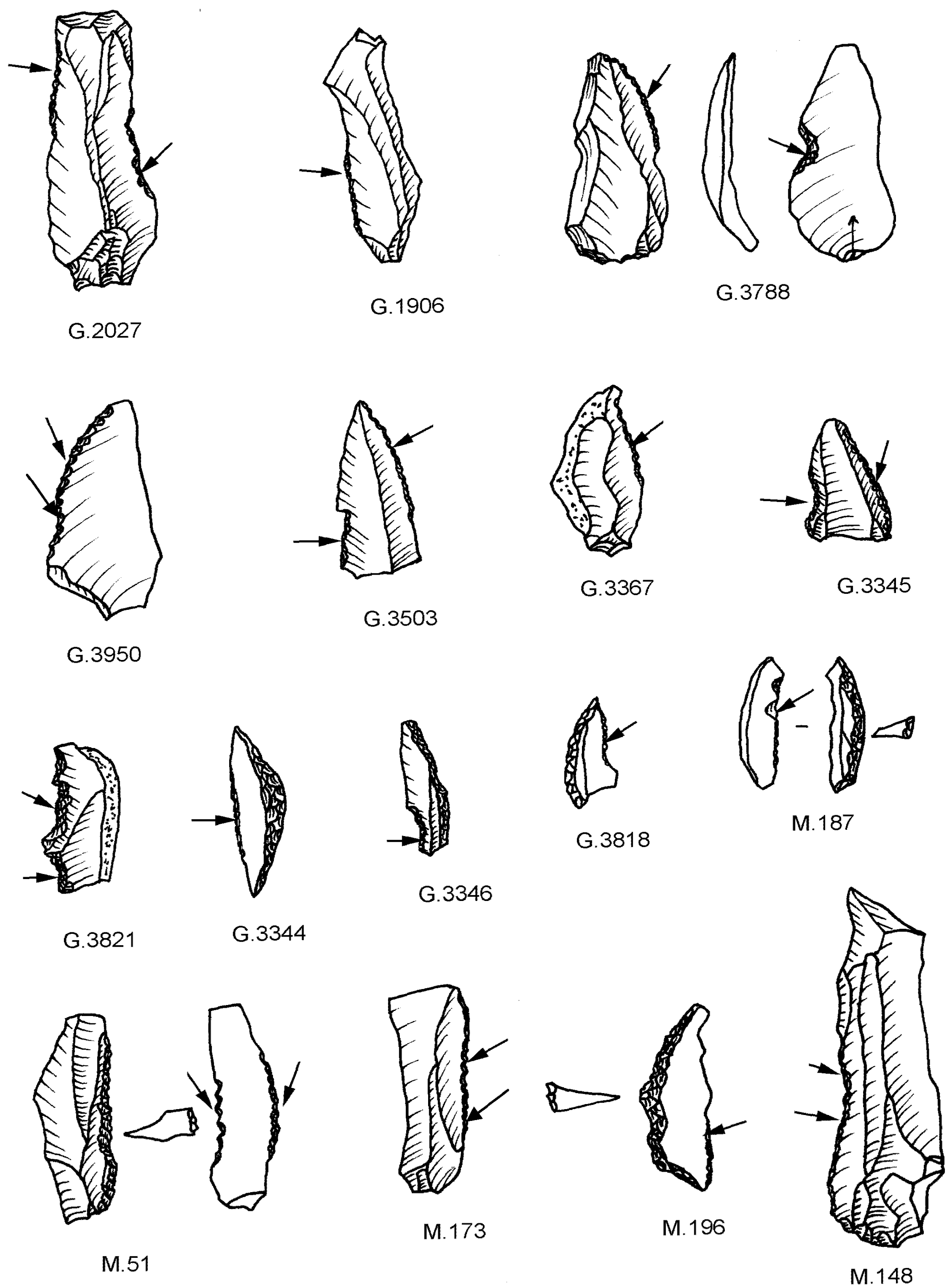

Figure 1. Lithic illustrations showing the locations of edge damges as indicated by arrows.

Figure 2. Selected artifacts with microwear traces at a resolution of ~500 dpi.

Gulf of Zula and Buri Peninsula Paleolithic Research **Microwear Analysis, June 2008** **Artifact Catalogue# ___________________**
Tool Class: 1) Geometric microlith, 2) Backed flake, 3) Backed fragment, 4) Other
Damage Type: 1**)** Edge fracture, 2) Striations, 3) Abrasion, 4) Indet.
Fracture Formation: 1) Step/snap, 2) Feather, 3) Hinge, 4) Spin-off, 5) Indet.
Fracture Position: 1) Ventral, 2) Dorsal, 3) Margin, 4) Ventral and Dorsal, 5) Indet.
Fracture Extent: 1) 0.1-0.5mm, 2) 0.6-1mm, 3) >1mm, 4) Indet.
Formation of Striation: 1**.** Linear, 2. Raking, 3. Transverse, 4. Not available
Striation Location: 1) Ventral, 2) Dorsal, 3) Margin, 4) Retouched edge, 5) Indet.
Polish Formation: 1) Ventral, 2) Dorsal, 3) Margin, 4) Retouched edge, 5) Indet
Macroscopic Note: 1) Edge Fracture, 2) Striations, 3) Polish, 4) Abrasion, 5) Indet.
Nature of Motion: 1) Impact, 2) Cutting/Sawing, 3) Scrape, 4) Indet.
Contact Surface: 1) Soft, 2) Medium, 3) Hard, 4) Indet.
Backing Technique: 1) Bipolar, 2) Hard-hammer abrasion, 3) Soft-hammer, 4) Indet.
Direction of Backing: 1) Unidirectional, 2) Bidirectional, 3) Indet.
Haft: 1) Present, 2) Absent, if yes location___________________
Inferred Use: 1) Whittling, 2) Wood cutting, 3) Hide scraping, 4) Other/Indet.
Remarks:
Analyst Initials: _______________________ **Date of Analyzed**: __D_ /___M____/__Y__

Table 1. Attributes recorded for microwear study.

Sites	Tool Class	Damage type							
		Abrasion only	Edge Fracture only	Edge Fracture, Abrasion	Edge Fracture, Striations	Edge Fracture, Striations, Abrasion	Indeterminate	Totals	%
Gelalo	Backed flakes			2				2	3
	Backed fragments		5	2	1	2	5	15	26
	Geometric microliths		5	4	1		8	18	32
	Other			17	1	4		22	39
Gelalo Total %		0	10 18	25 44	3 5	6 10	13 23	57	100
Misse	Backed flakes		2					2	12
	Backed fragments			2			1	3	19
	Geometric microliths	2	1	3			3	9	56
	Other			2				2	12
Misse Total %		2 12	3 19	7 44	0	0	4 25	16	100
Total count %		2 3	13 18	32 43	3 4	6 8	17 23	73	

Table 2. Inventory of artifacts subjected to microwear analysis.

Fracture Formation	Tool Class					
	Backed Flakes	Backed Fragments	Geometric Microliths	Other	Totals	%
Feather and Hinge				2	2	3
Indeterminate		7	12		19	26
Snap only	1	6	8	3	18	25
Snap and Feather		1	3	2	6	8
Snap and Hinge	1	3	4	10	18	25
Snap, Feather, Hinge	2	1		7	10	14
Totals	4	18	27	24	73	100

Table 3. Variability in fracture formation among the tools analyzed for microwear evidence.

Fracture Formation	Damage Position								
	Dorsal only	Dorsal and Margin	Indeterminate	Margin only	Ventral only	Ventral and Dorsal	Ventral and Margin	Ventral, Dorsal, Margin	Totals
Feather and Hinge	1					1			2
Indeterminate			15	4					19
Snap only		3		13			2		18
Snap and Feather	1	1		1	1	1	1		6
Snap and Hinge		5		3			4	6	18
Snap, Feather, Hinge		3		1	1		2	3	10
Totals	2	12	15	22	2	2	9	9	73
%	3	16	21	30	3	3	12	12	100

Table 4. Variability in microwear damage position among the analyzed sample.

Backing Technique	Tool Class				
	Backed Flakes	Backed Fragments	Geometric Microliths	Other	Totals
Bipolar, Bidirectional, hard-hammer abrasion		3	8		11
Hard-hammer abrasion, Bidirectional		5	7		12
Hard-hammer abrasion, Unidirectional	4	10	12		26
Indeterminate				24	24
Totals	4	18	27	24	73

Table 5. Variability in backing technique among the analyzed sample.

Nature of motion	Contact Surface	Tool Class				
		Backed Flakes	Backed Fragments	Geometric Microliths	Other	Totals
Cutting and scraping	Medium only				2	2
	Medium and Hard		1		4	5
	Soft only		7	8	2	17
	Soft and Medium	4	3	8	16	31
Cutting and scraping Total		4	11	16	24	55
Indeterminate/ Other	Indeterminate		7	11		18
Totals		4	18	27	24	73

Table 6. Variability in contact surface and motion pattern of the analyzed tools.

Sites	Macroscopic Observation	Backed flakes	Backed fragments	Geometric microliths	Other	Totals
Gelalo	Abrasion			1	1	2
	Edge Fracture	2	10	9	17	38
	Edge Fracture and Abrasion			1	3	4
	Indeterminate		5	7		12
	Polish				1	1
Gelalo Total		2	15	18	22	57
Misse	Abrasion			2		2
	Edge Fracture	2	2	3	2	9
	Indeterminate		1	4		5
Misse Total		2	3	9	2	16
Totals		4	18	27	24	73

Table 7. Macro-damage frequency on the tools analyzed for mircowear evidence.

Appendix IV

Lithic Analytic Protocols

Amanuel Beyin

Background to lithic analysis

Historically, there has been two main traditions in the field of lithic studies (Kuhn 1995). These are, i) the French school of thought, which grew out of the work of Francois Bordes in the mid 20th C, (Boëda 1991; Bordes 1961; Tixier, et al. 1992), and ii) the English-speaking school of thought variously developed in North America and Sub-Saharan Africa (Clark and Kleindienst 1974; Goodwin and Van Riet 1929; Sullivan and Rozen 1985). The French speaking dominates most of European, North African and Near Eastern Paleolithic practices. Although, both approaches place great deal of focus on flake production techniques or *chaînes opératoires,* the main emphases of the French school of thought is on core reduction, such as the process of flake removal and the different technological choices (mechanical characteristics and geometric aspects) involved in maintaining the core (ibid.: 81). In this regard, the Levallois method has been the main focus of investigation. Repeated experimental studies have been conducted to explore the technological principled underlying the Levallois strategy. As such, this technology is best defined in terms of the morphological changes that the core undergoes at different stages of the reduction sequence. The English-speaking school of thought on the other hand focuses on statistical analysis of assemblage variability by recording metric and discrete attributes on cores, flakes and tools. They rely on the products of cores to reconstruct past behavior, and define core and debitage relationship through refitting and/or experimentation. Refitting is an important component of the French school of thought as well, mainly geared towards reconstructing core design.

For the past several decades, the classification scheme developed by Francois Bordes (1961) has been a major reference for lithic analysts, especially in Europe, western Asia and North Africa. Bordes' typology contains 63 named and numbered tool types and was intended to classify assemblages based on typological markers, such as retouch patterns and Levallois signatures (*chapeau de gendarme*). The system has proven wide application by archaeologists as a way of sharing their results using fixed traits - "the relative frequency of retouched tools or *recloirs.*" Over the years, however, due to limitations with its regional palpability, the Bordes' approach has faced a number of criticisms and its scope has been limited to specific research questions (Bisson 2000; Dibble and Chase 1981). Nowadays, classifications are made based on research-specific criteria that consider local and regional variability.

Objectives and analytic protocols

Lithic analysis was necessary for understanding the cultural identity of the prehistoric settlements in the study area. Through lithic investigation, the research aims to address the following specific issues:

i. Variability in assemblage composition and lithic reduction strategies
ii. Variability in the kinds of raw materials reduced
iii. Raw material procurement strategies (sourcing)
iv. Typological variation of lithic end products (shaped tools)
v. Intra-site and inter-site assemblage variability.

Previous Paleolithic research is scarce for Eritrea and local analytic framework is absent. Thus, this work had to depend on regional syntheses or upon universally agreed frameworks. Perhaps the most useful and comprehensive analytic reference in Africa is that of Clark and Kleindienst (2001) : *The Stone Age cultural sequences: terminology, typology and raw material*. This publication provided basic terminologies for artifact description and attribute definitions. Additional useful reference to this work include

Kleindienst (2004: 35-39) typological approach for the Dakhleh Oasis material. When dealing with the excavated material, Nelson's (1973) comprehensive review of the Eastern African Later Stone Age has served as a useful reference. Lithic investigation involved typological classification and attribute analysis. Only attributes that can be consistently measured and easily describable were selected.

In the context of lithic studies, attributes refer to a set of criteria or characteristics based on which artifacts are classified into related groups (Andrefsky 1998). The advantage of attribute analysis over a holistic typological approach is that it depicts techno-typological variables consistently (Kuhn 1995). In attribute analysis, analysis can be repeated on other assemblages with less distortion. For example, instead of classifying retouched tools into end, side or transverse scrapers at a face value, the position of the retouch marks were recorded in reference to the lateral margins. Depending on the retouch position, one can then determine if the tool can be classified into side, end or other scraper type. Holistic classification based on morphological aspects limits the analyst's ability to control the magnitude of analytic criteria for classification. Two categories of attributes have been recorded on each artifact: the continuous or numeric variables and discrete attributes (Dibble, et al. 2003). In continuous data, there is a fixed zero point and the values for the selected variables are numerically expressed. Tool dimension (size) and weight were the common variables recorded as continuous data. This facilitates quantitative comparison and is intended to infer the technological processes involved in the production of specific stone tools (example, whether the assemblages is dominated by tools with greater length to width ratio, such as those fabricated from prismatic blade cores, or by thin and narrow debitage such as those from soft hammer or pressure flaking). Consistent measurement of technological attributes has greater applicability for inter-site and intra-site assemblage comparison.

The discrete variables (character attributes) are those observational criteria used to describe lithic morphology. In this approach, artifact definition is based on certain recurring attributes and analysis involves recording the frequencies of these attributes in ordinal or nominal scale (Holdaway and Stern 2004). Discrete attributes recorded during the analysis include, raw material, retouch pattern, tool shape and striking platform type. Various attributes were recorded on the platforms, such as dorsal surfaces and distal margins to infer reduction technique. Flake scars were counted on complete flakes and core surfaces to assess the intensity of core preparation before removing the intended blanks.

Raw material identification was performed in the NME with the help of Mr. Ghebretinsae Woldu. Source analysis of obsidian samples from the three excavated sites was conducted at the University of Missouri Archaeometry Laboratory with the assistance of Dr. Michael D. Glascock (Appendix II).

Lithic Classes and Analytic Attributes

The first step in the lithic analysis was to sort the assemblage into artifact classes. These include manuports, cores, complete flakes, shaped tools, proximal fragments and debries/shatters (Andrefsky 1998; Clark and Kleindienst 2001). Pertinent attributes were recorded for each class.

Manuports

Are rock nodules with signs of impact damage used as detaching percussors or hammerstones to remove flakes from the parent core. These include

<u>Hammerstones</u>. Are chunks and cobbles of rocks that show evidence of use as core striking implements. They preserve bruised and battered faces or edges.

<u>Abrading stones</u>. Are handstones characterized by striations and abrasions evidence of use to remove irregularities from a core or any other artifact. These retain less severe surface damage.

<u>Grinding stones/mortars</u>. Large, flat hard stones with one or more faces showing striations and smooth surface due to grinding and rubbing.

Three measurement attributes were recorded for each manuport. These are Length, width and thickness measured using a sliding caliper. Length was measured as the longest axis between two opposite points on the core, whereas width and thickness were treated arbitrarily as they are indistinguishable in most cases. Surface condition of manuports was indicated in the comment section.

Cores

Cores refer to blocks of rocks with signs of flake removal from which any kind of flake-blanks/debitage are detached. Various core types were recognized based on the nature of flake scar configuration. Traditionally, cores are classified into specialized and unspecialized (miscellaneous) based on the pattern of scar removal (Kleindienst 2004). Specialized cores include those produced from more formal method such as Levallois, linear (prismatic) and discoid. Unspecialized (*ad hoc)* cores are those resulted from less regulated flake removal strategy. Unspecialized cores include multiple platform-massive nodules and "situational" tools. The so called situational tools are implements that show deliberate modification, but lack consistent form (ibid.). Cores were classified into 7 major types and those miscellaneous ones. These include:

<u>Discoidal/ centripetal Levallois</u>. The defining feature this class of cores is the direction of flake removal from the perimeter towards the center (Khun 1995: 83). Here, multiple convergent flake scares occur on the flake release surface. Multiple striking platform and concavities may be also observed along the core periphery. In centripetal (discoid) core reduction, flakes could be removed from one or both faces.

<u>Linear (lineal) Levallois</u>. This class of Levallois core refers to specimens that preserve short flake scars along the core margin truncated by the removal of a single, large flake along the middle axis, usually on one surface (Bordes 1961).

<u>Prismatic cores</u>. These include cores that preserve parallel scars along a single or multiple axes. Single or opposed platforms can be preserved, respectively used for a single or bi-directional removals (Khun 1995). Prismatic cores are intended to produce elongated convergent and/or parallel edged- blades in the MSA/Middle Palelolithic.

<u>Bipolar/outils écaillés</u>. These are variably reduced pieces, distinguished by the presence of chisel like straight edge resulting from step flaking on one or both faces (Barham 1987). Bipolar cores or *outils écaillés* are common in many MSA and LSA sites

of Africa. Kleindienst and Clark (2001) assign those to utilized artifact class while still favoring their classification into core category.

Core fragments. Any piece of worked rock with a truncated edge, but preserving some flake scar concavities.

Core on flakes. Large flakes (with discernable ventral and dorsal faces) that preserve a single or multiple flake scars on the ventral face. Striking platform and bulb of percussion can be preserved on the proximal edge of the original flake.

Core scrapers. Large tools (>100 mm) that preserve small flake removals along the edge as a result of retouching (Clark and Kleindienst 2001).

Other. Cores that can't be classified to either of the above categories. A few among others are choppers and polyhedrons, which their classification to either tool or core class is subjective. These are common in the Asfet surface assemblage.

Core Attributes

The continuous attributes recorded on cores include: Maximum Length, Width and Thickness. There were two approaches in applying these measurements. a) when measuring formal cores such as prismatic and Levallois; the core was oriented relative to the platform and the maximum length was measured along the technological axis from which the longest flake is struck (Holdaway and Stern 2004: 189). In this case, width and thickness were measured between two arbitrary points on the core surface; perpendicular and mid-point to length, b) in measuring discoidal and/or other *ad hoc* cores, length was measured as the dimension between the platform and an arbitrary point where maximum distance can be obtained (ibid.: 189). Here, width and thickness were interchangeably recorded at right angle to the length. The length of the longest flake scar in each core has also been measured to assess the range of flake size removed (ibid.:188).

Various discrete variables were also recorded on cores. These include:

Flake removal pattern: *1) Unidirectional*, if the core preserves scars that originate from a single platform and flakes are struck in the same direction (ibid.:180). 2) *Bidirecional:* if cores have two opposite platforms and flakes have been struck in opposite direction (ibid.:180). 3) *Multidirectional:* if cores have more than two platforms and there is a mixed flake scar orientation (ibid.). 4) *Bifacial:* cores have a single platform and flakes are struck from two faces (ibid.).

Number of flake scars: This is the count of flake scars longer than 15 mm on the core surface. This didn't consider the presence or absence of bulb scar; all flake scars including partial scars were counted and the aim is to assess core reduction intensity (Holdaway and Stern 2004: 146). Generally, the higher the number of scars on a flake or core surface, the more the core has been worked intensively.

Flake scar shape: This describes the relative shape of flake scars counted on the core. It is important to describe scar shape in order to infer the general characteristics of the last flakes removed from the core. But this criterion is highly elusive, because recurrent removals from the core surface can result in incomplete scars that may distort our view. 1) *> 60 % elongate*, if majority of scars are longer than they are wider (ibid.:183). 2) *>60% Expanding*, if scars have broader shape, width greater than length (ibid). 3) *Other,* intermediate or indeterminate nature of scars.

Relative scar size: this criterion attempts to rank the relative size range of scars, so that to evaluate the nature of commonly produced blank types, such as flakes vs blades. Afterwards this pattern can be compared with the debitage composition. 1) *>60 % long scars*, if majority scars extend more than half of the core length. 2) *>60 % short scars*, if majority scars extend less than half of the core length. 3) *Other*, intermediate or indeterminate.

Whole flakes

Often referred to as debitage, this class includes all kinds of complete flakes possessing; a) striking platform or a bulb of percussion, b) ventral and dorsal faces, c) distal end, but not preserving evidence of deliberate lateral retouch or modification. All other fragments that lack these landmarks were grouped as debris (fragments). Artifacts that preserve random retouch marks and/or seemingly natural scars were considered as whole flakes. Two major blank types were recognized based on dimension: blades and non-blade flakes. Prismatic blades are those flakes that meet the standard definition of a blade (length to width ratio greater than 2), parallel to semi-parallel lateral edges, and dorsal scars running longer than the midpoint of the tool along the technological axis (Bar-Yosef and Kuhn 1999). Within the non-blade category, several debitage types were identified based on cortex distribution and platform type.

Different blank types were recognized based on the kinds of continuous and discrete landmarks they display.

Cortical flakes. These are flakes with dorsal face completely or nearly completely covered by cortex (original exterior surface). Flakes with patinated surfaces, but preserving even faded flake scar ridges were not classified as cortical, because these only suggest postdepositional effects.

Partially cortical. Flakes partly covered by cortex and with one or more flake scars on the dorsal surface.

Non-cortical flakes. Are blanks that don't retain any cortex and lack facetted platform (pertaining to Levallois), and can't be classified as blades. These can have any type of platform feature and can be any size.

Levallois flakes. This group refers to those flakes that feature facetted surface and *chapeau de gendarme* outline of the striking platform. Blanks with dihedral or plain platform were sometimes classified as Levallois if the flake has symmetrical form, an overlapping long axis with technological axis, and more than one dorsal scar truncated by the flake lateral edges. Sub-classes of this group include Levallois blades and Levallois points that are flakes with the above morphological properties, and can be characterized as blades if the ratio of technological length to width is equal to or more than 2. Levallois points preserve converging distal tip along the long axis/technological axis (Dibble, et al. 2003). Pseudo Lavallois are flakes/points with an oblique platform and bulb of percussion occurring slightly on either side of the platform (ibid.).

Prismatic blades. Are flakes with 2:1 length to width ratio and more than one dorsal scars running half of the technological length. These are presumed to be produced from formal cores and can feature parallel or convergent lateral edges. Blanks featuring blade dimensions, but preserving more than 70% cortical surface were excluded from the blade category, but simply classified as partially cortical.

Burin spall. Flakes with a triangular mid-point cross-section that are produced by a burin blow usually from an edge portion of a core or flake (Tixier 1992).

Core trimming flakes. Refer to those crested flakes that preserve one or more striking platform remnants on the dorsal surface. These are important to infer core rejuvenation removals, such as bifacial reduction (Clark and Kleindienst 2001).

Debitage Attributes

Three flake dimensions: technological length, technological width and mid-point thickens were recorded to measure artifact size. Two additional dimensions, the platform thickness and platform width were also measured for those artifacts that preserve the striking platform. Dimension measurement requires identification of specific flake landmarks. In this case, before any measurement was executed, the point of percussion on the proximal edge and the distal end (termination point) of the flake were defined. Flake dimensions were measured using sliding caliper. The recorded measurements include.

Flake length. Is measured along the flaking axis from the point of percussion at the proximal end to the flake termination at the distal end, right angle to the platform width. This is also referred to as percussion length or technological length (Holdaway and Stern 2004: 138). Technological length provides the best estimate of the length of the fracture plane (axis of force from the initiation point to the termination) and is used to reconstruct the way the flake was produced (ibid.). For instances, flakes that are broader along the bilateral axis suggest that the propagation force has diffused more towards the lateral edges than towards the distal portion. Some experimental studies have shown a positive relationship between platform width and percussion length (Pelcin 1997). It would be more legitimate if this pattern is corroborated by an archaeological sample.

Flake width. This is the width at mid-point measured at a right angle to the technological length between the flake lateral edges (ibid.).

Flake thickness. This is the thickness from the ventral to the dorsal surfaces, measured at the intersection point of the flake length and flake width.

For whole flakes that possess characteristic blade dimension, two additional size measurements were taken: width at ¾ length and thickness at ¾ length. The aim of recording these measurements is to assess thickness distribution along the technological axis and provide a feasible way of depicting blade disto-lateral margins. This means that, instead of simply reporting flake shape as convergent or parallel sided, taking the actual measurement on lateral width at the mid-point and at ¾ length could provide a concrete way of examining variation among blade class.

Striking platform type. This characterization follows the same procedures as discussed above (common attributes for all artifact class). Both continuous and discrete platform attributes were recorded on each whole flake.

Overhang removals. This criterion depicts the nature of striking platform dorsal edge modification or platform trimming. Small flake scars initiated on the core platform that subsequently appear on the dorsal edge of a flake's platform surface usually suggest core preparation, and thus controlled steps over flake production (Holdaway and Stern 2004). Overhand removals have been recorded as crushed, beveled, facetted, and cortical or plain. Such classification is hoped to infer more about core preparation strategies.

Number of dorsal scars. As stated above, this is simply the count of number of scars on the dorsal surface of a flake, which is intended to provide some information about the condition of the artifact in the reduction stage. Such information can be useful to infer if most of the artifacts were made at the final stage of the core reduction, which would be identified by a higher number of flake scar or at the early phase of reduction. We can also investigate if there are more scares on larger flakes than on smaller ones. More scars on relatively small flakes would imply intensive reduction and possibly curated technology (Holdaway and Stern 2004). Only flake scars longer the 15 mm were recorded, because a debitage/flake longer than this can be manipulated effectively as a tool (e.g., microliths).

Lateral margin. This attribute records the nature of flake lateral margins in a nominal scale, such as 1) curved (if the distal end of the flake is bowed to either side on a plan view), 2) parallel (parallel lateral sides and almost straight distal end), 3) convergent if the lateral margins come to a pointed end, and 4) expanding, if the distal end is wider than the proximal end.

Mid point cross section. This is a relative description of thickness variation along the technological width (width at mid point) of a flake. The conventional standard when making this observation was that the artifact is oriented with the distal end up, proximal edge down and ventral surface facing down. Three cross section styles were recorded: 1) symmetrical, if the thickness at mid point is uniform, 2) skewed right, if the thickest part of the flake is on the left lateral margin and 3) skewed left if the thickest part is on the right lateral margin.

Termination pattern. This attribute refers to the shape of the distal end of a whole flake, which depicts the nature of energy propagation as the flake was detached from the core(Cotterell and Kamminga 1986, 1987). Four different flake termination patterns were recorded. 1) *Feather termination*- if the flake has a smooth termination with the minimal thickness restricted towards the distal end. 2) *Hinge Termination*-formed due to an abrupt termination where the flake detaching energy changes course away from the objective piece resulting in a thicker distal end slightly winding towards the dorsal surface of the flake. 3) *Step Termination*-occurs when a flake is snapped at a right angle during termination. There is usually a flat distal face. 4) *Plunge Termination*-the kind of termination also known as *outrepasse* that occur due to the propagation of the impact force towards the objective piece as it approaches the distal edge of the core. This results in a flake with a curved distal end that preserves a portion of the distal face of the core.

h) Bipolar hammer feature. This attribute was included here to register the presence of any bipolar signature on a flake: 1) opposed end fractures, 2) opposed impact rings, or both. The presence of any bipolar signatures on flakes will then be correlated with the proportion of bipolar cores in each assemblage.

Shaped tools

Are artifacts that show evidence of deliberate modification by human action, such as edge retouching, unifacial or bifacial reduction and use marks (this is often less diagnostic though). Several tool types have been recognized based on the location, nature and size of retouch. These include bifacially reduced large cutting tools (handaxes, cleavers, lanceolates >100 mm long), partly reduced heavy duty tools (core axes, choppers, core scrapers, >100 mm long), and light duty tools which include microliths, points, scrapers, and various small reduced tools such as foliate points < 100 mm long (Clark and Kleindienst 2001).

Several tool types have been recognized based on the location, nature and size of retouch.

Scrapers. This tool class includes all implements variously retouched on one or more edges by hard or soft hammer percussion. Different kinds of scrapers can be recognized based on the distribution and intensity of retouch.

Edge damaged. Semi-continuous marginal flake scars, crushing, battering and rubbing, mainly as a result of minor modification or use of the implements on a hard material characterize these tools (Clark and Kleindienst 2001). Moreover, regularly retouched implements on either faces of the tool with $\leq$ 2 mm scar length were classified as edge damage as well. Edge damaged artifacts are common in the investigated assemblages, but accidental breaks sometimes hindered identification of true utilized edges from naturally modified ones. For this reason, edge damage classification was performed on the excavated material only, because trampling or post-discard rolling could cause edge damage on the surface ones.

Backed tools. These are blanks (flakes or blades) >30 mm in size, unifacially or bifacially backed by shallow, steep or blunt retouching (Clark and Kleindienst 2001: 54). Striking platform may or may not be preserved.

Microliths. This tool class refers to small backed pieces, < 30 mm in length that are commonly produced on bladelets or diminutive flakes (ibid.: 54). Usually, they exhibit unifacial backing by steep retouch, while the opposite margin (cord) remains sharp and straight. In this study, they were classified into several geometric classes: convex (lunates), straight, triangles, trapezes based on overall tool shape. Microliths are techno-typologically the most diagnostic class of artifacts, mainly uncovered from Gelalo NW and Misse East sites.

Burins. Flakes or blades that are struck at one end by a burin blow (from the distal or proximal surface towards the lateral edge). This produces an edge with three faces formed by the removal of a burin spall (Dibble, et al. 2005). True burins are generally rare in the samples studied.

Bifaces (handaxes, oviates, cleavers, picks). Heavy duty tools, bifacially or unifacially worked, cutting edge usually extending more than 50 % of the total edge circumference (Clark and Kleindienst 2001). They could be symmetrical or asymmetrical with biconvex or plano-convex cross-section. These are common in the Asfet surface assemblage. Other commonly encountered tools were those small bifaces weighing less than 100 gm, but exhibiting recognizable shape.

Foliate points. Leaf shaped, bifacially or parti-bifacially retouched tools with one or two pointed ends (ibid.:57). They look symmetrically biconvex in cross-section and sinusoidal straight on profile view. Most of the time they are produced from flakes, but it is possible that such artifacts could be reduced from flat pebbles, such as in the case of lanceolates. They are represented by a modest number in the Asfet surface material.

Biface or foliate fragments. These are all incomplete pieces, presumably broken off larger bifaces or smaller foliate points. They are rare in the investigated sites.

Denticulates. These are tools that contain one or more serrated edges by adjacent notches. In this work, notches should be more than 2 mm deep and more than 3 in number along one edge in order a specimen to be classified as a denticulate. This class is common in the excavated material from Gelalo NW and Misse East sites.

Notches. Are tools with a single or more edges preserving more than 3 mm deeper scar formed by a single blow or multiple retouches towards either face. In practice, it was problematical to distinguish incidentally formed notches from those intentional ones. This is particularly true with obsidian flakes, because of the delicate nature of obsidian.

Backed fragments. These are small segments that reveal snapped end/s and one edge preserving a continuous backing retouch. These were further differentiated into tip right, tip left and medial based on the alignment of the retouched edge with respect to the dorsal surface and complete end.

Tool Attributes

Measurements. By default, most shaped tools are incomplete because retouching removes certain portions of the original dimension (mass and size). Therefore, dimension and mass measurements on shaped tools may not be precise and are not used here to make any major inference about assemblage variability. Major size variables were recorded to assess the general trend in the investigated assemblages. These include maximum length, mid-point width, mid-point thickness and mass. Maximum length is measured as the furthest distance between two points on the flake furthest apart from each other (Holdaway and Stern 2004). Although it would be possible instead to take technological length on those flakes that preserve the platform, this has to be measured consistently on all the incomplete specimens. And maximum length is still useful to depict the artifact volume and mass (ibid.). Mid-point width was measured across the lateral sides through the mid-point and at the right angle to the maximum length. There is no justification to label this as maximum width, because most shaped tools lose their lateral margins variably by retouch. Mid-point thickness is the distance taken from the dorsal to the ventral surfaces at the intersection of length and mid-point width.

Striking platform morphology. This describes the nature of the platform on those artifacts that preserve it as described below.

Retouch morphology. This describes the nature of retouch on the tool edge, and is intended to infer the technique, extent of tool reuse, and to a lesser extent site occupation history. Retouch morphological attributes were recorded using a combination of ordinal and nominal categories as follows (Holdaway and Stern 2004; Inizan, et al. 1992): 1) *>50% Invasive*- if tool-edges are characterized by more retouches that extend towards the dorsal or ventral surface. Holdaway and Stern (2004) suggest that invasive retouch is formed when retouches are initiated from the ventral surface. Invasive, shallow retouch scars may indicate soft hammer technique (ibid.). 2) *> 50 Steppe*- edges with heavily stacked, steppe like retouch scars. This kind of edge morphology indicates recurrent edge modification and is common on thicker blank edges (Inizan, et al. 1992). 3) *Notch*- deep, concave and localized scar formed either by a single blow (clactonian notch) or repeated retouches on specific portion of the tool edge. 4) *> 50% scalar*- edges that contain moderately invasive, short retouches that display wider distal extremities and slightly hinged on their distal zone (Inizan, et al. 1992: 91). 4) *Edge damage*- this criterion depicts if there is any damage mark due to use or blunting of the tool. For the purpose of drawing a conventional boundary between edge damage and other forms of retouch, retouches that appear intentional, but less than 2 mm long were also placed in this category. This class of retouch has witnessed some limitations, as it was found difficult to distinguish incidental (natural breaks, trampling) from intentional use marks. 5) *Serrated*- a tool that displays adjacent small notches along the worked edge. This kind of edge morphology designates a denticulate, 5) *Backed*- this refers to tool edges modified by abrupt retouching ($\geq 80^0$), formed by unidirectional or bi-directional blow along one or two sides. Backing may involve the use of bipolar-anvil technique.

Retouch position. This criterion depicts the distribution of retouch marks on either parts of the tool: 1) ventral face, 2) dorsal face, 3) on both faces, 4) alternating pattern, or 5) along the edge, which includes backing, edge damage, notch or serration.

Retouch distribution. This refers to the manner of retouch scar distribution on the tool edge; 1) continuous if removals occupy the edge without interruption (distal or lateral), 2) discontinuous, if retouches are not uniformly distributed along the worked edge, 3) partial, if removals are continuous at one portion and discontinuous on another part of the edge. This criterion is intended to infer the re-sharpening style and the mode of tool use.

Retouch size. This is an ordinal depiction of the size of retouch removals from either the dorsal or ventral faces. These include: 1) > 2 mm or 2) ≤ 2 mm, and if the edge modification involves burination or blunting, it is recorded as shaved; edge damage and mixed if it combines any of the above retouch styles.

Retouch location. This describes the location of retouched edge with respect to the striking platform and applies only to those tools that preserve striking platform and or bulb of percussion (any landmark that can be useful to identify the proximal side of the flake). This involves laying the artifact on its ventral face along its technological axis, with the proximal side down and the distal end up. This also requires the preparation of a quadrant chart designated by a big "X" numbered from 1- 4 in a clockwise manner starting with 1 on the lower sector. Careful recording of retouch location may be useful to assess the variation in the working edge. Instead of simply describing tools as side or end scrapers, the retouched edge can be depicted more accurately using the coordinate chart. This method seems useful to compare scraper forms in a replicable manner.

Retouch extent. This describes the extent of the retouched portion of the lateral edge relative to the total edge circumference. It was recorded in an ordinal manner: 1) < 33%, 2) 34 – 67%, 3) > 67%. The aim of making this observation is to compare the relationship between retouch morphology and extent. In other words, which retouching technique modifies the flake edge to a higher lateral extent in the investigated samples? And how do the different retouching styles relate to the overall modified edge portion?

Modified edge from. Tool edges were classified into different forms based on a plan view profile of the retouched portion. Such classification was based on a combination of retouch traits and intensity. The commonly noted edge forms include, 1) straight, if it is a simple side scraper or backed blade, 2) Concave, a notch looking edge, 3) convex, a curved scraper or crescentic microlith, 4) mixed, any tool with a combination of 1-3, 5) denticulate, serrated edge, 6) bifacial thinning, if modified by alternating retouch on two faces at the same portion.

General tool shape. This variable describes the general shape of the whole artifact resulting from collective effects of retouch removals or the original feature of the tool when flaked off the core. Tools were classified as, 1) crescentic, 2) trapezoid, 3) parallel, 4) tip left, tool segments backed on the left margin, 5) tip right, segments retouched on the right margin, 6) medial, backed tools snapped on both ends, 7) sickle or concave, 8) convergent, those triangular points, 9) other

Completeness. Shaped tools were described as complete if they retain the platform and a portion of the distal margin that the retouch removals don't compromise the overall tool size. On the other hand, if tools were highly modified by retouch removals they would be regarded as incomplete and any measurement incorporating size or mass would be void.

Proximal fragments

These are flake fragments that preserve the proximal end, specifically the striking platform surface. The reason for measuring these tools is that, because they preserve the minimum diagnostic feature (the platform) from which to estimate the total original number of complete flakes in the assemblage. Three proximal attributes (platform type, platform width and platform thickness) were recorded.

Platform and cortex attributes

Platform type. This criterion refers to the kind of platform preparation as can be seen on the striking surface of a core or that end of a flake known as the proximal surface (Dibble, et al. 2003). Four platform types are commonly recognized on cores, flakes and shaped tools: cortical (if the platform is covered with cortex), plain (without any cortex or any preparation marks), dihedral (with two facets) and facetted (with three or more facets on the platform). On flake products, cortical platform indicates initial stage of preparation, whereas facetted platform suggests tool production or prepared core reduction strategy. Platform characterization on cores and retouched tools is similarly aimed at exploring if there have been any standardized removals.

Two attribute measurements; platform thickness and width were taken on flakes to assess variation in striking platform size. Width was measured as the maximum distance between the two lateral edges on the platform surface, and thickness the distance between the dorsal and ventral faces, at a right angle to the platform width's mid-point. Platform dimension, specifically platform thickness is believed to influence the overall flake size ((Dibble 1997; Pelcin 1997). According to Pelcin's (1997) experimental work, there is high correlation between platform thickness and the flake length and thickness. Similarly Dibble's (1997) experimental work has demonstrated a high correlation between platform area and mass. Platform measurement was not performed on cores and tools, because these types either not all preserve platform (in the case of shaped tools because retouching can remove them) or there could be multiple kinds of platforms preserved (in the case of cores).

Cortex coverage. Cortex refers to the amount of original exterior surface of the raw material retained on the surface an artifact (core, flake, tool). Primarily, cortex analysis is used to examine if core reduction or tool production has taken place in a certain site, thus to obtain technological information (Dibble, et al. 2003). If the entire dorsal surface is covered by cortex, we can infer primary core reduction activity. Therefore, cortex based classification of assemblages was employed to infer site function and raw material procurement strategy (if cores were transported in curated form or as natural blocks). Cortex was recorded judgmentally in percentage scale, consisting of three arbitrary scores: 1: 0-33%, 2: 34-67%, 3: 68-100%.

Mass. This is the weight in gram for every artifact, be it a core, manuport, a flake or shaped tool. The purpose of weighing artifacts is to investigate variability between assemblages using number of artifacts to mass index or any other combination of mass and artifact dimensions (Dibble 1997).

Debris/Shatter

Are incomplete and undiagnostic flakes and broken pieces that lack discrete flake landmarks. They were only counted and weight as a group.

Microsoft Access was used to store and manage raw data. Statistical analysis was performed using Microsoft Excel and Minitab software. Univariate and multi-variate analyses were performed to determine attribute relationship and assemblage variability.

Illustrations

Selected artifacts from all tool classes: Hammerstones, cores, blanks and shaped tools were drawn on plan view, right profile and occasionally mid-cross section with the help of Lalemba Tsehaye from the National Museum of Eritrea.

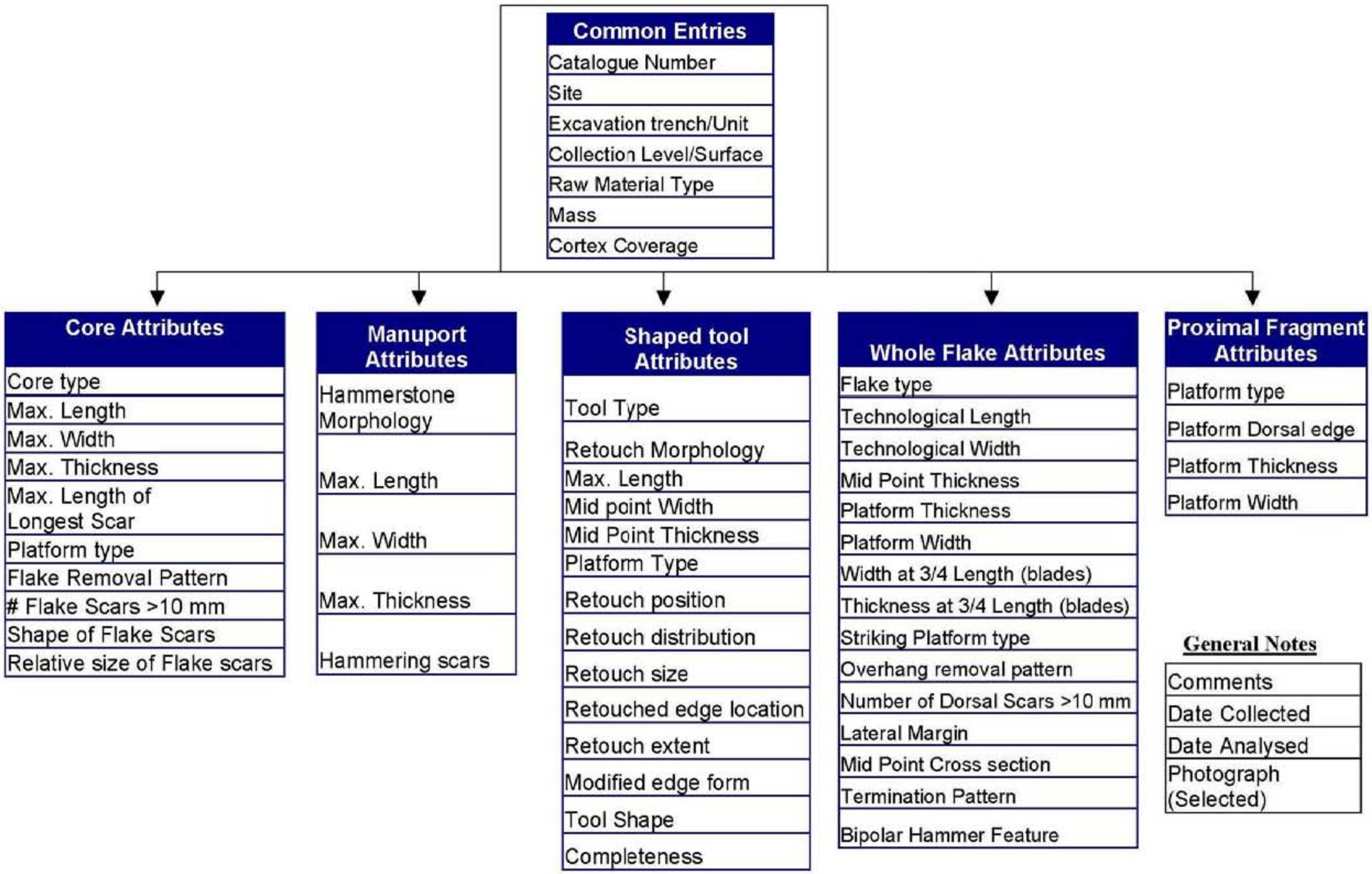

Figure 1. Lithic analytic framework employed in the project.

Parent Rock	Common types	Major mineral/grain constituents	General Properties *	Knapping suitability for tool production*
Igneous	Obsidian	Mainly Silica (potassiu-m Feldspar), occur as a volcanic pyroclastic	Fine grain, glassy, lack crystal structure, extru-sive, homogeneuous	Soft hammer (bifacial, blade), Pressure (blade and retouching)
Volcanic process after intensive melting under surface	Basalt	calcic plagioclase, pyroxyne, maffic (iron and magnesium)	Extrusive, dark, fine equivalent of gabro, phenocrystic	highly variable: soft hammer (bifacial), and Pressure retouching
	Rhyolite	phenocrysts of quartz and potasium feldspar (silicate family)	Extrusive, fine equivalent of granite, light, glassy to cryptocrystaline	soft hammer (blade and bifacial)
	Andesite	mafic and sodic feldspar	drak, Fine equivalent of diorite, phenocrysts+ ,	?
Sedimentary	Chert	silica (SiO_2)	Hard, dense cryptocry-stalline, color vary due to impurities	Soft hammer (bifacial, blade), Pressure (blade and retouching)
Formed by chemical weathering: precipitation of organic/inorganic material, usually occure in secon-dary deposits	Flint	"	a variety of chert with dark color due to organic inclusions	"
	Chalcedoy or Agate	"	A variety of chert, with no impurity, translucent and pale	"
	Jasper	"	Red chert, due to high content of iron oxide	soft hammer (biface), and pressure retouch, but not for blade pressure
	Shale	Detrital sediments (clay, silt, mud)	fine grained, laminated, well indurated (hardened by pressure), color vary	-
	Sandstone	detrital sediments (sand and silt) with >85% quartz, mica, feldspare	hetergeneous, firmly consolidated by cementing material	grinding and polishing: hard hammer for heavy duty tool production
	Limestone	Calcite (Ca_2Co_3)	Consolidated, various color, impurity	-
Metamorphic	Quartzite	recrystalized quarz (SiO_2) rich sandstone	granoblastic (structured crystal boundaries),white or gray, lacks foliation	hammerstones
Heat and pressure. Rocks display foliation /cleavage: linear arrangement of crystal boundaries	Quartz	silica (SiO_2)	hard, resistant to weathe-ring, colorless in pure form, no cleavage, disp-lays conchoidal fracture	hammerstones
	Slate	metamorphosed shale	compact, fine grained, strong cleavage, udually dark in color	-
	Schist	shale, mica, hornblende	strongly foliated, crysta-lline, with parallel/laminar mineral structure	-

Summary of common rock types for stone tool manufacturing in prehistoric times. *= case study after Inizan et al. (1992: 17), # = Bates and Jackson (1984).

Appendix V

Buri Peninsula and Gulf of Zula Archaeological Project

2005-2006, Eritrea

Survey Form for Individual Localities

Usage guideline: In this survey form three types of information must be recorded. These are: GPS reference of the locality, physiograhic and archaeological contexts of the study area and a sketch map. Recorders should use pencil when documenting on this form.

Site Name______________________Date recorded __________ Revisited (y/n)

Site #________, Major reference around______________, Site area in m^2 (est.)_____

Map Reference

GPS coordinates of site datum: Longitude __________ E UTM Zone______

Latitude __________ N

Elevation _______m

Survey method________________, grid dimensions (if systematic)________________

Topography

Highland plain flat_____, highland ridge_____, terrace______ canyon bottom ______,

River bed______, lowland plain/Wadi __________direction of inclination______

Distance to water _____, Direction to water________, Vegetation cover__________

Surface visibility:__________, Erosion: None_____ Severe ______moderate_______

Site disturbance: ________________

Site type: Habitaion______________quarry__________workshop________others______

Archaeological remains: Lithic_________________Fauna_______________Other ____

Common raw material types____

Raw material source: local ___________, exotic _______ Indeterminate_________

Diagnostic artifacts drawn: Yes ________ No_________

Number of photographed/drawn artifacts_______, number of measured artifacts_______

Site and surrounding area sketch map handout # ______________

Recorders' initials:__________________, PI Sig.__________Date_________