UNIVERSITAT ROVIRA I VIRGILI

TECHNOLOGY OF LARGE FLAKE ACHEULEAN AT LALITPUR, CENTRAL INDIA

Neetu Agarwal

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Technology of Large Flake Acheulean at Lalitpur, Central India

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UNIVERSITAT ROVIRA I VIRGILI

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TECHNOLOGY OF LARGE FLAKE ACHEULEAN AT LALITPUR, CENTRAL INDIA

TESI DOCTORAL

dirigida pel Dr. Robert Sala i Ramos

&

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Departament
d'Historia i Historia de l'Art

UNIVERSITAT ROVIRA I VIRGILI

Tarragona

2014

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FAIG CONSTAR que aquest treball, titulat "**Technology of Large Flake Acheulean at Lalitpur, Central India**", que presenta **Neetu Agarwal** per a l'obtenció del títol de Doctor, ha estat realitzat sota la meva direcció al Departament d'Historia i Historia de l'Art d'aquesta universitat i que acompleix els requeriments per poder optar a **Menció Internacional**.

Tarragona, 10 de Julio de 2014

Directores de la tesi doctoral

Dr. Robert Sala i Ramos

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THESIS ABSTRACT

ENGLISH

The present thesis attempts to study the Acheulean at Lalitpur, Central India in terms of site context, formation processes and technological organization employed by the hominins. It attempts to understand the characteristic features of the Acheulean technological organization at the site of Lalitpur. This has been done through the examination of the entire assemblage from the site and not just focusing on bifaces as the 'type fossil' of the Acheulean as has traditionally been done. For this purpose, the *chaîne opératoire* approach has been used to understand the entire technological organization from raw material procurement, to core reduction, blank production, modification into tools, use, resharpening, discard and alteration subject to post-depositional processes. Quantitative attributes have also been recorded to enable comparisons.

Since the assemblage is recovered from near surface contexts, detailed studies of site context and formation processes were also undertaken to assess the integrity of the assemblage.

Raw material has often been considered as an important factor affecting stone tools, particularly since the assemblage is predominantly made on granite, therefore detailed raw material studies were carried out.

Finally the Acheulean at Lalitpur was compared it with other well studied assemblages in India, Africa and Europe to place the Indian Acheulean in global context

The study of the technological organization of the Acheulean hominins at Lalitpur has helped in deriving a comprehensive picture of the stone tool technological repertoire of the Acheulean hominins. It has helped redefine the Indian Acheulean and place it in global context. Further it has helped in clarifying the concept of 'Large Flake Acheulean' and the behavioural implications of this technology.

It has also highlighted the importance of 'surface' sites in the study of the Lower Palaeolithic, particularly in India and pointed out the importance of site formation studies in understanding the nature of Palaeolithic sites.

CATALAN

Aquesta tesi es proposa d'estudiar l'Aixelià a Lalitpur, Índia Central, sota l'òptica del context del jaciment, el procés de formació del jaciment i l'organització tecnològica duta a terme pels hominins. Pretén comprendre els trets característics de l'organització tecnològica aixeliana al jaciment de Lalitpur. S'ha dut a terme mitjançant l'anàlisi del conjunt complet recuperat en el jaciment i no només focalitzant-la en els bifaços com a "fòssil tipus" de l'Aixelià com s'ha fet tradicionalment. En aquest sentit, s'ha emprat l'aproximació pròpia de l'anàlisi de la *cadena operativa* per comprendre l'organització tecnològica completa des de l'obtenció de la matèria primera, a la reducció dels nuclis, la producció de les ascles, llur modificació en eines configurades, l'ús, el reavivat, el seu abandonament i l'alteració en el decurs de processos post-deposicionals. També s'han tingut en compte atributs quantitatius per permetre les comparacions amb altres conjunts.

Com que el conjunt va ser recuperat en contextos pròxims a la superfície, s'han emprès també estudis detallats del context del jaciment i dels processos de la seva formació a fi de confirmar la integritat del conjunt.

El tipus de matèria primera ha estat sovint considerat com un factor important que afecta les eines de pedra, sobretot des del moment en què el conjunt està manufacturat principalment en granit. Per aquesta raó, s'han dut a terme estudis detallats de la matèria primera.

Per acabar l'Aixelià de Lalitpur ha estat comparat amb d'altres conjunts ben estudiats de l'Índia, Àfrica i Europa a fi de situar l'Aixelià indi en un context global.

L'estudi de l'organització tecnològica dels hominins aixelians de Lalitpur ha servit per a deduir-ne una imatge entenedora de la variabilitat tecnològica de les eines de pedra dels hominins aixelians. Ha ajudat en una redefinició de l'Aixelià de l'Índia i en la seva situació en un context global. A més ha servit per clarificar el concepte de "Aixelià de Grans Ascles" i les implicacions comportamentals d'aquesta tecnologia.

També ha destacat la importància dels jaciments "de superficie" en l'estudi del Paleolític inferior, especialment a l'Índia i ha mostrat la importància dels estudis de la formació dels jaciments en la comprensió de les característiques dels jaciments paleolítics.

SPANISH

Esta tesis se propone el estudio del Achelense de Lalitpur, India Central, bajo la óptica del contexto del yacimiento, el proceso de formación del mismo y la organización tecnológica llevada a cabo por los homininos. Pretende comprender los rasgos característicos de la organización tecnológica achelense en el yacimiento de Lalitpur. Se ha llevado a cabo mediante el análisis del conjunto completo recuperado en el yacimiento y no tan sólo focalizándolo en los bifaces como 'fósil tipo' del Achelense, tal como se había hecho tradicionalmente. En este sentido, se ha empleado la aproximación propia del análisis de la *cadena operativa* para comprender la organización tecnológica completa desde la obtención de la materia prima, a la reducción de los núcleos, la producción de lascas, su modificación en herramientas configuradas, su uso, el reavivado, su abandono y la alteración a lo largo de procesos post-deposicionales. También se han tenido en cuenta atributos cuantitativos para permitir las comparaciones con otros conjuntos.

Como el conjunto fue recuperado en contextos próximos a la superficie, se han emprendido también estudios detallados del contexto del yacimiento y de los procesos de su formación a fin de confirmar la integridad del conjunto.

El tipo de materia prima ha sido a menudo considerado como un factor importante que condiciona las herramientas de piedra, sobre todo desde el momento en que el conjunto está manufacturado principalmente en granito. Por esta razón, se han llevado a cabo estudios detallados de la materia prima.

Para terminar el Achelense de Lalitpur ha sido comparado con otros conjuntos bien estudiados de la India, África y Europa con el fin de situar el Achelense indio en un contexto global.

El estudio de la organización tecnológica de los homininos achelenses de Lalitpur ha servido para deducir una imagen clara de la variabilidad tecnológica de las herramientas líticas de los homininos achelenses. Ha ayudado a la redefinición del Achelense de la India y en su situación en un contexto global. Además ha servido para clarificar el concepto de 'Achelense de Grandes Lascas' y las implicaciones comportamentales de esta tecnología.

También ha destacado la importancia de yacimientos de 'superficie' en el estudio del Paleolítico inferior, especialmente en la India y ha mostrado la importancia de los estudios de la formación del yacimiento en la comprensión de la naturaleza de los yacimientos paleolíticos.

THESIS SUMMARY

The Indian subcontinent occupies an important position in the story of early hominin behaviour and dispersals. In the light of recent dating attempts which push the chronology of the Indian Acheulean much farther back in the Lower Pleistocene, and suggest near equivalence of age with the African Acheulean, the picture of early hominins in the subcontinent assumes even greater importance. The record of the Acheulean is very rich in India, but very few studies have been made of the technological organization of Acheulean hominins, and rarely of whole assemblages. In this context, the present thesis is an attempt at a comprehensive restudy of the Acheulean at Lalitpur, Central India in terms of site context, formation processes and technological organization employed by the hominins. The study of the technological organization of the Acheulean hominins at Lalitpur using a combination of the *chaîne opératoire* approach and attribute analysis, focusing on the study of the entire assemblage including cores, flakes and tools as against the traditional approach focusing on shaped tools, has helped in deriving a comprehensive picture of the stone tool technological repertoire of the Acheulean hominins. It has helped redefine the Indian Acheulean and place it in global context. Further it has helped in clarifying the concept of 'Large Flake Acheulean' and the behavioural implications of this technology.

This work has also highlighted the importance of 'surface' sites in the study of the Lower Palaeolithic, particularly in India and pointed out the importance of site formation studies in understanding the nature of Palaeolithic sites.

I. Methodology

Geoarchaeological Context and Formation Processes

It was necessary to understand the contexts of sites, and processes responsible for the formation of assemblages and the nature of geological processes affecting them. For this purpose:

1. Intensive explorations were carried out in the site and also in the entire Betwa basin to relocate and find more prehistoric sites, and understand the context of sites.
2. Further remotely sensed imageries were used in a GIS platform to throw light on the fluvial dynamics and geotectonic context and understand the geomorphic processes shaping the past landscape.
3. Site Stratigraphy: Documentation and description in the field of sedimentary deposits and their vertical and lateral variations, along with their relationships to archaeological occurrences;
4. Sedimentology: Sedimentology of archaeological deposits and associated sediments to reconstruct site formation and disturbance by geological processes;
5. Formation Processes: The artefact assemblage, its nature and physical condition alongwith the taphonomy of natural clasts are an important indicator of the formation processes and nature of postdepositional disturbances, particularly in case of 'surface' or 'near surface' sites. Therefore, several attributes like assemblage composition, artefact density, artefact size *vis-a-vis* natural clasts, raw materials present, degree and type of weathering and abrasion, rounding, patination, breakage and damage patterns were observed to understand the depositional context of the artefacts.

Lithic Technology

The main aim was to understand the lithic technological strategies employed by the Acheulean toolmakers, and answer questions pertaining to the role of raw material selection, core organization, bifacial shaping, standardization, symmetry, existence of mental templates, and curation, resharpening and discard of tools.

In the present study, the entire artefact assemblage from the site has been analysed. The focus has not only been on LCTs, their typology and shaping as has traditionally been done. The study attempts to understand the technology of flake blank production at the site.

This was done through a combination of attribute analysis and *chaîne opératoire* approach aimed at determining the position and role of each diagnostic artefact in the knapping process and understand the technological organization right from the initial stage of raw material selection and procurement to core reduction, obtaining blanks for tools and shaping them, use, resharpening, curation, transport, discard and retrieval by archaeological methods.

The *chaîne opératoire* approach has so far has not been used on a major scale in Indian archaeology and the use of this method has led to new insights in Indian archaeology.

Besides, a detailed study of metrical, taphonomic, typological and technological attributes was undertaken to help in quantitative comparisons.

The lithic studies have focused on the technological organization in terms of:

1. Nature of the raw materials used;
2. Taphonomic condition of the artefacts to infer formation processes at sites;
3. Techniques used in the manufacture of different tools;
4. Typology and composition of the lithic assemblage;
5. Morphometric study to understand issues of standardization, refinement and symmetry;
6. Reconstruction of the reduction sequence or chaîne opératoire of stone tools from morphotechnological observations on cores, debitage and finished tools;
7. Possible reuse, resharpening and rejuvenation of tools and discard;
8. Curation identified by differential raw material selection, resharpening of tools, long-distance transport of raw material, blanks or finished tools and differential discard patterns;
9. Use of granite as a raw material and its flaking qualities;
10. Answer specific questions pertaining to Acheulean lithic assemblage morphological variability, role of bifacial shaping, symmetry, refinement, standardization and the existence of mental templates; and
11. Infer about the degree of planning and sophistication in technology, cognitive abilities of the hominins, mobility and landuse.

I. Summary of Chapters

The present thesis has been organized into the following chapters

Chapter I: Introduction – it provides the basic framework of the research, outlining the aims and objectives of the study and justifies the need for restudying the Acheulean at Lalitpur.

Chapter II: Geoarchaeological Context of the Betwa Basin: introduces the study area, and discusses the results of geoarchaeological explorations in the region.

Chapter III: The Acheulean at Lalitpur: Site Contexts and Formation Processes - It discusses the nature of the Acheulean record in the Biana Nullah and the formation processes responsible for the preservation and geological disturbance.

Chapter IV: Methodology for Lithic Analysis- A discussion of the methodology followed during the course of study of Acheulean lithics is provided.

Chapter V: Lithic Technology during the Acheulean at Lalitpur - Results of the metrical and typo-technological study of the assemblage are dealt. Further, the nature of the Acheulean culture phenomena at Lalitpur vis-à-vis the world is discussed.

Chapter VI: Conclusions - This chapter summarizes and highlights the major results obtained from the research.

II. Conclusions

A. Formation Processes and Surface Sites

i. The nature of the sites show that understanding of formation processes is critical.
ii. The 'surface' sites are not essentially surface, but recently exposed due to erosion.
iii. The assemblages are found as large concentrations of several thousand artefacts distributed over a large area. The artefact spreads are landscape wide features and not just confined to limited site areas.
iv. Further, concentration of sites in the small stretch of the interfluve between the Betwa and Shahzad Rivers only suggests differential preservation and exposure of Acheulean age sediments in that area. However, these are not the result of concentrated hominin activity only at those spots. Only they are found preserved in those locales.

v. Wherever, the sediments associated with the Acheulean age are found exposed, the artefacts are found to occur. The rarity of the sites is however related to destructive processes, and it does not reflect population densities.

B. The Acheulean at Lalitpur and defining features of the Large Flake Acheulean

i. The study of the Acheulean at Lalitpur and its comparisons with other assemblages shows that it is distinctive from the European Acheulean.
ii. It is essentially 'Large Flake Acheulean' which is a distinct entity found in Africa, Southwest Asia and South Asia.

C. Defining Features of the Large Flake Acheulean

i. It is based on the production of large flakes;
ii. Small flakes constitute a distinct chaîne opératoire within the Acheulean. However it lacks small retouched tools like points, notches and scrapers;
iii. It is characterized by the technological features of low amounts of cortex, low number of previous scars, and mostly plain platfom with angles of 105-120°;
iv. Minimal use of river cobbles, dominated by use of weathered corestones;
v. Low amounts of debitage owing to the nature of knapping methods and not site integrity;
vi. It is also characterised by very little or no secondary modification with little or no bifacial shaping of tools; Most handaxes are unifacial large pointed tools on flakes with abrupt, invasive retouch. Bifacially shaped 'true' handaxes are found in very low frequencies.
vii. Lack of symmetry and standardization. Cleaver predetermination is only in obtaining a large flake with a broad cutting edge;
viii. It is characterized by fragmented chaîne opératoire and extensive curation and transport of tools which has behavioural implications for a carrying technology.
ix. Core strategies show simple reduction strategies with minimal effort in detaching LCT blanks, but they point to considerable skill, planning, forethought and ability of the Acheulean hominins to produce suitable LCT blanks without complex preparation.

III. Concluding statements

i. The present thesis is one of the few attempts to analyse the entire assemblage from an Indian Acheulean site in terms of technological organization, focusing also on the site context and formation processes.
ii. Analysis of the Acheulean assemblage at Lalitpur and comparison with other Acheulean assemblages in India shows that the Indian Acheulean is largely based on large flakes
iii. The Indian Acheulean is earlier in time to the European Acheulean and nearly contemporaneous to the African Acheulean. The technology of making stone tools also is distinctively different from the European Acheulean
iv. Early Acheulean industries in India, Africa and Southwest are essentially 'Large Flake Acheulean'.

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ACKNOWLEDGEMENTS

First of all, I would take this opportunity to thank my mentor and co-guide, Prof. Sheila Mishra, without her unflinching support and guidance this dissertation would not have materialized. She initiated me into the field of Prehistoric Archaeology and motivated me in gaining the knowledge necessary for this work. Her belief, patience and encouragement at every stage only made completion of this dissertation possible.

Next I would like to take this opportunity to thank Prof. Robert Sala i Ramos for always providing encouragement and support in my researches since my Master in Quaternary and Prehistory and then agreeing to provide me guidance during my doctoral program. His support made this task possible. I am thankful to the Departament d'Història i Història de l'Art, (Facultat de Lletres), Universitat Rovira I Virgili, Tarragona, Spain for administrative support during my doctoral program.

I am thankful to the Curator and Director, Deccan College, Pune for allowing me to study the collection of tools from the excavation and surface collection at Lalitpur stored in the repository of the college.

Gratitude is also expressed towards Muséum Nationale d'Histoire Naturelle and Institut de Paléontologie Humaine, Paris and Servei de Recursos Científics i Tècnics, Universitat Rovira i Virgili, Tarragona, Spain for providing support for raw material characterization which was part of my Erasmus Master dissertation and has also been used here.

I would like to thank Prof. I.B. Singh and the Department of Geology, University of Lucknow for allowing me to use their laboratory for grain size analysis. Specially, I would like to thank Anju Saxena for training me in this work.

Next, I would like to thank Late Prof. Banvir Singh, Late Prof. C. Verma, Prof. Indu Sahai, Prof. B.R.K. Shukla, Dr. K. Kant, Prof. A.P. Singh and Prof. Nadeem Hasnain of the University of Lucknow for supporting me in my research and academic endeavours.

I would like to express my gratitude to Gurudas Shete for help at every stage of my thesis beginning with fieldwork, discussions on geoarchaeology; making maps and stratigraphic sections. Without his help this thesis would have been impossible.

Many others have been involved directly in the completion of this thesis. My heartfelt thanks are due to Biswajeet Thakur for morphometry of the Betwa basin and GIS analysis; Tosa, Yogesh and Jayshree for the enormous help in editing the photographs and drawings. Manjil has also provided instrumental support not only in editing the references and formatting the thesis but also providing constant encouragement and academic discussions.

Sincere thanks to Devadutta Phule, draughtsman, Deccan College for teaching me artefact drawing and also rendering the drawings of artefacts.

Thanks also go to my friends, Salim, Riza Abbas, Veena Mushrif, Madhulika Samantha, Smita Patil and Tejaswini Nadgauda for helping me in fieldwork.

My sincere thanks to Prof. K. Paddayya, Richa Jhaldiyal, S.B. Ota, Sushama Deo, Shanti Pappu, Tosabanta Padhan, Riza Abbas, Kumar Akhilesh, Yogesh Mallinathpur and Jose Raphael for discussions on several issues of the Acheulean and help, support and guidance at various stages of this work.

Sincere thanks to Claire Gaillard for her insightful comments on the thesis draft and for her support and encouragement.

I would also like to thank the Regional Director, Archaeological Survey of India, Bhopal Region for providing us accommodation in the Guest House of the Archaeological Survey of India during the period of our fieldwork.

I would also like to thank the Warden, Ladies' Hostel, Deccan College for providing good accommodation and also help, support and encouragement during my period of study at Deccan College. With her there, I always had a shoulder to lean on.

Help, support and encouragement given by all my friends are beyond words. In particular I would like to thank my friends, Reshma, Sarwat, Veena, Kanchana, Jayshree, Smita, Tejaswini, Shikha, Rukshana, Pallavi, Shruti, Shuchi, Pournima, Sayantani, Hocine, Redha, Nadia, Souhila, Vaishali, Anita, Aditi, Azadeh, Madhulika, Ditipriya, Nilam, Bina and Lathasree for their constant support and encouragement in this endeavour and timely criticism.

Last, but not the least, I would like to thank my entire family for always supporting for me. Their emotional and moral support and love cannot be expressed in words.

Neetu Agarwal

CHAPTER I

INTRODUCTION

1.1 INTRODUCTION

The Indian subcontinent occupies an important position in the story of early hominin behaviour and dispersals. In the light of recent dating attempts which push the chronology of the Indian Acheulean much farther back in the Lower Pleistocene, and suggest near equivalence of age with the African Acheulean, the picture of early hominins in the subcontinent assumes even greater importance (Pappu *et al.* 2011, Gaillard *et al.* 2010, Paddayya *et al.* 2002). The record of the Acheulean is very rich in India, but very few studies have been made of the technological organization of Acheulean hominins, and rarely of whole assemblages (Corvinus 1983). Therefore, this research was conceived to undertake a comprehensive restudy of the Acheulean at Lalitpur and attempt to arrive at a better understanding of the early hominin tool makers during the Acheulean period in India vis-à-vis the world.

The study focuses on the reconstruction of Acheulean lithic technological strategies, archaeological site contexts, formation processes of sites and Quaternary landscape at the Acheulean site of Lalitpur, Central India. Thereby, it attempts to throw light on the expansion of hominins, their migrations, dispersals and the ecological milieu in which they lived and hopes to contribute towards the study of early hominin behaviour and modes of adaptation during the Pleistocene in South Asia, and help place this important period of our evolution in context.

The region of Lalitpur in the Betwa basin was chosen for the present study as it lies on the boundary between the peninsular craton and the Gangetic alluvial plain, and can therefore help shed light on the interaction between the archaeology and geology, besides the presence of excavated Acheulean sites in good contexts. A broad overview of the archaeological context in the region of the Betwa basin (between longitude 77°00' to 81°00' E and latitude 23°00' to 26°00' N) during the Early-Late Pleistocene and Early Holocene was also dealt in order to understand the regional geoarchaeological context.

1.2 REVIEW OF PREVIOUS RESEARCHES IN THE AREA

Bundelkhand found place on the prehistoric map of the world as early as 1880s owing to the efforts of Rivett-Carnac, Carlleyle and Cockburn, three officers of the British-Indian government. However the Betwa basin, an important river draining the region, could only be placed on the prehistoric map of the world in the years after independence, as a result of the investigations carried out by Singh (*IAR* 1959-60, 1961-62, 1965), Joshi (*IAR* 1963-64), Pandey (1969), Wakankar (1962, 1973, 1975, Wakankar and Brooks 1976), Jacobson (1974, 1975, 1976 a & b, 1985), Pant (1982) and several others.

Singh surveyed the valleys of Betwa, Dhasan, Bina and Shahzad and their smaller tributaries (longitude 78°10' - 79°25' E and latitude 23°9' - 25°5' N) in the late 1950s (*IAR* 1959-60, 1960-61). He discovered a very rich Acheulean industry at Lalitpur where he recovered artefacts from six localities on the Biana Nullah, the Chhatrapal temple site and from the river section (Singh 1965). The Acheulean horizon at Lalitpur was later excavated by Deccan College (*IAR* 1961-62). In addition, Singh also noticed a cluster of Middle Palaeolithic localities at Sihora, Semraghat, Hasrai, Gonchi and Mohasa.

In 1958-62, the Prehistory Branch of the Archaeological Survey under Joshi surveyed the Betwa from Bhilsa to Mungaoli, Deogarh to Moth and Lalitpur bringing to light more than a dozen Lower Palaeolithic sites (*IAR* 1961-62). The Prehistory Branch under Joshi also conducted an excavation in 1962 (*IAR* 1963-64) at some of the localities near Lalitpur to trace the extent and richness of the deposit noticed by Singh earlier.

Pant (1982) investigated the lower course of the Betwa in Hamirpur and Jhansi discovering a number of Palaeolithic sites, including a pebble-tool complex at Lahchura (79°8' E and 29°10' N) on the river Dhasan.

Bhimbetka (77°37' E and 22°50' N) the largest known complex of cave and rock-shelter sites in the Betwa source region of the Vindhyan hills was discovered by Wakankar (1962). It is located 45 km south of Bhopal and 2 km south of Bhianpur hamlet on the Bhopal – Hoshangabad highway. The hill rises 650 m AMSL and 100 m above the surrounding plain. Over 200 caves and rock shelters have formed at the feet of these rocky ridges. It was excavated first by Wakankar (1973, 1975). Later Misra excavated a number of rock-shelters between 1973 and 1977 (Misra 1978a & b, 1985). In the rockshelter IIIF-23 a deposit of 3.90 m was divisible into eight layers belonging from the Lower Palaeolithic to the Mesolithic cultural stage. The majority of the shelters contain paintings in red, white, green and other colours depicting wild animals and scenes in the lives of hunter-gatherers and the later urban societies of the region.

From the Acheulean levels about 18721 artefacts were recovered (Alam 2001: 21, 1990, Misra 1985: 40). In a preliminary analysis Misra (1978a & b) had analysed 4737 artefacts. From the excavations at Shelter III F-23 (Misra 1985), the picture that emerges is that only 1.65% (308 pieces) were bifaces with the ratio of cleavers to handaxes being 2.30:1. There were 93 handaxes (0.5%) and 215 cleavers (1.15%). Both handaxes and cleavers were fashioned on flake blanks by soft hammer technique and had symmetrical outlines and thin cross sections. A very high percentage, 28.50% of non-biface tools were recovered, side-scrapers being the most numerous, 41.26%. Notches, truncated flakes, denticulates and Levallois flakes were also found. In the Middle Palaeolithic there is no change in tool types and only an increase in non-biface tools is encountered suggesting development from the Acheulean. Misra (1985) classifies it as a highly evolved Acheulean comparable to the Mousterian of Acheulean Tradition.

Wakankar (*IAR* 1956-57: 79, *IAR* 1959-60: 70 – 71, *IAR* 1960-61:61, 1962, 1973, 1975, Wakankar and Brooks 1976) reported nearly 60 painted rock-shelters near Kharwai, 35 in Bhimbetka – Barkheda, 17 at Putlikarar, and also in Raisen, Pandunagar, Lakhajuar.

Pandey (1969) also discovered several painted rock-shelters at Deogarh near Lalitpur on the river Betwa.

V. Singh (1987) of Deccan College carried out a doctoral dissertation on the rock-paintings of Sagar area. He discovered a few rock-shelters at Amori, Chitoli, Karta, Ramgarh, etc. in Sagar. Most of the shelters bear paintings in red and ochre depicting scenes of warriors carrying swords and shields, bows and arrows, and male and female figures in dancing pose. Wild buffaloes, lions, cheetahs, horses and elephants have also been depicted.

Few rock paintings have also been discovered near Nariavli in Sagar, Gopisar, Ahmadpur and Neemkheria in Vidisha, Bairagarh in Bhopal, Ramchhajja, Loharpur and Gadadiatola in Raisen and other localities by the Madhya Pradesh State

Department of Archaeology and the Bhopal Circle of the Archaeological Survey of India (*IAR* 1953-54 to 2002-2003).

Jacobson in his surveys near Raisen conducted in 1965 and 1973-74 (1970, 1974, 1975, 1976a & b, and 1985) discovered more than 90 Lower Palaeolithic sites in a small area of 175 sq km (a radius of 9 km). The area of the eastern Malwa plateau - Vindhyan hills forms a watershed between the Narmada and Betwa river systems, lying 50 km to the north of Narmada and 20 km to the south of Betwa. The sites mostly lie at elevation of about 400 m between the Malwa plateau and the Vindhyan ranges away from perennial streams. Of these six sites were in 'undisturbed' condition and others were 'disturbed' sites in ploughed fields, stream banks and eroded surfaces. The sites occur on the foothills or plateau plains either completely exposed or buried in black soil, both in cultivated fields and in forest settings in areas drained by small headwater rivulets draining into the Betwa or Narmada drainage. According to Jacobson most of these sites are surface scatters. Yet the nature of the occurrences shows that they are virtually 'in situ'.

Jacobson made systematic sample collection of over 11600 artefacts from nine localities and informal collections from 16 occurrences for studying intra and inter-site variability. The artefact clusters range from 1500 to 4500 sq m. The average density per sq m is 3 (compared to 21 per sq m at Lalitpur Singh 1965: 70). He found that the density of artefacts in cultivated fields is only one-eighth of that in uncultivated settings indicating dispersion because of agriculture practices.

He studied 700 artefacts from Minarawala Kund locality. The artefacts are mostly made on quartzite, clay stone and siltstone of the Upper Vindhyans. Out of 621 artefacts, 73.6% comprised shaped tools, 4% cores, 15.8% flakes and 6.6% fragments. Among the shaped tools, cleavers constituted a very high proportion 18.6%; handaxes are only 2%, knives 16.4%, core scrapers 5.7% and other scrapers 27.0%. The ratio of bifaces to other tools is 1: 1.2. Cleaver to handaxe ratio is 9.4:1. Knives and cleavers are found in negative correlation. The proportion of tools to flakes is 3:1, cores to flakes is 4%. Discoidal cores have the largest proportion of 44%. Levallois cores are also found. He classified the industries as Late Acheulean or transitional Mousterian-Acheulean on the basis of high cleaver: handaxe ratio, high frequency of scrapers. It is also characterized by a high proportion of bifaces and choppers and few unifacial tools, blades and Levallois flakes. Typologically the artefacts have been placed in the Late Acheulean.

He also found aceramic microlithic remains assigned to the Late Stone Age at 46 open air sites on the tops, slopes and bases of hills. About 90% of the artefacts were made on chalcedony. The site size ranged from 50 to 10,000 sq ft with an average of 7000 sq ft. In the rock shelters, the microliths were usually associated with pottery. Jacobson envisages a central based wandering pattern for this region.

Explorations conducted by the Bhopal Circle of the Archaeological Survey of India and the Madhya Pradesh State Department of Archaeology have also brought to light remains of the prehistoric period right from Lower Palaeolithic to the Chalcolithic, including a number of rock-shelters with paintings (*IAR*: upto 2000-2001).

Mesolithic sites have also been found in the vicinity of Sagar such as Bhapson, Chandala Bhata, Chandera, Makronia and Reta. In the excavation at Vidisha (*IAR* 1963-64: 16, 1964-65: 14) pre-pottery non-geometric microliths and pre-pottery geometric microliths have been found. Besides, microliths have also been found from Ahmadpur hills, fields adjoining Udaigiri caves, Tila, Pathari Sothiya, Murel Khurd, Chiklod and Kharwai.

Singh's discovery of the site of Lalitpur, and later work by Joshi has been an important contribution to Acheulean studies in India. However, due to Singh's untimely death these assemblages did not receive the attention they desired, despite finding a mention in most papers and texts on the Lower Palaeolithic in India. Other previous researches in the region also show that the area has preserved a rich evidence of early human cultures and it has a vast archaeological potential. Further, there is an urgent need for a comprehensive study in the region to be able to focus more light on the archaeology of the region as the area is undergoing fast surface changes due to intense agricultural and industrial activities. Many localities have already been submerged by the waters of the Betwa due to the Rajghat Dam and Govindsagar Reservoir. Therefore there is an urgent need for a comprehensive study in the region to be able to focus more light on the archaeology of the region.

1.3 OBJECTIVES OF THE RESEARCH

- To undertake a detailed study of the Acheulean at Lalitpur to understand the lifeways of the Acheulean people and their culture in the light of the ecology of the area.

- To explore the basin area and identify more localities for a detailed study of the prehistory of the region.
- To study the sites in the geological context, study the stratigraphic and other details and reconstruct the Quaternary stratigraphy of the region. To undertake preliminary analysis of sediments, including grain size and analysis of coarse clasts.
- To understand the process of formation of sites in a stable upland setting and evolution of landscape during the Quaternary.
- To study the assemblages of artefacts obtained from the sites.
- To try and find an explanation of past human behavioural patterns in the region.

1.4 THE ACHEULEAN CULTURE

The Acheulean hominins were the first to effectively populate South Asia with remains of Acheulean found extensively from the Siwalik Hills in the north to near Chennai in Peninsular India (see Gaillard *et al.* 2010, Gaillard and Mishra 2001, Mishra 2006-2007, Misra 1989, 1987, Chauhan 2009, 2004, Pappu 2001, Petraglia 2006, 2001, 1998, for overview of studies on Acheulean in India).

The Acheulean refers to Lower and Middle Pleistocene archaeological assemblages characterized by the technological tradition of bifacial large cutting tools, such as handaxes, cleavers, picks, flakes and cores, and distributed widely over East, South and North Africa, western and southern Europe, and Southwest, East and South Asia dating to >1.7 - 0.25 ma. Emergence of Acheulean marks a significant advance over earlier small flake and core Oldowan tools with the ability to detach large flakes and preconception of form of tools before manufacture (Semaw *et al.* 2009). It was also characterized by behavioural modifications and important change in the relationship between humans and their environment.

The beginning of Acheulean is thought to have coincided with the emergence of *Homo ergaster/ Homo erectus* (Cachel and Harris 1998) and also associated with the evolution of brain and body size and emergence of several behavioural traits like increased terrestriality, endurance running, intensification of gathering and routine transport of tools (see Mishra 2011 for detailed overview).

Emergence of the Acheulean in Africa

It is believed that the Acheulean tradition of tool making began in South and East Africa 1.76 - 1.4 ma and spread into southwest Asia and Europe between 1.5 to 0.6 ma. The earliest well dated Acheulean is from Kokiselei 4 in the Nachukui Formation at West Turkana, Kenya dated to 1.76 ma (Lèpre *et al.* 2011, see also Roche and Kibunjia 1994, 1996, Roche *et al.* 2003) making it closer in age to KNM-ER 3733 partial cranium (Lèpre and Kent 2010) dated to ~1.7 ma, with definitely delimited ages of between 1.78–1.48 ma. It is characterized by picks, crude unifaces/ bifaces mostly made from large cobbles and tabular clasts, with few cores. Other early sites in East Africa include Konso Gardula, Ethiopia with large picks and crude unifaces/ bifaces made on large flake blanks dated to ~1.75 ma (Asfaw *et al.* 1992, Beyene *et al.* 1997, 2013); middle and upper Bed II sites, including EF-HR, in Olduvai Gorge, Tanzania, dated to ~1.5 ma (Hay 1976, 1992, Leakey 1971); Melka Kunturé in Ethiopia dated to 1.5 – 1.4 ma (Chavaillon and Piperno 2004); Koobi Fora dated to 1.4 - 1.2 ma (Harris and Isaac 1997); and Peninj, Tanzania earlier dated to around 1.5–1.4 ma (Isaac and Curtis 1974) but new age estimates place it at ~1.2–1.01 ma (Deino *et al.* 2006, Dominguez-Rodrigo *et al.* 2009). Herries *et al.* (2011) have however placed lower age estimates for most early sites in East Africa ranging from 1.6 – 1.4 ma.

Early Acheulean sites in South Africa include the Vaal River (Rietputs Formation) dated by cosmogenic nucleide burial dating to 1.57 ± 0.22 ma to 1.26 ± 0.10 ma with picks, crude handaxes and a cleaver (Gibbon *et al.* 2009); Sterkfontein Member 5c dated to 1.7 – 1.4 ma (Kuman and Clark 2000); Wonderwerk Cave in South Africa dated to ~1.6 ma with only two crude bifaces (Chazan *et al.* 2008) and Swartkrans Members 2 and 3 estimated to date ca. 1.5 and 1.0 ma respectively (Kuman and Gibbon 2007, Leader 2009, Couzens 2012).

In North Africa the oldest dates come from Thomas Quarry 1, Unit L placing it at 0.989 ± 0.208 ka (Raynal *et al.* 2001, Rhodes *et al.* 2006), Tighennif in the High Plateaus is also assigned to the Early Acheulean based on typology (Balout 1967), however palaeomagnetic studies indicate it to be within the Brunhes chron (Géraads *et al.* 1986). Acheulean occurrences occur within sediments of the Oulad Hamida Formation to Kef el Haroun Formation dated to 1.0 ma to 163 ka in the Maghreb (Rhodes et al. 2006). Other potential Early Acheulean occurences include the Ain Hanech upper level deposits, Monts Tessala, and Bordj Tan Kena (Sahnouni 2012)

Acheulean in Middle and East Asia

Outside Africa, the Acheulean appears around 1.4 ma at Ubeidiya in Israel (Bar-Yosef *et al.* 1993, Ronen 2006). However, hominin presence has now been recorded in Eurasia earlier than 1.0 ma, with Dmanisi hominins and their flake and core tools dated to around 1.8 ma (Gabunia and Vekua 1995, Gabunia *et al.* 2000, de Lumley *et al.* 2002, Vekua *et al.* 2002, Lordkipanidze *et al.* 2005, 2007). However, recent studies based on the palaeoenvironmental context of the site, fossil remains and stone artefacts show that Dmanisi does not correspond to the very first 'out of Africa'. Hominin expansion into Eurasia must have happened during an interglacial between 2.4 – 1.9 ma aided by a humid river corridor between Africa and the Mediterranean (Agustí and Lordkipanidze 2011).

New findings also point towards occupation of Java between 1.8 - 1.6 ma (Swisher *et al.* 1994) and mainland China at ~2.0 ma, at sites such as Longuppo, Renzidong, Longgudong and Yuanmao, however with contentious artefacts and fossil remains (Huang *et al.*1995, Jin *et al.* 2000, Chen *et al.* 2001, Dong 2006, Zhu *et al.*, 2008, Hou and Zhao 2010a & b, Böeda *et al.* 2011). The earliest widely accepted tools in East Asia come from Majuangou in Nihewan basin dated to 1.6 ma (Zhu *et al.* 2004, Gao *et al.* 2005).

By 0.83 ma, hominids with an Acheulean-like technology appear in East Asia, with well dated sites in south China's Baise basin (Hou *et al.* 2000). However the relationship of these 'Acheulean-like' technologies to the Acheulean is debated (see Corvinus 2004; for Movius Line see Schick and Clark 1994, Movius 1948, Keates 2002, Norton and Bae 2008, Petraglia and Shipton 2008, Lycett and Bae 2010).

Mishra *et al.* (2010b, 2011) argued that *Homo erectus* in Java reached there from India basing the argument on affinities of faunal remains at *Homo erectus* sites with Pinjor fauna and association of Acheulean with Pinjor sediments and Soanian with post Siwalik, Late Pleistocene and Holocene sediments (Gaillard and Mishra 2001).

Acheulean in Europe

The Early Acheulean is however not found in Europe. Dispersal of Acheulean into Europe appears to have been later around 700 ka (Moncel *et al.* 2013). However, early hominin presence has now been documented in Southern Europe by ~1.5 – 1.0 ma at several sites including Barranco León and Fuente Nueva 3 in Guadix-Baza basin, southern Spain dated to 1.4 – 1.2 ma (Agustí *et al.* 1996, Martinez Navarro *et al.* 1997, Oms *et al.* 1999, 2000, Toro Moyano *et al.* 2011), TE-9 at Sima del Elefante dated to 1.4 ma (Rosas *et al.* 2001, Parés *et al.* 2006, Carbonell *et al.* 2008, Bermúdez de Castro *et al. 2010,* 2011) levels TD3 - 6 at Gran Dolina dated to ~1.0 – 0.8 ma (Carbonell *et al.* 1995, Parés and Pérez-González, 1999, Falguères *et al.*, 1999, 2001, Berger *et al.*, 2008, Rodriguez *et al.* 2011), Pirro Nord in Italy dated to 1.6 - 1.3 ma and Monte Poggiolo dated to ~0.85 ma (Arzarello *et al.* 2007, Arzarello and Peretto 2010, Muttoni *et al.* 2011), Lézignan-le-Cèbe in the lower Hérault Valley (Languedoc, southern France) dated to 1.57 ma (Crochet *et al.* 2009), Vallparadis dated to between 980-780 ka (Martínez *et al.* 2010, Duval *et al.* 2011) La Boella dated to >780 ka (Vallverdú *et al.* 2009), Pont de Lavaud and other sites in the Middle Loire basin, France dated to 1.1 ma (Despriée *et al.* 2010, 2011), Kozarnika Cave in north-western Bulgaria dated to 1.6–1.4 Ma (Sirakov *et al.* 2010), Bogatyri/Sinyaya Balka and Rodniki sites in southern Russia in the Taman Peninsula dated to 1.6–1.2 Ma (Shchelinsky *et al.* 2010).

The above evidence indicates continued presence in southwestern Europe until the beginning of Middle Pleistocene (Arzarello and Peretto 2010, Garcia and Carbonell 2011, Rodriguez *et al.* 2011). This early human occupation in Western Europe took place during periods of mild, interglacial conditions (Agustí *et al.* 2009). However, these Lower Pleistocene sites still have a Mode 1 technology, even though by this time Mode 2 technology was widespread in East and South Arica, West and South Asia.

The earliest Acheulean in Europe is still dated to only 600 – 700 ka, MIS 16, with continuous widespread occupation only after 500 ka, around MIS 11 associated with *Homo heidelbergensis* (Moncel *et al.* 2013, Despriée *et al.* 2011, Santonja and Villa 2006, Santonja and Pérez González 2010, Jiménez-Arenas *et al.* 2011, Mosquera *et al.* 2013). The earliest Acheulean sites include La Noira dated to 665 ± 55 ka (Moncel *et al.* 2013), Notarchirico dated to 650 ka (Piperno *et al.* 1998, Lefèvre *et al.* 2010), Caune de l'Arago, levels P-Q dated to 570 ka (Barsky and de Lumley 2010), Galeria dated to <500 ka, Sima de los Huesos dated to 530 ka and TD9 at Gran Dolina dated to 480 ± 130 ka (Bischoff *et al.* 2007, Falguères *et al.* 1999, Berger *et al.* 2008, Rodríguez *et al.* 2011, Ollé *et al.* 2013) and Boxgrove dated to 500 ka (Roberts and Parfitt 1999). Cueva Negra del Estrecho del Rio Quipar and Solana del Zamborino in Southern Spain however constitute the only evidence till date for a late

Early Pleistocene (>780 ka) presence of Acheulean-Levallois elements in Europe (Walker *et al.* 2012, 2009, Scott and Gibert 2009), though much debated as the polarity reversal could be related to the Brunhes chron (Jiménez-Arenas *et al.* 2011).

In Northern Europe the earliest occupation is also now dated to >0.78 ma, MIS 25 or 21 at Happisburgh 3 with flint artefacts, cut-marked bones and hominin footprints associated to *Homo antecessor* at the southern edge of the boreal climatic zone (Parfitt *et al.* 2010, Ashton and Lewis 2012, Ashton *et al.* 2014). However Westaway (2011) considers it to be MIS 15c in similar climatic situations as Pakefield at MIS 15e climatic optimum (Parfitt *et al.* 2005, see also Preece and Parfitt 2012). Several other sites in Northern Europe also document early Middle Pleistocene occupation between MIS 19-12 (Hosfield 2011)

Acheulean in South Asia

The earliest human colonization in South Asia has been much debated not only in terms of chronology, but also in terms of the artefact assemblages, particularly with regard to the Soanian - Acheulean dichotomy (Chauhan 2010a, 2009, 2008, 2007, Dennell 2011, 2004b, 2003, 1995, Dennell *et al.* 2006, Gaillard 2006, Gaillard and Mishra 2001, Mishra 2010a &b, 2006/2007, 1995, 1994, 1992, Rendell *et al.* 1989, Petraglia 2006, 2001, 1998). The earliest artefacts in South Asia come from Riwat dated to 2.5 ma (Rendell *et al.* 1987, 1989, Dennell *et al.* 1988a & b) and Pabbi Hills dated to 2.2 – 1.2 ma (Dennell 2004a) suggesting very early presence of hominins in South Asia. Several claims of a pre-Acheulean in Peninsular India (Khatri 1963, Armand 1985) have however recently been refuted (Mishra 2010a, 2006-2007).

It is generally believed that the Acheulean entered India after 500 ka like in Northern Europe (Dennell 2009). But recent research in India and other sites throughout the world, like Gesher Benot Ya'aqov, Syria, Dmanisi, China, Indonesia show that Acheulean dispersals to Asia had happened earlier than we believed. Pappu *et al.* (2011) obtained minimum age of 1.07 ma with a pooled average of minimum 1.51±0.07 ma and maximum 1.68±0.07 ma on the basis of palaeomagnetism and cosmogenic ^{26}Al/^{10}Be burial dating directly on six quartzite artefacts for the earliest Acheulean levels (6 & 8) at Attirampakkam. Dina and Jalalpur in Pakistan have been dated to 700-400 ka (Rendell and Dennell 1985). Besides, a number of other sites have also yielded early ages which have however been doubted (Chauhan 2010b). At

Isampur, a mean ESR age of more than 1.27 ± 0.17 ma, assuming linear U uptake, on two herbivore teeth has been obtained for the Early Acheulean (Paddayya *et al.* 2002). At Bori, tephra underlying colluvial gravel containing unabraded Early Acheulean artefacts has been dated by Ar/Ar method to 0.67 ma (Mishra *et al.* 1995) and by K/Ar to 0.538 ± 0.047 ma; their fission-track age is 0.64 ± 0.29 ma (Horn *et al.* 1993). At Morgaon the tephra has been shown to be in reversed sediments (Sangode *et al.* 2007) and probably dates to the OTT time period (Westaway *et al.* 2011). The tephra at Bori, Gandhigram, Andora, and Nevasa also shows palaeomagnetic reversal (Sangode *et al.* 2007). However, some scholars had earlier dated all tephra occurrences in peninsular India to the YTT at 75ka based on geochemical analysis (Acharya and Basu 1993, Shane *et al.* 1995, Westgate *et al.* 1998, but see Mishra and Rajaguru 1996). Calcrete at Amarpura Formation has been dated to 0.8 ma by ESR and the Acheulean at Singi Talav comes from the same formation (Kailath *et al.* 2000). Acheulean artefacts and faunal remains have also been uncovered from sediments correlated to the Early Pleistocene Dhansi Formation; however the stratigraphic association of the artefacts has been doubted (Patnaik *et al.* 2009). Th/U dates at Didwana (Misra 1995, Raghavan *et al.* 1989), Yedurwadi, Nevasa and several sites in Hunsgi-Baichbal basin show that the Acheulean is beyond the range of Th/U dating, that is >350 ka (Mishra 1992, Szabo *et al.* 1990). The lithics associated with the Acheulean also indicate closer resemblance to the African than to the European Acheulean.

Recently Haslam *et al.* (2011) obtained ages of 140-120 ka for the Late Acheulean at Bamburi 1 and Patpara in the Middle Son Valley suggesting a very late continued presence of Acheulean hominins in South Asia. However, these ages based on OSL are doubted due to the nature of the sediments at the site. Other sites with late persistence of Acheulean are Umrethi (>190 Ka), Adi Chadi Wao (ca. 69 Ka) in Gujarat (Baskaran *et al.* 1986), Bhimbetka (ca. >106 Ka) in Madhya Pradesh, and Kaldevanhalli in Karnataka (166 and 174 Ka) (Szabo *et al.* 1990). Presence of diminutive bifaces has been recorded till well into the Upper Pleistocene.

Early and Late Acheulean in India

The Acheulean in Africa has been divided into different arbitrary phases, Early (1.75 – 1.0 ma), Middle (1.0-0.6 ma) and Late (0.6 – 0.3 ma) based on few radiometric dates and typo-technology, essentially biface refinement, size and shape and symmetry (Kuman 2013, Sahnouni *et al.* 2013, Beyenne *et al.* 2013).

Early Acheulean handaxes and picks are predominantly unifacially worked, with low flake scar counts, lack of cortex and lack of bifacial component. Middle Acheulean handaxes are more refined with advanced symmetry of form, circumferential flaking and substantial thinning, significant increase in flake scar count and a decrease of relative thickness, shallow and invasive flake scars implying soft hammer use, edge modification that involved steeper flaking that does not result in thinning and some standardization of edge and tip shape/form. Late Acheulean is characterized by well refined handaxes with three-dimensional symmetry, both in plan view and cross-section form.

Leader (2013) defines three distinct assemblages in the Vaal River basin based on core preparation and organization, the 'Basal Early Acheulean' lacking prepared and organized cores dated to >1.51 ma, the 'organized core assemblage' dated to 1.51 ± 0.8 Ma and the 'prepared core technology assemblage' dated to 1.2 ± .07 ma.

In the case of India also, Misra (1978) during his study of the Bhimbetka assemblage classified the Indian Acheulean into Early and Late Acheulean based on typo-technological considerations of decreasing size, increased refinement and core preparation (Misra 1978a & b, Chauhan 2004). Pappu (2001) includes sites like Singi Talav in Rajasthan, Chirki-Nevasa, Bori, Morgaon and Yedurwadi in Maharashtra, Hunsgi and Isampur in Hunsgi-Baichbal basin, Anagwadi in Karnataka, Umrethi in Gujarat, Lalitpur in Uttar Pradesh and Mayurbhanj in Orissa in the Early Acheulean stage. The Late Acheulean is present at Gangapur in Maharashtra, Rallakallava basin in Andhra Pradesh, Attirampakkam in Tamil Nadu, Bhimbetka and Raisen complex in Madhya Pradesh and Paleru and Gunjana valleys in Andhra Pradesh and Paisra in Bihar in this stage. However, there is no stratigraphic evidence for succession from Early to Late Acheulean in India.

Based on his studies in the Hunsgi-Baichbal basin, Paddayya (2006-2007) finds an evolution within the Acheulean in this region. The basis for these stages is mainly typology and technology aided by absolute dating. He found three main stages: the Early Acheulean found at Isampur, Yediapur IV and Fatehpur V where the artefacts are marked by a primitive typo-technology and lack of core preparation; the Middle Acheulean found at Kolihal, Trench 3 at Isampur, and Teggihalli II, characterized by core preparation, regular and smaller flakes and shaped tools; and the

Advanced Acheulean represented at Yediapur IV and Mudnur X, and characterized by well-shaped, refined smaller sized tools.

Shipton *et al.* (2014) confirmed the presence of these patterns in Early and Late Acheulean assmeblages based on a small sample from four earlier Acheulean assemblages of Isampur, Morgaon, Chirki-on-Pravara and Singi Talav and four later Acheulean assemblages of Teggihalli II, Mudnur X, Bhimbetka IIIF-23, and Patpara. They noticed decreases in mean biface size, elongation, frequency of bifaces and shape variation and increase in the relative thinness of bifaces; flake scar density, use of flake blanks and cryptocrystalline materials.

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Debates in understanding of the Acheulean

The Acheulean with its wide spatio-temporal span is important for understanding human evolution, raw material choice, landscape use, and cognitive development of hominins.

The transition from the Oldowan to the Acheulean remains a problem. Near equivalence in ages of the Acheulean in India and Africa (Mishra *et al.* 2010a) implies relatively rapid technological development by 1.7 ma. Mishra (2011, see also Semaw *et al.* 2009, Lepre *et al.* 2011) notes that the lack of transitional signatures from the Oldowan to the Acheulean may have implications for the dispersal of Acheulean. Further there is evidence for the co-occurrence of the Oldowan and Acheulean at the Kokiselei site complex (Lepre *et al.* 2011). Moreover the earliest evidences for hominins out of Africa are still with a Mode 1 technology despite being contemporaneous in time with the Acheulean, except for the early evidence of the Acheulean in Southwest Asia from the site of Ubeidiya (Bar-Yosef *et al.* 1993, Ronen 2006) and South Asia (Pappu *et al.* 2011) . These evidences strongly indicate that we need to reassess the story of hominin migrations out of Africa.

During the long timespan of the Acheulean it has often been considered as a period of technological stasis owing to considerable homogeneity in artefact form over a wide geographic and temporal distribution (Mithen 1996, Pope *et al.* 2006, Lycett and Gowlett 2008, Nowell and White 2010). However variability has been noticed coupled with conservatism (Clark 1994, Sharon *et al.* 2011). There is evidence for an accelerated tempo of change during the Late Acheulean (after 700 ka) (Wynn 2002, Malinksy-Buller *et al.* 2011). Wide variability is recorded during the long temporal and spatial distribution of the Achuelean (Beyenne *et al.* 2013).

Increased encephalization (Ruff *et al.* 1997), behavioural innovation seen in varied and prepared core reduction (Sharon 2007, White and Ashton 2003), increased refinement in tools (Wynn 2002), increased tool transport, increasing use of innovations like fire (Goren-Inbar *et al.* 2004, Alperson-Afil 2008)and soft hammer all attest to rapid change despite continuity.

Another significant debate in the understanding of the Acheulean has been with regard to the role of raw material (White 1995, 1998a & b, Ashton and White 2003, Sharon 2007) versus reduction intensity in LCT variability (McPherron 1994, 1999, 2006). Other factors that have been pointed out include 'mental templates' (Davidson 2002, McPherron 2000, Gowlett and Crompton 1994, Machin *et al.* 2007, Wynn and Tierson 1990, McNabb *et al.* 2004) and cultural or stylistic factors (Vaughan 2001). However, limited functional studies hamper conclusion (Utrilla and Mazo 1996, Dominguez-Rodrigo *et al.* 2001, Kleindienst and Keller 1976).

The Acheulean-MSA transition also remains enigmatic. The Acheulean is succeeded by the Acheuleo-Yabrudian in the Levant, the Fauresmith or Sangoan in Africa and the Mousterian in Europe (see McBrearty and Tryon 2005, Tryon and McBrearty 2002, Klein 2000, Bar-Yosef 1994 for transition from Acheulean to later stages). Regarding the exact timing, it is believed that the MSA replaces the Acheulean between 250 to 200 ka in East Africa (Klein 2000), though recent evidence from Kathu Pan shows that the MSA replaces the Acheulean at 464 ± 47 ka (Porat *et al.* 2010). In India the transition from Late Acheulean to later phases is unclear, promoting scholars to doubt the marked presence of Middle Palaeolithic in India (Mishra 2010b).

Concept of the Large Flake Acheulean

Till now our understanding of the Acheulean lithic technological organization is based on the European Acheulean. However the Indian Acheulean is quite different from the European Acheulean being predominantly a 'Large Flake Acheulean' (LFA) and much earlier in time (Mishra *et al.*2010a).

LFA is based on the production of large flakes, larger than 10 cm and is considered specific to a particular phase of the Acheulean. This phase with striking resemblances is found distributed over South, East and North Africa, Levant, Caucasus and India. But the Acheulean in Europe, particularly north of the Pyrenees dated to no more than 700 ka is a non-LFA with predominance of handaxes shaped on flint nodules and cobbles (Sharon 2007, 2009, Goren-Inbar *et al.* 2011, Moncel *et. al.* 2013).

Sharon (2007, 2009) also notes the presence of few pre-LFA assemblages in Africa dated to more than 1.0 ma, characterized by a high frequency of picks and crude unifacial/bifacial handaxes, absence of cleavers, and lack of emphasis on large flake blanks. However, it may be noted that the earliest Acheulean at Konso is predominantly based on large flake blanks (Beyenne *et al.* 2013)

Role of South Asia

A number of studies have been made on the Acheulean cultural phenomenon in India. The emphasis has largely been on regional studies, geoarchaeological contexts and site formation processes (Misra 1978a & b, Paddayya 1982, Misra *et al.* 1982, Pappu 1985, Misra and Rajaguru 1986, Misra 1995, Pappu and Deo 1994, Korisettar and Rajaguru 1998, Pappu *et al.* 2003,Marathe 1981, 2006, Paddayya *et al.* 2006, Deo *et al.* 2007a & b, 2011, Patnaik *et al.* 2009, Mishra *et al.* 2009), though faunal and ecological context have also been highlighted by several investigators (Badam 1979, Dennell 2004a, Patnaik *et al.* 2009). There is a paucity of fossil hominin remains with the exception of Hathnora in the Narmada valley (Sonakia 1984, Salahuddin *et al*. 1986-87, de Lumley and Sonakia 1985, Kennedy *et al.* 1991, Sonakia and Biswas 1998, Sankhyan 1997, 2005, Cameron *et al.* 2004, Athreya 2007).

However, the study of Acheulean archaeological assemblages is marred by the paucity of sites in a good stratigraphic context. Due to emphasis on 'primary' context sites, most Indian Acheulean sites were until recently ignored.

However, South Asia with its rich find of Acheulean assemblages, some of which are now well dated and studied, has an important role in the understanding of the Acheulean Complex. Therefore, this research was undertaken with the intention to improve our understanding of the Acheulean in India, focusing on the lithic technological strategies.

1.5 RESTUDY OF THE ACHEULEAN AT LALITPUR

Singh (1965) and later Joshi ((*IAR* 1961-62) had found extensive scatters of Acheulean sites on the interfluves between the Betwa and the Shahzad. The excavations carried by Deccan College (*IAR* 1961-62) and Archaeological Survey of India under Joshi (*IAR* 1963-64) brought to light high density of artefacts including large flakes, bifaces and debitage from a thin horizon underlain by regolith and capped by a thin silt cover. Surveys of Singh and Joshi show that the Acheulean horizon is extensively exposed in the upland areas of Lalitpur on the interfluves between the Betwa and the Shahzad.

It is one of the few excavated Acheulean assemblages in India. It was also considered one of the few open-air 'primary' sites in the country. However, no detailed study of the palaeoenvironmental context of the site and the lithic technological strategies employed by the toolmakers has been undertaken despite the fact that the site is subject to most discussions on Indian Acheulean (Misra 1978a & b, Jayaswal 1978, Pappu 2001, Corvinus 1983, Mourre 2003).

Further, significant conceptual developments have taken place in World Prehistory and Quaternary studies since the discovery and study of the sites by Singh and Joshi. Therefore while surveying the Betwa basin a restudy of this site, its geostratigraphic context and lithic technology was undertaken with the realization that it may help greatly in understanding of the Acheulean Complex in India. It was found to hold immense potential, both for shedding light on tool technology and informing on the site formation processes operating in slope or pediment, stable upland 'non-accreting' open air archaeological sites.

The site of Lalitpur was also chosen because the assemblage is dominated by tools on granite. Granite is a multi-mineral hard rock which is usually considered unsuitable for knapping (Inizan *et al.* 1999). However, Sharon (2007, 2008) opines that raw material is not a constraint for knapping and coarse grained rocks were preferred for knapping large flakes. There are very few Acheulean assemblages dominated by granite including Isimila (Howell *et al.* 1962, Cole and Kleindienst 1974) and Yediyapur (Paddayya 1987, 2010). However, Lalitpur remains perhaps the only Acheulean assemblage almost exclusively on granite. Therefore it was decided to study this assemblage to be able to understand knapping of this hard, multi-mineral rock.

Moreover, the assemblage at Lalitpur comes from a surface or near-surface context. Generally surface sites are considered to be in disturbed sedimentary context and therefore discarded as not amenable to understanding hominin behaviour. However, many studies (Jacobson 1985, Jhaldiyal 1997, 2006, Paddayya 2008) in recent years have shown the importance of surface sites. Therefore, Lalitpur was chosen for the study to be able to shed light on the nature of surface sites, particularly Lower Palaeolithic sites in India.

This restudy focuses on the entire assemblage including bifaces, cores, and debitage and attempts to reconstruct the c*haîne opératoire* employed. The study also focuses on reconstruction of the palaeoenvironmental context in the region through a study of the geoarchaeology of the region and assessment of post-depositional processes at the site. This comprehensive study enables to evaluate the Lalitpur Acheulean in the context of the Indian Acheulean and help place the South Asian Acheulean in a global context.

1.6 ORGANIZATION OF THE THESIS

This dissertation has been organized into the following chapters.

Chapter 1: Introduction

This chapter provides the basic framework of the research. It starts with a brief introduction of the subject of study. It then discusses the previous researches conducted in the area. It outlines the aims, objectives and scope of the study.

A critical review of the nature and character of Acheulean culture worldwide and debates regarding human evolution and hominid behaviour patterns during this time period are also discussed. Finally it outlines the need for restudying the Acheulean at Lalitpur.

Chapter 2: Geoarchaeology of the Betwa Basin

This chapter introduces the study area, its location, geology and geomorphology. It discusses the results of geoarchaeological explorations conducted in the Betwa basin along with the drainage basin characteristics derived from GIS analysis, which has implications for the archaeology of the region. A brief discussion of the stratigraphy of individual localities and sections is followed by a summary of observations in each area.

Chapter 3: The Acheulean at Lalitpur: Site Contexts and Formation Processes

It discusses the nature of the Acheulean record in the Biana Nullah. The depositional context of sites is assessed in relation to its topography and sedimentary context. The formation processes responsible for the preservation of the site and nature of the site are also discussed in this chapter.

Chapter 4: Methodology

A discussion of the methodology followed during the course of study of Acheulean lithics is provided.

Chapter 5: Lithic Technology during the Acheulean at Lalitpur

It is followed by a restudy of the Acheulean assemblage at Lalitpur which was discovered by Singh (1965). Results of the metrical and typo-technological study of the assemblage are given here. Further patterns of tool maintenance, use and discard are also discussed in this chapter.

Besides, a comparison of the nature and typo-technology of the Acheulean assemblage from Lalitpur is made with other similar industries worldwide. Published accounts of Chirki (Corvinus 1983), Hunsgi-Baichbal basin (Paddayya *et al.* 2006, Paddayya 2010), Bhimbetka (Misra 1978a & b), global study of Acheulean by Sharon (2007) dealing with artefacts from Isimila, Olduvai Gorge, Gesher Benot Ya'aqov,and other sites and the database by Mourre (2003) on cleavers have been used for purposes of comparison. Besides, the biface database (Marshall *et al.* 2002) has also been used. Brief comments are made regarding the nature of the Acheulean culture phenomena at Lalitpur vis-à-vis the world at large.

Chapter 6: Conclusion

This chapter summarizes and highlights the major results obtained from the research.

CHAPTER II

GEOARCHAEOLOGICAL CONTEXT OF THE BETWA BASIN

2.1 INTRODUCTION

The study area comprises the Lalitpur region in the Betwa basin (comprising SOI 1:250,000 Grid No. 54 L). Special focus has been given to the region lying between longitude 78°11' - 79°0' E and latitude 24°11' to 25°28' N (SOI 1:50,000 Grid No. 54L/6) because well excavated Acheulean localities were previously discovered and studied in this area (Singh 1965) which have been restudied in this research. However, adjoining areas of the Betwa basin (between longitude 77°00' to 81°00' E and latitude 23°00' to 26°00' N) were also surveyed to understand the geomorphic history of the region and fluvio-tectonic dynamics.

This region is part of the peninsular foreland basin comprising the Malwa Plateau – Vindhyan Escarpment – Bundelkhand Massif giving way to the vast Marginal Alluvial Plain. It is bounded by the Aravalli hills to the west, the Indo-Gangetic plains to the north, the Bundelkhand plateau to the east and the Narmada-Son lineament to the south (Fig. 2.1).

The region forms the boundary between the Peninsular and the Himalayan cratons, between the Deccan trap and the Vindhyans, the Vindhyans and the Archaeans and between the Peninsular Shield area and the Gangetic Alluvial Plain. The region is particularly important as it is the meeting point of the peninsular region, with bedrock exposed, and the Indo-Gangetic plain where it is buried to great depths. Since it acts as a peninsular foreland basin, it is affected to a large extent by the northward shift of the Indian plate which may have implications for the distribution and preservation of the Palaeolithic record.

Owing to varying lithology and structure through its stretch, the region affords an ideal opportunity for studying the interrelation between lithology, structure, geomorphic expression of landforms and its impact on the archaeology of the region.

In this chapter the geological, tectonic and landform context of the broad region (comprising the entire Betwa basin, with special emphasis on the Lalitpur

Upland) is discussed based on exploratory fieldwork through the basin stretch combined with remote sensing and GIS based studies and review of published literature. It has helped in understanding the formation, preservation and exposure of the archaeological record.

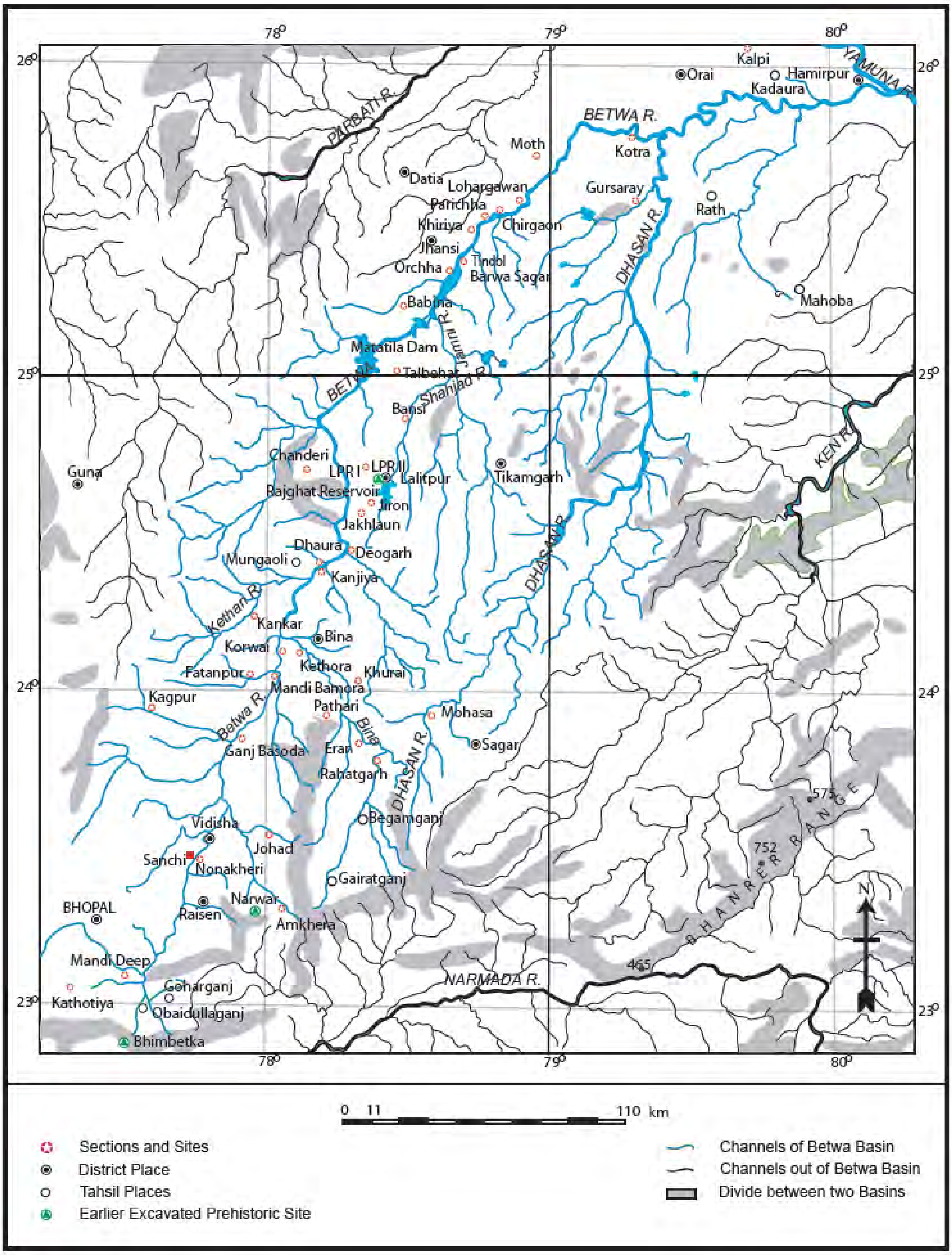


Fig. 2.1: Map of the Betwa Basin showing explored sites and sections

2.2 GEOLOGY AND GEOMORPHOLOGY

The area is composed essentially of the following geological systems from the most recent to the oldest (Fig. 2.2):

- Recent Deposits
- Ferricretes
- Deccan Trap
- Vindhyan System
- Transitional Systems of the Bijawar series
- Bundelkhand Gneissic Complex

Fig. 2.2: Geological Map of Central India showing the Bundelkhand Gneissic Complex (after Kumar 2005)

2.2.1 The Bundelkhand Gneissic Complex

The Bundelkhand Gneissic Complex is an Archaean - Early Palaeoproterozoic magmatic terrain forming the Super sequence I.

The Bundelkhand Granitic Massif forms a semi-circular outcrop which is flanked to the south, west and east of Jhansi by unconformably overlying patches of the Palaeoproterozoic Bijawar sedimentary formations and trap flows and the flat lying Vindhyan sediments of Mesoproterozoic – Early Neoproterozoic age, mainly sandstones of the Kaimur, Rewa and Bhander series to the south. It is covered by the Quaternary sediments in the north, and continues under the Quaternary sediments of the Ganga Plain as the Faizabad ridge. It forms a distinct crustal block to the north of the Narmada-Son lineament (Fig. 2.2).

The term Bundelkhand Gneiss was introduced into the geological literature by Mallet in 1872 and later adopted by Medlicott and Blanford in 1879 (Saxena 1957, 1961, 1966).

It comprises of a complex suite of coarse to fine non-foliated Early Palaeoproterozoic granites with enclaves of gneisses intrusive into the Archaean low to medium grade metasedimentary formations which have undergone polyphase deformation and regional metamorphism (Jhingran 1958, Saxena 1961, Prakash *et al.* 1975). These granites are gradational without distinct boundaries and are cut by a sequence of acid and mafic igneous rocks.

Jhingran (1958) classified the granites on the basis of grain size, varying amount of K-feldspar or plagioclase and the presence or absence of ferromagnesium minerals into ten types. The pink feldsparic coarse-grained granites are the most commonly found rock types.

Prakash *et al.* (1975) have classified the rocks in the Jhansi region into three distinct areas:

1. The Mehroni-Madaura Mesoarchaean meta-sedimentary formation flanks the Bijawars and is cut by younger granites and mafic rocks. They are highly deformed granite – greenstone terrain consisting essentially of ultramafics, chlorite-amphibole-talc schists, fuchsite quartzites, lenticular impure limestone, marbles, banded hematite-shale-quartzites and calc-silicates. These are intensively intruded by undeformed granitoids. Sharma (1998) identified

three greenstone-gneissic belts: Khera-Jhansi, Babina-Kuraicha-Kabrai and Madaura-Rajanla-Girar-Baraitha.

2. The Mauranipur-Saprar migmatitic rocks within coarse-grained granites cut by quartz reefs and doleritic dykes.
3. The granite massif itself comprised of pink to grey coarsely crystalline rocks. These are cut by the granite porphyry which is further cut by the dolerite-diabase dykes.

Regarding the origin of the Granitic Complex there are varying views. Some opine that the granites were formed by metasomatic replacement of the pre-existing meta-sedimentary formations by hydrothermal effects (Mathur 1954, Saxena 1961, Mishra and Sharma 1975). Jhingran (1958) however observes that though the granites are of a more or less homogenous composition, the relict rocks are of divergent composition. He argues that the K-feldspars (pink) are later and fresher than the plagioclase suggesting two phases of intrusion – one during anatexis and another phase of metasomatism. Intense weathering of the plagioclase has been noted in the petrographic thin sections (see Section 5.2.2.2). Rao *et al.* (1999) suggest that these batholithic K-rich granitoids of adamellite-monzonite character were formed by reworking of the tonalitic crust which evolved in the middle to late Archaean due to anatexis.

With regard to the age, the Bundelkhand Granites have been correlated with the Singhbhum-Orissa Bastar and Dharwar cratons on the basis of close resemblance (Jhingran 1958, Krishnan 1960, Sharma 1998). Heron (1953) states that there is a small but distinct erosional unconformity between the Bundelkhand granites and the Aravalli schists and hence regards them as older than the Aravallis. Dubey and Merh (1991) are of the opinion that the regional granites are 2300 Ma and that they are Pre-Dharwarian. Mondal *et al.* (2002) dated the Mahoba gneisses and metabasaltic enclaves as forming the oldest metamorphic melting event at ~3.3 ga by $^{207}Pb/^{206}Pb$ ion microprobe of zircons. The trondhjemitic gneiss at Baghera has been dated at 3.5 ga (Sarkar *et al.* 1995). Some gneisses (Babina gneiss) are younger showing ages of 2.7 and 2.5 ga, with multiple protolith components within the nucleus. Rao *et al.* (1999) have classified the Bundelkhand gneisses as belonging mainly to the Archaean-Early Proterozoic Transition (APT).

Rao *et al.* (1999) carried out mineralogical studies and they opine that these APT granites differ substantially from the Archaean gneisses, and consist predominantly of orthoclase, quartz and hornblende, while plagioclase and biotite are subordinate. Microcline is abundant in some of these K-rich granites and the majority of these granites show replacement of plagioclase by orthoclase (orthoclase often contain corroded, partly digested plagioclase); apatite and zircon are the main accessories. Chemically these granites are not much different from the gneisses and have similar silica values (average of 71.98 in gneisses and 71.93 in granites) slightly higher $A1_2O_3$, lower Fe_2O_3 (T), CaO and MgO with substantial increase in K_2O. They are rich in Rb, Ba and occasionally in total REE (Table 2.1).

Table 2.1: General chemical composition of the Archaean-Early Proterozoic transition granite in Bundelkhand (after Rao *et al.* 1999)

Chemical Composition	**SiO_2**	**Al_2O_3**	**K_2O**	**Na_2O**	**MgO**	**FeO**	**Fe_2O_3**	**CaO**	**TiO_2**	**Rb**	**Ba**
Wt %	71.36	13.39	5.10	2.30	1.58	1.39	1.52	1.11	0..41	300	800

Kumar (2005) established the stratigraphy of the Bundelkhand Complex (Table 2.2) based on studies by Basu (1986), Upadhyaya *et al.* (1993), Shukla *et al.* (1995) and Mondal and Zainuddin (1997).

Table 2.2: Stratigraphy of the Bundelkhand Gneissic Complex (after Kumar 2005)

Age	Lithology
Unknown	Dolerite dykes
	Quartz reefs
	Light pink, medium grained, occasionally porphyritic granite with mafic segregations
	Rhyolite/ rhyolite porphyry
Late Archaean to Early Palaeo-proterozoic	Leucogranite, fine and coarse-grained
	Porphyritic granite with biotite and hornblende, pink non-porphyritic fine-grained granite
	Medium to coarse-grained pink granite, occasionally porphyritic granite with milky white or purplish quartz
	Fine grained light pink granite with grey greasy quartz
	Grey granite and granite gneiss
	Hornblende granite
	Fine to medium grained pinkish gneiss
	Coarse grained pinkish porphyroblastic granite gneiss
Early Archaean	Trondhjemitic gneiss
	Mehroni Group:
	ii) Mauranipur Formation (deformed metavolcanics and metasediments consisting of banded iron formations, quartzite, schistose hornblende-chlorite rock, quartz schist, sandstones and shale/slate
	i) Rajaula Formation (high grade metamorphic rocks including migmatites, quartz-feldpsar-biotite gneisses, chlorite schists and metabasalts

2.2.2 The Bijawar Transitional System

The Bijawar series is a transitional system formed in the post-Aravalli or pre-Vindhyan Mesoproterozoic period. These are essentially sedimentary strata of sandstones and limestones intruded later by lavas unconformably overlying and bordering the southeastern parts of Bundelkhand Gneissic Massif in Jhansi and Lalitpur districts of Uttar Pradesh. These are unconformably overlain by the Khardeola grits consisting of conglomerates, grits, greywackes and slates intercalated with Aravalli slates.

They consist of metavolcanics and metasediments ranging in thickness up to 1000 km which have undergone polyphase deformation. The base is composed of oligomictic conglomerates and stromatolitic dolomites overlain by mafic lavas which are covered by sandstone grading into chert and breccia.

The Bijawars have undergone two phases of folding. They strike ENE-WSW to E-W with low to moderate dips of 25° to 30° towards south.

Khan *et al.* (2012) derived a lithostratigraphy of the Bijawar Group near Sonrai, Lalitpur (Table 2.3 & Fig. 2.3) after studies carried out by Prakash *et al.* (1975), and Roy *et al.* (2004).

Table 2.3: Lithostratigraphy of Bijawar Group at Sonrai, Lalitpur (after Khan *et al.* 2012)

Formation	Member	Lithology
Rohini Granite		
----------------	---------------	------------------ Unconformity ------------------
Solda	Solda	Ferruginous shales
	DhoriSagar	Massive quartzite and grits
	Chloritic Shale	Chloritic shale, hematite, quartzites and calc. sandstone possibly in part pyroclastic
------------------	---------------	------------------- Possible Break -----------------------
Sonrai	Bandal	Sandstone
	Kurrat Volcanics	
	Rohini	Calcareous interbedded calc-irudite and well laminated bituminous shale with massive pink and grey carbonates and silicified phosphatic breccia at the base.
	Gora Kalan	Grey to black carbonaceous shale often pyritic
	Jamuni	Calcareous laminated shale, calc-irudite, brown thick bedded limestone, dolomite and grit
-----------------		------------------------ Unconformity ------------------
Berwar		
Rajaula		
-----------------		------------------------ Unconformity ------------------
		Basement of Bundelkhand granites and gneisses

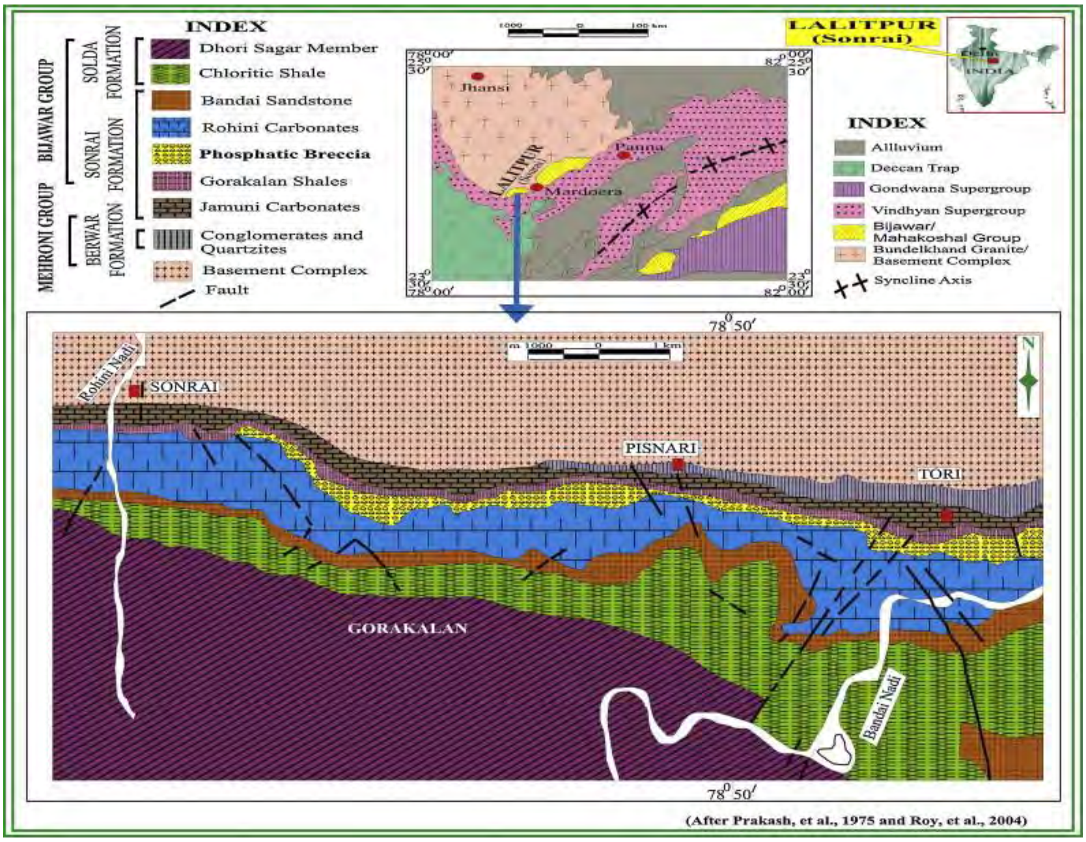


Fig. 2.3: Stratigraphy of the Bijawars at Sonrai (Khan *et al.* 2012)

2.2.3 The Vindhyan System

To the south of the Jhansi-Lalitpur granitic region are the Vindhyan ranges. The Vindhyans are an intracratonic Proterozoic formation forming the largest sedimentary basin of continental India spreading over an area of more than 103,200 sq. km (from Dehri-on-Son in the east to Chittorgarh in the west) some of which is covered by the Deccan Traps in the southwest and the Indo-Gangetic Alluvium in the north. It was formed around 1400 ma to 500 ma.

It abuts against the Aravalli along the Great Boundary Fault in the west, while in the south it rests unconformably over the Parsoi Formation. In the north it overlaps the Bijawars and rests over the Bundelkhand Gneissic Complex. It extends further north underneath the Gangetic Plain sediments on either side of the Faizabad ridge forming the basement of the Siwaliks. In the southwest it is covered by the Deccan Traps and ends along the Son-Narmada Lineament.

According to Wadia (1961:126), "The Vindhyan system is a vast stratified formation of sandstones, shales and limestones encompassing a thickness of over 4,267 metres."

The Vindhyans are composed of undeformed and unmetamorphosed sub-horizontal sedimentary beds of quartzose sandstones, shales, limestones, bedded cherts and pyroclastics.

The Vindhyan Supergroup has been sub-divided into four groups, (i) Semri, (ii) Kaimur, (iii) Rewa and (iv) Bhander Series by Medlicott (1860), Mallet (1869), Vredenburg (1906) and Auden (1933). Earlier the Vindhyans were divided into the lower and upper groups but now a conformable relationship has been established between the two (Soni *et al.* 1987).

Prasad (1984) has suggested a seven fold lithological classification of the Vindhyans: the Satola/Mirzapur group, the Sand/Deonar group, the Lasrawan/Kheinjua group, the Khorip/Rohtas group, the Kaimur group, the Rewa group and the Bhander group.

The Vindhyans were deposited in fluvial to deep marine environments (Bannerjee 1974). The basal parts consist of carbonates which have laminated algal mats and stromatolites deposited under a tidal environment during the Riphean (1650 to 600 ma).

They were later uplifted as a result of isostatic adjustments in the south and tectonic movements in the west and subjected to the process of denudation, scarp retreat and peneplanation resulting in three prominent erosional surfaces of the Kaimur, Rewa and Bhander plateaus. They were later covered by the lavas which have eroded at places exhuming the old Vindhyan topography. Erosion of the scarps is still continuing. The scarp forming nature of the Vindhyan sandstones makes the topographic relief more prominent.

The Vindhyans have been highly folded into broad synclines and anticlines trending NE-SW to ENE-WSW. The important faults traversing the Vindhyans close to the Betwa basin are the Bundi fault, the Great Boundary Fault between the Vindhyans and the Aravallis, the Agori fault, the Hoshangabad fault and the Son-Narmada lineament. The contact between the Vindhyans and the Archaeans northeast of Barman (23°02' N and 79°01' E) is a faulted boundary. West and Choubey (1964) have suggested a fault boundary between Vindhyans and older Bijawars to the east of Katangi and south of Majholi.

Geomorphologically the Vindhyans form a series of moderately flat-topped high ridges and plateaus with intervening valleys. The sandstones occur mostly in the ridges and plateaus while the shales occur in the valleys and lower parts of scarps. Hogback, cuesta, plateau, mesa and butte forms occur due to dipping strata. Cuestas developed due to gentle synclines while linear structural ridges with steep cuesta-hogbacks and fault escarpments developed due to severe structural deformation.

Chiefly the Upper Vindhyans comprising the rocks of the Bhander, Rewa and Kaimur series are exposed in the area. The Upper Vindhyans are profusely intruded by lava dykes and sills.

The Kaimurs show a basal conglomerate containing pebbles of jasper with fine grained grey to brown quartzites with current bedding above the conglomerates (Pascoe 1950, Ghosh 1974, Haldar and Ghosh 1981). Volcanic breccia and tuffaceous rocks indicate volcanism at the end of Kaimur sedimentation.

The Bhander sandstones are fine-grained and soft red with white specks. They are thickly bedded and show ripple marks. Upper Bhander sandstone forms wide plateaus and occurs as inliers among the traps. Lower Bhander series consist of from the base Ganurgarh shales, Bhander limestone, Lower Bhander sandstone with subsidiary band of shales known as Sanchi shales and Sirbu shales exposed at the base of the scarps.

Upper Rewa sandstones are occasionally exposed at the base of the scarps while Lower Rewa Sandstone form scarped ridges. Lower Vindhyan shales have a small outcrop at the base of the Bamnor hill, 11 km north of Amrawad.

The Vindhyans have been uplifted and peneplained in several phases as evidenced by the presence of many dissected flat-topped hills having the same elevation with the pediment in between. Kumar (2005) suggests that the Vindhyan Scarp is of sub-recent origin formed by epeirogenic uplift of the tableland sometime during the Pleistocene.

2.2.4 The Deccan Traps

The rocks of the Vindhyan Supergroup are overlain by Deccan traps. These are remarkably homogenous basalt flows probably extruded from fissures towards the end of the Cretaceous. The lavas were probably poured out onto a landscape which had already attained advanced maturity. The general elevation of this lava landscape is 500-600 m and it has been extensively eroded since the Tertiary forming a level surface.

The Deccan traps occur as both irregular patches among the Vindhyans and also forms wide plateaus. The Deccan traps are usually microcrystalline basalt without olivine, plagioclase and monoclinic pyroxene with small amoebiform vesicles filled with palagonite. Intertrappeans are exposed at few places locally.

2.2.5 Ferricretes

The traps are capped by later formations including the laterite/ferricrete of the Miocene/Late Neogene period, alluvium and black cotton soil.

Ferricrete and its formation have been studied by various scholars but it still remains largely uncomprehended. Ollier thinks that it is mostly precipitated on lower slopes and valleys. The ferricretes on hilltops are a result of inversion of relief (Ollier 1991, Ollier and Galloway 1990).

The term laterite has also been variously used to refer to ferricrete. Sometimes it also includes the associated weathering profile and red soils. Ollier and Rajaguru (1989) however use the term 'laterite' to strictly refer to the hard mottled zone of a weathering profile in saprolite which can be cut into bricks.

Schmidt *et al.* (1983) estimated the age of the ferricretes on the basis of their occurrence on low or high altitudes: the low altitude valley bottom ferricretes were estimated to be younger and belong to Middle to Late Tertiary, while the rich profiles on Deccan trap plateau tops were estimated to Late Cretaceous to Early Tertiary as they must have formed soon after the eruption of Deccan traps.

2.2.6 Recent Deposits

The valleys are covered extensively by recent deposits. These deposits are either the alluvium transported by the Betwa and its tributaries or the residual deposits of laterite and weathered rock mostly found on the hilltops or pediments, though at times also occurring in the valley. The residual soils vary according to the surface lithology. In the region capped by trap flows, mostly black cotton soil or 'regur' formed from the weathering of the trap occurs, while in the granitic terrain to the north red weathered soils are found.

The alluvial sediments are sands, silts and clays of fluviatile and aeolian origin. The alluvium is not restricted to the floodplains but is spread extensively up to the divides which may indicate subsidence of land surface. The sediments become finer in texture as we move towards the Yamuna. The alluvial deposit also becomes thicker as we move northwards with the maximum depth of bedrock reported at Jalokhar in District Hamirpur at 158 m.

2.2.7 Stratigraphic Relationship

The stratigraphic relationships of the rocks according to the different workers may be summarized here (Table 2.4).

Table 2.4: Lithostratigraphic relationship of different rocks in the Betwa Basin

Pascoe (1950)	**Jhingran (1958)**	**Saxena (1961)**	**Prakash *et. al.* (1970)**
Traps Gwalior-Bijawar Series-Aravalli	Lower Bijawar Series	Bijawar sediment = Cuddapah (?)	Khajraha-Angor alkaline formation [tuffaceous serpentine-calcite rock] (Panna Volcanics = Post Vindhyan)
- - - - - - - - - - - -	- - - - - - - - - - -	- - Unconformity- -	
Basic Dykes	Basic Dykes P	Dolerite and other P	
	O	basic dykes O	Bundelkhand Mafic Formation [dolerites, mafic dykes, plagioclase porphyry, post Bijawar traps]
	S	S	
	T	Quartz Reefs T	
			(Post Bijawars ?)
	D	Pink Granites D	
	H	H	Bundelkhand Granite Formation
	A	A	Milky quartz
	R	R	Pink fine granites (Singhbhum Granites)
	W	W	
Mehroni Schists = Pre-Aravalli	Quartz Reefs A	Migmatites and A	Pink coarse granites
	Granites R	Migmatitic R Derivatives	
Granite Complex and Quartz Reefs (Old Basement)	Meta-sedimentaries = Dharwars	Meta-sedimentary Rocks = Middle Dharwars (?)	Mehroni Formation Meta-sedimentaries (Dharwars) Grey gneiss and granite

2.3 DRAINAGE BASIN CHARACTERISTICS

Channel characteristics, landforms and structural controls can be inferred from the study of old topographic maps and recent remote sensing images. These drainage basin characteristics may have important implications for the archaeology in the region.

In the present study the Betwa basin has been drawn from 1:250000 scale Survey of India (SOI) topographic maps delineating its basin boundary and drainage network. For detailed investigations 1:50000 scale SOI maps were used and modified using satellite imageries (Landsat and ETM+). Shuttle Radar Topographic Mission (SRTM) data 53_02, 53_07, 53_08 (Source: http://srtm.csi.cgiar.org) has been used with the aid of void filling interpolation methods (Reuter *et al.* 2007). These data have been processed with the help of ArcGIS 9.2 and Global Mapper softwares.

Geomorphic indices, namely, elevation to distance profile, gradient, stream gradient index (SL Index) and valley index, and morphometric analysis of the trunk river and channel divides were undertaken to investigate processes influencing river dynamics and reveal palaeo-morphotectonic activities. Besides digital elevation model (DEM), slope and aspect maps were generated to study microgeomorphic elements of the study area.

2.3.1 DIGITAL ELEVATION MODEL (DEM)

Digital terrain model recording a topographic (geo-morphometric) representation of the earth terrain as sampled arrays of surface elevations in raster form was generated using SRTM data and SOI topographic maps. The color variations of the DEM indicate varying topographic signatures that accumulate information regarding elevation and slope constraints.

The DEM (Fig. 2.4) of the entire Betwa basin shows that the general slope of the area is from SW to NE which is also the flow direction of the major drainages. The elevation ranges from 79 to 710 m in the basin area. Four distinct geomorphic regions can be recognized based on elevation change with reference to reflection contrast: the gentle sloping alluvial plain near the confluence with the Yamuna River with elevation ranging from 79 to 185 m; the peneplain with elevation ranging from 185 to 307 m; the upland surface with elevation ranging from 307 to 387 m; and the steep sloping hills in the upstream region with elevation from 387 to 710 m. The DEM also clearly shows the second Vindhyan escarpment which is the last surface exposure of the Vindhyans after which the Vindhyans only continue as a subsurface feature. This is a major tectonic feature which also influences the drainages in the area as discussed earlier.

The high depth of alluvium in the marginal plains (discussed in Sections 2.2.6 &2.5.4) precludes the finding of archaeological sites in these plains. Therefore, areas with potential of finding archaeological sites include the peneplain and the upland surface. Here a number of Palaeolithic and Microlithic sites were found (discussed in sections 2.5.1 to 2.5.3)

2.3.2 SLOPE MAP

Slope of a region refers to change in elevation profile. Slope map of the entire Betwa River has been derived from SRTM data (90 m resolution) using Spatial Analyst in Arc GIS 9.2 (Fig. 2.5).

In the basin area the slope ranges from more than 1° to 74°. The general slope is low indicating a flat terrain with few ridges and residual hills having a steep slope ranging from 21° to 74°. Eroded surfaces of the Vindhyans and Deccan trap have slopes ranging from 11° to 21°. Slope in the pediment zone is very low ranging from 1° to 6°. Low slopes have allowed preservation of archaeological sites. In the thickly accumulated alluvial plains the slope hardly ranges from 1° to 3°. Occasional higher slopes in the plains region from 3° to 7° indicate steep incision or gullying (badlands). These areas may be explored for archaeological sites. Thus the basin area shows mainly two types of slope morphology, one governed by the Vindhyan escarpment, and the other being the alluvial terrain with low slope values. The granitic pediment also has low slope values.

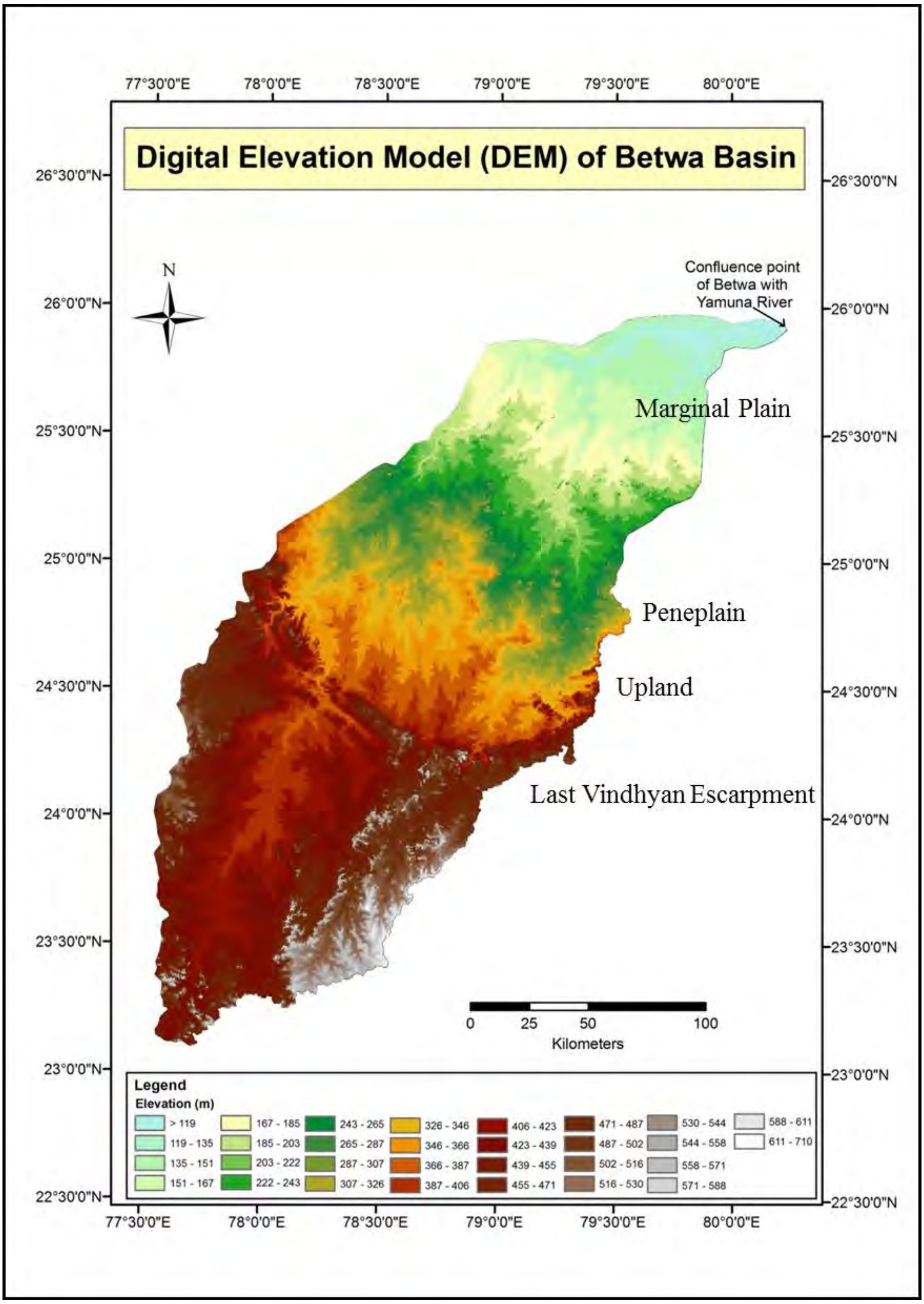


Fig. 2.4: Digital Elevation Model of the Betwa Basin

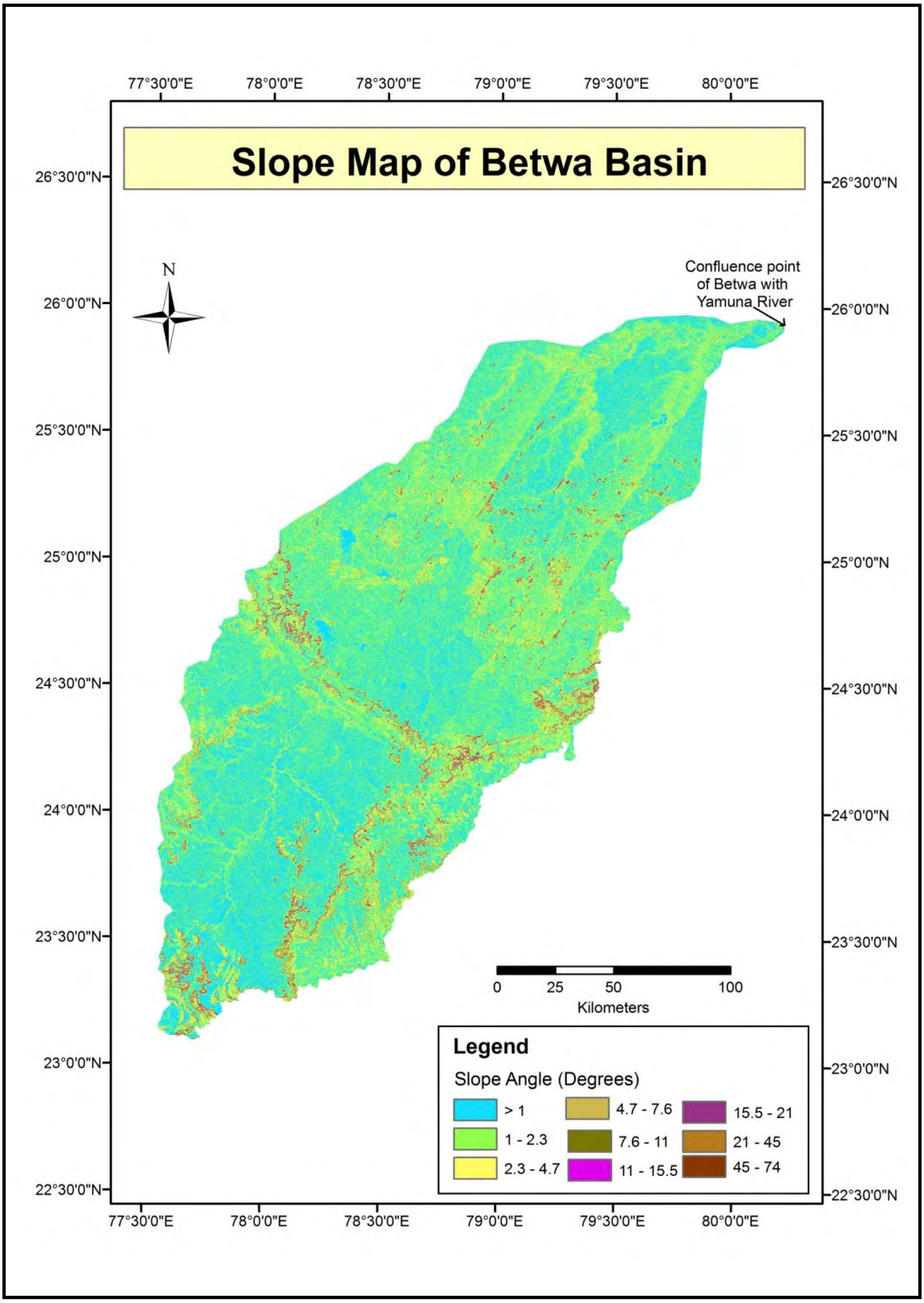


Fig. 2.5: Slope Map of the Betwa Basin

2.3.3 DRAINAGE DELINEATION

The drainage system gives information on flow regime, sinuosity behaviour and shifting morphology. Drainage network was delineated from SOI maps and SRTM data and digitized in Arc GIS 9.2 using ArcHydro tools.

The Betwa River known in ancient times as the *'Vetrawati'* which is the third largest river on the Vindhyan Plateau, arises near Bhopal from the foot of Dhondi Dant hills (23° 2' N and 77° 29' E) with an elevation of 642.2 AMSL in the Vindhyan ranges on the northern side of the Narmada-Son lineament. The Vindhyan ranges form the divide between the Narmada and the Betwa. It flows for ~590 km in a north to northeast direction up to its confluence with the Yamuna near Hamirpur at an elevation of 106.68 m (25° 55' N and 80° 12' E). The average annual discharge of the Betwa River is about 815,000 cusecs but seasonal fluctuations are marked.

The drainage of the Betwa is generally SW-NE. The major streams are intermittent to perennial. Major tributaries of the Betwa include Kaliasot, Ajnar, Besh Bah, Sagara, Kethan, and Orr on the left bank and Dhasan, Bina, Jamni, Shahzad, Ricchan, Dabar, Nion, Parasri, and Birma on the right bank.

The drainage system of the Betwa River encompasses a wide variety in its distribution and flow regime (Fig. 2.6). The drainage appears to be controlled by the joints on a regional scale and gives evidence of structural controls.

Elevation to distance profile (longitudinal profile) of the Betwa (Figs. 2.7 & 2.9) drawn by plotting elevation of riverbed against respective downstream distance using Google Earth, and drainage delineation reveal interesting characteristics.

The river flows from an elevated terrain at an elevation of 512 m as most channels have their source in the Vindhyan hills. There is a sharp fall in elevation upto a distance of 50 km downstream at an angle of more than 70° with consistent upwarps and downwarps. Then it continues to flow in a low angled slope upto a distance of 250 km, but in this distance the high degree of knick points signify considerable upwarping and downwarping at frequent intervals indicating subsurface manifestations (inferred as faults).

In this upstream region, most streams have carved out steep gorges and precipitous rocky banks with drainage generally varying from sub-dendritic to dendritic formed by rills and *nullahs* before the river enters the last exposure of the Vindhyan escarpment. The Betwa flows through a land surface of 380 AMSL upto Narain River near the last Vindhyan escarpment with little relief. It appears that the Betwa is not downcutting much in its early course. This may be due to the higher elevation in the middle part at the Vindhyan escarpment near Jakhlaun beyond the 380 AMSL surface which acts as a structural control and prohibits the gradient and the channel flow. Perhaps there is some lateral cutting and channel widening.

A sharp fall in the elevation of the river flow from 380 to 150 m in the midstream region after cutting through the last Vindhyan scarp when the river enters the granitic country of Lalitpur downstream of Jakhlaun. Drainage direction also changes abruptly becoming parallel. It becomes a well graded channel flowing within a broad conduit till the river enters the thick alluvial plain. This belt extends upto a distance of 180 km which is mainly the peneplain deposits and is also marked by the presence of two sharp knicks. These knicks are clear indication of faults. This also suggests that during the traverse in this realm the river flows in a tectonically controlled area. It is in this region that the Acheulean sites of Lalitpur are located.

Below the knick points the alluvial system in the Betwa basin starts. The streams show braided-meandering pattern becoming broad shallow intermittent bedload streams. The channels mostly show incision in the bedrock with active erosion forming conspicuous ravines or badlands but in the most part the profile shows gentle topography with slight undulations

A prominent downwarping is recorded just near the confluence with the Yamuna River which may be a signature of peripheral bulge of the Peninsular Craton.

Fig. 2.7: Longitudinal Profile of the Betwa River

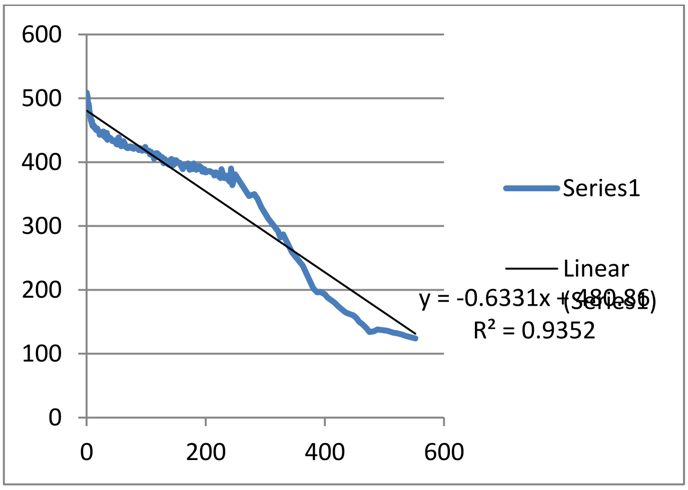


Fig. 2.8: Graph showing significance of the Longitudinal Profile of the Betwa River

2.3.5 MORPHOMETRIC ANALYSIS

Morphometric analysis provides a useful parameter for the assessment of geographic characteristics of a drainage system (Clarke 1966). The following morphometric parameters were calculated: (1) Basic parameters: basin area, perimeter, basin length, stream order and stream length; (2) Derived parameters: bifurcation ratio, stream length ratio, stream frequency, drainage density, drainage texture and basin relief ratio; and (3) Shape parameters: elongation ratio, circularity index, form factor and ellipticity index (Table 2.5).

Table 2.5: Morphometry of the Betwa River (Basic, Derived and Shape Parameters – derived from Hydro tools in Arc GIS 9.2)

Basic Parameters		**Derived Parameters**		**Shape parameters**	
N1	3546	Rb1	3.6	E	3.49
N2	985	Rb2	1.89	Re	0.61
N3	519	Rb3	1.59	Ff	0.22
N4	325	Rb4	0.61	Rc	0.30
N5	201	Rb5	2.54		
N6	79	**Rb**	**2.05**		
L1 (km)	6328	RI 2-1	0.48		
L2 (km)	3069	RI 3-2	0.47		
L3 (km)	1499	RI 4-3	0.52		
L4 (km)	780	RI 5-4	0.43		
L5 (km)	335	RI 6-5	1.35		
L6 (km)	454	**RI**	**0.54**		
A (sq. km)	38678	RHO	0.26		
P (km)	1273	Fs (km-2)	0.19		
L (km)	415	Dd (km-1)	0.32		
H_{max} (m)	710	T (km-1)	0.06		
H_{min} (m)	79	R (m)	631		
Sb	1.52	Rr (m km-1)	1.52		
		Lg (km)	1.56		

Area (A), perimeter (P), Basin length (L), Stream order (Nu), Stream length (Lu), Slope (Sb), Basin relief (R), Relief-ratio (Rr), Bifurcation ratio (Rb), Stream length ratio (RI), RHO coefficient (RHO), Stream frequency (Fs), Drainage density (Dd), Drainage texture (T), Length of overland flow (Lg), Elongation ratio (Re), Ellipticity index (E), Circularity Index (Rc) and Form factor (Ff)

Stream order in the Betwa basin shows the 6th order stream as the highest order. The area of the basin is 38678 km^2. Basin length (L) is 415 km (Fig. 2.9).

Slope (Sb): Gentle slope gradient in this basin (1.52 m km^{-1}) indicate low to moderate surface run-off, low sediment production, and high infiltration rate. This is due to the presence of older sediments and rocky floors along the channel region. This indicates an erosional basin. Gentle slope has implications for the preservation of Palaeolithic sites in the region.

Basin relief(R) or the difference in elevation between the highest and lowest point of the basin has a high value of 631 m which indicates quite high run-off and large sediment transport. This is due to the elevated terrain of Vindhyans and the presence of uplifted bulge of the Vindhyan Plateau where the river comes in contact with Ganga alluvial system. The high relief again implies high rates of erosion.

Relief-ratio (*Rr*) or the ratio between basin relief (*R*) and basin length (*L*) is 1.52 which also indicates high surface run-off, and moderate stream power for erosion.

Bifurcation Ratio **(Rb)** between number of streams of any given order (Nu) to the number of streams in the next higher order (Nu+1) has a mean value of 2.05 which falls in the gentle to moderate drainage basins indicating that the geological structures are less disturbing and the drainages are natural and not much influenced by geological structures.

Stream-length Ratio (RI) value of 0.54 for the Betwa watershed shows middle mature stage of erosion and good surface run off.

RHO Coefficient (RHO) or the ratio of *RI* (stream length ratio) and *Rb* (bifurcation ratio) has a value of 0.26 indicating medium to low water capacity.

Stream Frequency (Fs) is 0.19 km^{-2} which indicates low permeability due to rocky and elevated cliff sections in the flow regime.

Drainage Density (Dd) is 0.32 reflecting low to moderate permeable and erodible terrain with well-defined drainage. It is mainly influenced by the resistance of the bed material to erosion, and capacity of infiltration.

Drainage Texture (T) is 0.06 which shows coarse grained texture in the region.

Length of Overland Flow (Lg) value of 1.56 shows longer path for the concentration of flow implying that peak discharge take place only in the distal part of the river system.

Elongation Ratio (Re) value of 0.61, ***Ellipticity Index (E)*** value of 3.49, ***Circularity Index (Rc)*** value of 0.30 and ***Form Factor (Ff)*** value of 0.22 indicates elongated shape of the basin, mature topography and supports dendritic pattern of drainage network.

The Betwa River arises as a small stream in the Vindhyan hills fed by underground water and monsoon precipitation. It flows through a narrow valley cutting the Vindhyan escarpment developing into a broad well matured river downstream. It forms an elongate basin trending SW-NE. The drainage network represents both braiding and meandering pattern. Surface run-off is high due to rocky and undulating terrain. However, in areas covered by granitic residuum or thin alluvial cover most of the precipitation is absorbed. The drainages are mainly controlled by the Vindhyan structural setup and nature of the alluvium. Geomorphometric indices show natural drainage system and intra-basinal tectonics.

2.4 GEOMORPHOLOGY

The geological system also determines the geomorphological landscape. Geomorphologically, the region can be divided into four broad geomorphic provinces: (i) the Alluvial Plain, (ii) the Deccan Trap Plateau, (iii) the Bundelkhand Inselberg-Pediplain, and (iv) the Vindhyan Structural Plateau.

The topography is smooth and undulating in character. Spate (1954:433) calls it 'senile topography'. Southern areas retain the features of a dissected plateau. Near Deogarh, the Betwa River cuts through a magnificent gorge to enter the vast granitic country. The northern region is marked by subdued topography which grades into the vast alluvial plain further north.

2.5 GEOARCHAEOLOGICAL CONTEXT

For purposes of discussion the study area can be divided into four sections on the basis of different lithology and landform context: (1) The area up to the last exposure of the Vindhyan Escarpment near Jakhlaun, or the Malwa-Vindhyan Plateau; (2) The Lalitpur Upland comprising the granitic country north of Jakhlaun up to Talbehat; (3) The adjoining region of Jhansi Upland from Talbehat to Moth which is a continuation of the granitic country but it is discussed separately for several reasons outlined below; and (4) The Marginal Alluvial Plain from Moth up to the confluence with the Yamuna River.

2.5.1 THE MALWA PLATEAU-VINDHYAN UPLAND

This plateau consists of the rocks of the Vindhyan Supergroup - Deccan Trap in Bhopal-Vidisha-Sagar region. It receives an average annual rainfall of 110 cm falling mostly in the monsoons. The general elevation of the area is 650-400 m. Interestingly, the traps and Vindhyans have the same average elevation.

This upland is characterized by different plateau surfaces with differing elevations. These are the Vidisha tableland (520 m), the Bhopal Plateau (580 m) and the Lalitpur Plateau.

The Bhopal Plateau has an open synclinal structure with flat-top ridge. It is mainly comprised of the Bhander sandstone. Bold scarps form the divide between the Narmada and the Betwa basin. It is an inlier within the Deccan trap representing a palaeo-erosional surface.

The Vidisha valley is formed between the spur fangs of the Vindhyans bordered by the Garhi-Teonda ranges in the east and the Ganiari-Raghogarh ranges in the west as a gently rolling plain extending from south to north and is about 50-60 km wide covered by rich black soil derived from the weathering of the trap. In this region the drainage pattern is mostly dendritic to sub-dendritic and controlled by structural joints. Palaeo-erosional planation surfaces between the Vindhyans and the Deccan traps are exhumed where the trap cover has eroded.

The Lalitpur Plateau is bordered to the northeast by the Bundelkhand Pediplain, north and west by the Chambal Alluvial Plain and to the south by the Deccan Trap Plateau. It comprises of the Kaimur and Rewa groups of rocks forming two distinct plateau levels descending in steps, each with an east facing scarp. The Kaimurs show bold back-scarp against the Bundelkhand Pediplain.

Observations based on explorations in the area show that bedrock is found often at great depths, and there is an extensive and thick alluvial cover in the valleys running from divide to divide (Fig. 2.19). Basalt bedrock is reported to occur at 12 – 15 m, and at places even at 30 m below ground level near *Kankar*, Nonakheri and Ambawati. Valleys show extensive silt deposits near the rivers as seen at Kagpur (Vidisha), Nonakheri (Sanchi), Kethora (Bina River) and other places. Presence of deep gorges and waterfalls in the upstream and extensive alluvial cover in the valleys extending from divide to divide may be explained by tectonics.

In this area the Vindhyans are exposed in the form of hills and ridges at a higher elevation while the younger Deccan trap is often found as irregular patches at a lower elevation in the valleys between surrounding sandstone ridges. It is hypothesized that this inversion of relief may be due to differential weathering and erosion as Deccan Trap weathers at a faster rate (Mishra 1986, 1982). Further in the adjoining Sonar-Bearma basin the lowermost trap flow rests directly on the uneven surface of the older rocks (Rai 1980). However, Fermor and Fox (1916) during their study of the Linga area in Chhindwara district suggested that the pre-Deccan Trap surface itself was uneven with depressions and elevations.

Laterite exposures were noticed in the river section and on the river bed near Ganj Basoda (Fig. 2.10), Nonakheri (Fig. 2.13) and Khiriya. Joshi (*IAR* 1958-59: 22) also found laterite at Pagnesar. Laterite which is known to be present on the divides, capping the summits of hills and plateau, in other basins, including the adjoining Parbati basin (Abbas 2006) and Sonar-Bearma Basin (Rai 1980) is present in the Betwa basin at a low level in the valleys. In the Sonar-Bearma Basin laterite is observed at 610 metres and above (Rai 1980). But laterite is found to occur at depths of 14 to 21 m in Hoshangabad area also as revealed by boreholes. This indicates that laterites were formed by sub-aerial weathering of gently sloping peneplain and pediplain surfaces with free movements of sub-surface water (Supekar 1985).

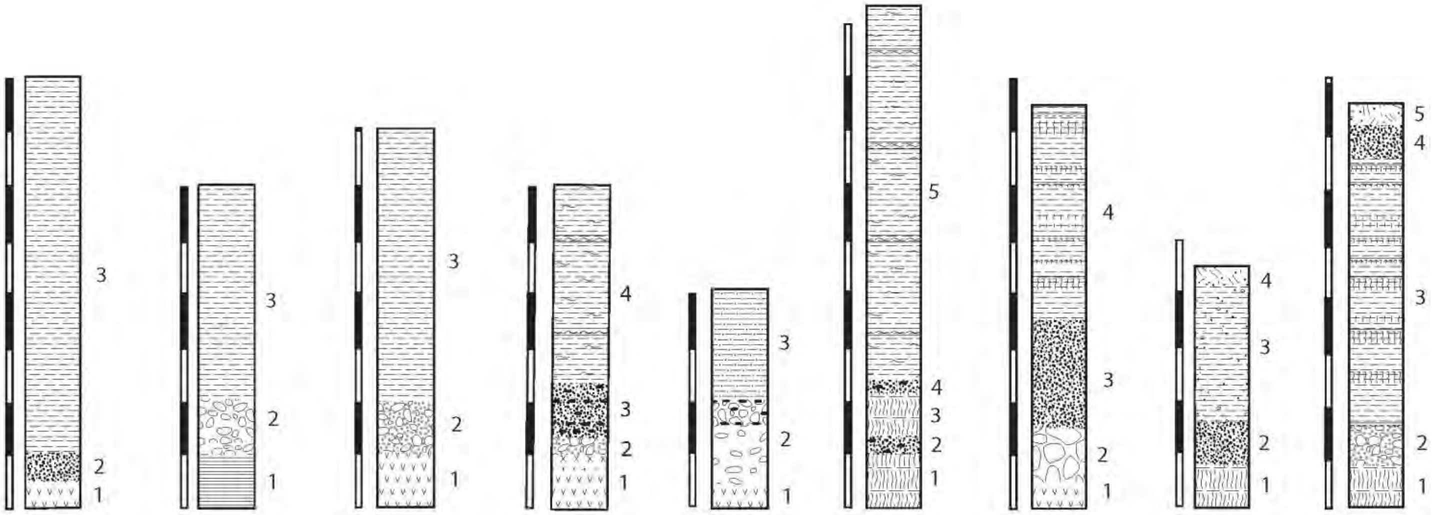
Study of river sections, dug well and bore holes shows that the general stratigraphy of the area (Fig. 2.11) is murrum or weathered regolith often overlain by black fissured clay. The third unit is cobbly-pebbly or cemented gravel which is often associated with Middle Palaeolithic artefacts. It is composed of subangular local basalt clasts, rolled sandstone and quartzite pebbles and cobbles, and heavily rounded laterite pellets in a sandy matrix, but it is devoid of any calcrete. The next unit exposed at places is fine gravel (Fig. 2.12) which is found to be associated with Upper Palaeolithic artefacts at Kagpur including 4-5 cm sized flakes and flake-blades. Calcrete is found in this gravel unit which may be Late Pleistocene in age. The next unit is silt associated with microliths which may be Late Pleistocene to Holocene in age. The last unit is thick deposits of laminated silt with calcrete bedding indicating overbank flood deposits (Figs. 2.17 & 2.18).

Jacobson (1975) in his surveys near Raisen conducted in 1965 and 1973-74 found more than 90 Lower Palaeolithic sites in a small area of 175 sq. km (a radius of 9 km). Of these six sites were in 'undisturbed' condition and others were 'disturbed' sites in ploughed fields, stream banks or eroded surfaces. The sites are located on foothills or plateau plains near small streams or rivulets draining into the Betwa or Narmada drainage. According to Jacobson most sites are surface scatters, yet the nature of the occurrences show that they are virtually '*in situ'*. This would imply that the artefacts have been lying exposed on the surface without being covered by sediments. But the fresh nature of the artefacts rules this out. Quite interestingly recent studies of the Raisen Acheulean (Deo *et al.* 2011, Ota and Deo 2014) revealed extensive artefact scatters at Tikoda, close to Narwar hill. Their studies show that the artefacts are not actually surface scatters, but that they are recently getting eroded from a buried context (Mishra *et al.* 2012). This buried context was found preserved at Tikoda. Our observations also show that in the adjoining area of Lalitpur, discussed below, we find surface scatters of Acheulean artefacts which seem to be recently getting eroded onto the surface.

Middle Palaeolithic artefacts are found to occur in cemented or cobbly-pebbly gravel (Lithounit 2) in river sections near Korwai on the Betwa River (Figs. 2.10 & 2.14), Khiriya, District Bhilsa on the Bina River and Mohasa near Sagar on the Dhasan River. However Joshi (IAR 1958-59: 22) reported cleavers, handaxes and flakes on quartzite from compact cobbly gravel on sandstone bedrock at Pagnesar.

Microlithic artefacts are found from erosion gullies as at Kethora on the Bina River (Figs. 2.15 & 2.16). They are exposed on the surface in clayey silty sediments along with calcrete clasts, basalt and quartz pebbles. At Kethora the site is extensive ranging for about 200 m diameter, though the artefact density is not very high. The artefacts include quartzite flakes (7 – 8 cm in size), blades on quartz, chert and chalcedony, broken blades and rock nodules. Artefact size, broad typo-technology and nature of the sediments indicate an early age, probably in the Late Pleistocene.

Fig. 2.10: Laterite exposure near the bridge at Ganj Basoda, Vidisha



a. Ganj Basoda b. Nonakheri c. Korwai d. Khiriya e. Fatanpur f. Roshan Pipariya g. Kankar Village h. Kagpur i. Johad

Fig. 2.11: Stratigraphic Sections recorded in the Malwa Plateau - Vindhyan Upland

Fig. 2.12: Section at Ganj Basoda, Vidisha showing fine gravel below 7 m of silt

Fig. 2.13: Section at Nonakheri near Sanchi showing laterite exposures

Fig. 2.14: Close up of cemented gravel at Korwai associated with Middle Palaeolithic artefacts

Fig. 2.15: Microlithic finds at Kethora on the surface of erosion gullies

Fig. 2.16: View of the microlithic site at Kethora

Fig. 2.17: Overbank silt deposits at *Kankar* on Kethan River

Fig. 2.18: Stratigraphic section on Kethan River at *Kankar*

Fig. 2.19: View from the Sanchi hill showing thick alluvium just near the divide

2.5.2 THE LALITPUR UPLAND

The Malwa Plateau – Vindhyan region gives way abruptly to the granitic upland of Lalitpur. This granitic pediplain extends south of 25°30' from Lalitpur to Jhansi bordered in the south by the Vindhyan scarp, dipping below the Bijawar structural hills in the southeast and in the north it is bordered by the extensive alluvial plain.

The general elevation of the area is between 150 to 300 m (NAO: Lucknow Physical Plate, 1959). It represents an old erosion surface carved out of the Bundelkhand Granitic Massif. It is an undulating rocky upland marked by inselbergs, isolated tors and residual hills sloping northeast. Sub-aerial denudation has given it an undulating character with moderate relief characterizing a late mature landscape. It is drained by broad shallow intermittent bed-load streams.

The areas surveyed included Chanderi, District Guna; Rajghat Reservoir area; Lalitpur – Jiron – Jakhlaun – Deogarh - Dhaura; Shahzad River from Kapasi to Bansi; Lalitpur to Mehrauni; and Lalitpur to Tikamgarh.

Besides the area near the Acheulean sites of Lalitpur was also explored in order to relocate the sites and understand the site context and formation processes. This included the area around the Chhatarpal temple, Biana *Nullah* and the Shahzad River.

Extensive erosion in the catchment zone of the numerous ephemeral streams gives the area a deeply furrowed character. The low-lying plains and valley depressions are covered with weathered granite whose thickness is variable in the region, over which is a thin cover of top soil. The granite has been subjected to decomposition and disintegration forming a granitic residuum which is granular and porous as quartz grains, feldspars and other minerals are broken loose without being decomposed. The thickness of the granitic residuum varies from place to place.

The granitic basement has an uneven configuration. Fresh rocks generally occur below weathered regolith.

In the gneissic area of Lalitpur the laterite is conglomeratic and frequently contains grains of sand and large rounded or subangular fragments of gneiss and other rocks, imbedded in a ferruginous matrix. It is of the nature of ferruginous gravel than of true laterite. The small pisolitic nodules appear to become cemented with the accompanying sand and clay. Underlying the laterite, the upper part is decomposed into sandy clay which becomes a kind of lithomarge grading into laterite. The lithomarge is more ferruginous above than below and varies in color from red through yellow to white being usually mottled. Sometimes the infra lateritic formation contains pebbles (Fig. 2.20).

Exploration of the upper part of the Biana *Nullah* from Siddhapura to Burwar and Siddhapura to Patora Kalan was undertaken to understand the context of the Acheulean sites.

In the granitic upland of Lalitpur, the general stratigraphy is brown soil 15-30 cm capping black or red soil of 0.5 – 1 m. The black or red soil overlies ferricrete interspersed by quartz veins. It is underlain by weathered gruss or saprolite (Fig. 2.21).

The depth of bedrock ranges from 0.5 - 3 m between the Betwa and Shahzad Rivers with a thin soil cover, but between Shahzad and Jamni Rivers bedrock depth increases to 6 – 15 m where we find thicker alluvial cover of ~6 m.

As we move from Siddhpura to Naigaon, we find bedrock exposed near Siddhpura (Biana *Nullah*), but from Berwara to Burwar, the depth of bedrock is a bit lower. Again, just before Surar, bedrock is exposed at around 0.5 - 1.5 m below red weathered granular sand.

The soil cover over gruss in granitic upland between Betwa and Shahzad Rivers is only a thin 15 – 30 cm while near the streams the alluvial cover is 1 – 3 m. This perhaps indicates lack of any net aggradation or incision since the Pliocene and consequent stable landscape. This may be the result of rheological differences between the Archaean and younger continental crust (Westaway *et al.* 2003).

Apart from the localities at Lalitpur on the Biana Nullah, a few other locations have also yielded Lower Palaeolithic artefacts. Joshi (IAR 1961-62) had also reported a number of other localities

During the course of exploration, in the forests close to the temple complex of Deogarh, a large number of Lower Palaeolithic artefacts were found. The artefacts were made on quartzite. Many Kombewa flakes were also noticed (Figs. 2.26 & 2.27). However no detailed study of the artefacts was undertaken as this was beyond the purview of this work. Earlier Joshi (IAR 1961-62) had also reported artefacts from Deogarh.

Besides, on the slopes of a low hill at Aira near Jiron, sandstone cleavers, handaxes, flakes and core were found. The site had a large number of battered cobbles and cobbles with cup-like depressions (Figs. 2.22 – 2.25).

Microliths were found from several localities in the area as it is rich in quartz and other cryptocrystalline siliceous rocks. They are found in varying contexts.

On the road to Burwar, microliths were found on the slopes of a granite tor. The artefacts are made on quartz, chert and chalcedony which included cores, blades, flake blades, a burin, a point and a number of broken blades and debitage (Figs. 2.28 & 2.29).

At Patora Kalan on the left bank near Semri Tal, a dense scatter of microliths was found on the surface in a ploughed field. The extent of the site is 180 × 100 m. The artefacts are found within black clay which is 25 – 30 cm deep. Artefacts included few cores, extensive debitage and flakes. Debitage of small size (< 1 cm) was also found. The artefacts are made on quartz, chalcedony and chert. The area is rich in quartz pebbles of 1 – 15 cm.

Besides, eroded surface of gullies near a *nullah* close to Burwar yielded a number of microliths. These microliths are mostly made on agate and include truncated blades (Figs. 2.30 & 2.31).

Near Naigaon, on the slopes of a low granitic hillock (10 m high) found parallel to the Mangrai *Nullah* and about 100 m away from it, microliths were found. The hillock is laterally 25 – 30 m in extent. The microliths are made on quartz, chalcedony and chert and flakes range in size from 4 cm to 1 cm. Blades are 1 – 3 cm in size. Small chipping debitage is also found, which is fresh in nature, as if the artefacts were made just yesterday (Figs. 2.32 & 2.33).

About 0.5 km before Jijawan, red sand was exposed in the fields 50 m away from the *nullah*, where few microliths were found including a flake and few debitage consisting of six - seven artefacts. Quartz nodules are found extensively in the field. Granite bedrock is seen in the *nullah* section about 5 – 6 m below. Red sand is capped by top silt at places. In the well near Jijawan we find two alternating layers of gravel and silt capped by 0.5 m of top soil.

Palynological study of three sediment cores from lakes in Talbehat, Madaura and Dhaura in Lalitpur district revealed succession from Moist Deciduous Forest (~4000 yrs BP) to Mixed Deciduous Forest (~2000 yrs BP) and finally to Dry Deciduous Forest since ~1400 yrs BP. Decline of moisture loving taxa since ~1400

BP indicate an increase in aridity/weakened monsoon. These lakes were formed during the Early Holocene ~8300 yrs BP as a result of river channel abandonment due to change in base level and tectonic activity. High sedimentation rates in deeper sediments indicate increased precipitation and high surface run-off characterized by higher percentage of coarser sand. Average net rate of sedimentation in the upper sediment is comparatively low at 0.029 cm yr-1 suggesting reduced precipitation (Farooqui and Sekhar 2011).

Fig. 2.20: Regolith capped by quartz stoneline and thin silt cover near Lalitpur

Fig. 2.21: Laterite in the quarry section near Siddhapura

Fig. 2.22: View of hill at Aira with Lower Palaeolithic artefacts on hillslopes

Fig. 2.23: Close up of the artefact spread at the site of Aira

Fig. 2.24: Cleaver from the site of Aira

Fig. 2.25: Retouched Flake from the site of Aira

Fig. 2.26: Lower Palaeolithic surface finds at Deogarh, Lalitpur

Fig. 2.27: View of the Betwa River close to Deogarh

Fig. 2.28: Microlithic finds on the hill slope near Siddhapura, Lalitpur

Fig. 2.29: Close up of the microlithic artefacts scattered on the hills lope surface

Fig. 2.30: Microliths found on the surface of erosion gullies near Burwar, Lalitpur

Fig. 2.31: Closeup of the microliths from the surface near Burwar, Lalitpur

Fig. 2.32: Microlithic finds at Naigaon, Lalitpur

Fig. 2.33: View of the hill at Naigaon, Lalitpur with microliths

2.5.3 THE JHANSI UPLAND

This area is lacking in geological and geomorphological studies of this nature, though few studies based on remote sensing and geophysical surveys have been conducted to understand the hydrology and mineralogy of the region. Therefore much of our understanding is based on our own explorations in the region. For this purpose the area on the road from Babina - Talbehat – Jakhaura – Rajghat; and Jakhaura – Bansi - Babina was explored. It focused mainly on the following localities: Barwa Sagar, Ramnagar Ghat/ Lohargawan, and Khiriyaghat.

Observations around the area showed that alluvium is mainly confined to river sections, and the entire area is covered with bedrock exposures or regolith. From the Betwa River up to Barwasagar (78° 45' to 25° 25') continuous alluvium was noticed. Near Tindol nearly 8 m of pale yellow silt with occasional lenses of calcrete and angular stone gravels was noted in the river section. The top of the section contains calcrete nodules. The thickness of alluvium as seen from dug wells between Barethi to Barwasagar is 18 – 24 m at most places; gravel is found often at 8 – 9 m depth.

A microlithic surface site was located near Khiriya, a few m away from the Betwa River. This locality yielded some quartz flakes, debitage products and one microlithic fluted core from surface erosion gullies. It is probably late Pleistocene in age.

At Lohargawan, District Jhansi (78° 55' 25° 35'; SOI Grid No. 54 K14) **g**ranite bedrock is exposed at the base with nodular calcrete appearing as a rhizolith horizon on regolith (Lithounit 1). It is overlain by silt with thick nodular calcrete ≤ 5 cm in diameter (Lithounit 2). Rhizoconcretions and mottles suggest strong pedogenesis. It is succeeded by yellow silt which is covered by vegetation and is not well exposed (Lithounit 3).

Upstream of bridge the regolith horizon (Lithounit 1) above the bedrock is covered by a rubble gravel (Lithounit 2) which is 2 ½ to 3 m thick (Fig. 2.34). This is overlain by a pebbly gravel unit (Lithounit 3). Above this is a pink silt horizon with large calcrete nodules (Lithounit 4). This is again overlain by a gravel lens (Lithounit 5) which is capped by 2 m thick yellow silt (Lithounit 6) (Figs. 2.35 & 2.36).

A lone trihedral handaxe made probably on dolerite was recovered from the basal gravel (Lithounit 2). The tip is broken. It is moderately abraded and weathered. Edges are moderately rounded indicating perhaps low fluvial transport (Fig. 2.37).

Though it could not be dated, high antiquity is indicated by lithostratigraphy (reddening of sediments, massive calcretization, rhizoconcretions), relict nature of the landscape, taphonomy (weathering/patination) of the artefact and the natural clasts. These parameters were indicated by Mishra (2011) in their review of the geological context of the Indian Acheulean.

The discovery of this lone handaxe is significant as it is the northern most place of its recovery in the basin. Beyond this, the landscape is covered with alluvium buried to great depths.

It may be noted that the ongoing shift of the Indian plate towards the Eurasian plate may have consequences for the archaeological record in the region. The Indian Plate is currently moving north-east at ~5 cm (2.0 in) per year (Searle *et al.* 2011, 1998), while the Eurasian Plate is moving north at only 2 cm (0.79 in) per year. This is causing the Eurasian Plate to deform, and the India Plate to compress at a rate of 4 mm (0.16 in) per year. Last major uplift of the Himalayas took place ~500 ka in the Middle Pleistocene. Himalayan orogeny leads to sagging of the Bundelkhand shield and consequent sedimentation and subsidence. Further extension of the Vindhyan orogenic belt in the form of Faizabad ridge has also been noted (Sastri *et al.* 1971). This may be taken to imply that the landscape of this region may have been quite different in Acheulean times, probably closer to the present day landscape around Lalitpur. With the collision of the India-Asia plate still continuing, the region is still witnessing tectonic induced changes.

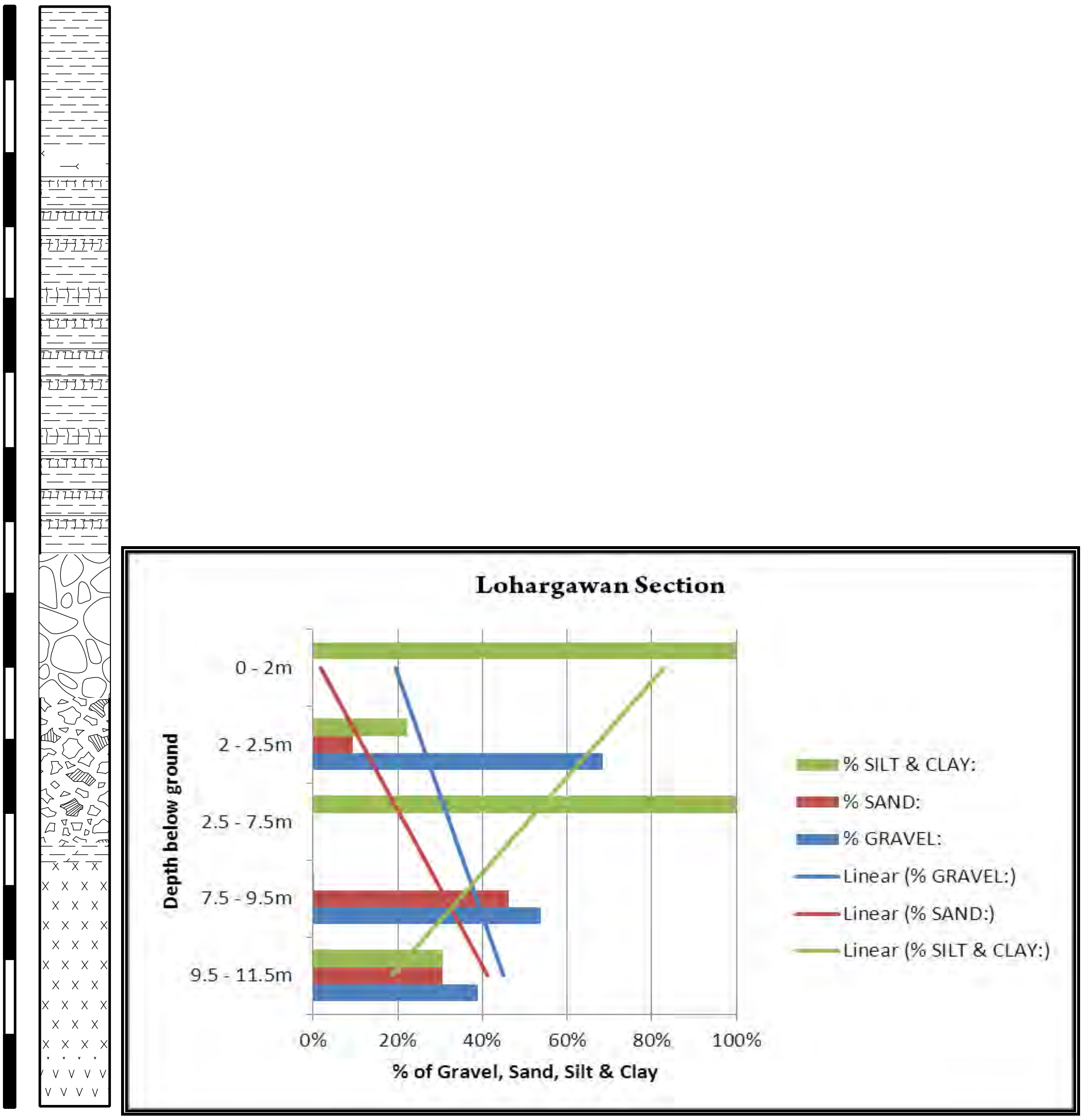


Fig. 2.34: Stratigraphic Section and Granulometry at Lohargawan

Fig. 2.35: Section at Lohargawan, Jhansi

Fig. 2.36: Gravel at Lohargawan yielding a lone trihedral handaxe

Fig. 2.37: Trihedral handaxe from Lohargawan

2.5.4 THE MARGINAL ALLUVIAL PLAIN

The Betwa River has its source in the Central Indian craton and it joins the plains south of the axial Yamuna River following a north to northeast trend. Near its confluence with the Yamuna, the piedmont gives way to the Marginal Alluvial Plain north of 25° 30'. It exhibits an undulating topography with ravines resulting from gully erosion acting as drainage divide. Its average elevation is 150 m and extends for about 110 km with an average slope of 2°.

Information about this area is mainly gathered through study of cliff sections in the rivers and ravines and sub-surface stratigraphy (Mukherji 1963, Sastri *et al.* 1971, Rao 1973, Joshi and Bhartiya 1991, Sinha 1995, Singh 1996, Bajpai 1989, Singh and Bajpai 1989, Sinha *et al.* 2002, 2005, Srivastava *et al.* 2003, Gibling *et al.* 2005, Tandon *et al.* 2006, Yadav *et al.* 2010).

This geomorphic region consisting mainly of craton derived sediments is mostly classified with Older Alluvium or Bhangar (Oldham 1917, Pascoe 1950) surface of the Ganga basin. It is contemporary to the T2 surface of the northern Ganga Plain (Singh 1996). It is equivalent to the Upper Siwalik and is made up of Lower Pleistocene sediments. This surface was a result of the Himalayan Orogeny – 4.

This area is characterized by entrenched meandering or ephemeral NE-flowing gravelly to coarse sandy rivers. The valleys are narrow, deeply incised while the interfluves are broad exhibiting lakes, eolian deposits, gullying and ravine development (Pascoe 1950, Gibling *et al.* 2005).

Singh (1996) considers climate change, base level change and neotectonics as the prime riders.

Many studies have noted evidence for neotectonics in the cratonic peripheral bulge (Singh and Rastogi 1973, Singh and Bajpai 1989, Bajpai 1989, Mohindra *et al.* 1992, Mohindra and Prakash 1994, Singh and Ghosh 1994, Srivastava *et al.* 1994, Mishra *et al.* 1994, Kumar *et al.* 1996, Singh 1996, 1999, 2001, Singh *et al.* 1996, Parkash *et al.* 2000, Agarwal *et al.* 2002, Sinha *et al.* 2005, Gibling *et al.* 2005).

Agarwal *et al.* (2002) found evidence of extensional tectonics in the form of W-E lineaments, normal fault and graben-like features in the northern part and SW-NE trending southern part shows channel incision, conjugate fractures, bending, tilting, updoming of sediment deposit and triangular facets in cliff section.

Major Late Quaternary tectonic events identified in the area include 45 ka BP seismic event in the Kalpi section (Singh *et al.* 1999, Singh 2001); and a Middle Holocene (8-5 ka BP) event causing channel disruption and upwarping and siltation of ponds (Srivastava *et al.* 2000, 2003, Singh 2001, 2002). Besides tilting of alluvial surfaces have been documented using DEMs in north Bihar (Jain and Sinha 2005).

Sastri *et al.* (1971) and Rao (1973) studied the basement structure of the Ganga Plain noting many basement highs and lows and basement lineaments which have controlled the thickness of the alluvial fill (Bajpai 1989, Singh 1996, 1999) and river channel behaviour (Singh 2001). The Bundelkhand Massif continues as basement high between Kanpur and Allahabad in NE direction as Faizabad Ridge. Vertical uplift in this area is indicated by narrow valleys and meandering Ganga River, and incision and gullying in the Gomati and Sai Rivers and their interfluves (Singh 1996).

Neotectonic activity is in the form of reactivation of basement lineaments (SW-NE) and block vertical uplift on the regional scale. The response to neotectonic activity has generally been vertical incision, lateral migration, channel disruption and avulsion and net accretion of sediments in the peripheral bulge region (Singh 1996, Srivastava *et al.* 2003).

Tandon (2008) however argues to the contrary that minimal tectonic activity has only led to creation of accommodation space through modest subsidence at the southern margin. They attribute the strong incised valleys to climatic factors.

The basin is actively subsiding as a response to ongoing shift of the Indian plate towards the Asian plate and Himalayan orogeny. Subsurface data shows increasing depth of alluvium towards the Ganga plain, recording subsidence of ~150 m below land surface at Hamirpur. The process started during the Early Miocene

(Singh 1996). Subsurface data also suggests that the Ganga plain foreland basin has substantially migrated cratonward during the Middle Miocene to Middle Pleistocene (Lower to Upper Siwalik). Cratonic 'Betwa' sands have been identified below Himalayan sourced mica-rich sediments in borehole logs by Sinha *et al.* (2005) near Kalpi and Bhognipur between 35-43 m depth, and also by Bajpai and Kumar (1988) and Singh and Bajpai (1989) as far north as the present channel of the Ganga River near Kanpur. Singh and Bajpai (1989) note that the Ganga basin expanded southward by ~100 km in the Kanpur–Hamirpur region since the Middle Pleistocene. This was due to the last major tectonic event leading to uplift of the Upper Siwaliks by ~2000 m that took place ~500 ka (Singh and Bajpai 1989; Singh 1999). The feldspathic sand from Unit 1 of Kalpi section gave a date of 119 ka (Gibling *et al*. 2005).

Singh *et al.* (2003) suggested very high sediment accumulation rates in excess of downflexing of the crust beneath the plain leading to rapid syndepositional subsidence (10 mm/yr). This was based on two OSL dates of 32.8 ± 6 ka and 31 ± 6 ka separated by ~150 m sediment from a 350 m deep core near Meerut. Bulandshahr core also gave OSL ages of 49.2 ± 11.3 ka and 37.4 ± 6 ka from 259-190 m and 197-193 m depths. On this basis Singh (1996) opined that the basin is in a mature stage of evolution, with excessive sediment supply and underfilled condition, building to 300 - 50 m above sea-level, exclusively by fluvial processes.

Tandon *et al.* (2006) however used data from Kalpi to estimate a long-term (over ~100 ka) accumulation rate of about 0.25 mm/yr for the southern margin of the Ganga Plains. Lower average sedimentation rates were also suggested in the highly aggrading north Bihar plains ranging from 0.7-1.5 mm/yr over 10^3 year time scale (Sinha *et al.* 1996), and 0.2 mm/yr in the eastern UP plains (Joshi and Bhartiya 1991).

Yadav *et al.* (2010) inferred shallow sub-surface stratigraphy in the interfluve areas between the Yamuna and Betwa rivers in the western plains using Vertical Electric Sounding (VES) showing vertical extension of the valley fills and interfluve sequences down to~100 m (~200 ka).

It has been proposed that since the Ganga basin drains into the sea, developing a graded longitudinal profile with low altitude, it is therefore affected by base-level changes. (Kumar and Singh 1978, Singh and Bajpai 1989, Singh *et al*. 1990, Singh 1996, Singh *et al*. 1999) However Tandon (2008) notes that the upper and middle Ganga Plains are located ~1500 km and ~800 km respectively from the sea, while the landward limit of influence of sea level changes for low-gradient, high sediment supply systems like the Ganga may not be more than 300-400 km, thus ruling out any influence of base level changes.

The sediments comprise clay-*kankar*, silt with intercalations of sand and gravel lenses of varying thickness. The thickness of the sediments varies from 50 – 150 m. The strata as indicated by numerous dug-wells in the area consists of top soil and clays, brown to grey, with abundant calcareous nodules followed by white mottled clay with quartz grains and rock pieces. In some cases partly weathered granite has been encountered. At Musaoli the strata reported from small borings constitutes mainly of clay with *kankar* followed by coarse-grained granular material (pink sand).

The thickness of alluvium generally increases towards the north in this region of Baragaon-Chirgaon-Moth and partly in Gursarai-Mau areas. The maximum thickness of alluvium is 158 m reported at Jhalokhar (25° 57' 40" N, 80° 01' 10" E) in District Hamirpur (CGWB: 2000). The top clay layer has a thickness of 10 – 35 m and persists in the region.

Stratigraphic discontinuities have been noted in the upland interfluve areas manifested as pedogenic development, erosional surfaces or strong lithological contrasts as in the 29 m Kotra cliff section along the Betwa River (Sinha *et al.* 2005). These suggest repeated cycles of floodplain aggradation and degradation as a result of climatic fluctuations during the last 30-40 ka (Gibling *et al*. 2005).

Singh (1996) related the geomorphic surfaces to climate cycles of the late Pleistocene-Holocene based on hierarchy, incision and nature of deposit. Kumar *et al.* (1996) on the other hand proposed that the Banda Older Alluvium (Marginal Plain Upland Surface) is Early to Late Pleistocene (Middle Siwalik) and the Varanasi Older Alluvium (Upland Interfluve Surface) as Middle-Late Pleistocene in age. Srivastava *et al.* (2003) dated the Marginal Plain Upland Surface (MP) to 128-74 ka BP (OIS 5), luminescence age of upper part coming to 76-32 ka BP. At Kalpi, a 33 m cliff section along the Yamuna River revealed human occupation around ~30 ka (Singh *et al.* 1999). The dates ranged from 35.8 ± 4.1 ka near the top to 119.2 ± 12 ka near the base. The 20 m Muhana section on the banks of Betwa River was dated to 63 ± 12 ka at its base and 48 ± 7 ka few meters below the top. Dating of the Dhasan Section gave ages of 69 ± 12 ka in the middle part and 49 ± 9 ka near the top.

Yadav *et al.* (2010) report that present valley-interfluve configuration goes back to more than 200 ka.

Presence of cratonic sediments in the Ganga-Yamuna interfluve right upto Kanpur, high sediment accumulation rates and evidence of neotectonics has implications for understanding the archaeological record in the area.

2.5.4.1 Consequences of Himalayan Orogeny

Northward migration of the Indian plate towards the Asian plate began in the Mesoproterozoic around 2000 Ma and continued up to the Quaternary. The drift of the Indian plate is still continuing. Initially there were shifts in the northward migration, but after around 36 Ma India resumed a stable northward progression with a constant rate of 5 cm a-1 (Searle *et al.* 2011, 1998). Dewey *et al.* (1989, 1988) have suggested that the northern margin of the Indian plate was greater than 1000 km south of the southern margin at 70 Ma.

Earlier it was thought that the Vindhyan and Aravalli orogenic belts have nothing to do with the Himalaya. However, ONGC drillings and geophysical data show that the Aravalli, Vidhayan and Faizabad ridges extend into the Himalaya (Sastri *et al.* 1971).

The last phase of Himalayan Orogeny took place during the Middle Pleistocene. The Himalayas, the Indo-Gangetic Plain and the Peninsular India are still undergoing crustal adjustments due to thrustfold loading of the Indian plate against the Asian plate.

The peripheral bulge of the southern Gangetic plain has been tectonically active causing deep incision of rivers and a 40 ka seismic crust (Agarwal *et al.* 2002).

With the Himalayan orogeny the Bundelkhand shield sagged resulting in a depression which became the site of future sedimentation. With the collision of the India–Asia plate still continuing, the region is still witnessing tectonics induced changes.

2.6 SUMMARY

Geoarchaeological observations through the Betwa basin with special focus on the Lalitpur Upland from upstream to downstream coupled with RS & GIS show that:

- Lithology has a great influence on drainage development.
- The basin has moderate to low relief with a mature dissected drainage.
- However, morphometry rules out major neotectonics in the area.

- But thick alluvial cover right at the divide near Tikoda (20 m) (Ota *et al.* 2012) which decreases to 2 m near Sanchi and 0.5 m near Lalitpur indicates subsidence.
- Subsidence and great depths of alluvium in the Marginal Alluvial Plain may account for the lack of early sites in the region. In this context presence of cratonic sediments in the Ganga - Yamuna interfluve right upto Kanpur, high sediment accumulation rates and evidence of neotectonics in the region has implications for understanding the archaeological record.
- However the discovery of a single trihedral handaxe from the northernmost limit of the Jhansi Upland beyond which lies the thick alluvial plain is significant. Since the region lies on the cratonic boundary, the northward shift of the Indian plate has consequences for the Quaternary archaeological record of the region. Himalayan orogeny leads to sagging of the Bundelkhand shield and consequent sedimentation and subsidence. This may be taken to imply that the landscape of this region may have been quite different in Acheulean times.
- Presence of laterite in the valleys below Pleistocene sediments is interesting as most Acheulean sites in India are associated with laterites or ferricretes.
- During the course of geoarchaeological explorations in the area, a number of microlithic and few Middle Palaeolithic artefact occurrences were discovered in cemented or cobbly-pebbly gravel in the river sections near Korwai and Sagar on the Bina, Dhasan and Betwa Rivers. Microlithic artefacts including quartzite flakes, blades on quartz, chert and chalcedony, and rock nodules are found from erosion gullies at Kethora. Artefact size, broad typo-technology and nature of the sediments indicate an early age, probably in the Late Pleistocene. In the Lalitpur Upland also besides well exposed Acheulean horizons, we also find microliths on the slopes of small granite hillocks near streams at Durjanpur and Naigaon; from erosional gullies at Burwar; or in reddish or brown clay sediments exposed on the surface at Patora Kalan.
- It is mostly an erosional landscape.
- This has implications for the survival and exposure of the archaeological record. Many surface scatters of Lower Palaeolithic artefacts in the Malwa – Vindhyan Plateau and Lalitpur Upland have been noted both by previous workers and in this study. These artefacts are actually recently getting eroded from the underlying sediments.

CHAPTER III

THE ACHEULEAN AT LALITPUR: SITE CONTEXT AND FORMATION PROCESSES

3.1 INTRODUCTION

Previous surveys in and around Lalitpur had produced artefacts that were assigned to the Early Acheulean phase in India. The Acheulean site at Lalitpur was discovered by Singh (1965). Here Singh recovered artefacts from six localities on the Biana Nullah, the Chhatrapal temple site and from the conglomerate in the Shahzad River section. Surveys of Singh (*IAR* 1959-60, 1960-61) and Joshi (*IAR* 1961-62, 1963-64) show that the Acheulean horizon is extensively exposed in the upland areas of Lalitpur on the interfluves between the Betwa and the Shahzad.

The Acheulean industry at Lalitpur was later excavated by Singh (*IAR* 1961-62) and then by Joshi (*IAR* 1963-64). It is one of the few excavated Acheulean assemblages in India. It was excavated in the early 1960's. It was also considered one of the few open-air 'primary' sites in the country. However, apart from the preliminary studies carried by Singh (1965), no detailed reports have been published about the nature of the site and its assemblage. Joshi carried out extensive surveys in the area, but no reports were published for his researches. In this light, the industry at Lalitpur was found to hold immense potential for restudy, both in terms of its potential for shedding light on the tool technology employed by the hominin tool makers as well as for its potential for informing on the site formation processes operating in 'stable' upland open air archaeological sites. In the light of researches being carried out in World prehistory and recent advances in Indian prehistory, and the Early to Middle Pleistocene in particular, the restudy of the Acheulean horizon at Lalitpur becomes even more interesting. This restudy has revealed many new aspects in the Indian Acheulean. It has contributed to redefining the nature of Early Acheulean in India as well as distinguishing it from Late Acheulean/Middle Palaeolithic.

3.2 DISCOVERY OF THE SITE

The Acheulean site of Lalitpur (78^0 30'E and 24^{0}45' N) is located close to the Biana Nullah, a first order stream draining into the Shahzad Nadi, a tributary of the Betwa River. The site of Lalitpur is situated close to the main town of Lalitpur in Uttar Pradesh. It was discovered by Singh in December 1960 while making a careful exploration of northern Bundelkhand region (*IAR* 1959-60: 21-22; 1960-61: 35). The tools were found exposed on the surface or buried beneath the soil. It may be mentioned here that Klaus Bruhn had earlier reported discovery of tools of Series I and II from Lalitpur (*IAR* 1956-57: 79).

The tools were first found scattered on the streets of Dhaura, a small village situated near the contact of the Bundelkhand Granitic Complex with the Vindhyan Escarpment. Here the Betwa River flows about four miles south and the Naraini River, a tributary of the Betwa flows two miles east in a north south direction. The tools were found in the thin forest to the south and east of the village away from the river. Singh collected about 30 tools consisting of handaxes, cleavers, choppers, scrapers, discs and flakes on local sandstone. He observed that the tools were getting exposed because of the erosion of the soil in which the tools were buried.

The next discoveries of tools belonging to the Acheulean culture were made in the Biana Nullah, a tributary of the Shahzad Nadi. The Biana Nullah is an ephemeral stream originating near a lake called the 'Semri Tal'. It flows from near the divide between the Betwa River and the Shahzad Nadi. The surface has a low relief here, of the order of 20 m. After flowing for about six miles in a west-east direction it meets the Shahzad Nadi. The tools were found clustered at six different localities in the cultivated fields within a stretch of about a kilometre. Out of these five localities were situated to the right of the river while one was to the left. The localities are close but away from the riverbank. The area is a plain ground, partly wasteland, partly under cultivation.

These localities are situated about half a mile from the Old Railway Bridge on the left of the Old Chanderi Road between the villages of Siddhapura and Patora Kalan (henceforth referred to as LPR I, Localities Bn 1 to Bn 6).

Besides tools were also found near the Chhatarpal Temple (henceforth referred to as LPR II) and embedded in the conglomerate of the Shahzad Nadi (henceforth referred to as LPR III). Few off-site scatters of tools were also found at Burwar and Barod.

The sites are located in the Bundelkhand granite and Vindhyan sandstone region. They are found as scatters or clusters on or below the surface, in the loose river gravel or embedded in the basal conglomerate.

Joshi also explored the area between Deogarh to Moth and discovered six Series II sites (1959-60: 46-47).

Singh carried out a small-scale excavation at Locality I lying about 200 m away from Biana Nullah (*IAR* 1961-62, 1965). Later Joshi also undertook an excavation at the site (*IAR* 1963-64).

3.2.1 Excavation by Deccan College

Deccan College carried out excavation at two localities under Sankalia (*IAR* 1961-62: 57). At LPR I, Locality 1 the tools are getting exposed from an erosion gully on the edge of a cultivated field about 1.6 km NW of Lalitpur town and 200 m from the Biana Nullah. The excavation at LPR I, locality 1 yielded 1048 specimens from a trench measuring 7 x 3.5 m indicating a fairly high artefact density. The excavations revealed artefacts occurring sandwiched as a thin rubble layer of 30 cm between weathered bedrock and brown soil deposit of 15 cm. The rubble layer consisted of quartz and granite fragments, quartzite pebbles, laterite nodules, finished and unfinished tools and debitage in a sandy matrix. The weathered saprolite contained pockets of kaolin.

Singh (1965) took trial trenches at three other locations and observed that the tools were lying '*in situ*' below the soil and were gradually being exposed due to tilling and erosion. In the well behind the Chhatrapal temple there is a black soil layer between the artefact horizon and the top soil.

The classified artefacts included 65 handaxes, 49 cleavers, 43 cores, 410 rounded pebbles, 270 angular fragments, 18 worked pebbles, and 723 waste flakes. Because of the presence of a high number of waste flakes, freshness of the artefacts and little signs of transportation, it was considered as a factory site (*IAR* 1961-62: 57).

However Singh (1965) notes the following artefact inventory of a total 1048 pieces from the excavation: 43 unifacial handaxes, 48 bifacial handaxes, 47 prepared flakes for handaxes, 21 cleavers, 51 prepared flakes for cleavers, 25 large cores, 14 small cores, 16 core-flakes, 211 large flakes, 186 small flakes, 34 angular fragments and 340 chips. Singh (1965) notes that the quartz fragments, small quartzite pebbles and many chips were discarded, and were not included in the final artefact inventory.

3.2.2 Excavation by Prehistory Branch, ASI

The Prehistory Branch of the Survey conducted excavation at some of the localities near Lalitpur under the direction of Joshi (*IAR* 1963-64: 49-51) to trace the extent and richness of the artefact horizon.

The excavation at LPR II (Chhatrapal Temple area) revealed a disturbed artefact horizon without any factory debris with only three quartzite artefacts recovered in the excavation.

At LPR I, locality 2, the tools were found in a cultivated field on the left bank of a small tributary stream of the Biana Nullah. The locality lay at the eastern upper slope of the Betwa terrace lying at an elevation of 381 m. They occur on or underneath black soil in a thin kankar bed mixed with brownish earth and sub-rounded gravel. The artefacts are exposed on or near the surface. The artefacts were made predominantly on granite, with few on quartzite, sandstone and quartz.

A trench measuring 2 X 2 m was excavated on the right bank of the Biana Nullah revealing the following sequence from bottom upwards:

1. Bedrock at a depth of 70 cm
2. Compact, reddish–yellow soil, yielding microliths
3. Slightly compact reddish brown soil, also yielding microliths; and
4. Slightly loose reddish humic soil as the top layer

The western slope of this terrace towards the Betwa was marked predominantly by quartzite artefacts while on the eastern slope granite artefacts were more common.

3.3 REVIEW OF STUDIES OF LITHIC TECHNOLOGY AT LALITPUR

Though no detailed studies have been undertaken of the technological strategies utilized at Lalitpur by the Acheulean toolmakers, but preliminary analysis of the typology was made by Singh (1965) along with some remarks on the technology of manufacture. Jayaswal (1978) also analysed tools from the collection at

Lalitpur while carrying out an extensive study of Indian Palaeolithic typo-technology. Some others (Pappu 2001) have also remarked on the nature of the Lalitpur assemblage.

3.3.1 Singh (1965)

1. The main tool types are handaxes and cleavers made on side or end flakes.
2. Most of the tools are made on granite, though few tools are also made on sandstone and quartzite pebbles and quartz.
3. The handaxes and cleavers were found in different 'stages of manufacture' at Locality 5. He divided them into three 'groups' according to the stage of manufacture.
    a. Group I included unfinished tools in the first stage of manufacture where the flakes were detached from the core by direct hammer percussion. The flake scars were large, bold and deep and no attempt was made to make the outline regular or the body symmetrical by secondary flaking. He included 11 handaxes on side and end struck flakes, 3 cleavers and large number of large flakes in this group. However, the flakes from this group were not collected.
    b. Group II included tools where secondary flaking was done to make the outline regular and the body symmetrical though the tools are not completely finished. Besides, direct hammer percussion, soft hammer was also used for resolved flaking. This group included 43 handaxes, 26 cleavers, 6 scrapers and 10 large flakes.
    c. Group III included refined tools with symmetrical body and regular outline. In this group he included 10 handaxes and 11 cleavers.
4. The bifaces were associated with factory debris at Locality No. 1.
5. The finished handaxes were found scattered at the habitation site while the cleavers were found three to four miles away from the site.
6. Singh made a comparison of the surface collection with the tools from the excavation and drew the conclusion that refined bifaces were more in the surface collection. On this basis he said that finished bifaces were taken away from the site of manufacture at the locality of excavation.

3.3.2 Jayaswal (1978)

Jayaswal (1978) in her study of the prepared core technique in Indian Palaeolithic analysed the collection of 606 artefacts from Lalitpur. She had grouped the artefacts from different sites into three typological units.

Group I or Chopper-Chopping and Handaxe-Cleaver Group consisting of chopper – chopping tools with small proportion of handaxes and cleavers. She included the sites of Bariarpur, Mahadev Piparia and Vadamanu in this group;

Group II or Cleaver Group in which there was a marked increase in the proportion of cleavers. Handaxes are found in considerable proportion, chopper – chopping tools and bifaces constitute a small proportion, and scrapers and pebbles are almost absent.

Group III or Handaxe Cleaver Group where handaxes dominate, while cleavers are found in low proportion. There is a considerable frequency of scrapers made on pebbles. In this group she included the sites of Vadamadurai and Gudiam.

The artefacts from Lalitpur along with Chirki were grouped in Group II or Cleaver group.

In her analysis she found the percentage of finished tools as 56.6%, cores 8.3%, blanks 63.2% and diverses 5.5%. She found that there were a large number of finished tools made on cores. Proportion of tools made on cores and flakes is 1.06: 1.00. Cleavers are the more numerous than handaxes. Handaxes are more often made on cores, than on flakes, the ratio being 1.8: 1. Cleavers are made more on flakes, the ratio being 1:17.6. A very small percentage of the pebble tool element is also present along with few side-scrapers, but no points and end-scrapers.

She classified 45 artefacts as cores. Most cores are irregular. Prepared flakes are dominant. She observed that the technologically highly developed Levallois element is present in good proportion, 15.5%. Levallois points though rare in Indian Palaeolithic are present. Mousterian and blade detaching techniques are also present. Angle variation of flakes is not much. Flake element is 63.2%, blade < 10%, and Levallois point < 2%. Few blades are present but there are no blade cores. She also notes the lack of correspondence between the scars on cores and the flakes.

3.3.3 Misra (1978)

Misra (1978b: 93) while comparing the Acheulean levels at Bhimbetka with other Acheulean industries in India notes that at Lalitpur:

"In a collection of 1048 artifacts 40 (3.82%) are made on quartzite pebbles and the remainder on granite and quartz blocks quarried from exposed rocks. Finished tools account for less than 12% of the collection. Among the finished tools, 91% are bifaces, while scrapers constitute less than 2%. The ratio of handaxes to cleavers is 4:1. From the description it appears that most of the handaxes and cleavers are made on end-struck flakes. Of the 88 handaxes, 36 are worked only on one face. Cleavers are rarely worked on the ventral face. The near absence of retouched flake tools is probably due to some extent to the difficulty of executing retouch on coarse-grained rocks like granite and quartz. Among 497 large flakes, 47 (9.46%) are described as prepared flakes for handaxes and 51 (10.26%) as prepared flakes for cleavers.

The Lalitpur industry presents a marked contrast to Bhimbetka IIIF-23 industry. In the latter bifaces account for only 14.68% of the finished tools against 90.91% in Lalitpur and scrapers and other non-biface tools account for 85.32% against 9.09 in Lalitpur. The ratio of handaxes to cleavers at Bhimbetka is 1:3 against 4:1 at Lalitpur. The complete absence of Levallois flakes, blades, end scrapers, knives, denticulates, notches and truncated flakes at Lalitpur is another significant feature. The Lalitpur industry therefore represents a typologically and technologically different and much earlier stage of Acheulian tradition than the Bhimbetka industry."

A brief mention is made by Pappu (2001) while reviewing the Indian Acheulean, and he writes that only 12% are finished tools, such as handaxes, cleavers, scrapers and pebble tools. Tools are mostly made on flakes by Vaal technique. He classifies the Lalitpur tools as Early Acheulean along with Chirki.

3.4 NEED FOR RESTUDY OF THE LALITPUR ASSEMBLAGE

While exploring the Betwa basin for prehistoric sites it was realized that the site of Lalitpur can yield important insights about early hominin behaviour patterns and therefore any study of Lower Palaeolithic in this area cannot be conducted without taking into account this site. Therefore it was decided to restudy the site of Lalitpur both in terms of site context and lithic technology.

Singh's collection of artefacts, collected by him in the late 1950s and early 1960s from different localities near Lalitpur was taken up for study. The collection of artefacts is presently conserved in the Deccan College Museum, Pune. This includes both surface collection and artefacts from excavation conducted by Singh at Locality 1 lying about 200 m. away from the Biana Nullah at LPR I.

The artefacts studied come from:

- LPR I: six localities identified on both the banks of the Biana Nullah and numbered as Bn 1 to 6; and
- LPR II – ground to the east of Chhatrapal temple in Lalitpur town.

Lalitpur is one of the few excavated Acheulean sites in India. Though the site was excavated in late 1950s and the excavation method and recording procedures were not methodical and scientific. The context of material retrieved from excavation has not been recorded well. Still the collection is quite intact. Singh reports 1048 artefacts from the excavation. Out of these 825 artefacts were available at the time of study. The missing pieces are most probably chips which were discarded and not stored. This means that the remaining collection is still quite informative. The collection comprises handaxes, cleavers, flakes, cores and fragments and does not seem to be selective or arbitrary and biased in favour of any specific type. Though the collection is from a surface site, it is quite representative of the original industry. On the basis of the study of the state of preservation and physical condition of the artefacts also it can be said that they are from a single assemblage.

Singh had studied the typology of the tools and made some remarks on the technique of manufacture. However, no detailed study of the tool typology and technology has been made, except a small study by Jayaswal (1978) mentioned above. In the light of recent advances made in the field of lithic technology, a restudy of the assemblage was imperative.

Arguments have been made that surface sites suffer from lack of chronological control, are highly influenced by both anthropogenic and geogenic processes and therefore disturbed and mixed. Hence it has been assumed that they are unrepresentative and therefore not fruitful for throwing light on the cultures. However, looking at the assemblage and site context of Lalitpur it can be said that that there is probably no such thing as a surface site when we are talking about the Indian Lower Palaeolithic (Mishra *et al.* 2012). At most 'surface sites' including Lalitpur, Hunsgi-Baichbal basin (Paddayya 1982, 2008, see also Straus 1983, Paddayya and Petraglia 1993, 1995, Jhaldiyal 1997, 2006) and Raisen Complex (Mishra *et al.* 2012, Ota and Deo 2014, Ota *et al.* 2012) the artefacts are only recently getting exposed onto the surface. The fresh nature of the artefacts and artefact category ratios point towards assemblage integrity. It also shows that the artefact horizon is not much disturbed. The major process affecting artefacts at Lalitpur has only been weathering and not fluvial transport. Further homogeneity in the state of preservation, particularly in the degree of weathering and patination also point towards a single assemblage. Therefore, sites like Lalitpur can yield significant information about the technological strategies employed, even though chronological control is lacking. When the sedimentary context is disturbed, artefact attributes and their spatial distribution in the landscape become all the more significant for inferring hominin behaviour (Lewarch and O'Brien 1981, Jacobson 1985).

3.5 GEOARCHAEOLOGICAL CONTEXT OF THE SITE

The area around the prehistoric site of Lalitpur was explored to study the archaeological context of the sites in the region, in particular the site formation processes responsible for assemblage formation and preservation.

Several sections of the Biana Nullah, a tributary of the Shahzad River in Lalitpur as well as the Shahzad and Betwa Rivers around the site of Lalitpur were visited to understand the geomorphic processes shaping the past landscape. Besides explorations in the Sajnam and Jamni Rivers, Malwa-Vindhyan Plateau region and Jhansi Upland also helped in understanding the geomorphic context at Lalitpur.

This included documentation and description in the field of sedimentary deposits and their vertical and lateral variations, along with their relationships to archaeological occurrences; sedimentology of archaeological deposits and associated sediments to reconstruct site formation and disturbance by geological processes;

Focus was to understand the various natural and anthropogenic formation processes operating at the site of Lalitpur. With this aim in mind, a study of the site stratigraphy, sedimentology, coarse clast analysis and artefact taphonomy was undertaken. It helped in assessing site integrity and the conditions responsible for the burial and re-exposure of the archaeological record and the nature and degree of geological disturbance underwent.

3.5.1 LPR I

3.5.1.1 Topographic Context

At LPR I on the Biana Nullah, a tributary of the Shahzad River in Lalitpur Acheulean assemblages are found mainly clustered in six localities in cultivated and waste lands in a stretch of about a kilometre. They are located away from alluvial settings along rivers or major sources of aggradation and degradation (Figs. 3.1 & 3.2).

The sites are located on the interfluve between the Betwa and Shahzad Rivers in the Lalitpur granitic upland (Fig. 3.4). The landscape around the site is marked by undulating topography and dotted by granite tors, inselbergs and low hillocks. Seasonal rivulets dissect the area.

The transverse profile drawn (Fig. 3.3) from Chanderi to Sajnam River near Lalitpur across the Acheulean localities shows that the sites are located on the pediplain at elevations of 356 to 368 m on the east facing slopes. The area has an average slope of ~ 1° (Fig. 3.5). Quite interestingly, the tributaries have eroded to a lower elevation than the Betwa River. This may explain the preservation of Acheulean sites in the area.

The landscape is underlain by acid intrusive igneous – metamorphic outcrops of Bundelkhand granite-gneiss (Fig. 3.7) with weathering resistant quartz rich dikes and veins. It is very near to the junction of the Vindhyan Escarpment - Bundelkhand Granite Massif.

The assemblages consist of large concentrations of several thousand artefacts distributed over a large area of 100 – 200 m. Along with this few non-sites were also reported by Singh (1965) in the form of 1-3 artefacts scattered near these large sites.

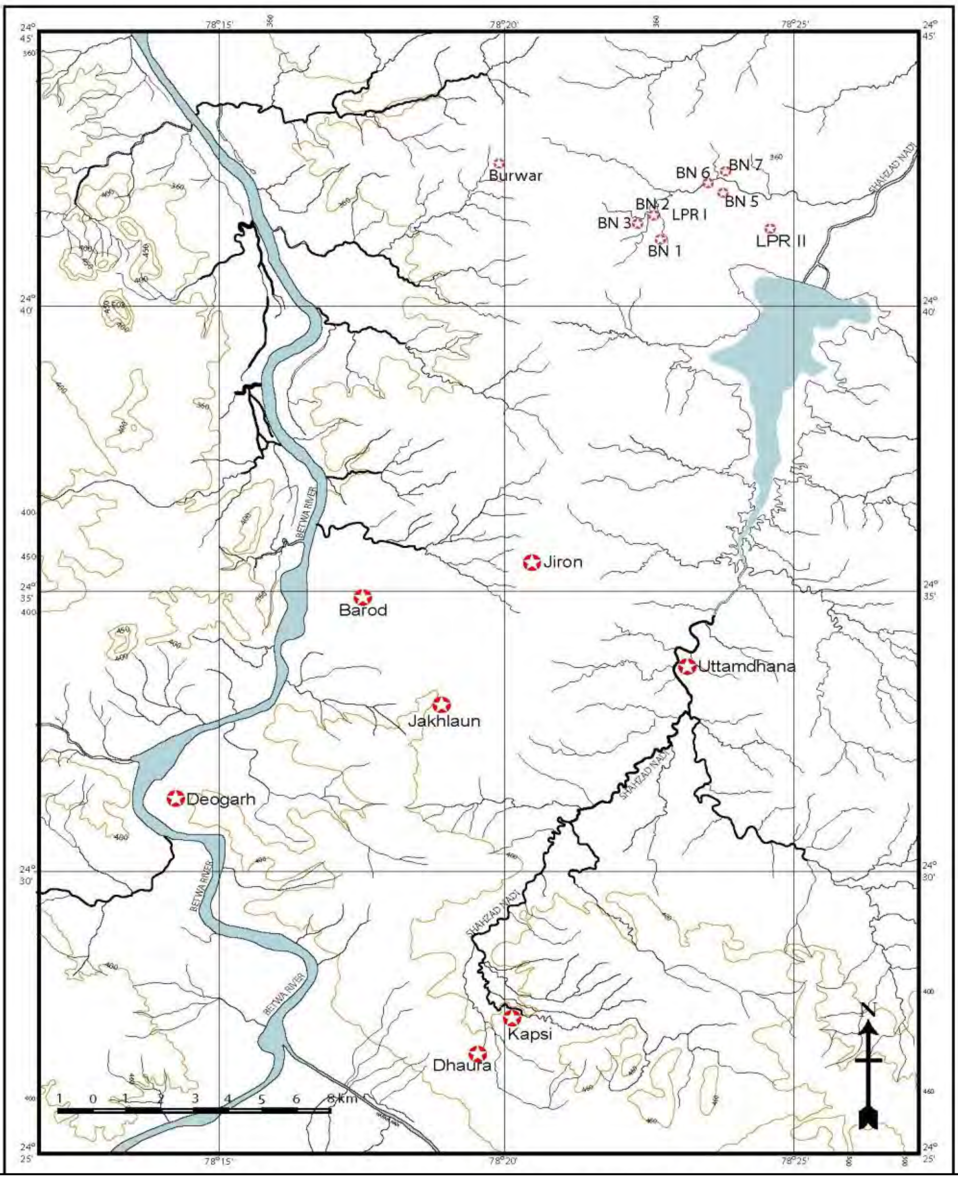


Fig. 3.1: Map of the region around Lalitpur showing explored sites and sections

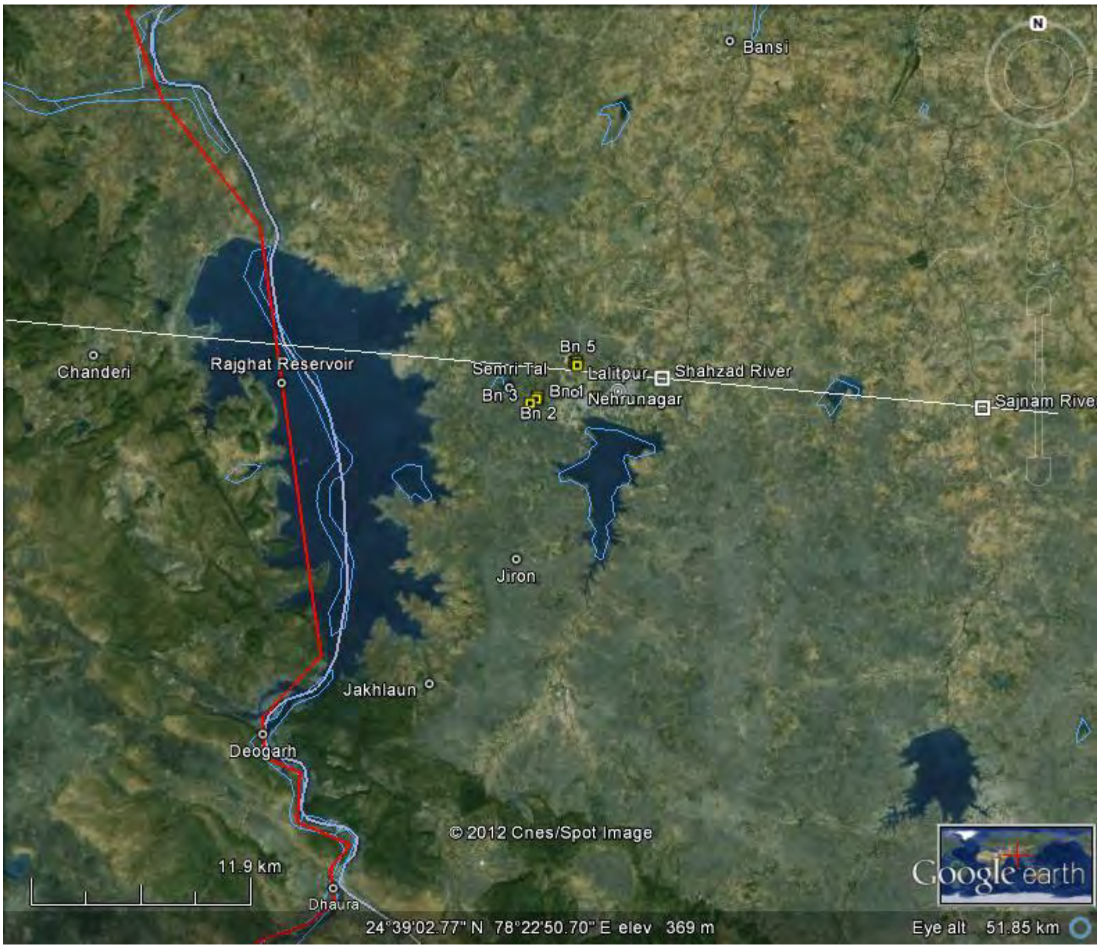


Fig. 3.2 Google Earth Image of the area near Lalitpur town showing the Acheulean sites (The white line depicts the area of the transverse profile shown below.)

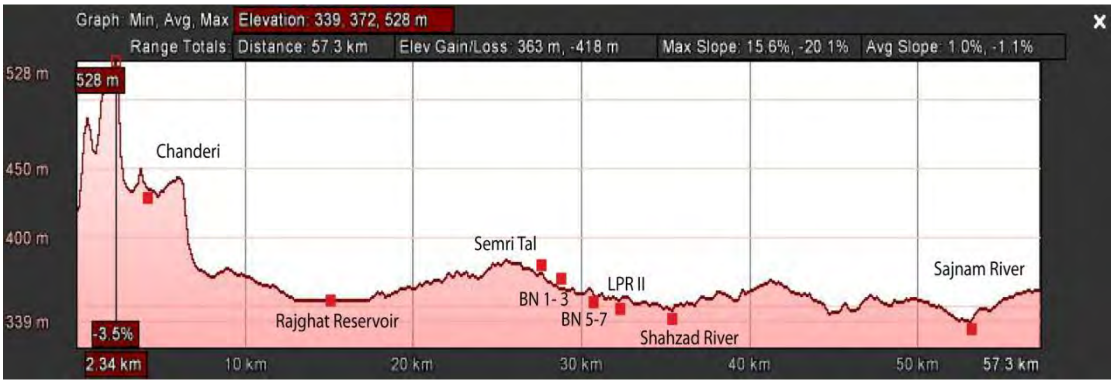


Fig. 3.3: Transverse Profile from Chanderi to Sajnam River, Lalitpur

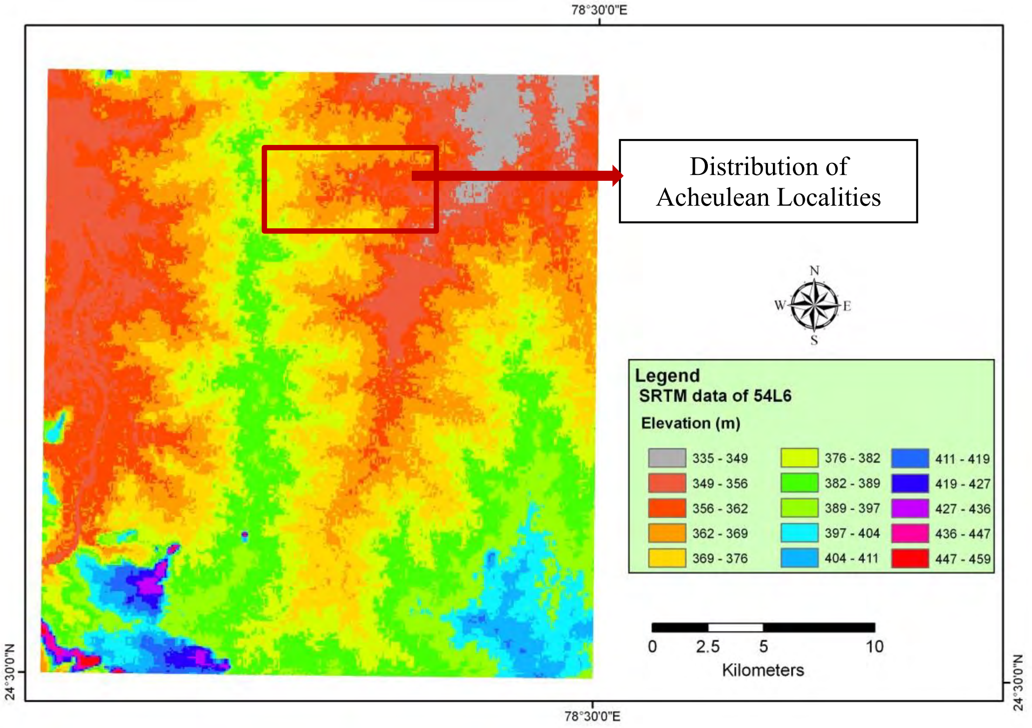


Fig. 3.4: Digital Elevation Model of SOI Grid 54L/6

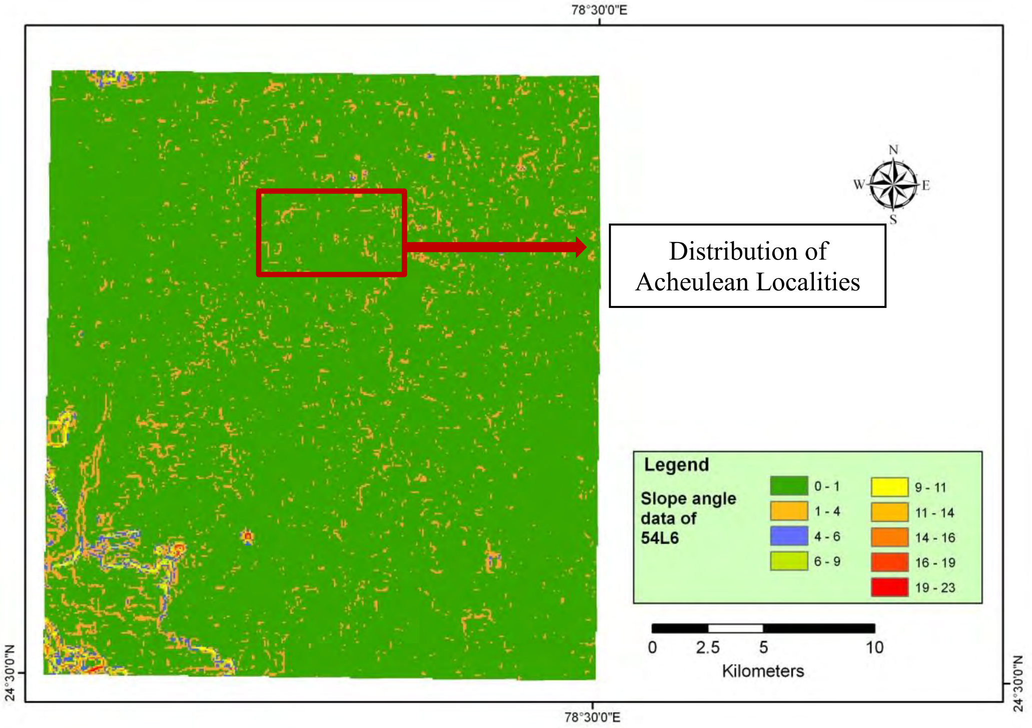


Fig. 3.5: Slope Map of SOI Grid 54L/6

3.5.1.2 Sedimentary Context

Localities Bn1 – 3

At Localities 1-3 near Patora Kalan, the Acheulean horizon appears to be disturbed. The artefacts are found exposed in the ploughed fields, with the enclosing matrix completely washed away (Figs. 3.8 – 3.11).

Wells in the area show mostly weathered granite (regolith) varying in thickness from 2 – 4 m capped by 20 cm to 2 m of silt. It is underlain by granitic basement rock.

The quarry section reveals regolith nearly 1m in thickness which is overlain by 0.5 m of red sand. It is capped by soil cover of 15 – 20 cm.

At locality 3, pits dug near the fields show brown highly compact clayey silt nearly 1 m in thickness with kankar nodules 3 – 4 cm in size. It is capped by soil cover of 30 cm.

At locality 3 the artefacts were found above a layer of weathered calcretised whitish deposit of kaolin formed from the basal weathering of granite. Calcrete rootcasts and nodules are present in the deposit. The artefact layer is mixed with kankar nodules, quartz and granite fragments and quartzite cobbles.

LPR I, Locality Bn 5

At Locality Bn 5 near Siddhapura on the Biana Nullah (Fig. 3.12), a large number of Acheulean artefacts are exposed on the surface. Locality 5 is about 150 m west from the old railway bridge. The site locality is 40x40 m in plan (Fig. 3.13).

A ditch was dug on the field boundary giving a good section with tools in it. The ditch section at the site was scraped clean and a photo-mosaic of the entire section was taken with each photograph covering a one-metre wide area of the section. The section was more than 20 metres wide (Fig. 3.14). Soil samples from each geomorphic unit were also taken at approximately 1-metre interval as minor variations were observed in the stratigraphy through the width of the section. All features in the section were also photographed separately, notes made on these, and then artefacts from the section were removed with utmost care.

At this locality, the Acheulean assemblages are preserved as a stone zone below a thin layer of unconsolidated fine sands/silt. The stone zone is 30-40 cm thick. This occurs just above weathered regolith (Fig. 3.6a).

The stone zone consists of artefacts associated with gravelly and detrital materials – well-rounded nodular laterite pebbles and pellets, angular to sub-angular clasts of granites, pebbles and cobbles of quartzite, angular pieces of quartz and calcrete clasts in a matrix of angular grit and brown sand. Quartzite pebbles appear to be manuports as no geological process seems to have brought quartzite to the site which outcrops 8 km SW near Jiron, and major outcrops are 18 km SW near Jakhlaun (Figs. 3.15 – 3.23). Presence of laterite and low amount of calcrete clasts in the matrix is significant as no laterite is present in the drainage today (Mishra *et al.* 2007).

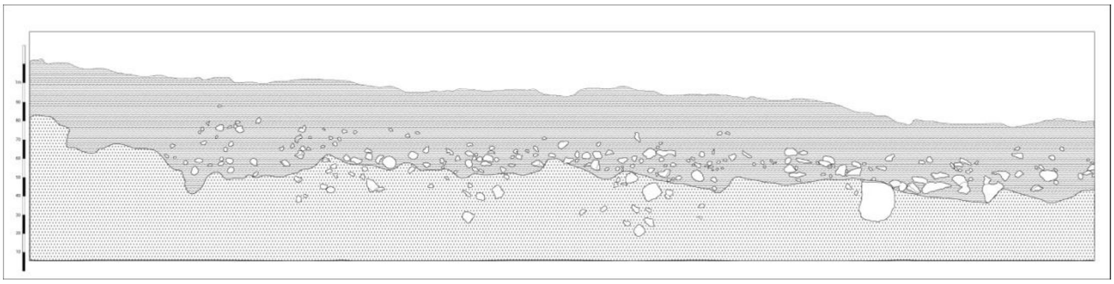
The layer above the stone zone is 10-30 cm thick (Fig. 3.18). This layer seems to be composed of fine unconsolidated sand and silt. The origin of these sands is a question to be investigated thoroughly. They may be Aeolian in composition, product of insitu weathering, a result of colluvial sheet wash or upward translocation of fines. At first they were thought to be Aeolian, however it is not an arid region, but during the summers some amount of dust blows with the wind. They are more probably a result of insitu weathering as they are distributed throughout the region of granitic bedrock and on the basis of sedimentology described below coupled with low relief and low rate of erosion (discussed earlier in Chapter II, Section….) they appear to be a product of weathering of granite. The age of these sands also needs to be assessed. Similar cover sands have also been noted in the western plains of Australia (Butt 1985, Ollier 1991)

Tools were lying '*in situ*' below the soil and were gradually being exposed due to tilling and erosion. Causes for the preservation and burial of artefacts have been assessed along with the formation of the stone zone and the origin of fine sands capping the stone zone. For this purpose attributes pertaining to state of preservation or taphonomy of the artefacts have been assessed along with basic granulometry of the sediments, and analysis of the coarse clasts recovered from the ditch section.

Sedimentology

Grain size analysis was done to assess on a preliminary basis whether the fine sands capping the stoneline are Aeolian in origin and to know whether the soil within and above the stone zone is homogenous or heterogeneous in fine fraction. The grain size analysis of the sediments from the ditch shows that the sediments capping the stone zone are polymodal, poorly sorted fine gravelly silt. The percentage of gravel increases after 20 cm and that of silt decreases. The artefact horizon is extremely poorly sorted gravel with fine silt (Fig. 3.6b).

a).



b).

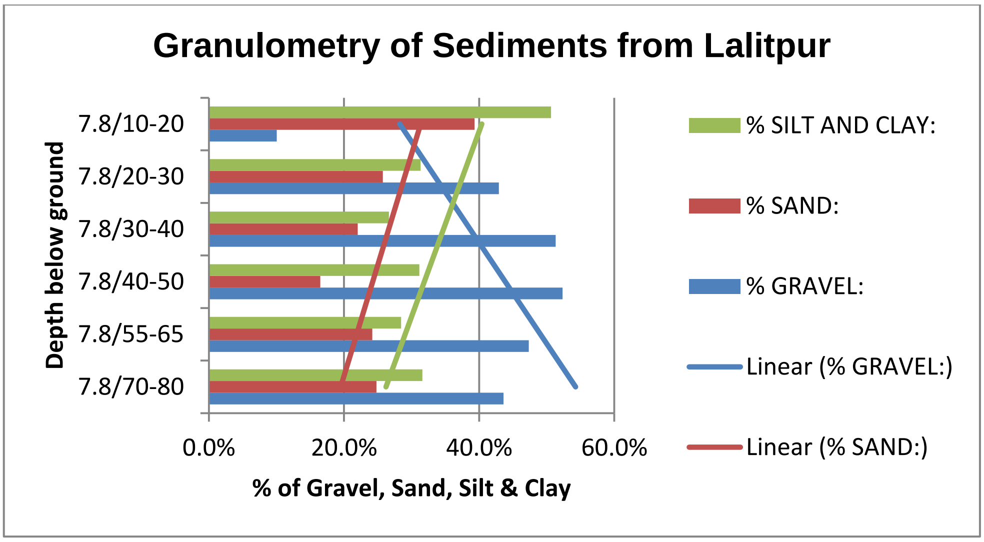


Fig. 3.6: a). Stratigraphic section and b). Granulometry of the sediments from LPR I, Locality BN 5

Fig. 3.7: Granite Outcrops near the site of Lalitpur

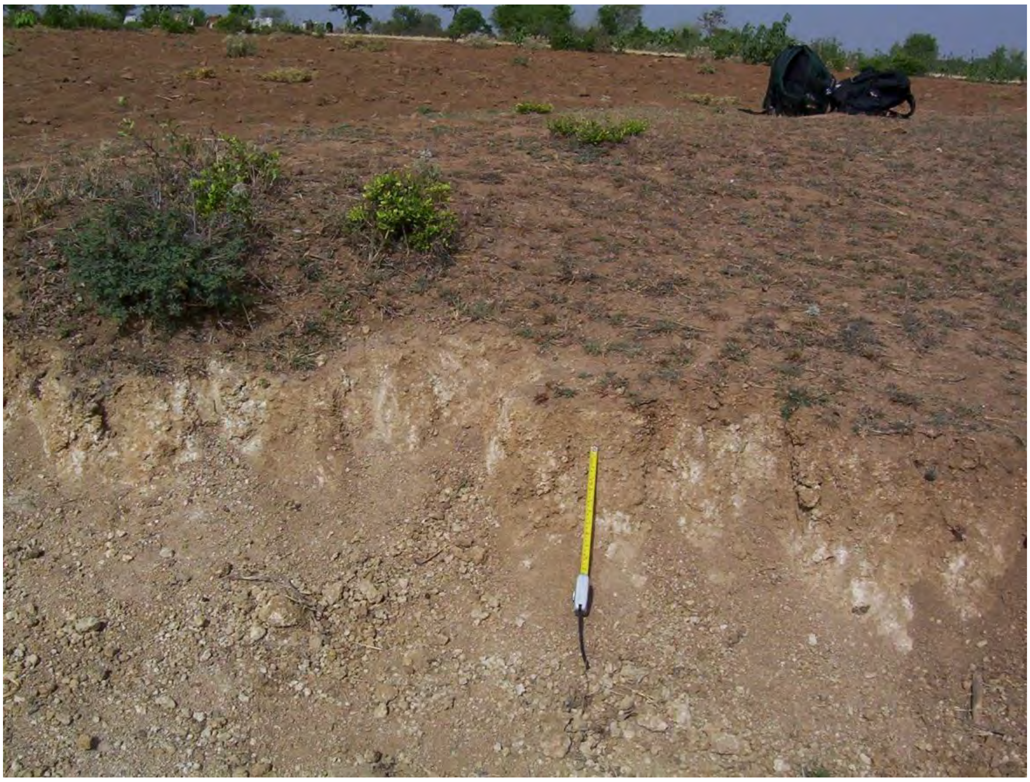


Fig. 3.8: View of LPR I, Locality 1 near the Biana Nullah

Fig. 3.9: Another of the same locality as above showing the artefacts exposed onto the surface

Fig. 3.10: Close-up of the surface scatter of artefacts at LPR I, Locality 1

Fig. 3.11: View showing disturbed artefact horizon at LPR I, locality 1

Fig. 3.12: View of the Biana Nullah close to Locality 5

Fig. 3.13: View of Biana Nullah Locality 5 and the ditch section

Fig. 3.14: View of the ditch section at the site of Lalitpur

Fig. 3.15: Artefact horizon at Locality 5 above regolith and capped by a thin sediment cover (Note the giant core lying on the surface of the ditch at the bottom right)

Fig. 3.16: Another view of the stratigraphic section revealed in the ditch at Locality 5

Fig. 3.17: Close-up of the stratigraphic section at Locality 5

Fig. 3.18: Close up of the sediment cover above the artefact horizon at Locality 5

Fig. 3.19: Close-up of the artefact horizon

Fig. 3.20: Another close-up of the artefact horizon sandwiched between regolith and unconsolidated silts

Fig. 3.21: View showing the artefacts in the artefact horizon

Fig. 3.22: Weathered regolith below the artefact horizon

Fig. 3.23: Laterite nodules in the section at Biana Nullah Locality 5

Analysis of Coarse Fraction

The coarse fraction sample recovered from the artefact horizon in the ditch section at locality BN 5 was analysed. The long axis diameters of natural clasts were recorded to understand size sorting of sediments and their taphonomic attributes also studied to infer site formation processes and aspects of burial and exposure of artefacts.

Size of Natural Clasts

Size data for natural clasts show that majority of the clasts are < 2 cm. But the mean length of long axis of clasts > 10 mm is 5.14 (Figs. 3.24 - 3.25).

The mass data shows that the mean mass for clasts bigger than 1 cm is 78.3 g. The minimum and the maximum ranges from 2 – 384 g. Most clasts are in the range of <100 g (Fig. 3.26).

This indicates the presence of both small and large clasts, but the frequency of very large clasts is low (though there are a few large slabs and boulders in the horizon). The percentage of gravel <2cm in size is quite high indicating that fluvial sorting or winnowing did not occur at the site. Presence of a few large pieces (not mentioned in the clast size graph below) also points that no geomorphic process was responsible for removal of large artefacts from the site.

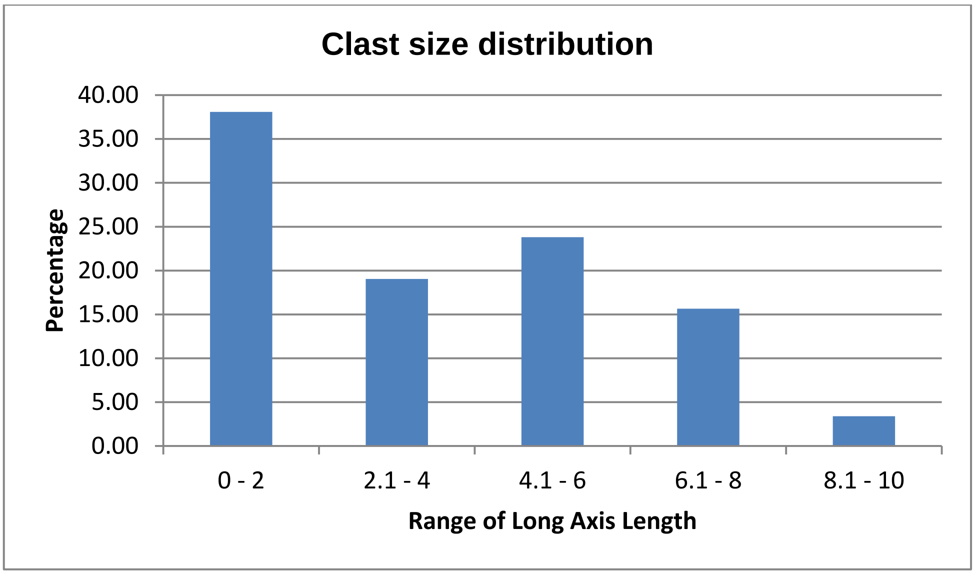


Fig. 3.24: Clast size distribution of natural clasts from artefact horizon in the ditch section

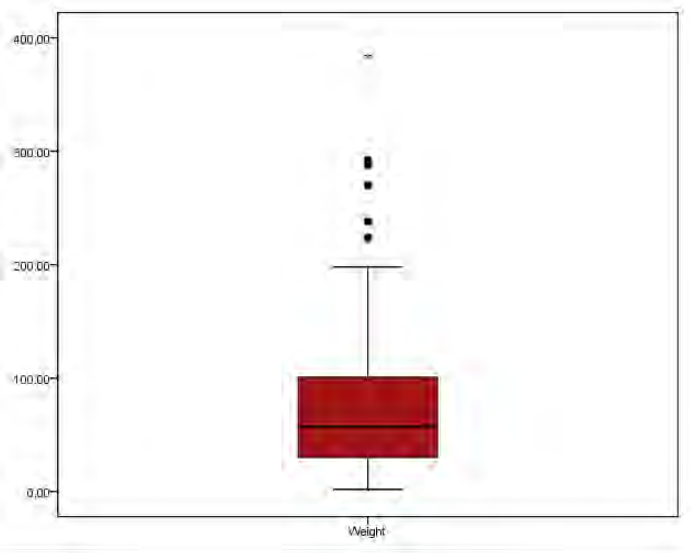


Fig. 3.25: Boxplot showing mass of natural clasts> 10 mm from the ditch section at LPR I, Locality BN 5

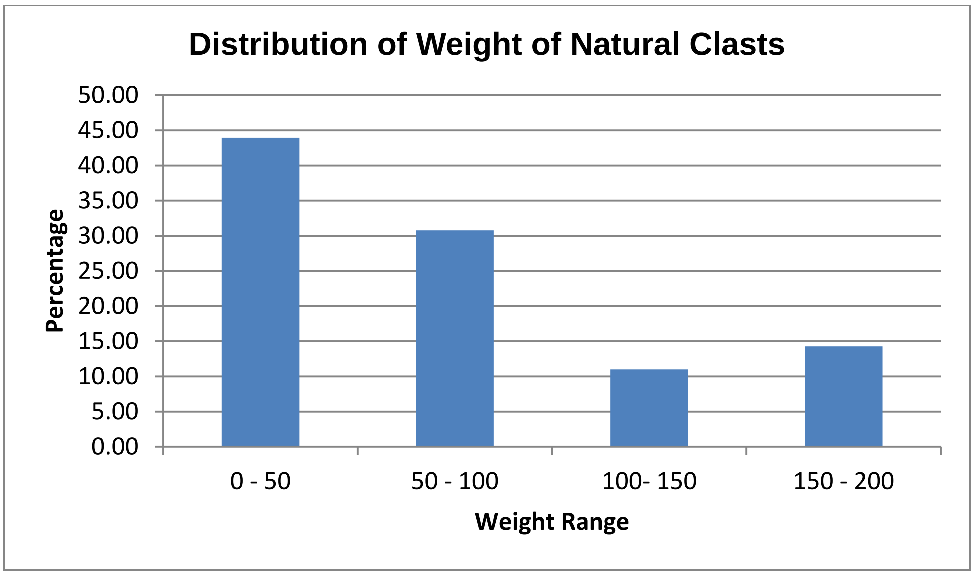


Fig. 3.26: Mass distribution of natural clasts> 10 mm from artefact horizon in the ditch section

Weathering

The weathering parameters of natural clasts indicate a moderate to slight weathering. The percentage of clasts not showing any weathering is negligible ~1% (Fig. 3.27). Clasts with heavy weathering also occur in a substantial proportion of 6.82%. Granular disintegration, cracking along joints and exfoliation are the main types of weathering seen on granitic clasts.

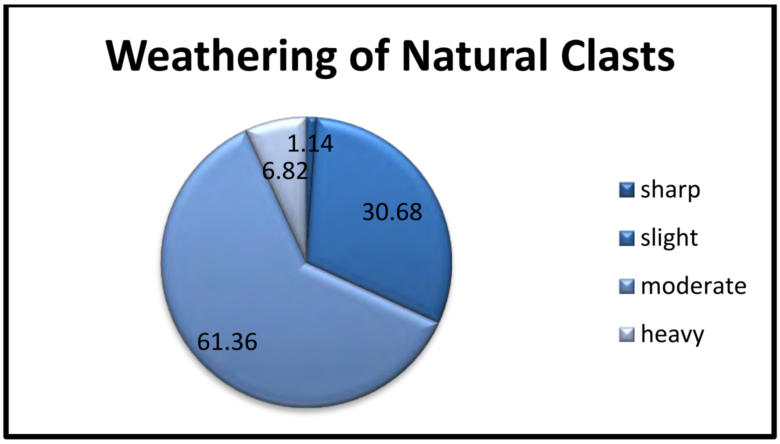


Fig. 3.27: Pie chart showing degree of weathering of natural clasts from the ditch section at LPR I, Locality BN 5

Degree of rounding

Rounding parameters of natural clasts in the ditch section indicate that the quartzite and laterite cobbles are mostly sub-rounded to rounded, while the granite and quartz fragments are mostly sub angular to angular (Figs. 3.28 & 3.29)

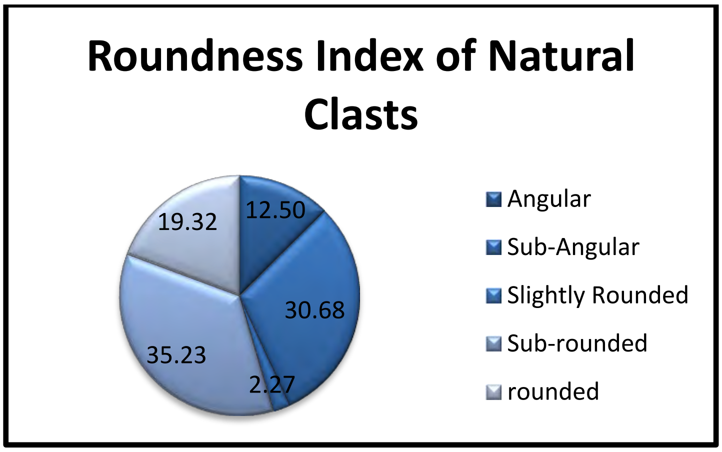


Fig. 3.28: Pie chart showing degree of rounding of natural clasts from the ditch section at LPR I, Locality BN 5

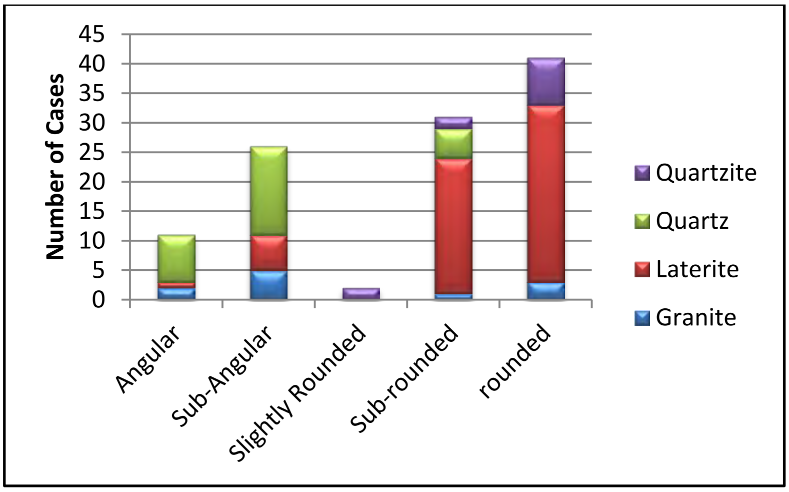


Fig. 3.29: Degree of rounding of natural clasts according to raw material

Though orientation data was not available from excavation and nor was it obtained during the study of the ditch section, but it was observed that many of the granite clasts are tabular in shape and are flat lying though some are tipped at an angle.

From the study of the topographic and sedimentary context of the site along with basic granulometry of the sediments and analysis of the coarse clast fraction it can be said that the Acheulean artefacts at Lalitpur occur as thin unstratified artefact horizon. They come from recently exposed sediments occurring on or very near to the surface, either completely or partially exposed, or buried under a thin sediment cover.

The artefact spread shows that the assemblages are found preserved across the landform as clusters with exceptional preservation occurring on or near the surface at Lalitpur mostly in agricultural fields or barren lands. This suggests that the artefact spread are landscape wide features and not just confined to limited site areas.

Weathering of the Achaean rocks and erosion of soils/sediments from the upland has been the predominant process in this landscape. Alongside small scale processes like channelized sheet flows within rills, gullies and streams and surface wash processes are responsible. The sites are found in a landscape dominated by low-energy erosional processes. There is a near absence of high-energy sediments.

In the absence of absolute chronology, the presence of Acheulean artefacts in the lowest levels, relict nature of the rubble gravel, presence of laterite and calcrete clasts in the matrix and high degree of weathering of the locally derived granite clasts as well as the artefacts suggest a high antiquity for the site. These parameters have been suggested by Mishra *et al.* (2007, 2011).

However, more detailed studies are needed to establish the role of soil (pedogenic), slope (sedimentation) and denudational processes and also confirm whether the unconsolidated fine sands/silts forming a thick (15-30cm) extensive mantle across the upland are Aeolian deposits, sand liberated by insitu weathering of underlying bedrock; colluvial transport (overland flow, channelized flow – gullying, creep, graviturbation) or runoff (unconfined sheet wash, rills, gullies). Investigations are also required to establish whether laterite is formed '*in situ*' or it gets incorporated into the sediment.

3.5.1.3 Site Formation and Assemblage Integrity Inferred from Artefacts

At Lalitpur, since the artefacts occur on or near the surface in an unstratified horizon, capped by loose sediments, the depositional environment and burial/exposure of the sites cannot be understood only through its topographic and sedimentary context. In this case, a study of the artefact assemblage, its nature, physical condition and composition can help a lot in inferring site formation processes (Isaac 1977, 1981, Binford1980, 1983, 2001, Potts 1984, 1988, Jhaldiyal 1997, 2006, Paddayya 2008). Therefore, several attributes like assemblage composition, artefact density, artefact size *vis-a-vis* natural clasts, raw materials present, degree and type of weathering, rounding, patination, breakage and damage patterns were observed to understand the depositional context of the artefacts themselves.

The assemblage composition, artefact category ratios and raw materials utilized have been discussed in the next chapter. Here we only focus on artefact size and weathering and rounding attributes.

Artefact size

The artefact size range indicates that majority of the artefacts range in size from 4 – 14 cm, with a fairly high percentage of artefacts between the size ranges of 8 – 14 cm. There are no artefacts> 20 cm and < 2 cm (Figs. 3.31 & 3.32). Even small flakes < 4 cm are lesser in number than the expected frequency. Large artefacts such as large cores are also absent, though one giant core was recovered from another locality, namely BN 5 (Fig. 3.30).

Fig. 3.30: Giant Core from Biana Nullah, Locality 5

Absence of large artefacts may be due to anthropic causes like transport of flake blanks into the site or due to geogenic causes. Another cause may be directly using the bedrock to remove large blanks.

The very low frequency of smaller artefacts (<20 mm) does not seem to be accounted by winnowing of the fines as when we look at the size of natural clasts there appears to be no size sorting and both small and large clasts are present. It must be mentioned here that the natural clast data is from locality 5, and the artefact data is from excavation of locality 1, but similar nature of gravel occurrence was noticed at both the localities, though it was much eroded at locality 1 and only remnants of the gravel lag occurred on the surface at locality 1. Further, these two localities are only situated at a distance of one kilometre without any difference in topographic and broad geological context. Therefore we may draw broad conclusions regarding the nature of formation processes at locality 1 using the data from locality 5.

Jhaldiyal (1997, 2006) in her geomorphological and experimental studies concluded that sheet wash and rill erosion in semi-arid settings on low angled slopes depletes the site of its smaller artefact content. However, this does not seem to be the case here, even though the site is situated on a low angled slope when taking into account the large number of small sized (0-1 cm) gravel.

The low frequency of small artefacts can only be accounted by the absence of screening of the lithics during the excavation and occurrence of the artefacts in a coarse deposit. Further, Singh (1965) mentions that small chips, quartz fragments and small quartzite pebbles were discarded (Singh 1965: 67).

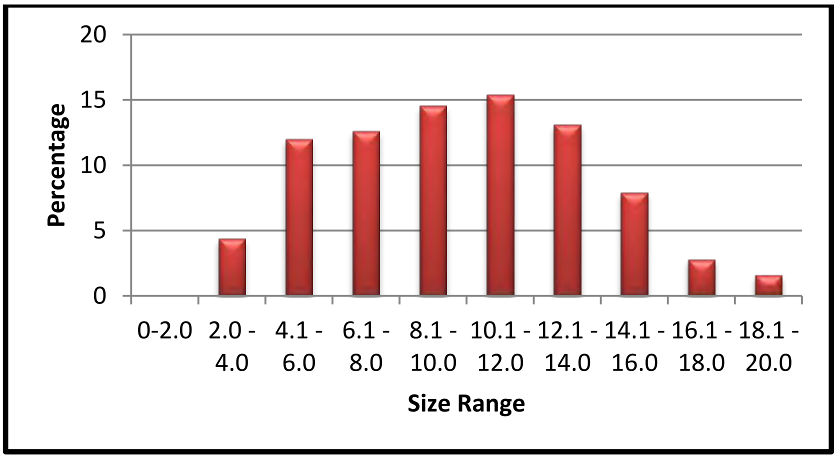


Fig. 3.31: Size distribution (Maximum Linear Dimension) of artefacts from LPR I, Locality BN 1

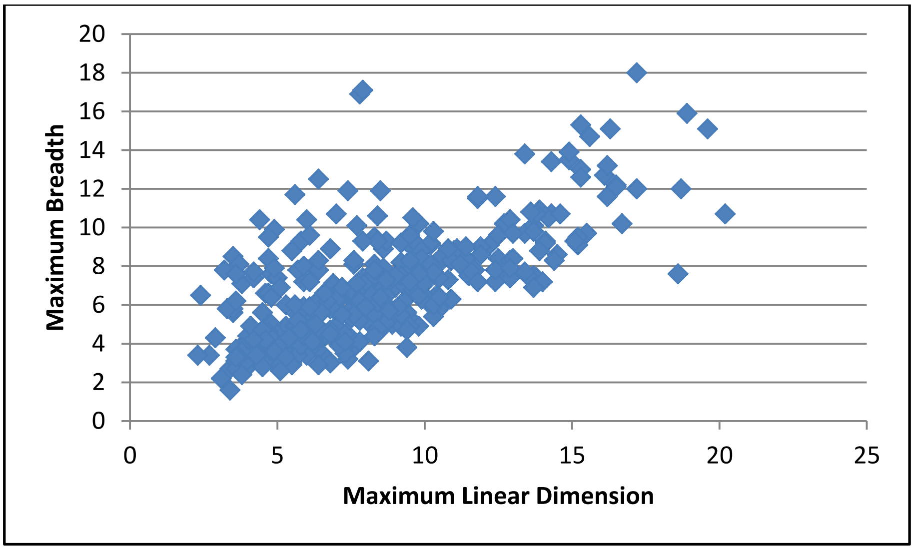


Fig. 3.32: Scatter Plot showing Length/Breadth of artefacts from Locality BN 1

State of Preservation

Weathering, rounding, patina and breakage patterns were noted to study the state of preservation of artefacts. They were studied following Paddayya and Petraglia (1993), Jhaldiyal (1997, 2006), Thompson (2009) and Burroni *et al.* (2002) subjectively on an ordinal scale to allow quantitative assessments. It helps infer the formation processes responsible for the preservation of the assemblage.

Weathering features

Weathering can inform on the assemblage homogeneity or integrity. It has often also been used to inform on the period of exposure but that is very much influenced by the local lithology and environment (Jhaldiyal 1997, 2006).

Geochemical and mechanical weathering can be inferred by weathering, rounding, patination, abrasion and breakage.

Degree of Weathering and Abrasion

It was noted subjectively on an ordinal scale from 0 to 3.

Grade 0 - Fresh: Absence of weathering and abrasion and presence of sharp edges and clear arrises and dorsal and ventral scars

Grade 1- Slightly Weathered: The artefact edges are sharp with clearly distinguishable dorsal scars.

Grade 2- Moderately Weathered: The artefact edges are fairly worn with the scars still noticeable but not sharply defined.

Grade 3- Highly Weathered: The artefact edges are highly worn and the scars not well defined.

Observations on the artefacts show very little to no abrasion. Only the arêtes are in some cases abraded. But majority of the artefacts are found in a moderate to slight weathering condition. However, the percentage of heavily weathered artefacts is also substantial (Table 3.1 & Fig. 3.33).

In the ditch section at locality BN 5 also there were a large number of natural clasts and artefacts with a moderate to heavy degree of weathering.

Table 3.1: Degree of weathering of artefacts from the excavation locality

Degree of weathering	Frequency	Percentage
Fresh	1	0.12
Slight	419	50.79
Moderate	227	27.52
Heavy	178	21.58
Total	825	100.00

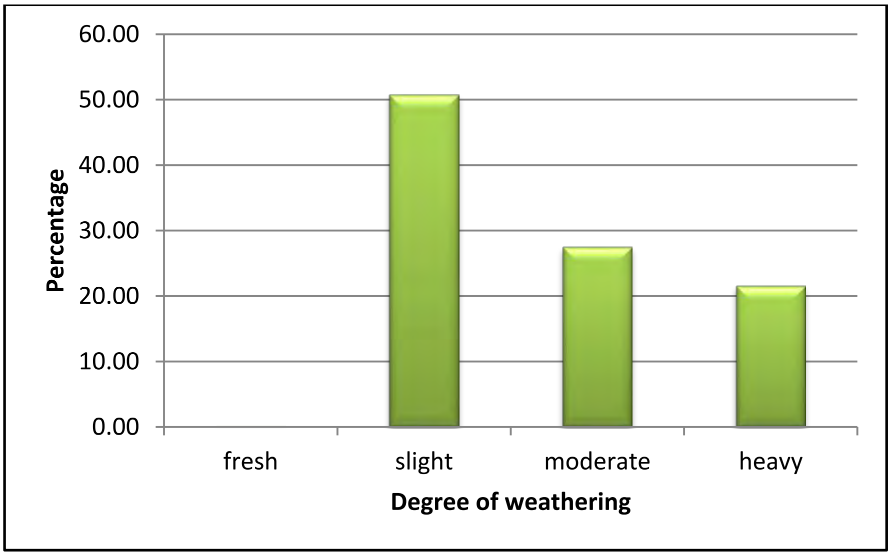


Fig. 3.33: Degree of weathering of artefacts from excavation at Locality 1

Type of Weathering Features

Moderate to heavy granular disintegration is the common type of weathering on artefacts (Table 3.2; Figs. 3.34, 3.38 & 3.41). The artefacts start to decompose and disintegrate as soon as they are removed from the enclosing matrix and exposed to the atmosphere. In granular disintegration, granules of quartz, feldspars and other minerals detach from the parent poly-mineral granite rock without decomposing and become part of the granitic residuum. Such weathering was also noticed on a granite corestone within the ditch section (Figs. 3.35 & 3.36) which seemed to have occurred only recently as the granitic residuum appeared quite fresh.

Exfoliation, cracking along joints, pitting and etching also occurs (Fig.3.39). The dorsal surface of quite a few artefacts appears plain, perhaps because the entire surface has been weathered most probably by exfoliation (Fig. 3.40). Quartzite artefacts show the development of a weathering rind.

The high degree and similar nature of weathering of artefacts and natural clasts suggests that weathering was one of the major processes shaping the landscape during the Acheulean and observations in the area suggest that weathering continues to play a dominant role in shaping the landscape even today (Fig. 3.37).

Table 3.2: Type of weathering feature on artefacts

Type of weathering feature	Frequency
Granular Disintegration	488
Cracking	71
Exfoliation	151
Pitting	43
Etching	35
Weathering rind	24
Other	110

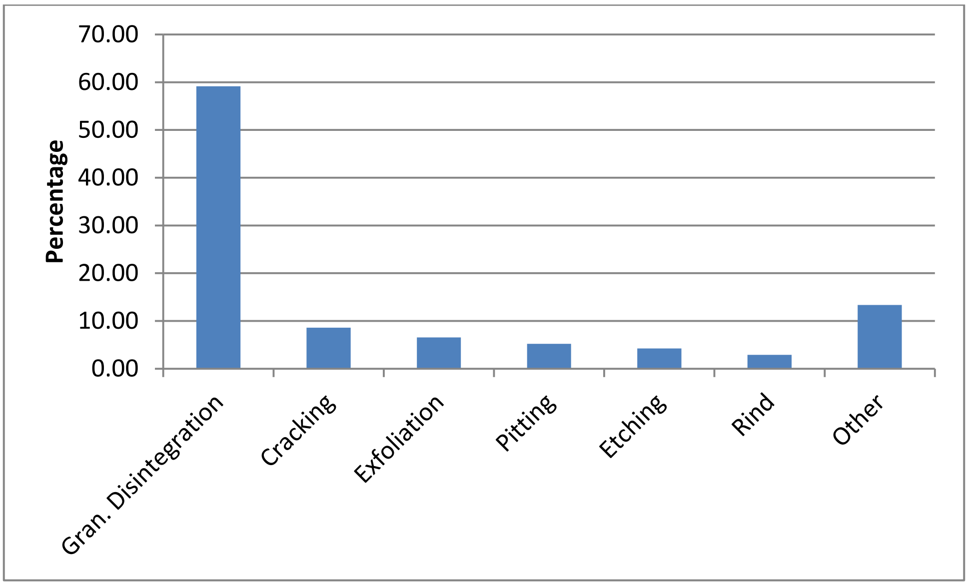


Fig. 3.34: Type of weathering observed on artefacts from excavation at Locality 1

Fig. 3.35: *In situ* weathering of granite observed at Biana Nullah Locality 5

Fig. 3.36: A heavily weathered artefact in the section at Biana Nullah Locality 5

Fig. 3.37: Weathered granite corestone at the site of Lalitpur

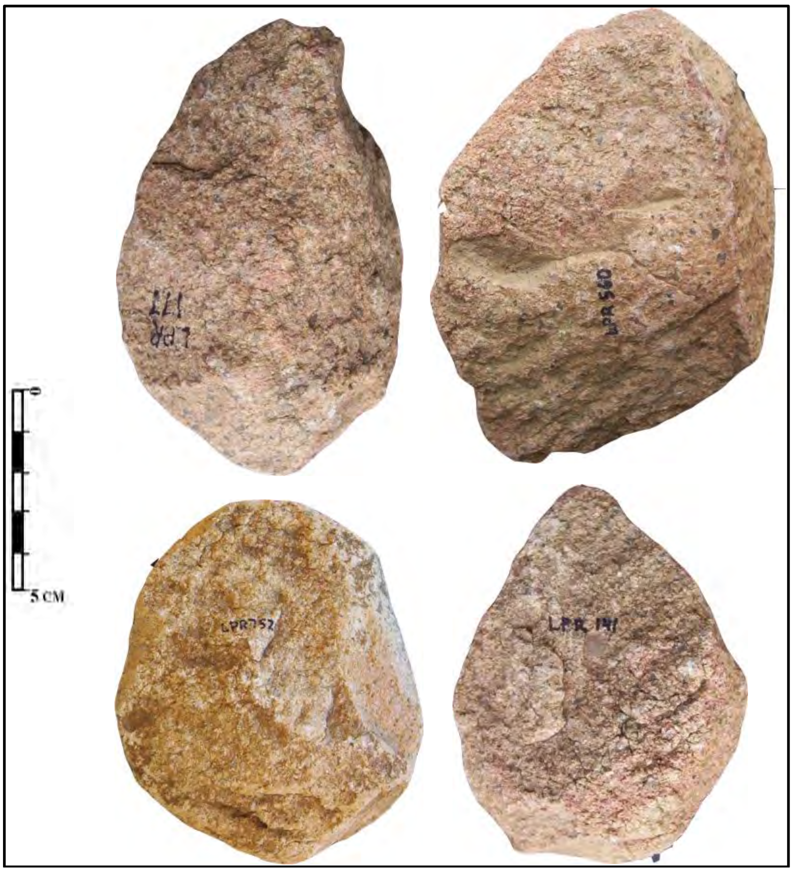


Fig.3.38: Some artefacts with heavy granular disintegration

Fig.3.39: An artefact showing heavy granular disintegration and cracking

Fig.3.40: Some artefacts from Lalitpur showing one surface completely weathered

Fig. 3.41: Heavily weathered cleavers from Lalitpur

Patination

Patination is a colour change or staining due to chemical weathering or alteration of the surface of stone resulting in loss of minerals and/or accretion of material to a stone's surface. Patination may also vary on the various artefact surfaces depending on the position of the buried artefact. Patina was qualitatively judged by looking at the surface colour of each artefact.

Degree and Type of Patination

None: No change is noticed in either the colour of the artefact, or surface features.

Slightly patinated: Artefacts show mild patina stains but the colour and texture of the artefact is not much altered.

Moderately patinated: Artefacts becomes more heavily stained with more prominent alteration of surface colour and texture.

Highly patinated: Artefact surface becomes completely altered in colour and texture.

Differential patination on the dorsal and ventral faces was also noted as this reflects on the position of the artefact in the sediment.

The type of patination was noted as:

a. Carbonate crust
b. Dust film
c. Whitening
d. Lithobiontic coating (black mossy)
e. Oxide film
f. Manganese staining

Table 3.3 and Fig. 3.42 below show that 99% of the artefacts show only slight patination. The nature of patina also shows that majority of the artefacts (>93%) appear to be covered by a mild patina of dust film. These dust films actually a result of the deposition of clay and silt sized particles derived mainly from the enclosing soil, which do not result in any significant change in original texture and colour of the raw material.

Only a miniscule percentage shows other types of patination. Among the other types, nearly 4 % are covered by lithobiontic coatings or organic mossy patina, >1% by calcrete coatings and only 0.48% by white patina (Table 3.4 & Fig. 3. 43). Lack or negligible percentage of carbonate and oxide accretions suggests that the artefacts were not exposed to repeated exposure and burial for long duration.

Table 3.3: Degree of Patination on excavated artefacts from Locality 1

Patination	Frequency	Percentage
None	0	0.00
Slight	822	99.64
Moderate	3	0.36
Heavy	0	0.00
Total	825	100.00

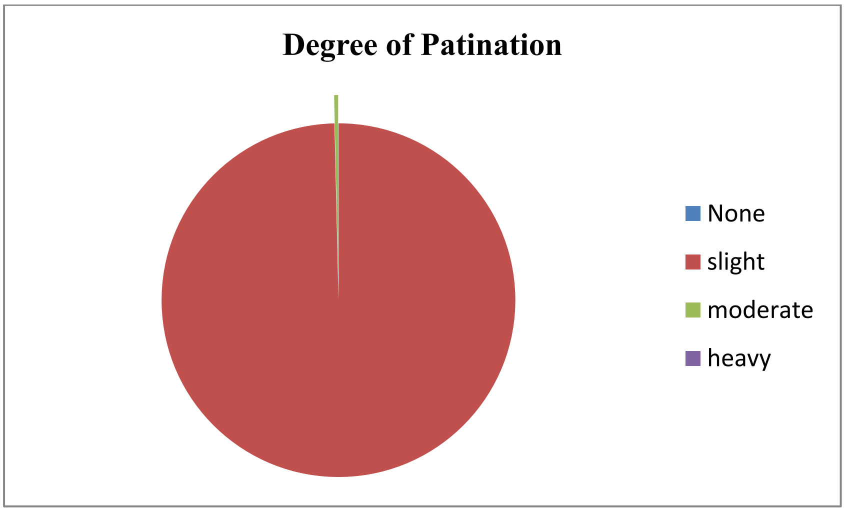
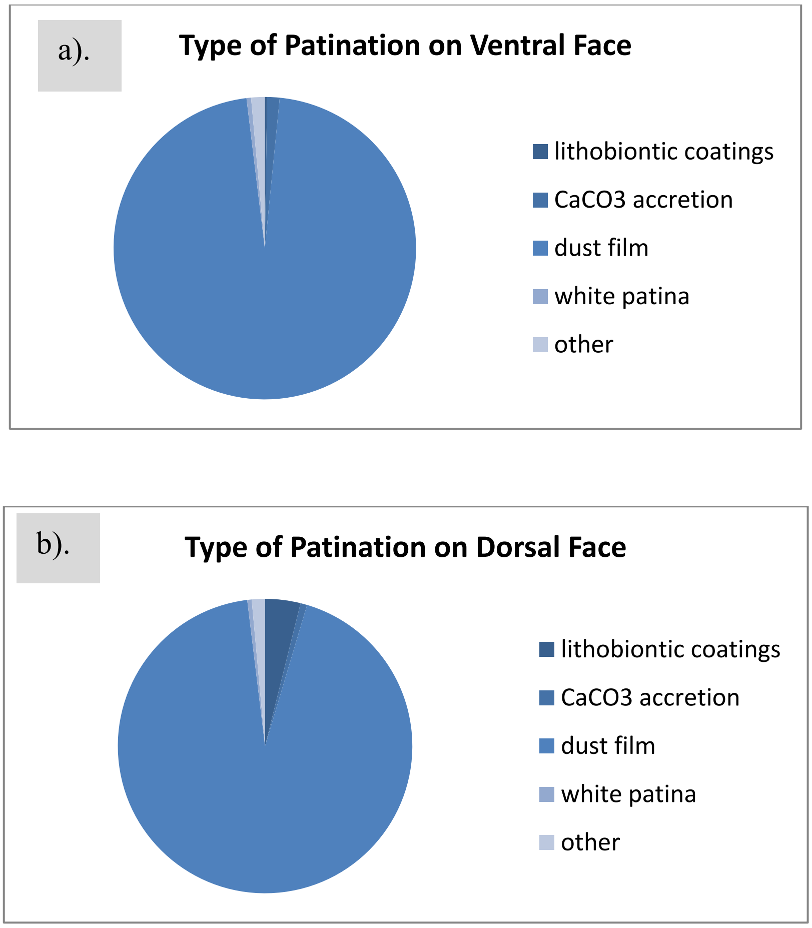


Fig. 3.42: Degree of Patination observed on artefacts

Table 3.4: Type of patination on ventral and dorsal surface of artefacts

Type of Patination	Percentage on Ventral Surface	Percentage on Dorsal Surface
Lithobiontic coatings	0.24	3.88
CaCO3 accretion	1.45	1.45
Dust film	1.33	0.73
White patina	96.48	93.45
Other	0.48	0.48



Figs. 3.43 (a) & (b): Type of Patination observed on (a) ventral surface, and (b) dorsal surface of artefacts

Degree of Edge Rounding and Arris Sharpness

The degree of rounding is indicative of fluvial transport and/or wind abrasion. It was deduced subjectively by looking at the thickness of edges and flake scar ridges. If the thickness of edges was high and flake scar ridges subdued and not sharp and clear, it meant that the artefacts were heavily rounded.

Grade 0 - Mint: Artefacts with very sharp edges and arrises indicating no rounding or rolling.

Grade 1 - Sharp: Artefacts with edges and arrises which are still quite sharp but begin to show dulling.

Grade 2 - Slightly rounded: Artefact edges and arrises are slightly rounded and dull.

Grade 3 – Moderate rounding: Artefacts become more rounded with subdued edges and arrises as seen from increased width of edges, major surface features are still apparent

Grade 4 - Highly rounded: Artefacts undergo heavy rounding and the edges and ridges develop broad convexities so that only the general outline shape is visible

Slight rounding observed on majority of the artefacts indicates the assemblage has not been transported much. The flake scars are relatively fresh. Edges are only slightly rounded in most cases or moderately rounded in a few cases (Tables 3.5 & 3.6; Figs. 3.44 & 3.45). This rules out fluvial transport and perhaps suggests that the artefacts were subjected to only slight mechanical movement in soil or slope.

Table 3.5: Degree of Edge Rounding on Artefacts from Locality 1

Degree of Edge Rounding	Frequency	Percentage
Mint	0	0
Sharp	14	1.70
Slight	713	86.42
Moderate	98	11.88
Heavy	0	0
Total	825	100

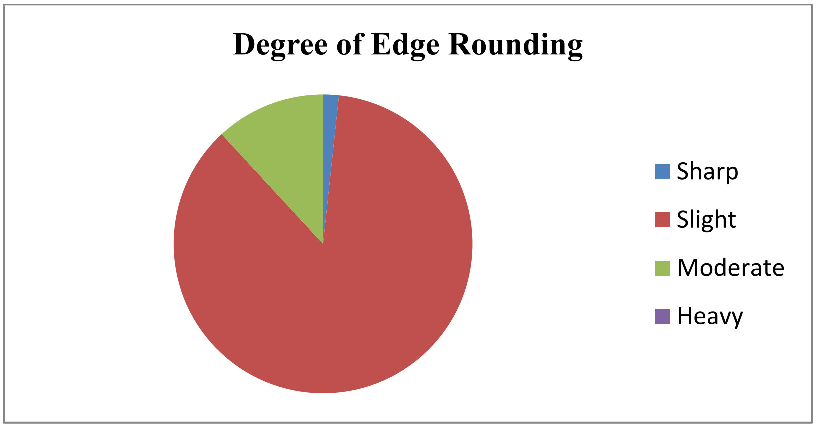


Fig. 3.44: Degree of Edge Rounding on Artefacts from Locality 1

Table: 3.6: Degree of rounding on ventral and dorsal surface of artefacts

Degree of Rounding	Ventral Surface %	Dorsal Surface %
sharp	1.09	1.21
slight	85.45	83.15
moderate	13.45	15.27
heavy	0	0.36

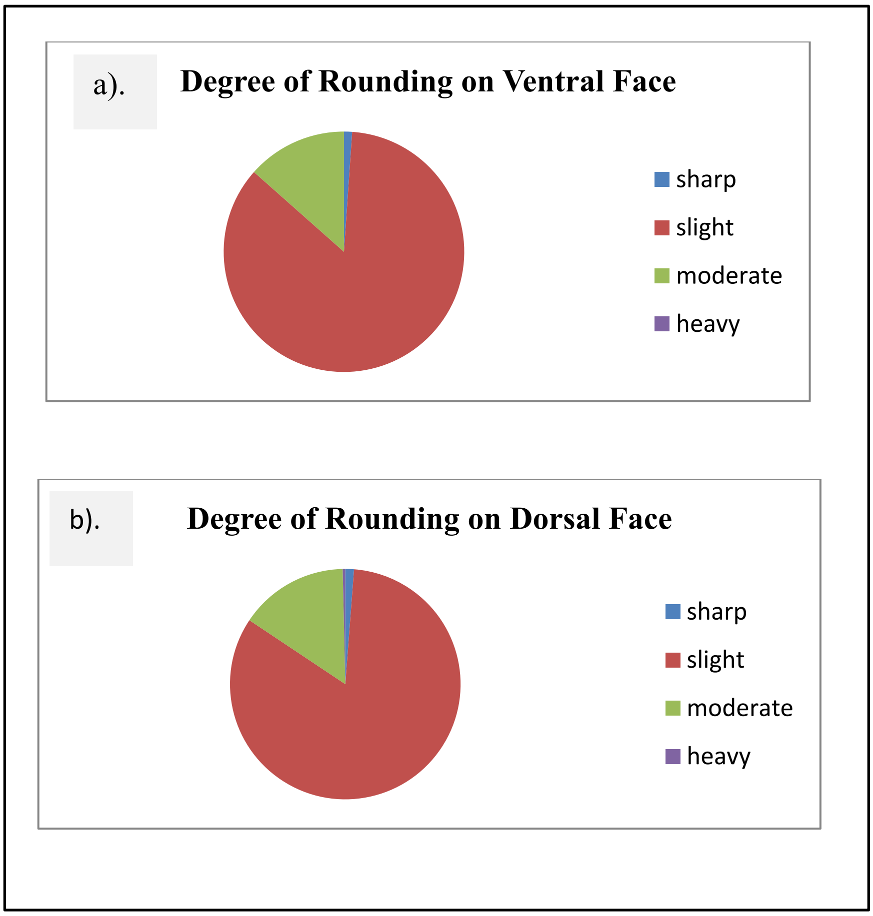


Fig. 3.45: Degree of rounding on (a). Ventral surface, and (b). Dorsal surface of artefacts

Completeness of the artefacts

Flake breakage patterns have also been looked at as they correlate with reduction strategies (Stahl and Dunn 1982, Ahler 1989, Shott 1994, Prentiss 1998). The following attributes have been noted:

Breakage Location

g. None
h. Lateral (side edge)
i. Distal (tip)
j. Mid-section
k. Proximal (base)
l. Lateral & distal
m. Distal & proximal
n. Proximal & lateral
o. Indeterminate

Type of Breakage

p. None
q. Old
r. Fresh
s. Indeterminate

Only 9.57% of the artefacts are broken and the rest are complete (Table 3.6 & Fig. 3.46). Among the broken tools, transversal breaks are more common (55.17%). Of these, distal breaks (34.48%) are more common, with proximal breaks being only 6.90%) are most common, followed by mid-section at 13.79%. Lateral breaks are also quite common at 44.83% (Table 3.7 & Fig. 3.47). Most breaks are old, as indicated by the patination and weathering of broken surfaces and flake scars (Table 3.8 & Fig. 3.48). Only 27.58% are freshly broken. This suggests that most of the tools were broken during manufacture or use.

Table: 3.7: Percentage of Complete tools in the collection from Locality 1

Percentage of Complete Tools	Percentage
Complete	90.43
Broken	9.57
Total	100

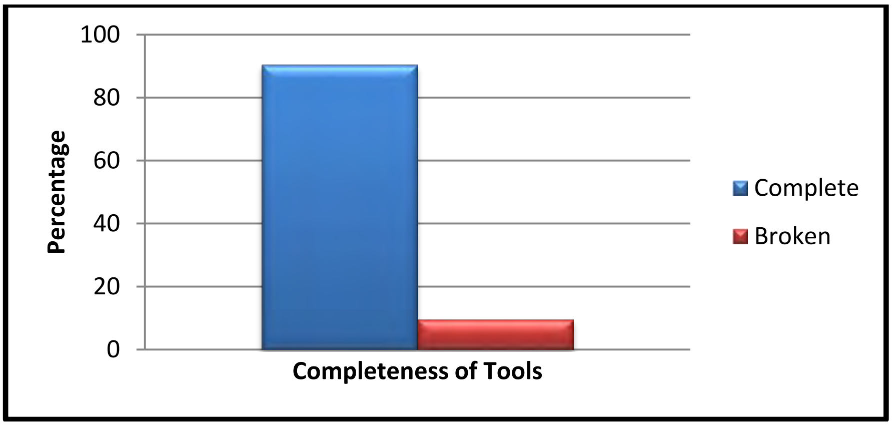


Fig. 3.46: Percentage of Complete tools in the collection from Locality 1

Table 3.8: Location of breakage on broken tools

Breakage location	Percentage
Distal	34.48
Proximal	6.90
Mid-section	13.79
Lateral	44.83
Total	100

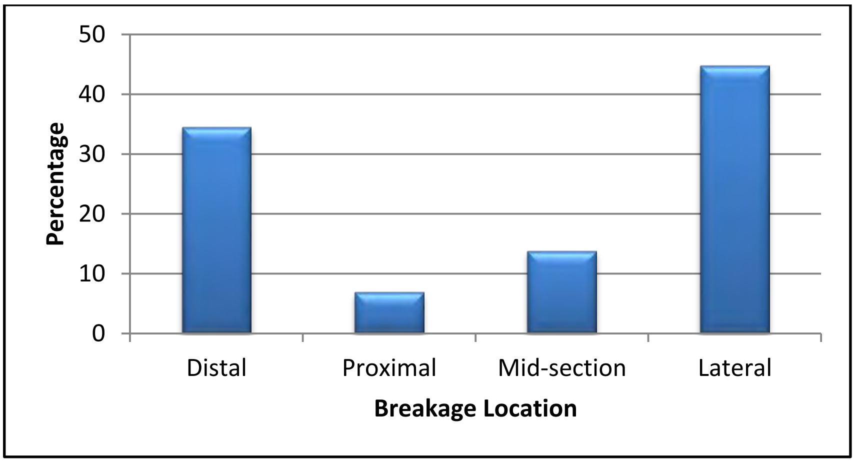


Fig. 3.47: Location of breakage on broken tools

Table 3.9: Type of Breakage on tools

Type of Breakage	Percentage
Old	72.41
Fresh	27.59
Total	100

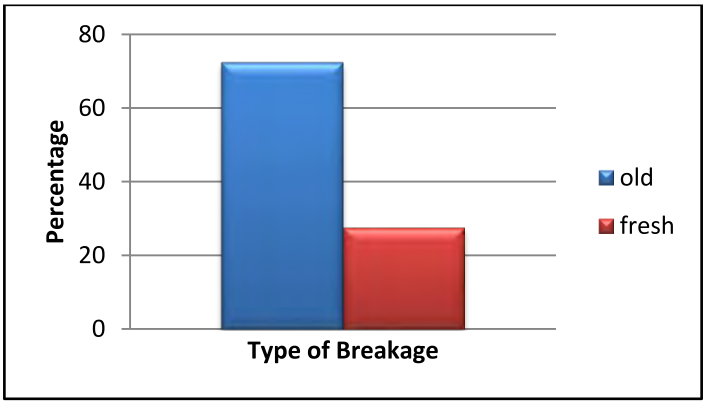


Fig. 3.48: Type of Breakage on tools

3.6 SUMMARY

The study of the physical condition of the artefacts themselves coupled with the topographic and sedimentary context of the site shows that:

- Geological and stratigraphic context indicates that the assemblages have not been subjected to disturbance by high energy fluvial processes.
- Low degrees of patination and rounding and absence of polish on the artefacts suggests that the artefacts were not subject to long periods of surface exposure.
- Weathering has been the major geomorphic process affecting the artefacts and shaping the landscape along with small scale soil and slope processes.
- The physical condition of the artefacts indicates homogenous nature of the patina and weathering. Homogeneity in physical condition of the artefacts suggests that all artefacts from a locality belong to the same chronological phase and rules out repeated or multiple occupation of the site.
- A high density of artefacts indicates a longer period of site occupation.
- The coarse grained nature of the deposit found in a thin 15 - 45 cm rubble horizon above regolith and capped by a thin cover of unconsolidated sands and silts.
- The thin silt cover capping the artefacts and low degree of disturbance of the assemblage may be explained by recent erosion of a thicker silt cover.
- The sites are not essentially surface sites, but recently eroded from a previously buried context inferred by the fresh nature of the artefacts except high degree of weathering.
- The assemblages are preserved as clusters on the landscape in discrete patches. Concentration of sites in the small stretch of the interfluve between the Betwa and Shahzad Rivers only suggests differential preservation and exposure of Acheulean age sediments in that area. However, these are not the result of concentrated hominin activity only at those spots. Only they are found preserved in those locales (see also Mishra 2007, 2011).
- Artefact size class shows absence of small and giant artefacts, but study of natural clasts rules out winnowing or size sorting by fluvial dynamics.
- Fragmented *chaîne opératoire* inferred by the very low frequency of small flakes and large cores (discussed in the next chapter in detail).

- Both Govindsagar Reservoir and Rajghat Reservoir in the vicinity of the site pose a threat to the sites, as they may be submerged if the reservoir capacity is increased any further.
- The assemblage though not found in a very good stratigraphic context, or recorded by modern archaeological methods is still suitable for technological study and may help reveal important aspects of Acheulean lithic technology.

CHAPTER IV

METHODOLOGY FOR LITHIC ANALYSIS

3.1 INTRODUCTION

This research constitutes the detailed technological study of an Acheulean assemblage. The goal of this exercise was to understand the lithic technological strategies employed by the Acheulean toolmakers, and answer questions pertaining to the role of raw material selection, core organization, bifacial shaping, standardization, symmetry, existence of mental templates, and curation, resharpening and discard of tools. This involved a combination of attribute analysis and *chaîne opératoire* approach aimed at determining the position and role of each diagnostic artefact in the knapping process and establishment of diacritical schema of core reduction. It entailed understanding the gamut of technological organization from the initial stage of raw material selection and procurement to core reduction, obtaining blanks for tools and shaping them, use, resharpening, curation, transport, discard and retrieval by archaeological methods.

For this a study of the entire assemblage remaining from the excavation was undertaken. It is worth mentioning here that most studies of Acheulean lithics have focused on shaping of LCTs and have therefore studied only the shaped tools to the exclusion of large flakes, cores and other components of the assemblage which can provide important clues to technological strategies used. Only a few studies have dealt with the core technology and organization of knapping strategies (Goodwin 1929, 1934, 1953, Goodwin and van Riet Lowe 1929, Jansen 1926, van Riet Lowe 1945, Alimen 1978, Balout *et al.* 1967, Biberson 1961, Tixier 1956, Dauvois 1981, Newcomer and Hivernel-Guerre 1974, Owen 1938, Corvinus 1983, McNabb 2001, White and Ashton 2003, Madsen and Goren-Inbar 2004, Sharon 2007, 2009, Goren-Inbar *et al.* 2011). Despite arriving at a detailed picture of Acheulean lithic technological strategies, the emphasis continues to be primarily on bifaces, namely handaxes and cleavers along with a few large flake blanks and cores to the exclusion of complete assemblages (Sharon 2007).

Moreover, the lithic analysis is often marred by typological preconceptions. Interestingly, Tryon and Potts (2011) tried to do away with typology and focused on flake production and variation through time instead of shape of large cutting tools in their study of the Olorgesaillie Acheulean. Here also, an attempt has been made to reduce the focus on typology and used simple classification schema, classifying the assemblage into cores, flakes and retouched pieces (including LCTs).

3.2 APPROACHES TO THE STUDY OF ACHEULEAN LITHICS

Various analytical approaches have been used over time to study Acheulean assemblages. Bordes (1950, 1961) was the first to develop a systematic approach to studying lithics classifying them typologically into several different types of handaxes including the lanceolate, micoquian, triangular, cordiform, amygdaloid, ovate, etc. He tried to explain them quantitatively, and proposed a few metric indices. His typological and metrical system continues to influence studies on lithic technology till date.

Later regional typologies were devised to suit specific needs. Texier (1956) examined cleavers from North African sites and classified six different types based on technology. Texier's types were later modified to incorporate observed variability (Benito del Rey 1972-73, 1986, Alimen *et al.* 1978, Corvinus 1983). Leakey (1971) and Kleindienst (1961, 1962) devised strictly descriptive classification systems based entirely on morphology of tools. Leakey's typology continued to influence research on Lower Palaeolithic worldwide till recently.

Roe (1964, 1968) developed an objective method in the form of 'tripartite shape diagrams' to graphically represent variability in handaxe plan form and degree of refinement by devising a few indices from eight set of tool measurements and three observations. It is argued that major part of the variability in Acheulean artefacts can be explained by shape and refinement. Roe's system was later modified to include cleavers (Roe 1994, 2001).

Wymer (1968) devised a visual system for handaxe form illustrating 10 shapes with actual examples and also represented in tables by letters D - N. Details of tip and but shape, presence of tranchet technique, straight or twisted edges were mentioned in lower case letters. Intermediate types were also recognized.

Cahen and Martin (1972) used multivariate techniques of cluster analysis on the basis of 19 measurements and 36 observations and developed an algorithm for measuring variability.

With the rise of processual archaeology, there was a shift in focus away from typology to technology (Roche 1980; Texier *et al.* 1980; Toth 1985, 1987; Boëda *et al.* 1990; Pelegrin 1990).

This led to the popularity of the *chaîne opératoire* approach to lithic analysis. First used by A. Leroi-Gourhan (1943), the *chaîne opératoire* approach refers to the reconstruction of the entire life history of an artefact or its reduction sequence right from selection and procurement of raw material to core reduction and artefact manufacture, use, re-use, re-sharpening, discard and post-depositional processes (Boëda *et al.* 1990, Perlès 1992, Sellet 1993, Roche and Texier 1991, 1995; Texier 1995; Texier and Roche 1992, 1995, Inizan *et al.* 1999, Noll 2000, Bleed 2001, Shott 2003, Tixier 1978, Texier *et al.* 1980; Soressi and Geneste 2011, Pelegrin *et al.* 1988, Pigeot 1988, Bar-Yosef and Van Peer 2009) reflecting on past hominin behaviour, cognitive abilities, technological sophistication, site formation, mobility and landuse.

Experimental approaches have shed light on reduction sequences (Crabtree and Butler 1964, Newcomer 1971, Newcomer and Sieveking 1980, Callahan 1979, Jones 1981, 1994, Toth 1982, 1985, Bradley and Sampson 1986, Bergmann and Roberts 1988, Amick and Mauldin 1989, Pelcin 1997, Bradburry and Carr 1999, Madsen and Goren-Inbar 2004, Shipton *et al.* 2009, Stout *et al.* 2014, Eren *et al.* 2014)

Developing on the concepts of Bordes (1961) and Roe (1964, 1968, 2001), in recent years a number of studies have tried to analyse biface morphological variability, symmetry and refinement using advances in technological and quantitative devices and methods. Some studies have focused on allometry (Crompton and Gowlett 1993; Gowlett 2006; Gowlett *et al.* 2001). Besides the geometric morphometric approach using three dimensional measures has been used in many recent studies (Saragusti *et al.* 1998; 2005, Lycett, 2007; Lycett and von Cramon-Taubadel, 2013, Lycett *et al.* 2006, Lycett *et al.* 2010, Eren and Lycett 2012, Archer and Braun 2010, Costa, 2010; Grosman *et al.* 2008; Bretzke and Conard, 2012). Elliptical Fourier analysis has also been used (Iovita, 2009, 2010, 2011; Iovita and McPherron, 2011).

Another recent trend has been 3D digital scanning of lithics which can be used to capture form leading to improved metrical and morphological analysis (Couzens 2012, Grosman *et al.* 2011, 2008, Lin *et al.* 2010).

Despite the traditional emphasis on 2D measurements still continues (McNabb, 2004; Sharon, 2007; de la Torre *et al.* 2003, de la Torre and Mora 2005, de la Torre *et al.* 2008, de la Torre 2011, Diez-Martin *et al.* 2012, Diez Martin *et al.* 2014a & b, Gallotti 2013, Gallotti *et al.* 2014, Santonja *et al.* 2014).

3.3 TRENDS IN LITHIC STUDIES IN INDIA

In Indian archaeology, there has been an emphasis on regional studies at the Acheulean sites of Hunsgi-Baichbal basin (Paddayya 1982), Chirki-Nevasa (Corvinus 1983), Raisen Complex (Jacobson 1985), Anagwadi (Pappu 1974), Gunjana valley (Raju 1983, 1985, 1988, 1989), Bhimbetka (Alam 1990, 2001, Misra 1985), Peera Nullah (Semans 1981), Banas-Berach basin (Misra 1967), Mayurbhanj (Ghosh and Ray 1964), Paleru (Rao 1983, 1979), Rallakallava (Gaillard and Murthy 1988), Didwana (Gaillard *et al.* 1986, 1990) and Gangapur (Arunkumar 1985, 1989), while studies of the artefacts themselves were ignored.

Whatever studies were made focused mainly on descriptive typology, using tool types as index fossils for culture stratigraphic succession. Mostly bifaces were the only artefacts that underwent detailed analysis and debitage was discarded.

Some studies have used Roe's (1964, 1968, 2001) metrical analysis of refinement and shape (Gaillard 1995, 1996; Gaillard *et al.* 1986, 1990, Raju 1985, Joshi and Marathe 1976, 1977, 1985). Gaillard *et al.* (1986) made a metrical analysis of handaxe assemblages from Didwana region to work out the evolutionary trends of the Acheulean culture in this region. 301 handaxes from 10 localities were studied following Roe's methodology, with some additional attributes. They were able to find some differences in size, shape and refinement between the collections. Statistical, factor and cluster analysis suggested a technological evolution within the assemblages indicating a chronology for the sites ranging between Early Acheulean and very Late Acheulean or even Early Middle Palaeolithic. However, all the above studies were focused on the study of typo-technological variation within and between assemblages through a metrical and typological study of handaxes.

Very few studies have emphasized tool manufacturing techniques or reduction technology (Corvinus 1983, Jayaswal 1978, Gaillard *et al.* 2008, 2010). Few, if any studies have been made on raw material procurement, refitting, experimental knapping or usewear.

The most comprehensive study till date has been that of Corvinus' study of the artefact assemblage from Chirki. She made a detailed attribute analysis of the artefacts with much emphasis on technique. She identified the use of Victoria West and Kombewa technique in the manufacture of cleavers which predominate at Chirki. Another detailed study has been that of Alam's study of Bhimbetka collection where he made a detailed morphological and metrical analysis of over 11,000 artefacts. The geometric morphometric approach has been used recently in lithic studies (Shipton *et al.* 2014)

Presently, studies going at Isampur, Morgaon, and Attirampakkam are also trying to use an integrated approach to studying the lithics. At Isampur various studies have been carried out, including studies on stone tool technology to inform on the reduction sequence (Shipton *et al.* 2009, Shipton 2013), natural formation processes through artefacts (Jhaldiyal 1997, 2006), experimental studies by Noll showing the practice of a standardized biface manufacturing technology and petrofabric analysis of limestone beds (Shipton *et al.* 2009, Paddayya *et al.* 2006, Petraglia *et al.* 1999). The artefacts from Morgaon excavation (pers. comm. S. Mishra) and Attirampakkam (pers. comm. S. Pappu) are also undergoing a comprehensive analysis mainly focusing on the reduction sequence analysis.

3.4 APPROACH ADOPTED AND OBJECTIVES OF LITHIC STUDY

The present study has tried to go beyond typology and morphology and tried to incorporate the current trends in lithic research worldwide. An attempt has been made to unravel the complexity of stone tool technology, understand the lithic *chaîne opératoire* and inform on early human behaviour and infer site formation processes from stone artefacts.

The analysis focuses on the study of whole assemblage and not just on bifaces, undertaking a detailed study of metrical, taphonomic, typological and technological attributes and *chaîne opératoire* or reduction sequence analysis of artefacts from the site of Lalitpur based on the reading of scars. The *chaîne opératoire* approach has so far has not been used on a major scale in Indian archaeology and the use of this method has led to new insights in Indian archaeology.

Though the *chaîne opératoire* concept has been used in this study, the efforts have led to only incomplete reconstruction of the reduction sequence. This is due to a fragmented *chaîne opératoire* and lack of refitting possibilities. Full reconstruction also requires experimental knapping, functional usewear analysis and understanding of mechanical properties of the raw material as well as provenance studies and landscape perspective of selection and discard of materials. However, such an undertaking involves a large investment of time, resources and effort which could not form a part of this exercise.

Unlike previous studies, here it was decided not to use any elaborate typology and metrical analysis. This was done so because it was realized that the typology that exists for classifying Acheulean assemblages is mostly based on shapes which are rarely found in the Indian Acheulean and therefore this typology does not suit the present assemblage. Further, it was observed that the tools mostly lack much bifacial shaping, refinement and bilateral and bifacial symmetry characteristic of European or Later Acheulean tools in Africa. Therefore, it was decided not to use any detailed metrical analysis like that of Roe (1964, 1968, 1994, 2001) which has specifically been designed as a graphic representation of shape and refinement. This study was conducted with the hope that it would help in understanding the nature of the Indian Acheulean so that later specific analysis can be pursued which is more suited to the Indian Acheulean.

The lithic studies shall focus on the technological organization in terms of:

- Nature of the raw materials used: their shape, size, lithology, procurement strategies, fracture properties and relationship with techniques used and tool types, retouch intensity, size, typology and symmetry.
- Taphonomic condition of the artefacts to infer formation processes at sites.
- Techniques used in the manufacture of different tools.
- Typology and composition of the lithic assemblage.
- Morphometric study to understand issues of standardization, refinement and symmetry.
- Reconstruction of the reduction sequence or *chaîne opératoire* of stone tools from morphotechnological observations on cores, debitage and finished tools.
- Possible reuse, resharpening and rejuvenation of tools and discard.

- Curation identified by differential raw material selection, resharpening of tools, long-distance transport of raw material, blanks or finished tools and differential discard patterns.
- Use of granite as a raw material and its flaking qualities and fracture properties and relationship with techniques used, size and tool types, and retouch intensity.
- Answer specific questions pertaining to Acheulean lithic assemblage morphological variability, role of bifacial shaping, symmetry, refinement, standardization and the existence of mental templates.
- Infer about the degree of planning and sophistication in technology, cognitive abilities of the hominins, mobility and landuse.

3.5 SAMPLE

The collection of artefacts from Lalitpur conserved in the Deccan College Museum, Pune were studied. Singh had collected artefacts from three site localities in Lalitpur:

- LPR 1 – six localities identified on both the banks of the Biana Nullah, a nullah tributary of the Shahzad River and numbered as Bn 1 to 6;
- LPR 2 – ground to the east of Kshetrapal temple in Lalitpur town; and
- LPR 3 – few artefacts were collected by Singh from the cemented gravel in the Shahzad River in Lalitpur.

The collection includes both random surface collection and artefacts from excavation conducted by Singh at Locality 1 lying about 200 m away from the Biana Nullah.

In our study we have used only the excavated artefact collection from LPR I, locality 1. The collection from LPR II remaining in the Deccan College Museum comprised only 17 artefacts and was therefore excluded from analysis. The collection from Biana Nullah localities 5 and 6 also comprised only a biased selection of mainly handaxes and cleavers comprising 51 and 27 artefacts respectively and was therefore excluded from the analysis.

The collection from LPR I, locality 1 comprised 825 pieces remaining of the original 1048 artefacts recovered by Singh (1965). However, the collection is still informative and the missing inventory comprises mainly chips (see section 5.4 for details on assemblage integrity and homogeneity).

Further, artefacts which had more than 10% of the piece broken were excluded from the final analysis, which numbered 41 artefacts. Heavily weathered artefacts on which it was not possible to discern technological attributes like striking platform, flake scar counts, etc. were also excluded from the analysis. Such indeterminates numbered 87 artefacts.

3.6. ARTEFACT CLASSIFICATION

Typological classification remains an integral part of any archaeological analysis even though it may have no functional meaning, as accurate classification allows comparisons with other assemblages. Typological classification which is essentially based on the morphology of the end product, was done following previous works (Bordes 1961, Isaac 1968, 1977, Tixier 1956, Kleindienst 1962, Clark and Kleindienst 1974, 2001, Isaac *et al.* 1997, Corvinus 1983), taking into account both the primary debitage product and also the morphological and technical attributes of artefacts. Technological analysis was carried out following Böeda *et al.*1990, Inizan *et al.*1999 and Andrefsky 2005. However, elaborate classification schema was avoided as it leads to confusion.

3.6.1 LARGE CUTTING TOOLS (LCTS)

It includes all unifacially and bifacially knapped Acheulean tools, including handaxes, cleavers, knives, scrapers, picks, trihedrals, etc. This term emphasizes the cutting edge of the tools. Others however prefer the term 'bifaces' or 'bifacial tools', as it does not qualify function. Sometimes, bifaces refer to only handaxes, excluding cleavers and picks in this usage. Such variously used terminology adds to the confusion. In this work, we prefer to use the term 'large cutting tool' despite its functional connotation as it reflects an important aspect of size and is inclusive of unifacially knapped tools.

3.6.2.1 Cleaver

The definition, typology, technology of manufacture, distribution and chronology, and methodology of studying cleavers have been approached vividly by various scholars (Champault 1953, 1966, Biberson 1954, 1961, Tixier 1956, Bordes 1961, Kleindienst 1962, Chavaillon 1965, Balout 1967, Alimen 1972, Alimen *et al.* 1978, Wymer 1968, 1971, Isaac 1968, 1977, Cahen and Martin 1972, Gilead 1973, Roe 1964, 1968, 1978, 1994, 2001, 2006, Bianchini 1973, Benito del Rey 1973, 1986, Corvinus 1983, Cranshaw 1983, Inizan *et al.* 1999, Ranov 2001, White 2006, Mourre 2003, Sharon 2007).

A number of contentious issues exist in the definition of cleavers which include inclusion of bifacial tools with a transverse edge as against only large flake tools, modification or retouch of the cleaver bit, inclusion of tranchet blow, inclusion of oblique edges, and distinction between cleavers and square-ended handaxes.

There are mainly two schools of thought. Followers of the French school follow a very restricted definition of cleavers, including only large flake tools with an unretouched transverse cutting edge (Texier 1956, Alimen 1972, Roche and Texier 1995). On the other hand followers of the American school have a liberal approach calling any bifacially knapped tool with a broad transverse cutting edge as a cleaver (Gilead 1973).

Texier (1956: 916) defines a cleaver as "*Le principe dominant qui a dirigé la fabrication d'un hachereau est, on le sait, l'obtention d'un tranchant transversal terminal. …Ce tranchant, qui est toujours naturel, c'est-à-dire exempt de retouches intentionnelles est obtenu, cela va de soi, par la rencontre de deux plans: plan de la face d'éclatement et un des plans de la face supérieure, ce qui impose immuablement un outil sur éclat. Le terme « hachereau sur éclat » devient donc un pléonasme. Il y a de plus des hachereaux dont les retouches envahissent presque totalement la pièce, mais il ne peut y avoir de hachereau entièrement bifacial."*[1]

This is further summarized as *"Le hachereau est un outil oeuvré sur un fragment de galet ou sur un grand éclat pouvant avoir fait l'objet d'une préparation*

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[1] The over-riding principal dominating the manufacture of cleaver is obtaining a terminal transverse trenchant. This edge which is always natural, that is to say, without any intentional retouch, is formed by the intersection of two planes: plane of the flake face and the upper face which requires a tool on flake. The term 'cleaver flake' becomes redundant. There are many cleavers with retouch covering the entire piece, but there can be no fully bifacial cleaver.

antérieure (technique levalloisienne), dont les retouches d'aménagement ont conservé intacte une partie du bord tranchant devenant de ce fait terminale par rapport à l'allongement obtenu de la pièce" (Tixier 1956: 921).[2]

Roe (1994, 151–153) however presented a metrical definition saying that "… a cleaver is defined by its possession of a characteristic transverse or oblique cutting edge at the tip end, having distinct points of junction with the implement's sides (which may be blunt or have working edges of their own)... if an implement is to qualify as a cleaver, the length of the distinctive transverse or oblique edge or 'bit' must be greater than half the implement's breadth (that is to say, if the ratio Cleaver Edge Length/Breadth gave a value greater than 0.500). If not, the implement counts as a square-ended handaxe."

Cleavers in the British Lower Palaeolithic have also been much debated and part of the debate is highlighted in Roe's definition above. Recently White (2006: 365) however opines in the context of British assemblages that cleaver shaped LCTs are "not a discrete, intentionally different form but part of the overall variation within handaxes/bifaces that occasionally emerges from a common technological practice."

Mourre (2003: 250) after a study of 14 series of cleavers from 12 sites in Africa and Europe defined a cleaver as "*un hachereau est un outil sur éclat présentant un tranchant brut formé par l'intersection de la face inférieure du support et d'une face supérieure correspondant selon les cas à un ou plusieurs négatifs antérieurs, à un positif, à un positif et un ou plusieurs négatifs, voire à une surface corticale, néocorticale ou naturelle. La prédétermination du tranchant n'est donc pas une caractéristique intrinsèque du hachereau à l'échelle de la pièce isolée; en revanche, elle l'est à notre sens à l'échelle d'une série dans la mesure où il n'existe pas de série représentative composée uniquement de hachereaux au tranchant non predetermine*."[3]

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[2] The cleaver is a tool worked on a cobble fragment or on a large flake which may have been subject to previous preparation (Levallois method), whose retouch is planned to conserve intact a part of the trenchant therefore becoming terminal to the long axis of the piece.

[3] "a cleaver is a tool on flake with a cutting edge formed by the intersection of the inferior face and the upper face corresponding with one or more previous negative

Mourre (2003) also argues for including angle of cleaver edge as an essential functional characteristic which can be used to exclude many obtuse angled pieces as cleavers with retouched bits generally have high angles. Mourre also argues for the exclusion of bifaces with a transversal bit as a class distinct from cleavers on account of different morphological and metrical characteristics from cleavers.

In this study a more liberal view has been followed taking into account technological factors rather than shaping and retouch into consideration. This study classifies any large flake tool with an intentional broad cutting edge at right angles to the long axis of the tool as a cleaver irrespective of shaping and retouch. This cutting edge is formed by the intersection of the ventral flake face with the dorsal face which can either be a cortical plane (Tixier's type 0), one or more negatives of the dorsal surface, or a positive flake scar (Tixier's type 6).

A number of studies have reported the presence of large numbers of cleaver flakes at Indian and North African sites (Corvinus 1983, Sharon 2007). Cleaver flakes were defined by Kleindienst (1962: 100) as "Flakes in the large size range which have a cleaver-bit edge, but which have not been secondarily trimmed, of the type on which cleavers or other large implements could have been made. Presumably, the shape is due to the type of core used." Cleaver flakes have also been found at the site of Lalitpur. In this study cleavers and cleaver flakes have been grouped together for purposes of analysis as no significant differences were noted in the size, technique and morphology except for lack of retouch on cleaver flakes.

In this study it has been observed here that some cleavers made on imported raw material, that is quartzite, have a retouched cleaver bit as an outcome of curation and resharpening. Recent studies at Bhimbetka (pers. comm. S. Mishra) also show retouched cleaver bits. However, no bifacial pieces with a transversal edge have been documented.

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scars, a positive scar, or a positive and one or more negative scars, or even a cortical, neocortical or natural surface. Predetermination of the edge is not an intrinsic characteristic of the cleaver across the discrete edge; however, it is in our view so far across the series analysed, as there is no representative series composed solely of non-predetermined cleavers."

Some scholars opine that cleavers are closely related to handaxes in terms of metrical properties and are also the result of the same technological strategies even though they have often been viewed as distinct tool types. Isaac (1977: 123) noted that of all the biface forms identified, cleavers did appear to form a "modality that is weakly separate from handaxes" (Isaac 1977: 120), but even these could be seen to blend into classic handaxes via chisel-ended forms.

A wide variety in the technique and typology of cleavers has been noted resulting from intentional design (Goren-Inbar and Saragusti 1996).

Mourre (2003) defines three fundamental phases of cleaver manufacture: preparation of trenchant for the removal of blank, detaching of the cleaver and retouch of the base and edges, however the first or third stage may be absent.

Cleavers have a wide distribution spread throughout Africa (with the exception of Nile Valley), the Near East, and South Asia. They are however not found in the European Lower Palaeolithic, except from some sites in south-western Europe (Santonja and Villa 2006). They have also not been reported from East Asia (Corvinus 2004). During the Late Pleistocene the distribution of cleavers declines particularly in the Franco-Cantabrian region as well as Sub-Saharan Africa (Ranov 2001).

3.6.2.2 Handaxe

The definition of handaxe or biface has been approached by a number of scholars (Kleindienst 1962, Isaac 1968, 1977, Debénath and Dibble 1994, Deacon and Deacon 1999, Noll 2000, Clark and Kliendienst 2001).

Kleindienst (1962: 85) defines a handaxe as "characterized by a cutting edge around the entire circumference of the tool, or more rarely around the entire circumference with the exception of the butt. The emphasis in manufacture, if distinguishable, seems to have been upon the point and both edges. Usually bilaterally symmetrical, and more-or-less biconvex in major and minor sections (i.e., along the major and minor axes). Points range from exceedingly acuate to linguate. There is large variation in size, degree and quality of workmanship, and plan-view, primarily according to the curvature of the edges, the length: width ratio and the placement of the greatest width relative to the length of the tool"

In general handaxe is referred to any bifacial (and occasionally unifacial) tool made on a cobble or large flake with a sharp cutting edge or edges which either converge to form a point or have an edge round the entire circumference of the tool.

Following Corvinus (1983), in this study the term handaxe is preferred over biface because of the presence of a large number of unifacial handaxes. It may be mentioned here that several workers prefer to use the term biface for only tools with significant retouch on both faces. Pieces with unifacial retouch are qualified as flakes rather than handaxes despite similarity in flake morphology and technology of manufacture (see Sharon 2007).

Besides true handaxes, there was noted the presence of a minor component of other large flake tools, namely knives, scrapers, picks, retouched large flakes and also slightly transformed large flake blanks,. These were however not found as distinct types and therefore discussed along with true handaxes.

Roughout

It may be noted here that a number of roughly formed bifacially worked artefacts are found at Acheulean localities which were probably discarded before finishing. They were perhaps knapped with the intention of producing a biface but they lack the formality in morphology of the edges to qualify as a biface and have therefore been variously termed as 'pre-form', 'unfinished' or 'unrefined' tools. Such tools have also been noted at Lalitpur. However, for purposes of analysis these bifacially worked pieces have been grouped along with nicely worked bifaces.

Knife

Knife has been defined in the present study following Kleindienst (1962:89) as a bifacially worked flake "characterized by having one side, or part of one side, blunted or 'backed' while the opposite side and one end, has a sharp cutting edge. The backing may be an original surface-cortex or a fracture plane in the raw material; it may be striking platform of the flake, plain or facetted; or it may be a deliberately trimmed surface. The cutting edge may be untrimmed, formed by intersecting flake surface, unifacially trimmed, or bifacially trimmed. If trimmed, it is thinned and sharpened. The backed edge is markedly thicker in minor section than the opposing cutting edge."

Pick

It is similar to the handaxe, but here the focus is clearly on the distal 'point' with the tip created by the intersection of three flaking planes (Sahnouni *et al.* 2013) leading to a triangular or sometimes quadrangular cross-section. The base of the tools is relatively thick. It can be bifacial or unifacial or even largely cortical, with minimal working apart from the tip. Many picks therefore show less overall shaping and symmetry than handaxes.

Scraper

It is defined as a flake tool which shows consistent small unifacial removals on one or more edges.

Finally, quoting Isaac we may say that the different artefact classes were "recurrent improbable combinations of attribute states" (Isaac 1977: 120), they were not real modalities but "arbitrary zones within a structured continuum" as the boundary between cleavers, handaxes and flakes is very hazy and they all grade into each other.

3.6.3. DEBITAGE TYPES

Debitage has been studied following simple approaches advocated by Andrefsky (2005) and Sullivan and Rozen (1985) and classified as complete flakes, broken flakes, flake fragments and angular chunk or debris. It may be noted that flakes can be part of knapping debris or blanks for other tools.

3.6.3.1. Complete Flake

It is a flake which possesses all of the following features: intact striking platform, bulb of percussion, and distal terminations and lateral edges.

3.6.3.2 Incomplete Flake or Proximal Fragment of Flake

It is a flake with a clear ventral and dorsal face, intact platform, point of percussion and bulb, but missing lateral edges or distal termination.

3.6.3.3 Flake Fragment

It is a portion of a flake that is usually recognized by its clear ventral and dorsal faces but which lacks the bulb and platform and sometimes missing lateral edges also. It may be the result of knapping breaks or damage, which may either be old or fresh

3.6.3.4 Angular Debris

It is a piece of knapping shatter that does not have the properties of a flake like clear ventral face and striking platforms but is not caused by nature. Debris refers to "shapeless fragments whose mode of fracture cannot be identified and cannot be assigned to any category of object" (Inizan *et al.* 1999: 138).

3.7 ATTRIBUTE ANALYSIS

The study is based on the analysis of a number of attributes (Isaac 1977, Goren-Inbar *et al.* 1992, Goren-Inbar and Saragusti 1996, Bar-Yosef and Goren-Inbar 1993, Sharon 2007). This included metrical, taphonomic, typological and technological attributes on each individual artefact. This was done to ensure reliability and aid comparison.

Here we discuss the key attributes used in analysis; their definition and method of measurement or observation (see Appendix 3 for a detailed list of attributes used).

3.7.1 METRICAL ATTRIBUTES

3.7.1.1 Orientation

Arbitrary, but well defined criteria were used for orienting the artefacts so that systematic measurements and attribute recording could be facilitated.

Detached pieces are oriented according to their debitage axis with the ventral or flake surface bearing the striking platform, bulb of percussion and other characteristic flake features is placed towards the observer, while the dorsal or upper face is placed downwards. The proximal end is placed near the observer, while the distal end faces away.

Flaked or battered pieces were oriented according to their morphological axis and the dorsal or upper face was arbitrarily the thicker face and the ventral or lower face was the flatter face.

Finished tools are also oriented according to their morphological axis and placed with the cleaver bit or handaxe point (distal end) placed away from the observer and the butt (proximal end) towards the observer and the ventral face resting downwards on the table. In case the artefact was fully covered with flake scars, the flatter face was considered as the ventral (face 2) face. In case of Kombewa flakes, it was mostly possible to identify the earlier of the two flakes and this was considered as the dorsal face.

3.7.1.2 Dimensions

Dimensions of artefacts for only complete flakes, cores and LCTs were recorded. Flake size is determined by the location of impact and the type of hammer or load applied. The following dimensions were recorded (Fig. 4.1):

1. Maximum length (in mm): measured according to morphological axis as the distance between the two most distant points on the artefact.
2. Flake Technological Length **(**in mm): measured as a straight line distance from the point of impact upto the point opposite on the distal end perpendicular to the wide axis of the striking platform at the centre of the striking platform.
3. Maximum breadth (in mm): measured perpendicular to maximum length as the straight line distance between the two most distant points on right and left lateral edges.
4. Maximum thickness (in mm): measured perpendicular to the plane of intersection of upper and lower surfaces as the maximum distance from the upper face to the lower face.
5. Weight or mass of the piece: noted in grams with a digital balance.

Measurements on flake striking platform

The striking platform is located as the surface contacting the upper and lower face of the flake and the two lateral margins and then the following measurements were taken (following Andrefsky 1998):

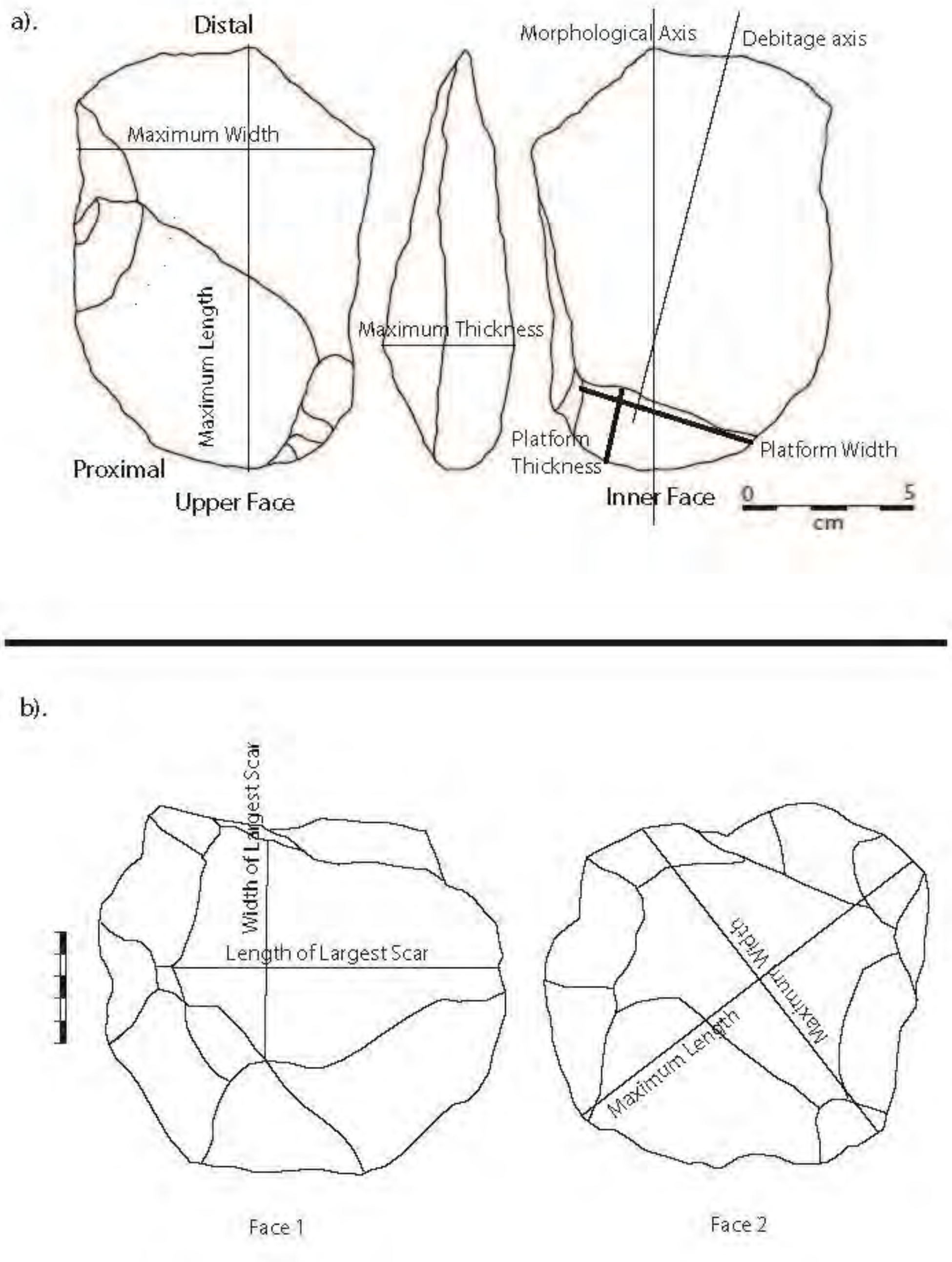
1. Width of the striking platform: taken as the maximum distance across the striking platform between the two lateral margins of the platform.
2. Thickness of the striking platform: it is defined by a line perpendicular to the striking platform width and noted as the maximum distance on the striking platform between the dorsal and ventral surfaces of the flake following that line.
3. Interior platform angle: It is the angle formed by the intersection of the striking platform surface with the ventral flake surface (Dibble and Whittaker 1981). It is a difficult measurement in that the striking platforms have varied morphologies and both the striking platform and the ventral surfaces are often curved and rounded so that varied measurements can result depending on where the line forming the angle is located. Therefore several measurements were taken with the goniometer on different points across the intersection of the platform and the ventral face to ascertain the angle. It was taken away from the bulb.

On cores (Fig. 4.1):

1. Maximum length: taken along the axis of symmetry of the core as the distance between the two most extreme points
2. Maximum width: taken in one vertical plane and perpendicular to the maximum length.
3. Maximum thickness: taken perpendicular to the plane of intersection of the upper and lower surface.
4. Maximum mass: measured in grams with a digital balance
5. Maximum length of the largest scar
6. Maximum width of the largest scar

These measurements were used to calculate several technological ratios:

1. Flake width/ Flake thickness.
2. Flake length/Flake width.



Figs. 3.1: (a). Orientation and measurement of flakes (b). Measurements recorded on cores

3.7.2 TECHNOLOGICAL ATTRIBUTES

This includes the type of blank used, number and location of dorsal scars, percentage of residual cortex and its position on the artefact face, direction of blow of flake, type and location of retouch, etc. This helped assigning an artefact to its relative position in the reduction sequence. Degree of predetermination of artefacts has also been evaluated and for this the number and direction of scars on the dorsal surface and the cleaver bit which inform on the degree of predetermination have been particularly noted.

ON FLAKES

3.7.1.2 Cortex

Cortex refers to the natural weathered surface of the rock which is produced by either chemical or mechanical weathering of the rock surface. It is usually apparent by a variation in colour and/or texture.

Sometimes, it is difficult to recognize cortical surface due to lack of variation in colour and/or texture. At Lalitpur heavy post depositional weathering of the artefacts which is similar to weathering on cortical surfaces often makes it difficult to recognize cortex.

Cortex can be indicative of stage of reduction during the knapping process (Magne and Pokotylo 1981, Odell 1989, Mauldin and Amick 1989). However it varies according to the kind and intensity of reduction and a number of other variables (Andrefsky 2005, Dibble *et al.* 2005).

Cortex was recorded on each artefact on an interval scale based on the percentage of cortex present, though it is often considered unstandardized (Sullivan and Rozen 1985, Dibble *et al.* 2005) as follows:

0: No cortex
1: 1-25%
2: 25-50%
3: 50-75
4: 75-99
5: 100
6: Indeterminate

The position of cortex on the dorsal (upper) surface was also recorded as found on:.

1. Striking platform
2. Dorsal
3. Left
4. Right
5. Distal
6. Mesial
7. Proximal

3.7.1.3 Toth Types

On the basis of presence and absence of cortex on dorsal face and striking platform, Toth (1985) classified flakes into six types. This classification is useful in understanding the broad stage of reduction:

1. Cortical striking platform, totally cortical dorsal surface
2. Cortical striking platform, partly cortical dorsal surface
3. Cortical striking platform, non-cortical dorsal surface
4. Non-cortical striking platform, totally cortical dorsal surface
5. Non-cortical striking platform, partly cortical dorsal surface
6. Totally non-cortical

3.7.1.4 Striking Platform Type

Striking platform refers to the surface on which the percussor impacts. Often they are isolated and prepared beforehand by abrasion, chipping or crushing to control flake detachment. The size of the striking platform determines the size and shape of the flake. The type of striking platform is therefore an important attribute, which also indicates the complexity of core organization management, in other words, the preparation and intensity of reduction as reflected by the number of facets on the platform.

The striking platform was classified according to the number of facets on the platform (modified after Inizan *et al.* 1999) as:

1. Cortical: covered by the natural weathered surface or cortex with no scar facets.

2. Plain: presence of a single scar facet
3. Dihedral: presence of two scar facets
4. Facetted: presence of more than two scar facets
5. Trimmed: secondary modifications occur on the platform obscuring the morphology

   If trimmed, the degree of modification was further noted as:

   a. Only 1 – 2 scars removed
   b. Partly trimmed, bulb removed
   c. Partly trimmed, bulb still present
   d. Trimmed all over, bulb removed

7. Completely removed: anthropic signs of old detachment of platform are seen
8. Broken: the platform surface is broken, indicated by a fresh scar.

These reflect the number of scars on the platform, and therefore inform on core preparation. Cortical platforms occur in the early stage of reduction, plain platforms indicate simple core management, while dihedral and facetted platforms indicate late stage of core reduction or more intense preparation to control flake removals and complex technological strategies.

It was noted that in many cases, particularly for the handaxes, that the striking platform had been removed deliberately by chopping off the portion of the striking platform and the bulb of percussion in order to remove excess mass. The frequency of 'removed' platforms was therefore noted whenever it occurred as a special technological feature.

3.7.1.5 Flake Scar Count and Dorsal Scar pattern

Dorsal scars are the negatives of removals before flake detachment. Count and morphology of the previous scars (scars of flakes produced prior to flake detachment) is an important attribute informing on the technology of manufacture, specifically core preparation and exploitation despite the fact that dorsal scars remaining on the flake or core represent only the last stage in the series of flake removals. Dorsal scars are influenced by core size, flaking technique, raw material, and artefact type. An ordinal scale was used for scar count as it is nearly impossible to count the exact number of scars.

However, because of the coarse-grained and highly weathered nature of the raw material, it was often difficult to establish previous scars. It was also not possible in most cases to determine the sequence of flake scars. Therefore, in such cases only the number of scars on dorsal and ventral surfaces and the pattern of dorsal scars were noted. In some cases, it was even difficult to count the number of scars.

Dorsal scar pattern refers to the direction of scars of previous removals on the cores and therefore aid in determining the sequence of actions prior to flake detachment. (Böeda 1994, de Loecker 2003-2004).

The following categories were used:

1. Cortical: the dorsal surface is covered completely by cortex
2. Unidirectional parallel: the scars originate from one direction and are parallel to each other.
3. Unidirectional convergent: the scars originate from one direction and converge, mostly distally.
4. Bidirectional opposed: the scars originate from two opposed striking platforms at 180°.
5. Bidirectional Perpendicular: the scars originate from two directions perpendicular to each other.
6. Multidirectional (but not centripetal): the scars originate from several directions but do not converge.
7. Centripetal: the scars are detached from more than two directions and converge centrally.
8. Along a median ridge: the scars follow a previous ridge
9. Convergent: the scars originate from one or more directions and converge, mostly distally
10. Positive flake scar: the dorsal surface bears the remnant of a flake surface indicating a Kombewa flake.
11. Irregular: the scars do not follow any clear discernible pattern.
12. Indeterminate: the scar pattern cannot be determined due to weathering or intense secondary modification.

3.7.1.6 Direction of debitage

For the direction of blow of the flake, eight possible directions were noted (following Tixier 1956, Goren-Inbar 1991) with the dorsal surface placed upwards from 1 to 8 (Fig. 3.2).

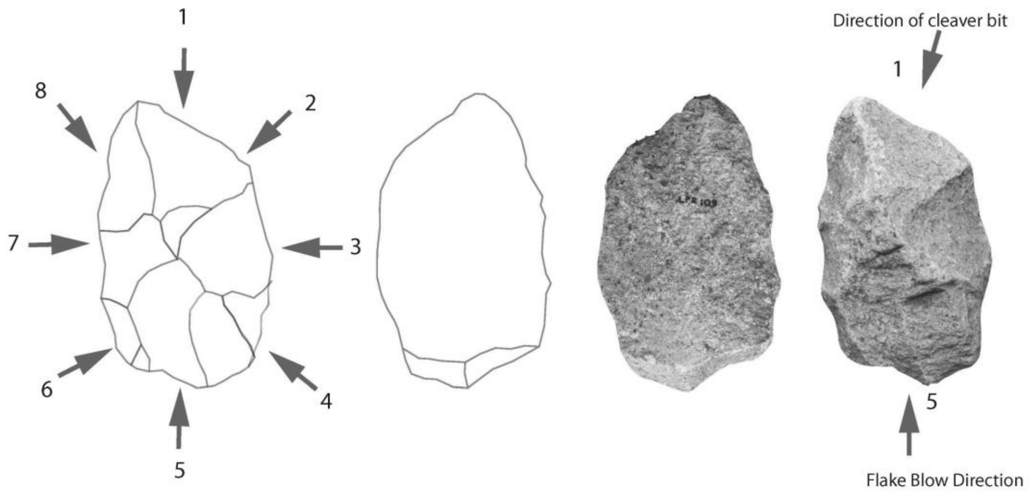


Fig. 3.2: Recording system for flake blow direction and direction of cleaver bit

3.7.1.7 Blank Type

Following Inizan *et al.* (1999), a blank refers to "any element from which an object is knapped, shaped, flaked or retouched. It can be a nodule, slab, cobble, debitage product (flake) etc."

In this study it was often difficult to identify the blank type due to heavy weathering or extensive secondary trimming of artefacts. Blank types have been defined here on the basis of the dorsal scar pattern, direction of debitage and nature of raw material as:

3.7.1.7.1 Kombewa

A Kombewa blank is a complete flake with two ventral faces. Large flakes produced from rock slabs, nodules, boulders or large cobbles are used as cores to detach another large flake, resulting in two ventral faces. In this study any artefact with a plain dorsal face has been viewed as a Kombewa flake, as it was observed that for most flakes, the striking platform has been trimmed away and therefore Kombewa blanks did not show two striking platforms.

3.7.1.7.2 Multidirectional

A number of cleavers displayed multidirectional dorsal scar pattern. However, this was only an intermediate strategy of blank knapping between Kombewa and radial blanks.

3.7.1.7.3 Radial

In this study a number of cleavers and cleaver flakes were observed with radial dorsal scar pattern and very little or no retouch. This indicates that it served as a distinct blank detachment strategy for cleaver manufacture which resulted in blanks which could be used as such without much secondary flaking.

3.7.1.7.4 Slab

Slabs or tabular blocks of rock have also been used for detaching both handaxes and cleavers. It was noted that with the use of slabs, blanks could be detached which served as handaxes and cleavers without much secondary flaking and so this blank detachment strategy may have been preferred.

3.7.1.8 Technological Features

Technological features present on flake were also noted like lip, eraillure, concave or irregular curvature of ventral face, débordant or relict core edges, éclat siret, thinning of bulb, deliberate removal of platform, step fractures and end-shock breaks on LCTs)

Besides accidents were also noted like éclat siret, hinge, step, or plunging termination of the distal margin or thick distal ends.

3.7.3 CORE REDUCTION

Cores provide good information about the knapping methods and techniques employed. They were studied following de la Torre *et al.* (2003) and de la Torre (2011) conceiving it as a geometric volume with six ideal planes. The classification was modified to suit the requirements of the present assemblage.

The following attributes were taken into consideration while classifying cores:

1. Number of faces knapped/flaking surfaces: unifacial, bifacial, multifacial
2. Direction of flake scars: unidirectional (parallel, convergent, irregular), bidirectional (opposed, orthogonal), centripetal, peripheral
3. Coverage: partial, total
4. Angle between the planes: simple, abrupt
5. Organization of knapping surfaces and arrangement of striking platform: hierarchical, non-hierarchical, peripheral
6. Core rotation: alternating

By studying the flaking features and core reduction methods utilizing a *chaîne opératoire* approach, we can arrive at a better understanding of tool making behaviour.

3.7.4 RETOUCH CHARACTERISTICS

Number of secondary scars: These include edge trimming scars.

Location of retouch: The location of retouch scars on both upper and lower faces was noted as:

1. Distal
2. Distal left
3. Distal right
4. Proximal
5. Proximal left
6. Proximal right
7. Mesial left
8. Mesial right

Distribution on edge:

It indicates the portion of perimeter modified and was noted following McNabb *et al.* (2004) as:

1. Complete marginal
2. Partial Marginal
3. Partial
4. Substantial
5. Complete

Extent of Retouch

1. Marginal (1/4 of tool half)
2. Semi-invasive (1/2 of tool half)
3. Invasive (3/4 of tool half)
4. Covering (entire half of tool or more)

Inclination/Edge Angle

1. Flat
2. Oblique
3. Abrupt
4. Step

Retouch Type:

It refers to order of scar superposition in terms of the surface from which retouch originates, the dorsal or ventral surface and was noted as.

1. v-d (dorsal only)
2. d-v (ventral only)
3. bifacial alternating (dorsal-ventral dorsal [DVD])
4. partly bifacial

Edge working:

On the basis of location of retouch scars edge working was classified as on

1. Single side (left/right)
2. Double sides
3. End (Distal)
4. Side and end
5. Convergent
6. All around
7. All tool's face

8. Butt (Proximal)
9. Proximal & sides

3.7.5 ANALYSIS ON CLEAVERS

Number of Scars and Direction

For cleavers, the number of scars predetermining the cleaver bit was also noted. The cleaver bit could be determined by a cortical surface, one or more negative scars, a positive, or a combination of positive (in case of Kombewa blanks) and negative scars (Mourre 2003).

It was usually found to be determined by a single or positive negative scar

Shape of Cleaver Bit

The shape of the cleaver bit was noted as:

a. Splayed
b. Parallel-sided
c. Convergent
d. Ultraconvergent
e. Shouldered
f. Divergent
g. Indeterminate

Delineation of the Bit

The delineation of the cleaver bit was noted as :

h. Straight
i. Convex
j. Concave
k. Convergent
l. Oblique

3.8 DATA ANALYSIS

The artefacts were photographed from various angles (for each artefact 2 to 6 photographs were taken) using Kodak CX6230 digital camera mounted on a stand. The photographs were taken in broad day light. This image archive was also used in data analysis. A computerized database was prepared for artefact analysis using Microsoft Access database program. It was then analysed statistically using Microsoft Excel 2010 and SPSS 17 software. Simple quantification methods were used which enabled a degree of standardization, and facilitated comparisons between sites. For comparisons with other Acheulean assemblages, data was used from Sharon (2007), Mourre (2003), Paddayya *et al.* (2006), and Alam (2001).

CHAPTER V

LITHIC TECHNOLOGY AT THE ACHEULEAN SITE OF LALITPUR

5.1 INTRODUCTION

As mentioned in Chapter IV, we have followed a combination of the attribute analysis integrating morphological, typological, and technological criteria and the *chaîne opératoire* approach to enable an understanding of the nature and acquisition of raw material, manufacture of blanks, shaping of tools, re-sharpening, rejuvenation and final discard at Lalitpur. The understanding so derived about the technological organization is evaluated in the context of the current discussions on the Acheulean.

The assemblage at Lalitpur is characterized by large flake production which is the defining feature of Acheulean lithic technology during the LFA phase (Sharon 2007, Goren-Inbar *et al.* 2011).

The assemblage originally consisted of 1048 specimens (Singh 1965), of which only 825 pieces were remaining for present analysis. The missing pieces from Singh's collection most probably correspond to chips which were not stored as part of the museum artefact inventory. This means that the artefact collection retrieved is informative and representative.

5.2 RAW MATERIAL

The assemblage from Biana Nullah at Lalitpur is made predominantly on granite (97.3%). However a very small percentage of artefacts are made on Vindhyan sandstones and quartzites (2.6%) while only one handaxe was found on quartz (Fig. 5.1 & Table 5.1).

Almost exclusive use of granite at Lalitpur makes the assemblage unique among the Acheulean sites. Only a few other sites including Isimila (Howell *et al.* 1962, Cole and Kleindienst 1974) and Yediapur (Paddayya 1987, 2010) have documented the use of granite for LCT production. Therefore study of the technological organization at Lalitpur becomes even more important towards understanding the role of rock fracture mechanics in the selection of raw material for tools.

Table 5.1: Raw Material Frequencies at Lalitpur

Raw Material	No	%
Granite	803	97.3
Quartz	1	0.1
Quartzite	21	2.6
Total	825	100.00

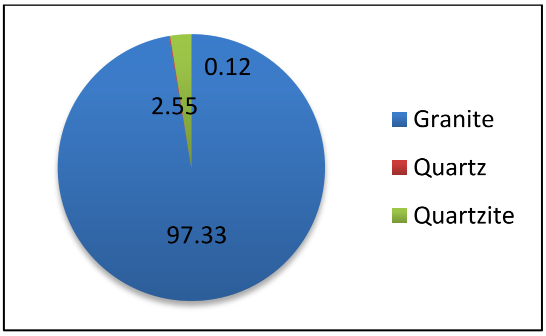


Fig. 5.1: Raw Material Frequencies at Lalitpur

5.2.1 Major Raw Material Types and Sources

5.2.1.1 Granite and Gneissic Rocks

The principal raw material used is granite. Usually fine grained quartzitic granite has been used. Very few artefacts also occur on porphyritic gneissose-granite also. Granite being a multi-mineral rock is quite prone to weathering, usually in the form of heavy granular disintegration. Only few artefacts show foliation in the rock.

It is locally available in good quantity. Outcrops of granite abound in the area as tors and rounded massifs (Fig. 5.2). Weathered corestones, cobbles and boulders lying on the pediplain as well as tabular slabs extracted from the jointed rock outcrops might have been used. It is also possible that the hominins may have used the tors and ridges directly to obtain flakes which have subsequently been weathered.

5.2.1.2 Gneisses

Few outcrops of gneisses are found in the area occurring in association with granites rich in ferro-magnesium minerals. The gneisses are medium to coarse grained with pink and grey feldspars and ferromagnesium minerals showing parallel orientation. Banded varieties also occur with alternating bands of quartz and feldspars and mafic minerals. The foliation varies from NE –SW to ESE-WNW with high dips. When foliation becomes ill defined the rock passes into granitoid gneisses or gneissose granite. Gneisses are highly jointed. The granites and gneisses are infused by pegmatite, microgranite and aplite veins usually 15 to 45 cm in width and up to 20 m long. Gneisses were however generally not selected for making stone tools by Acheulean hominins.

5.2.1.3 Basic Dykes

Numerous doleritic dykes are also found traversing the gneisses in a NW-SE direction, cutting across the quartz reefs at almost right angles, forming low hillocks at places. Dykes are however found in large numbers south of 25° 42' in the Lalitpur-Mehroni area, 40 km south of Lalitpur and therefore not used at the Acheulean site of Lalitpur. At Bijoli and Garhmau they form a series of discontinuous hillocks. Pascoe (1950) suggested that these basic dykes may be feeders to the traps. There are three generations of dykes from coarse to medium to fine grained aphanitic variety. Felsite and porphyry dykes are also noted intruding quartz.

5.2.1.4 Quartz

It occurs as reefs and veins within the granite-gneisses (Fig. 5.2). Quartz reefs either occur as isolated occurrences or run discontinuously for long distances as long narrow ridges along a general NE-SW to NNE-SSW strike with few deviations to NNW-SSE direction. They rise to about 175 m above the ground level. They generally consist of fine grained, compact, cherty quartz mixed with microcline, perthite and feldspar. At places quartz reefs are associated with quartz-schists, quartz-pyrophyllites chists and pyrophyllite deposits in the form of lenticular bands. They are generally greyish white but pinkish white or milky white colours are also noted. They are often jointed and highly shattered with local disseminations of pyrite, haematite and chalcopyrite. At Bar, Patha, Karesra Kalam and Garholi they seem to bifurcate (Kumar 2005). Sometimes reefs have dammed the courses of streams or obstruct the general surface run-off to form shallow tanks. Frequency of reefs diminishes south of Lalitpur-Mahroni line, maximum being found in the Talbehat – Babina region and North. Quartz reefs continue to occur in Chirgaon – Moth areas.

However it is not found in suitable sizes for LCT production. Only one handaxe on quartz was recovered in the excavation at locality 1.

6.2.1.5 Sandstone

Sandstone ridges are exposed in the southeast of Lalitpur in the Vindhyan escarpment. The nearest outcrop is at Jiron 6-8 km away. Better and more extensive outcrops are found near Jakhlaun, 18 km away from Lalitpur (Fig. 5.2), which could alternatively have been selected.

Fine-grained varieties of sandstone producing conchoidal fractures were mostly used. Red medium grained and pinkish white fine-grained varieties of sandstone were used to make finely retouched artefacts. Usually the artefacts on sandstone show the presence of a weathering rind.

It was collected either from the fluvial cobbly gravels in the riverbed or from the rock exposures or colluvial gravels near the Vindhyan escarpment. Rounding and weathering evident in the unflaked cortical portions show that colluvial cobbles must have been used.

Quartzite cobbles have been found in good quantity in the rubble containing artefacts, as they were perhaps brought to the site by Acheulean toolmakers as manuports.

Given the fine-grained and exotic nature of the raw material it was conserved heavily. The few artefacts on this raw material are heavily curated.

The assemblage from the excavation at Locality 1 demonstrates that raw material available in the vicinity of the site in suitable sizes and morphology was used for the production of stone tools. The area is rich in granite outcrops and quartz veins, but quartz is not found in suitable sizes for LCT production, and therefore granite was the predominant rock type. A minor percentage of LCTs were made on non-local quartzite and sandstone.

Use of rock types readily available in the local basin and planned extraction was both evident. The presence of non-local rocks signifies hominin transportation. Rock exposures, fluvial and colluvial gravels were a major source of raw material.

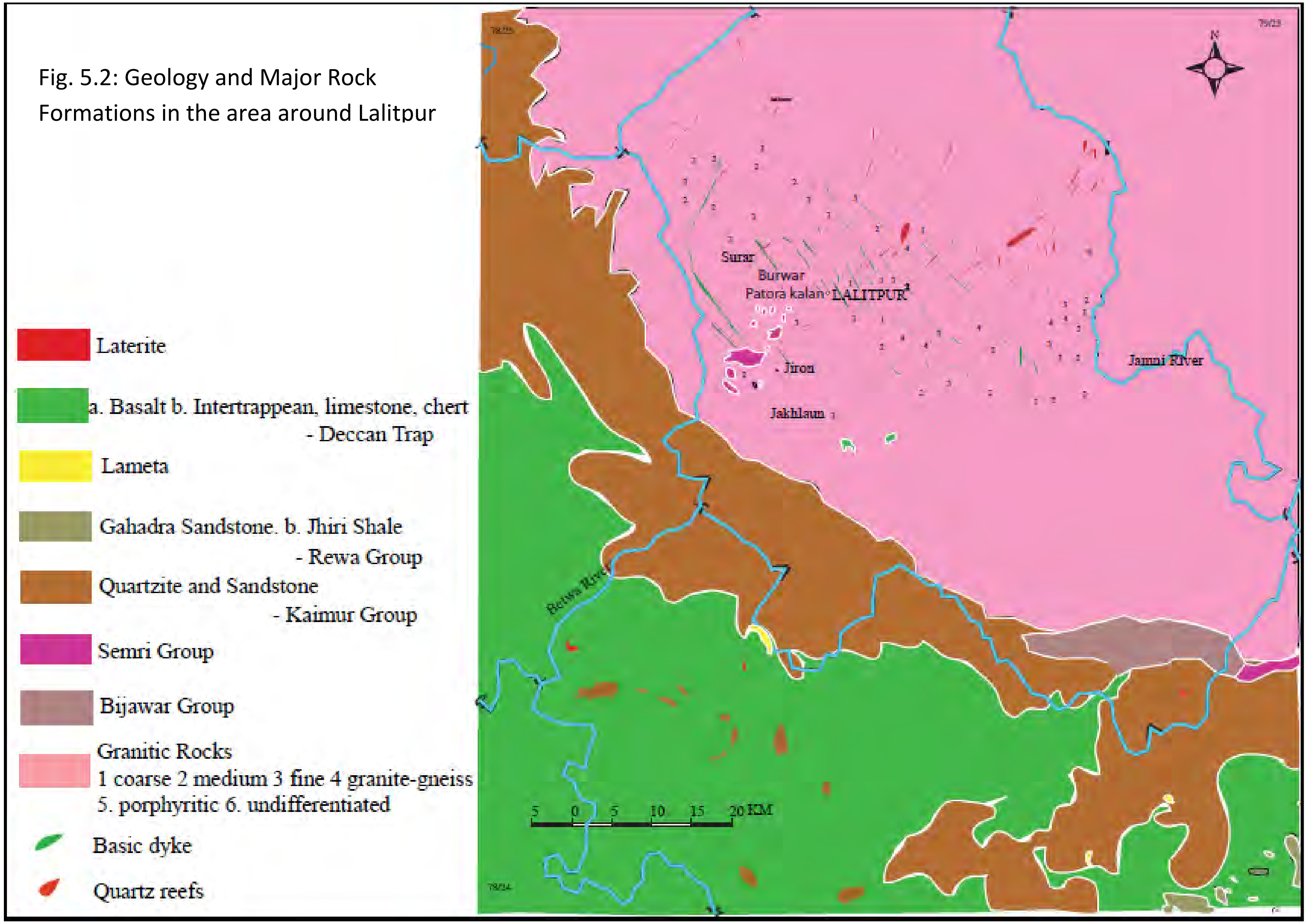


Fig. 5.2: Geology and Major Rock Formations in the area around Lalitpur

However, the picture is much more complex. The assemblage from another locality, LPR II in a similar geological terrain just 2 km away is made exclusively on Vindhyan sandstones and quartzites, which can be sourced 8 – 15 km away. It may be noted that suitable granite outcrops are found in the area. Similar differences in raw material selection have also been noted at neighbouring sites of GBY and Ma'ayan Barukh (Sharon 2007) and also in the Hunsgi - Baichbal basin sites (Jhaldiyal 1997, 2006, Paddayya 1982). This variability could either be due to the two assemblages not being contemporaneous and belonging to different timespans, or due to differential weathering of the two rocks. In this context it may be noted that the assemblage on quartzite comprises more refined and well-worked handaxes which may belong to a later time period. However, due to lack of any methods to date the sites, it cannot be ascertained. Experimental data from replication of tools on both granite and quartzite, and also on the nature of weathering of the two rocks may help clarify the picture.

5.2.2 Properties of Granite

Since granite was predominantly used at Lalitpur for making stone artefacts, and it has been previously assessed as a rock not very suitable for knapping artefacts (Inizan *et al.* 1999), it was decided to undertake detailed studies of the properties of granite used at the Acheulean site of Lalitpur in order to understand raw material selection strategies. Mineral composition, microstructure, and mechanical properties affect fracture properties.

5.2.2.1 Granite Composition

Granite is a complex heterogenous and often anisotropic, multi-mineral migmatic, plutonic rock. It has a medium to coarse texture, occasionally with some individual crystals larger than the groundmass forming a rock known as porphyry. It essentially has an acidic composition with quartz which makes up 10 to 50 percent of the felsic components and feldspars with the ratio of alkali to total feldspar between 65 and 95 percent. Quartz and feldspar make up 90% of the rock. It also has feldspathoids (alkali or plagioclase), microcline (alumino-potassic silicates), plagioclase (sodio-calcic silicates), mafic minerals rich in iron, micas like biotite or muscovite (silicates with aluminum, iron, magnesium and potassium), hornblende and some accessory minerals like zircon.

Granites can be pink to dark gray or even black, depending on their chemistry and mineralogy. It is nearly always massive (lacking internal structures), hard and tough.

Bundelkhand Granites

Granites in the region display great heterogeneity in texture and composition. They vary from fine to coarse grained to porphyritic. Pink and grey varieties are found depending on the nature of feldspars. Rahman and Zainuddin (1993) and Mondal and Zainuddin (1996) distinguished hornblende granites, biotite granite and leucogranite. Different varieties are sometimes found to occur together, at times showing gradual transition. North of Babina coarse-grained granites crop out extensively. The prominent joint directions are N-S, NNE-SSW, NE-SW and NW-SE dipping at high angles to nearly vertical. Fine and medium-grained varieties occur in Ratauli – Tanka – Khajraha and across the Betwa River in Barwasagar and in Mauranipur. Low isolated hillocks are also found in Chirgaon – Moth and Gursarai. Fine grained, hard, compact, quartzitic in appearance with little ferro-magnesium minerals (used at Lalitpur Acheulean site for making tools) and also medium grained varieties occur predominantly south and southwest of Babina. It outcrops extensively in Digara – Bijrotha – Jamalpur - Tenai area, in Baroda – Dang – Bas - Peron area, in Bansi - Jakhora area and in parts of Lalitpur and Mahroni areas. Porphyritic granite has a limited distribution in the area particularly on the NE of Talbehat along with coarse to very coarse granite. The rock is profusely traversed by quartz veins in N to NW direction.

5.2.2.2 Mechanical Properties of Granite

All the minerals in granitic rocks have different properties and behaviour. While quartz has indistinct cleavage and conchoidal fracture with a higher hardness and resistance to chemical alteration, stable structure and low solubility; feldspar and mica have perfect or good cleavage, uneven fracture and low hardness and are easily altered; plagioclase is chemically little bit stable, and mica also alters easily. The general physical properties of granitic minerals are outlined below (Table 5.2).

Table 5.2: General physical properties of minerals in granite

Physical Properties	**Quartz**	**Microcline**	**Albite**	**Orthoclase**	**Muscovite**
Cleavage	[0110] indistinct	[001] perfect, [010] good	[001] perfect, [010] good	[001] perfect, [010] good	[001] perfect
Hardness	7	6 – 6.5	6 - 6.5	6	2.5
Fracture	conchoidal	irregular/uneven	irregular/uneven, conchoidal	Uneven	micaceous
Density (g/	2.65-2.66	2.54 - 2.57	2.61-2.63	2.56	2.77-2.88
Tenacity	brittle	brittle	Brittle	Brittle	elastic
Habit	Crystalline – coarse, fine	Prismatic, granular, massive	Blocky, granular, striated	Blocky, crystalline, prismatic	Foliated, massive, micaceous

Previous studies show that in general, the strength of rocks is greater for finer grained rocks (Brace, 1961). The granite from Lalitpur has relatively larger feldspar and quartz minerals. Generally, larger mineral grain size in granitic rocks contribute to increased sensitivity to fracture (brittleness) in two ways: (i) mineral cleavage in feldspars can occur more easily (Hajiabdolmajid and Kaiser, 2003) and (ii) the larger the grain size, the larger the grain boundary, and then the less the energy needed to keep the crack growing because surface energies of grain boundaries should be less than those of the intact grains (Whittaker *et al.* 1992). Strength also increases as the quartz content increases while the abundance of easily cleavable minerals lowers strength. Feldspars have a very important role in strength reduction. According to Onodera and Asoka Kumara (1980), the presence of mineral cleavage and microfissures in feldspars within the intact specimen also lowers the tensile strength as it lowers the compressive strength.

The quartz/feldspar ratio has been recognized by some authors as a dominant factor affecting mechanical strength of granitic rocks (Tugrul and Zarif1999).

5.2.2.2 Petrographic and Chemical Analysis of Granite Used

Petrography, X-ray diffraction and Infrared Spectroscopic techniques were carried out by the present author used to determine the mineralogical composition of granite (Agarwal 2008). This study was actually conducted to understand the effect of rock composition on mechanical and micro wear properties, but it is relevant in the context of the present study also.

The granite from the site of Lalitpur which has been used for making tools shows abundant circular to sub circular anhedral crystals of quartz, with undulose extension, mainly potassium feldspars, microcline and orthoclases (orthose with its specific Carlsbad macle) and little plagioclase (albite macle is noticed alongwith probably oligoclase) and very little mica (probably muscovite but no biotite) in thin section (Figs. 5.2 &5.3). Secondary minerals included pyroxene, hornblende and magnetite. The thin section also showed the presence of ferric oxides which lent the color to the granite. Accessory minerals included zircon.

The feldspars are altered. Kaolinisation of feldspars with oxides of ferrum and titanium and red tint and also alteration into illite, montmorillonite or kaolinite (alkali feldspars) has been observed. Damouritisation of plagioclase is noticed with alteration pattern E with 0, 1, 2 and 3 classes (Stoops *et al.* 1979).

The Infrared spectroscopic analysis (Attenuated Total Reflection) based on differential absorption of IR radiation showed quite abundant quartz and feldspar (clear trough) and very little mica (little absorption) in ATR spectra of the granite from the site of Lalitpur (Fig. 5.4).

Powder X-ray diffraction (XRD) analysis to identify the main minerals (α-quartz, alkali feldspar, plagioclase, mica) shows that the granite from Lalitpur contains mainly quartz, microcline and albite. It does not show any clear signature for mica (Fig. 5.5).

SEM-EDX analysis of the granite from Lalitpur showed higher percentage and larger phenocrysts of quartz (Fig. 5.6).

The granite is finer grained, hard, compact, quartzitic in appearance, with ferro-magnesium minerals and less porphyry. It lacked cracks and fissures. Perhaps presence of quartz in abundance and finer grained texture makes it more suitable for flaking and gives a neat and regular fracture.

However, X-Ray Fluoresence may give better results. Further, in the future more detailed studies of mechanical properties like hardness, strength, etc. may help us better understand knapping on coarse-grained multi-mineral rocks like granite.

5.2.3 Raw Material Selection

At Biana Nullah, it was noted that at least two different varieties of granite outcrop quite close to the site of Lalitpur (as shown in Fig. 5.2). However, detailed mineralogical and petrographic studies of the raw material show a clear preference and deliberate selection of finer grained and more quartzitic granite to the exclusion of porphyritic or coarse to medium grained varieties also present at the site and its vicinity. This particular granite is shown to have a higher percentage of quartz which was present in the form of large crystals. Higher percentage of quartz made this particular granite type more suitable for flaking large flake blanks with a sharp cutting edge. It was not only finer grained but also more durable, and without foliations.

Only a very negligible proportion of flakes seem to be made on foliated gneissose-granite and these artefacts also do not have the morphology or size suitable for LCTs. Another point which may be worth mentioning here is that battered tools are preferably made on quartzite. A large number of quartzite cobbles were also found from the excavation at locality 1 which were however discarded after excavation (Singh 1965). High frequency of quartzite cobbles was also noticed in the ditch section at Locality 5 near Biana Nullah.

5.2.4 Source of Raw Material

The raw material source could be inferred on only 141 (13%) artefacts which showed dorsal cortex. Out of these only 9.2% are made on cobbles, while 57.5% are made on nodules derived from the local outcrop while 33.3% are made on slabs (Table 5.3). In cases where the source could not be determined, the artifacts are mostly on large flakes made from big weathered corestones.

Table 5.3: Source of Raw Material of artefacts at Lalitpur

Source of Raw Material	Frequency	Percentage
Cobble	13	9.2
Nodule/Block	81	57.5
Slab	47	33.3
Total	141	100.00

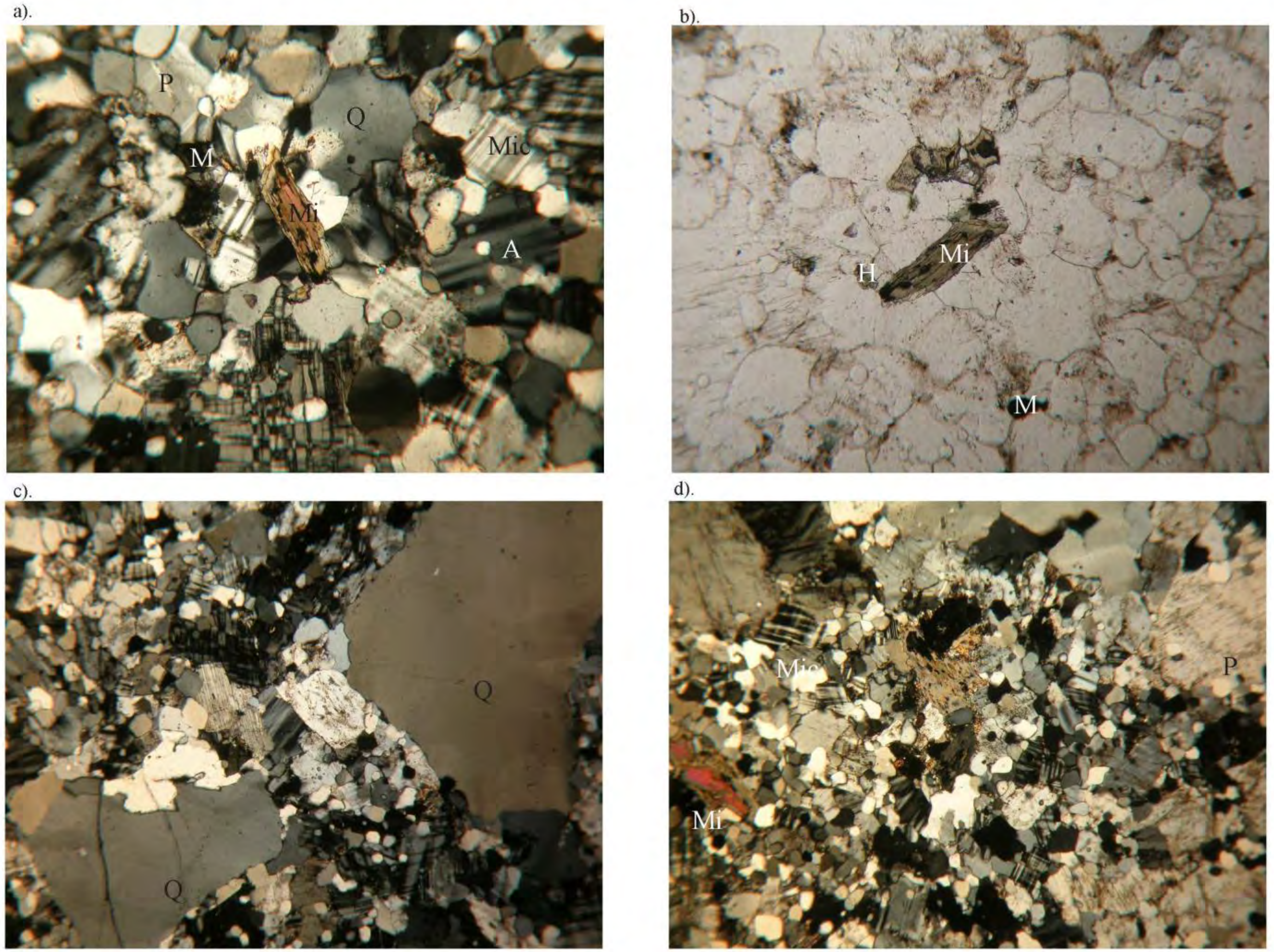


Fig. 5.3a: Minerals as observed in granite thin section: a). Large crystals of quartz and feldspars with smaller crystals in matrix along with mica and magnetite. (b). Hornblende, Mica and Magnetite in PPL. (c). Large quartz crystals in cross polarized light. (d). Another view of minerals in thin section

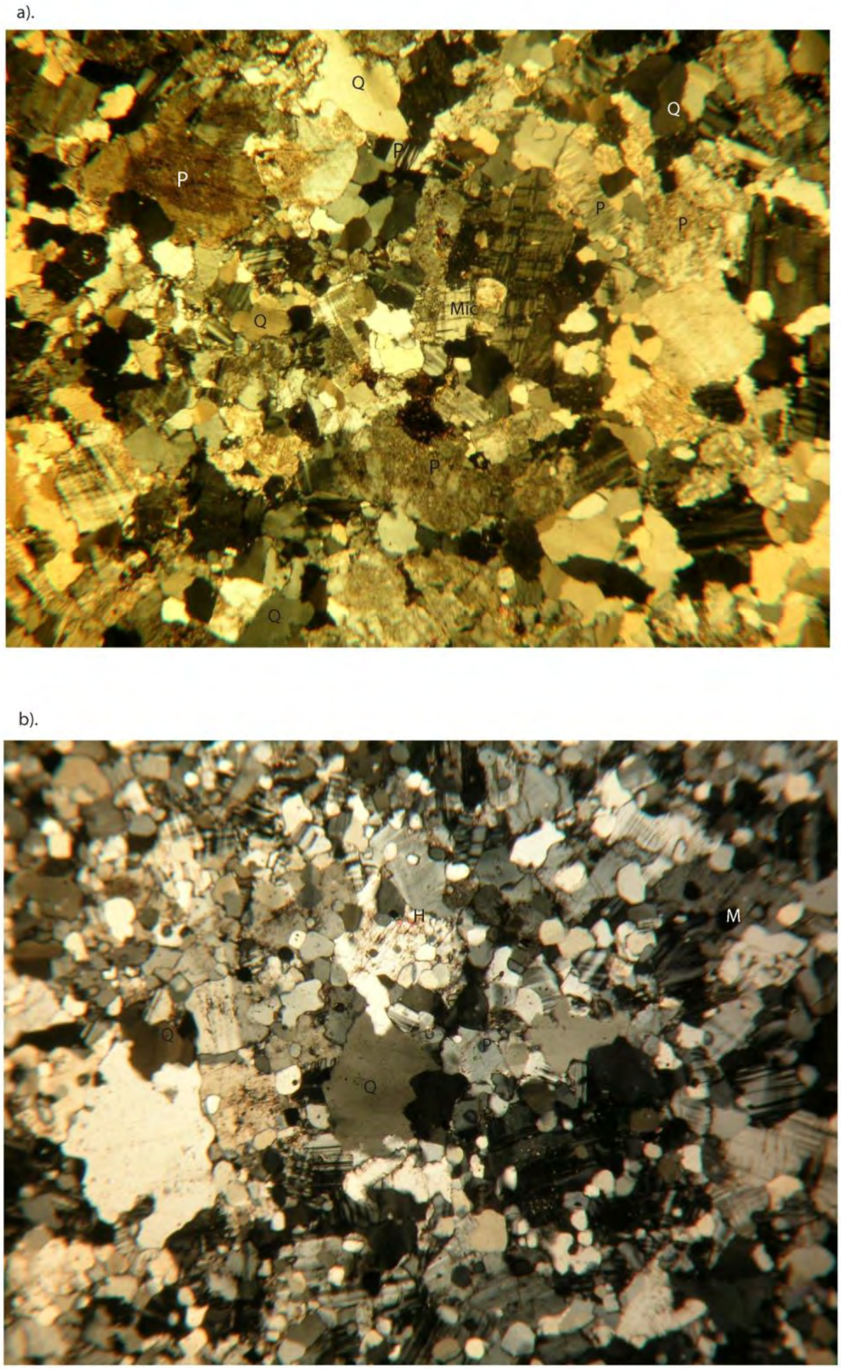
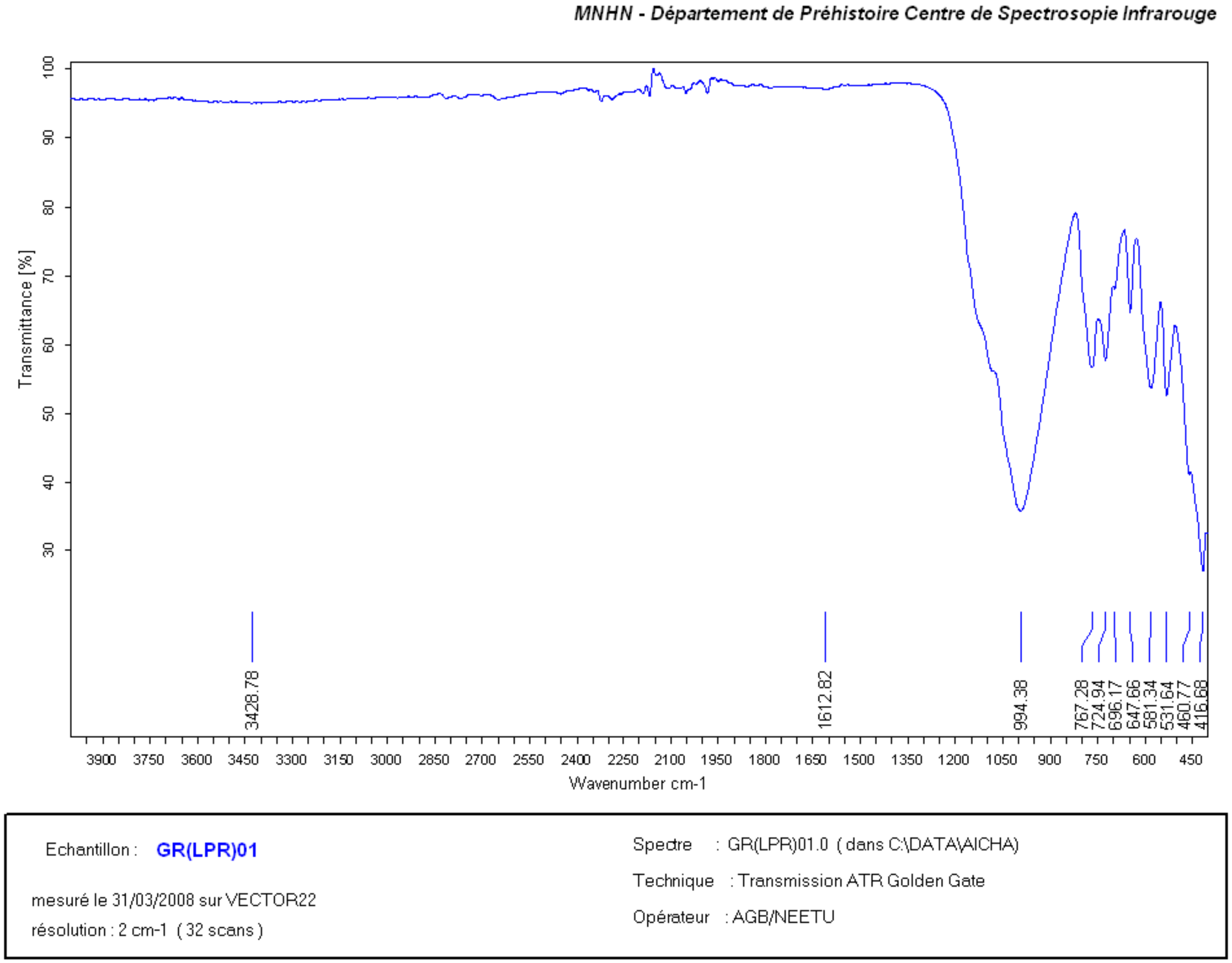


Fig. 5.3b: Thin section of granite from Lalitpur in Cross Polarized Light: a). Damouritization of Plagioclase. (b). Another view of the thin section. Q = Quartz, P = Plagioclase, Mic = Microcline, M= Magnetite, P=Pyroxene, H=Hornblende



MNHN - Département de Préhistoire Centre de Spectrosopie Infrarouge

Echantillon : **GR(LPR)01**

mesuré le 31/03/2008 sur VECTOR22

résolution : 2 cm-1 (32 scans)

Spectre : GR(LPR)01.0 (dans C:\DATA\AICHA)

Technique : Transmission ATR Golden Gate

Opérateur : AGB/NEETU

Fig. 5.4: Infrared Spectroscopic Spectra for the Granite from Lalitpur

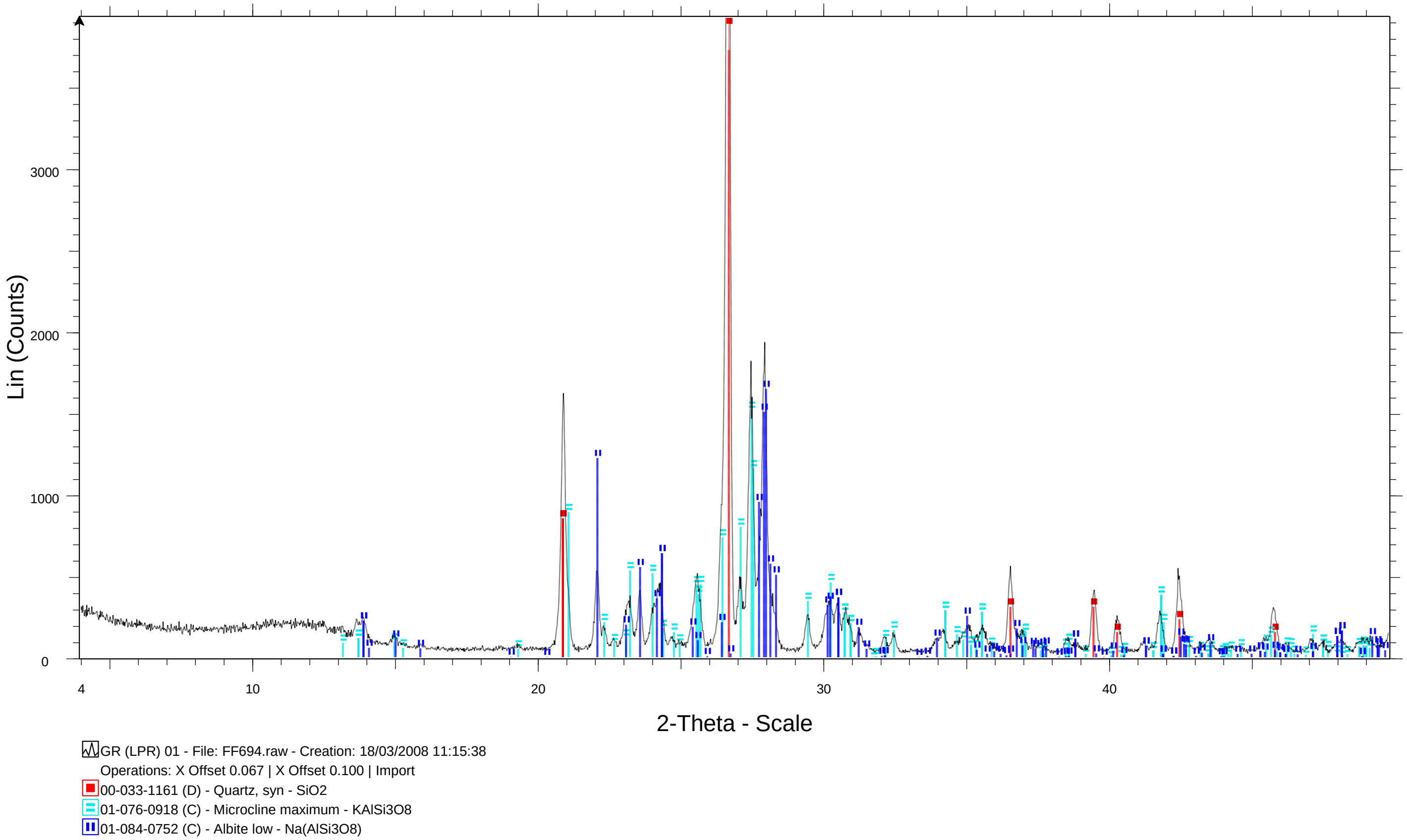
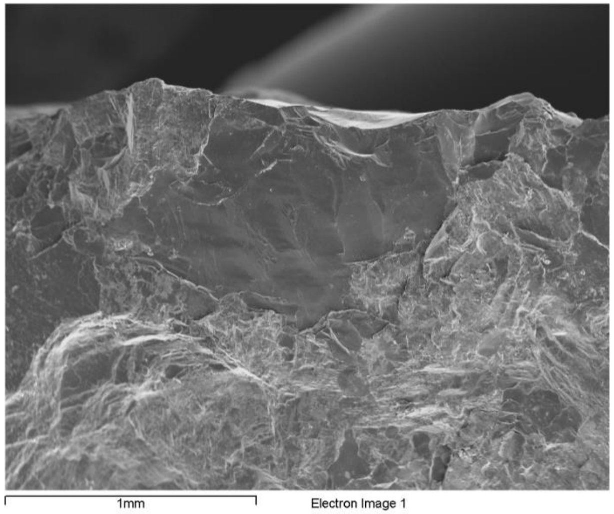


Fig. 5.5: X-Ray Diffraction Spectra of the Granite from Lalitpur



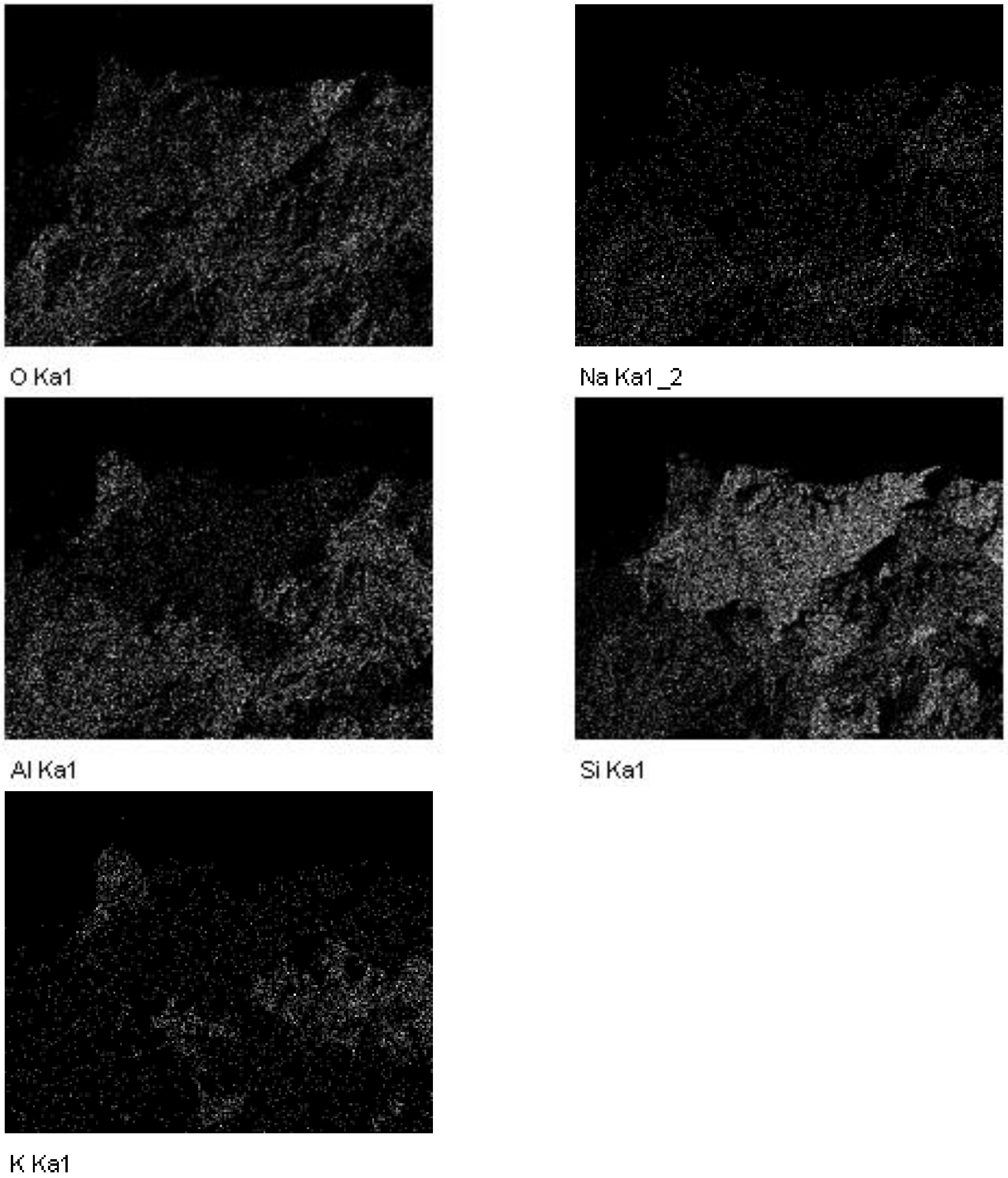


Fig. 5.6: SEM-EDX Analysis of the Granite from Lalitpur

To conclude, the artefact distribution patterns in relation to raw material vary according to the distance of raw material sources with predominant utilization of local (<5 km) raw material and fairly limited utilization of semi-local (5–10 km) and distant (>10 km) raw material (Moncel and Combier 1990, Feblot-Augustins 1997). However detailed sourcing studies can provide a better picture in relation to varieties of granite and quartzites used and their sources in the landscape.

5.3 ASSEMBLAGE COMPOSITION

Typologically the assemblage has been classified into:

1. Detached Piece
    a. Complete Flake
    b. Broken flake (proximal end, mid-section, distal end)
    c. Flake fragment
2. Large Cutting Tools (LCTs)
    a. Cleaver
    b. Other LCTs
3. Flaked Piece
    a. Core
    b. Core Fragment
    c. Angular Chunk
4. Battered Piece
5. Indeterminate

The typological breakdown for the lithic assemblage from the excavation at Locality 1 near Biana Nullah is presented in Table 5.4.

The assemblage is characterized by high values of large cutting tools and very low percentage of cores and debitage.

Debitage including flakes and flake fragments constitutes 51.27%, while LCTs (including large retouched pieces) constitute 22.67%, cores, core fragments, and battered cobbles make up 6.42% of the total assemblage. Flaking debris is only 8.6% (Fig. 5.7). A very high number of pieces (11.03%) could not be determined typologically due to the high degree of weathering making it difficult to identify features on the rock and were therefore labelled as indeterminates**.**

Flakes and flake fragments, including LCTs on flakes make up 71.51% of the entire assemblage, while cores and core fragments constitute a small 5.7%.

Of the flaking debitage, incomplete flakes form 3.51% of the entire assemblage and 9.57% of all flakes, including LCTs on flakes. Flake Fragments constitute a fairly high 34.79% of the entire assemblage.

The flake: core ratio (flakes and flake fragments divided by the number of cores and core fragments) is quite high at 12.55 flakes per core. This shows a predominance of detached pieces (unretouched and retouched flakes, flake fragments and LCTs on flakes) against flaked/pounded artefacts (cores and core fragments).

Table 5.4 Typological Classification of Artefacts from Lalitpur, Biana Nullah, Locality 1

	Granite	Quartzite	Quartz	Total	
	N	N	N	N	%
DEBITAGE					
Complete Flakes	105	2		107	12.97
Broken Flakes	28	1		29	3.52
Flake Fragments	287			287	34.79
Subtotal	**420**	**3**		**423**	**51.27**
LARGE CUTTING TOOLS					
Cleaver & Cleaver Flakes	84	4		88	10.67
Other LCTs	92	6	1	99	12
Subtotal	**176**	**10**	**1**	**187**	**22.67**
CORES					
Cores and Core Flakes	30	4		34	4.12
Core Fragments	13			13	1.58
Battered Tools	2	4		6	0.73
Subtotal	**45**	**8**		**53**	**6.42**
FLAKING DEBRIS					
Chips					
Angular Chunks	71			71	8.61
Subtotal	**71**			**71**	**8.61**
Indeterminates	91			91	11.03
Total	**803**	**21**	**1**	**825**	**100**

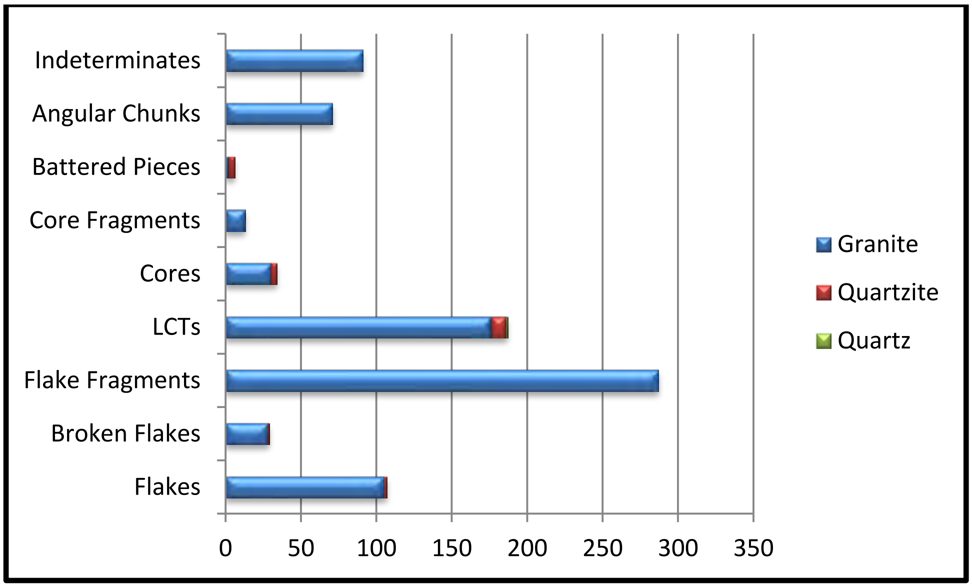


Fig. 5.7: Percentage Distribution of Artefact types

5.4 CORES

Cores inform about the knapping method employed during the last stage before being incorporated in the archaeological record. Though cores and core fragments together form a minuscule 5.7 % of total assemblage at Lalitpur, yet they reveal important information about Acheulean hominin technological organization.

As mentioned before, cores were studied following de la Torre (2011) and de la Torre *et al.* (2003) conceiving it as a geometric volume with six ideal planes.

The core methods have been classified taking into account a number of parameters including original core dimension, cortex cover, striking platform orientation and number of facets, angle between the platform and flaking surface, plane of intersection of platform and flaking surface, scar count for each surface including flaking and preparation surface, scar pattern, invasiveness of scars, and dimensions of the scars, particularly that of the largest scar.

5.4.1 Methods of Core Reduction

Core methods and study of large flakes and LCTs show that the basic methods of large flake blank production used at Lalitpur were (Table 5.5 & Fig.5.8):

1. Kombewa method

2. Bifacial exploitation
3. Multifacial exploitation
4. Hierarchical Preferential Core
5. Core on Flake
6. Casual Slab Core

Table 5.5: Frequency and Percentage of Core types

Core types		N	%
Simple	Casual Slab Core	5	10.6
	Bifacial Partial Chopper	4	8.5
	Bifacial	10	21.3
	Multifacial	3	6.4
	Core on Flake	8	17.0
Organized	Preferential	4	8.5
Others	Core Fragment	13	27.7
Total		47	100.0

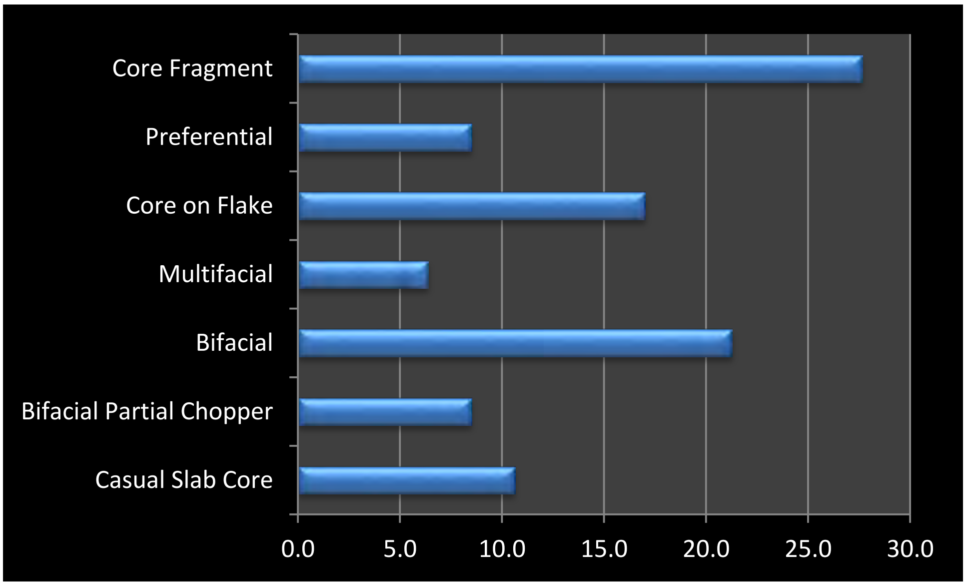


Fig. 5.8: Percentage Distribution of Different Core Types

5.4.1.1 Kombewa method

No Kombewa cores were found at Lalitpur. However, the presence of a large number of Kombewa blanks (41 pieces or 4.96%) suggests an extensive use of this method for blank production (see section 5.6.1.7 for details).

5.4.1.2 Bifacial Core

In this method removals are made from two planes or surfaces. Often, the scar left by the previous flake on one face is used as striking platform for the next removal on the other face. This involved alternation of surfaces and core rotation.

This is the most common method of exploitation at the site of Lalitpur. Bifacial methods have been recorded at a number of other Acheulean sites also (Sharon 2007, de la Torre *et al.*2003, 2008, de la Torre 2011,Mourre 2003)

Within this simple and broad schema of exploitation, there is considerable variability with partial (chopper core) exploitation, alternate or opposed flaking, radial exploitation and the discoid method (Mourre 2003).

Bifacial partial cores are flaked unifacially or bifacially along just one edge such that only part of the surface is flaked. They are actually classic choppers. The removals in case of chopper cores could either be for flake production or for creation of a 'chopping' edge. However, since heavy weathering precluded identification of use-wear, the four choppers recovered at the site were here classified as cores (Figs. 5.11 & 5.12).

In the **discoid method**, alternate radial extractions are made along the bifacial edge at an obtuse angle to the plane of intersection between two asymmetrical convex surfaces. There is no clear hierarchy of surfaces and the emphasis is on maintenance of peripheral convexities. The two surfaces are used alternately as striking platform and flaking surface for the production of radial flakes. However, flaking is much more organized resulting in efficient core management and effective utilization of the core volume. Only two such cores were found at Lalitpur (Fig. 5.13).

Radial cores involve systematic bifacial flaking of a core around the circumference in a centripetal manner. Four cores have radial flaking patterns and another four show alternate bifacial flaking around the circumference of the core but not in a radial manner (Figs. 5.14a & b).

5.4.1.3 Multifacial Core

Multifacial cores were knapped using three or more surfaces or planes in a random or unorganized pattern. This method was largely expedient and did not involve core maintenance or platform preparation as the platform was frequently changed. Three such cores were recovered at Lalitpur (Figs. 5.15a & b).

5.4.1.4 Preferential Core

This involves preparation of two asymmetrical and hierarchical surfaces separated by an intersection plane. The horizontal plane is used to detach large blanks, whereas transversal and sagittal planes serve to prepare the striking platform. The core is designed to remove one large preferential flake from the main exploitation surface serving as a large flake tool blank.

It is a fairly standardized reduction method involving core preparation and central volume management implying high technical knowledge. However, such large removals resulted in loss of convexities and necessitated reshaping before additional flakes could be removed. Use of this method has been documented at the Early Acheulean site of Peninj in East Africa (de la Torre 2011, de la Torre *et al.* 2008).

Only four such cores are found in the collection from the excavation at Locality 1 (Fig. 5.16).

One such core displays a pyramidal underside and a flat or slightly angled upper surface with few removals and much less volume. The removals on the upper surface which are largely parallel to this surface are indicative of a preferred flaking surface. Further it shows the negative of a large, final, preferential removal which is struck largely parallel with the surface rather than at an angle. The nature of the final removal shows that it is not accidental but probably deliberate. The asymmetrical shape was probably intentionally knapped and not influenced by the natural shape of the blank. Part of the platform remaining on one such core indicates a plain striking surface.

The morphology and size of the scar for preferential removal occupying more than 50% of the core flaking surface suggests that LCTs were detached from these cores. Only 1-2 LCTs could be detached from such cores.

5.4.1.5 Cores on Flakes

A few flakes seem to have been detached using previous large flakes as cores. Only those pieces were classified as cores on flakes from which either three or more flakes had been removed, or else the flake scar covered a large part of the flaking surface; and extraction relied on the geometry of scars and ridges left by the previous flake removals (Hovers 2010).

The cores on flakes enable extraction of flakes with relatively little investment in core preparation as the ventral and dorsal faces of flakes are parallel and intersect at a plane. The ventral face is used as a striking platform and the dorsal face scars provide the guiding ridges shaping the future flakes.

However, it appears that these flakes were specifically chosen for flake extraction. Cores-on-flakes are larger, wider and thicker than unretouched flakes and therefore selected for removing small flakes. The mean length of complete flakes is 10.25 cm, while that of cores-on-flake is 12.06 cm. The width is 9.01 cm while flakes have a width of 7.58 cm. They are also relatively thicker.

5.4.1.6 Casual Slab Core

These are cores made on tabular slab with only few removals. They have an irregular shape and the removals are in a random pattern with no clear organization of flaking and the irregular use of any available flaking angles.

Casual flaking indicate opportunistic use of raw material and an expedient technology with low flake count, low number of platforms and random flaking pattern utilizing the natural shape of the raw material.

5.4.1.7 Core Fragment

These are artefacts with large removals diagnostic of a core but which is broken.

Most of the knapping methods are based on bifacial exploitation (simple partial choppers, alternating, discoid, radial flaking). Only a few cores employ multifacial system of exploitation. There are a considerable number of casual cores with only 1-3 flakes removed from one or more surfaces. Cores with hierarchical preferential removals indicating organized flaking and high technical skills for volume management are also found though in less than expected frequency.

Even though we have only a small dataset, the core attributes for the different types of cores are discussed separately as they do indicate broad variations between the different types, though they may not be statistically significant.

5.4.2 Core Sizes

Cores mostly fall in the size range of 10 – 15 cm. However, they range from fairly small sized cores, as small as 5 cm and weighing about 60 gm. to larger cores measuring 20 cm and weighing nearly 3 kg (Table 5.6; Figs. 5.8 & 5.9).

It is possible that some cores may have initially started as larger cores, finally reduced to a smaller size before final discard. Madsen and Goren-Inbar (2004, also mentioned in Sharon 2007) in the experimental reduction of a giant core using the bifacial method detached 15 large flake blanks and 12 small flake tool blanks from a 23.4 x 13.5 x 10 cm core weighing 35 kg before finally discarding it.

Only one giant core measuring 38 x 27 x 13 cm was recovered from the ditch section at Biana Nullah. This indicates the presence of large sized cores for making large flake blanks for tools (Fig 5.17). From this giant core, flakes were removed by alternate bifacial knapping using the negative scar of the previous flake removal as a striking platform for detaching the next flake. This would have resulted in plain or dihedral platforms. There is no careful preparation of the striking platform as noted in core methods of the subsequent Middle Palaeolithic, namely the Levallois and Discoid methods.

The dimensions for the different core types show that the hierarchical preferential cores and the multifacial cores are slightly larger in size, while bifacial core and cores on flake are medium sized. Discoid cores and chopper cores are small sized cores (Table 5.6; Figs. 5.9 & 5.10).

Table 5.6: Dimensions of different core types from excavation at Locality 1, Lalitpur

	Length			Width			Thickness			Mass			
Core Type	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**N**
Bifacial Partial (Chopper)	9.13	5.5	12.2	7.05	3.9	9.1	5.78	3.3	8.2	441.5	66	833	4
Bifacial Core	13.48	7.4	17.2	10.64	6.5	13.4	7.71	3.8	10.6	1257.6	133	2325	10
Preferential	15.6	12.7	17.2	13.73	10.2	18	8.5	5.4	10.7	1950	1300	2800	4
Multifacial	16.23	14.3	18.9	12.1	9.7	15.9	10.17	7.7	13.6	2069	1282	2950	3
Core on Flake	12.63	8	20.2	9.43	4.7	14.8	5.99	2.8	10.7	762	201	2275	8
Casual slab core	12.86	9.5	16.1	10.56	8.2	13.5	6.92	4.9	9.3	1045.2	523	1550	5
Core Fragment	11.25	7.7	15.2	9.27	5.3	13.9	6.58	3.8	10.1	849.5	183	2050	13
Total	12.6	5.5	20.2	9.79	3.9	18	6.67	2.8	13.6	1001.3	66	2950	47

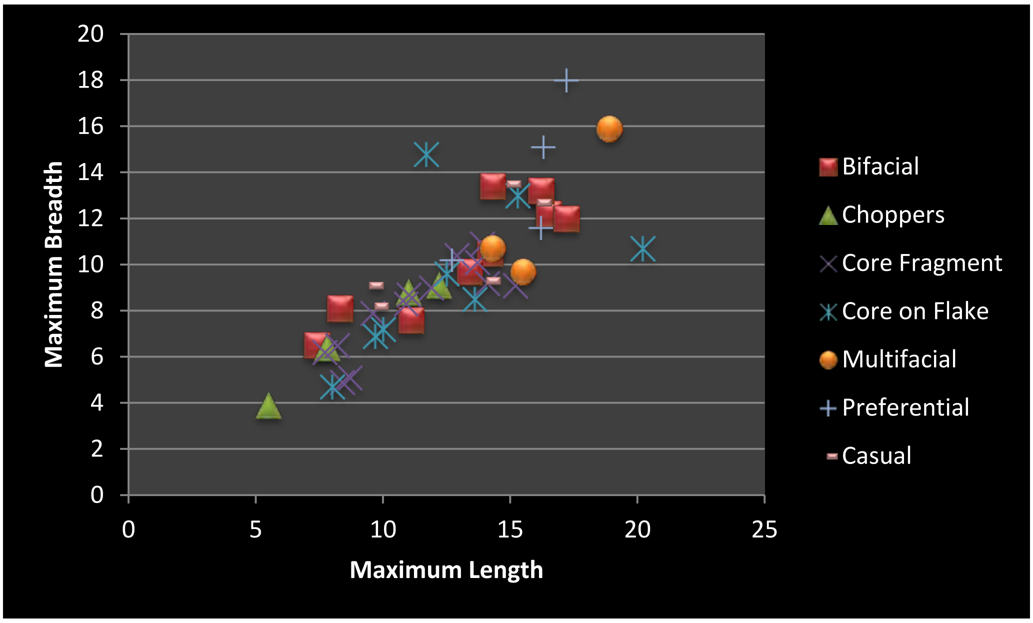


Fig. 5.9: Scatter Plot showing Length/Breadth for different core types

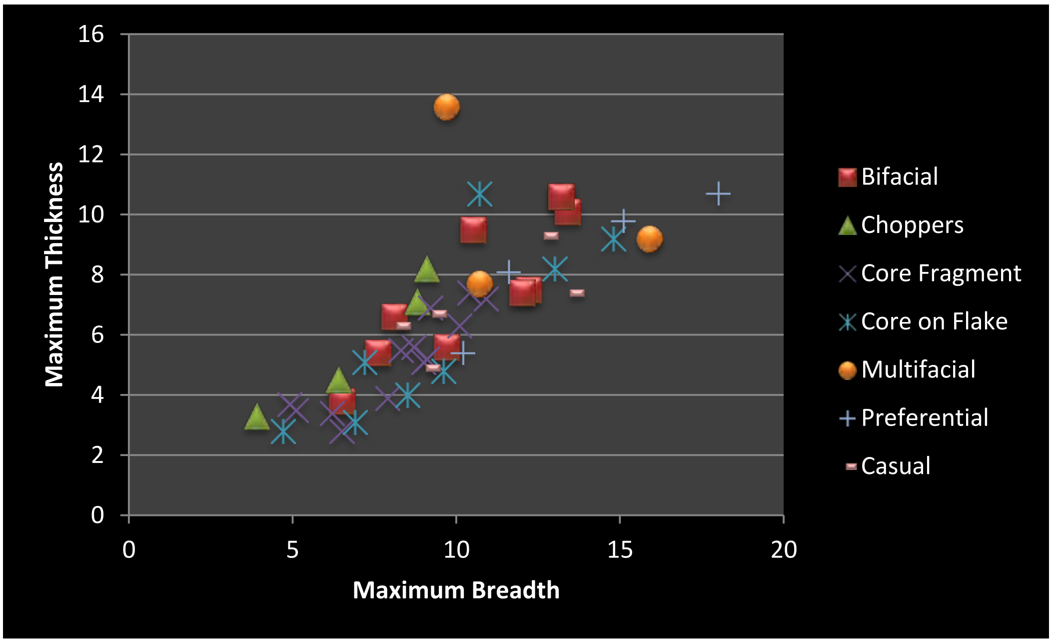


Fig. 5.10: Scatter Plot showing Breadth/Thickness for different core types

5.4.3 Cortex Cover

Percentage of original cortex remaining on cores indicates intensity of core reduction. Most cores (59.1%) do not retain any cortex, but a considerable proportion (31.8%) retain <50% cortex on at least one surface (Table 5. 7) while 9.1% have >50% cortex.

Sixteen cores (47.06%) have no cortex remaining with a median scar count of 8 scars, eight cores (23.53%) have <25% remaining cortex with a median flake scar count of 6 scars, six cores (17.65%) have 25-50% cortex remaining with a median flake scar count of 6 scars, while only one core has 50-75% cortex cover with a scar count of 6 scars. Three cores (8.82%) have 75-100% cortex cover with 4 scars per core (Table 5.7 and 5.8).

This shows that many cores still preserve a considerable portion of the original cortex and have only few flake scars indicating minimal exploitation. But most cores do not have any cortex, are fairly small sized and have a comparatively high number of flake scars. These are mostly exhausted cores with fairly intensive reduction and the original core size must have been larger. Therefore we see variability between large cores abandoned in the early phases of exploitation, to fairly small cores that seem to have undergone long reduction processes.

The nature of the cortex reveals that hominins were exploiting raw material from the rock outcrops available locally. Only a few bifacial partial chopper cores were fashioned on quartzite cobbles derived from fluvial contexts.

Table 5.7: Percentage of original cortex on different core types

Cortex	Nil	<25%	<50%	<75%	<100%	100%	Indeterminate	N
Bifacial	5	2	2	1	0	0	0	10
Chopper	0	0	2	0	2	0	0	4
Multifacial	2	1						3
Preferential	2	1	1					4
Casual slab	1	1	1		1		1	5
Core on flake	6	2						8
Core fragment	10	1					2	13
Total	26	8	6	1	3	0	3	47

Table5.8: Scar Count and Cortex Cover

Scar Count	Nil	<25	<50	<75	<100
Min	4	1	1	-	1
Median	8	6	6	-	4
Max	15	14	10	6	4
Mode	16	8	6	1	3

5.4.4 Scar Count

The median scar count is fairly low with 3-5 scars on each surface (Table 5.9). This suggests that the cores were not exploited intensively and that core reduction was expedient. Despite low number of scars, scars are invasive, covering entire flaking surface and hence result in good management of central volumes.

The number of flakes removed from the cores varies from 1 to 11 with most cores having 2-6 scars on face 2 and 1-4 scars on face 1.

Low scar count and cortical surfaces indicate that most cores were utilized expediently and raw materials were close by and easily accessible.

More expedient nature of core reduction viewed against the presence of a large number of prepared LCT blanks suggests differential mobility. LCT blanks were transported over distances and therefore detached after careful structuring and preparation of the core.

Table 5.9: Scar count for the different core types

Median Scar Count	**Face 1**			**Face 2**			**N**
	Median	Min	Max	Median	Min	Max	
Bifacial Partial (Chopper)	1	0	2	3	1	6	5
Bifacial Core	3.5	2	7	4	2	8	10
Preferential	4	1	6	5	3	8	4
Multifacial	2	0	2	4	1	4	3
Core on Flake	0	0	4	6	1	10	7
Casual slab core	0	0	0	1	1	2	5
Core Fragment	-	-	-	-	-	-	13
Total	3	1	8	5	1	11	47

Low number of scars but no cortex on LCTs indicates non intensive reduction yet invasive flaking leads to exploitation of central volumes.

5.4.5 Scar pattern

Scar pattern on the flaking surface of the core helps us understand the method of core reduction employed and the schema of core organization and management. Though most cores have a multidirectional to centripetal scar pattern, chopper cores have a unidirectional scar pattern mostly (Table5.10).

Table 5.10: Scar Pattern for the different core types

Core type	Uni Par	Bidirectional	Multidirectional	Centripetal	N
Bifacial Partial (Chopper)	3	1	1	-	5
Bifacial Core	-	4	-	6	10
Preferential	-	-	1	3	4
Multifacial	-	-	2	1	3
Core on Flake	-	2	5	-	7
Casual slab core	3	1	1	-	5
Core Fragment	-	-	-	-	13
Total	6	8	10	10	47

5.4.6 Scar Dimensions

The scar dimensions show that most cores were meant for the production of small flakes, though very few such flakes were recovered from the site (Table 5.11). Yet small flake production appears to be intentional as can be seen from their core organization. In this context it may be mentioned that Dibble and McPherron (2006) suggested that the intentionality of small flake detachment can be studied from the cores rather than the flake attributes.

Only a few medium sized cores (preferential and two multifacial cores) have been used to detach large flake blanks, which forms roughly 12.76% (6 cores) of the cores. From these cores also, generally only one large flake could be detached. However, since this flake was detached preferentially from the upper face in most cases, it can be said that this large flake blank removal was intentional. A few more cores on flakes and casual slab cores (9 cores or 19.14%) also resulted in one large to intermediate flake removal which may not have been deliberately planned however.

Table 5.11: Length and width of largest scar preserved on cores of different type.

	Length of Largest Scar			Width of Largest Scar			
Core type	Average	Min	Max	Average	Min	Max	Total
Bifacial Partial (Chopper)	5.93	4.2	7.5	5.43	3.1	7.6	4
Bifacial Core	7.57	5.2	12.2	7.45	4.2	10.4	10
Preferential	12.95	11.6	15	9.95	8.4	11	4
Multifacial	10.13	9.4	11.1	7.33	6.1	9	3
Core on Flake	7.74	4.9	10.5	5.7	3.2	7.5	7
Casual slab core	9.73	8.7	11.2	7.68	6.9	9.1	5

5.4.7 Platform Preparation

The scar pattern evident on the cores and also flake blanks suggest minimal platform preparation. Careful preparation evident in the form of facetted platforms is lacking. Flake blanks and also striking platform surfaces on cores show only 1-2 facets. Preparation thus involved only decortication and creation and/or maintenance of convexities. A large number of bifacial cores suggest rotation of the core through the entire perimeter. Bifacial rotation of cores implies simple methods without requiring core rejuvenation.

5.4.8 Relationship between cores and debitage

Considerable deviation is noted in the characteristics of the actual debitage as against the observations about the nature of debitage characteristics from core.

Flakes are generally larger than scars recorded on cores, but few scars on cores are just within LCT size. Perhaps a few cores (6 pieces) could have been utilized for LCT blanks. This indicates that the cores present at the site correspond to another production sequence meant for the production of small flakes, which is almost missing in the site perhaps due to taphonomic processes.

Flakes are found in much larger proportion than cores. Core to flake ratio is 1:12.55. Even if we exclude flake fragments, the ratio is 1:6.45. When taking into account the number and size of scars on cores and flakes, the small flake ratio is extremely low.

5.4.9 Discard

Many of the cores still had suitable angles that could be exploited. However, most cores have similar length width ratios (Table 5.3) suggesting that future flakes would have been too small resulting in core discard. Core geometry reflected in length-width ratio is considered an important factor in discard (Hovers 2009).

The core methods present at Lalitpur indicate predominantly simple strategies with use of natural convexities for flaking. They have short reduction sequences with the original form of the nodule often still detectable on the core. Even the single giant core recovered from the ditch section at Locality 5 shows the use of natural suitable angles and convexities and bifacial alternate removals using the surface of the first flake removal as striking platform for the next removal.

Only 4 preferential cores making 8.51% of the assemblage show use of organized flaking strategies. However the nature of the end products or LCTs and LCT blanks indicate that organized flaking was perhaps common than indicated by the cores themselves. These cores have asymmetrically convex surfaces and preferential removal of one or more large flake blanks. The shape of the core and the ridges were used as a guide in flake removal of a predetermined nature using the natural or purposely shaped asymmetry of the core surfaces and exploitation of the large and flatter upper surface. This probably implies selection of suitable shaped raw material, maintenance of asymmetry and convexity throughout the flaking sequence

Though most of the above core methods utilized by the Acheulean toolmakers required fairly low intensity of work, but nevertheless they were highly efficient in the production of suitable large blanks for LCTs which could be used without much secondary flaking. It is amazing to note the high degree of homogeneity in the size of the large flakes despite little investment effort in core preparation. This meant that a high degree of planning and core organization and volume management was involved. Such methods also resulted in very little debitage probably. This was a real advance over Oldowan technology and paved the way for the core preparation methods of the Middle Palaeolithic which resulted in complete control over flake size and shape.

Presence of few cores for both large and small flakes does show that some amount of flaking was carried at the site itself on locally available slabs and boulders. This can be indirectly implied from the presence of the raw material in close vicinity of the site. However, larger number of finished tools indicates greater transport and mobility of these tools resulting in higher presence of these tools at discard locations.

The study of cores and flakes reveals the existence of two distinct *chaîne opératoires*, one for the production of small flakes and the other for the production of large blanks. However, in case of the small flake *chaîne opératoire*, the small flakes are almost missing from the assemblage, while in case of large flake *chaîne opératoire*, the large cores to detach such flakes are fewer than expected. Further, the study of the core methods indicates simple reduction strategies with fairly low intensity of reduction, yet they display considerable skill, planning and the ability to detach suitable blanks without complex preparation.

Fig. 5.11: Bifacial simple partial (Chopper) cores

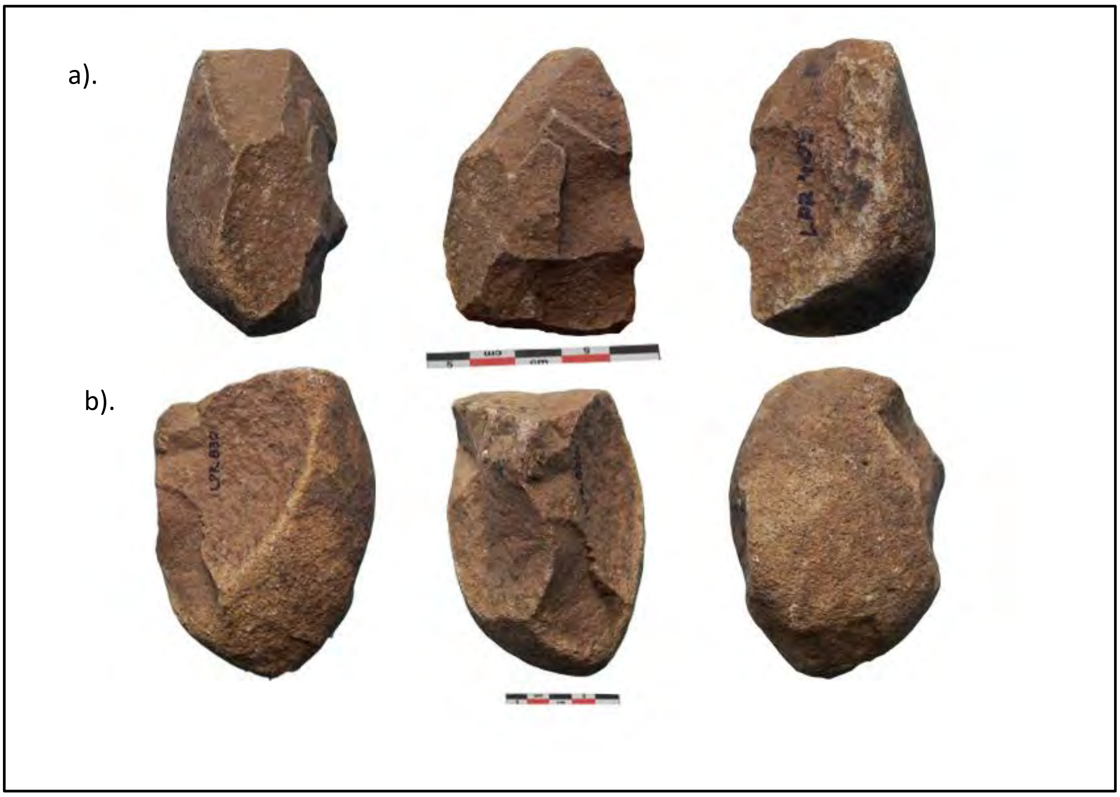


Fig. 5. 12: Bifacial Simple Partial Cores (a). One flake was removed from the ventral face and used as striking platform to remove elongated flakes from sides; (b). core with bifacial alternate flaking along the edge

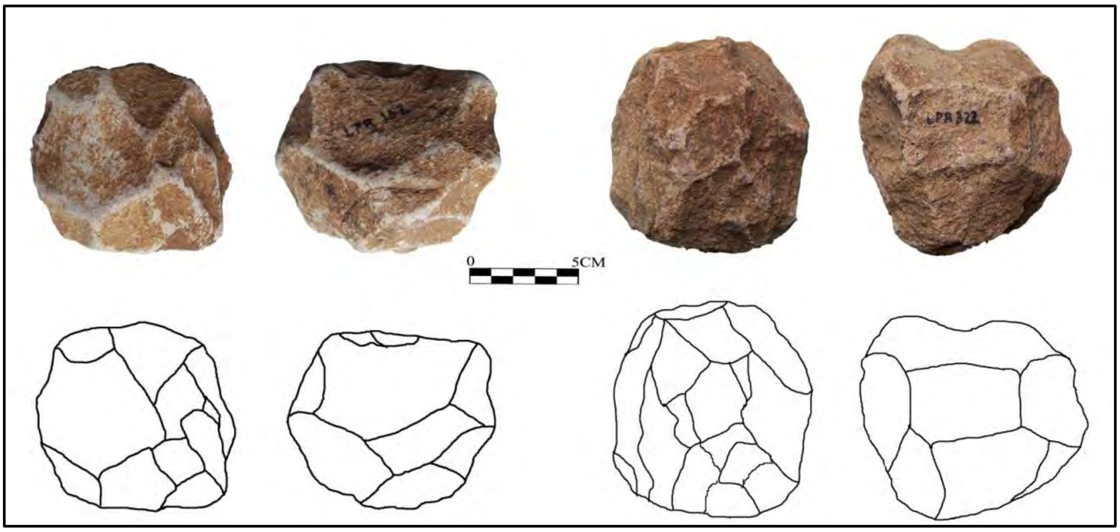


Fig. 5.13: Discoid Cores from Lalitpur

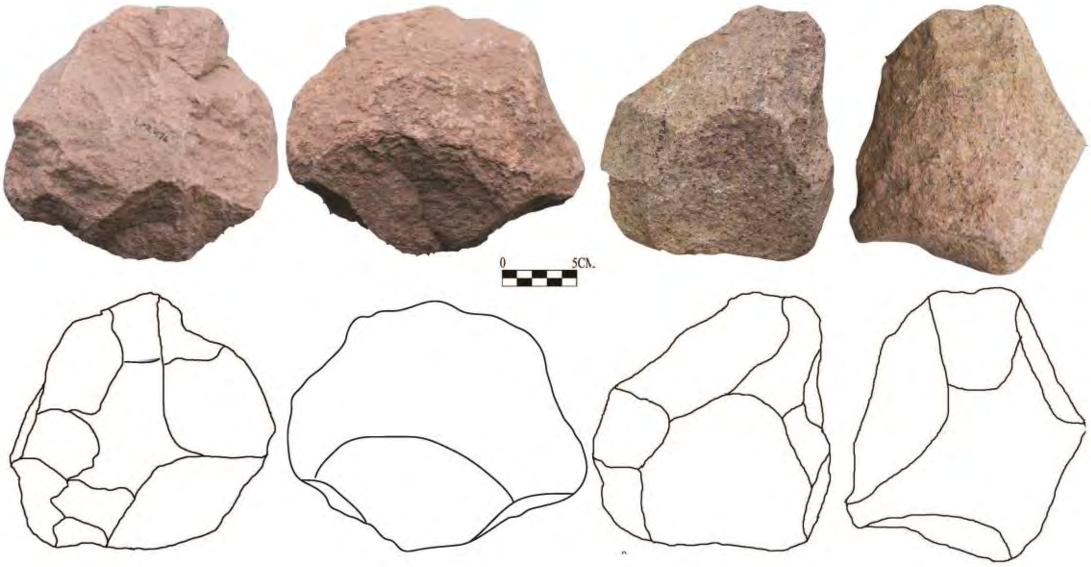


Fig. 5.14a: Bifacial Radial Cores from Lalitpur

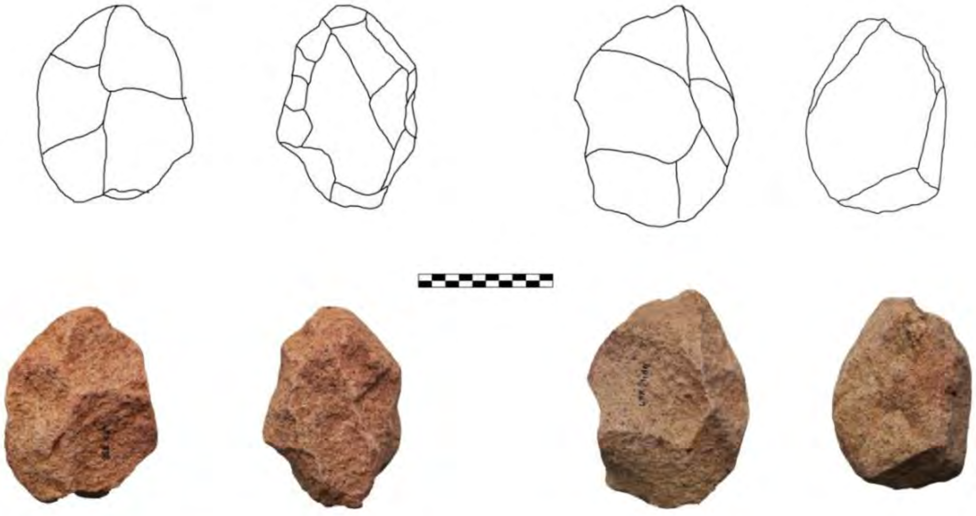


Fig. 5.14b: Bifacial Radial Cores from Lalitpur

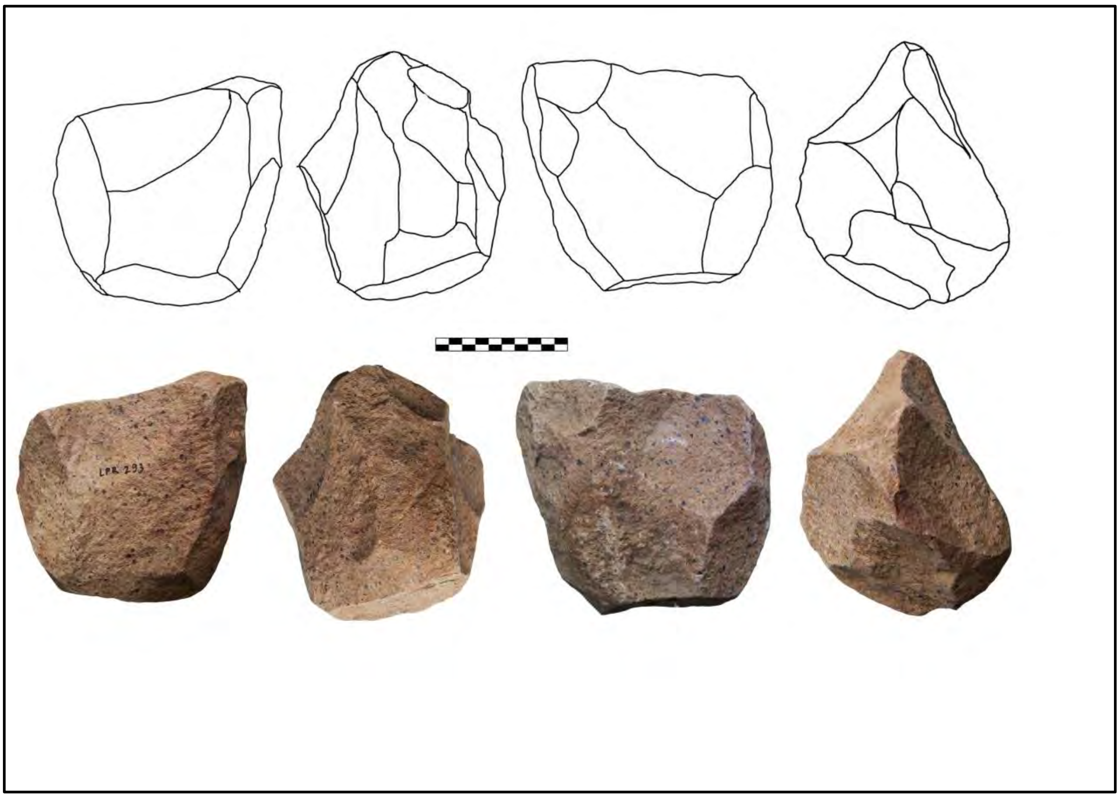


Fig. 5.15a: Multifacial core from Lalitpur

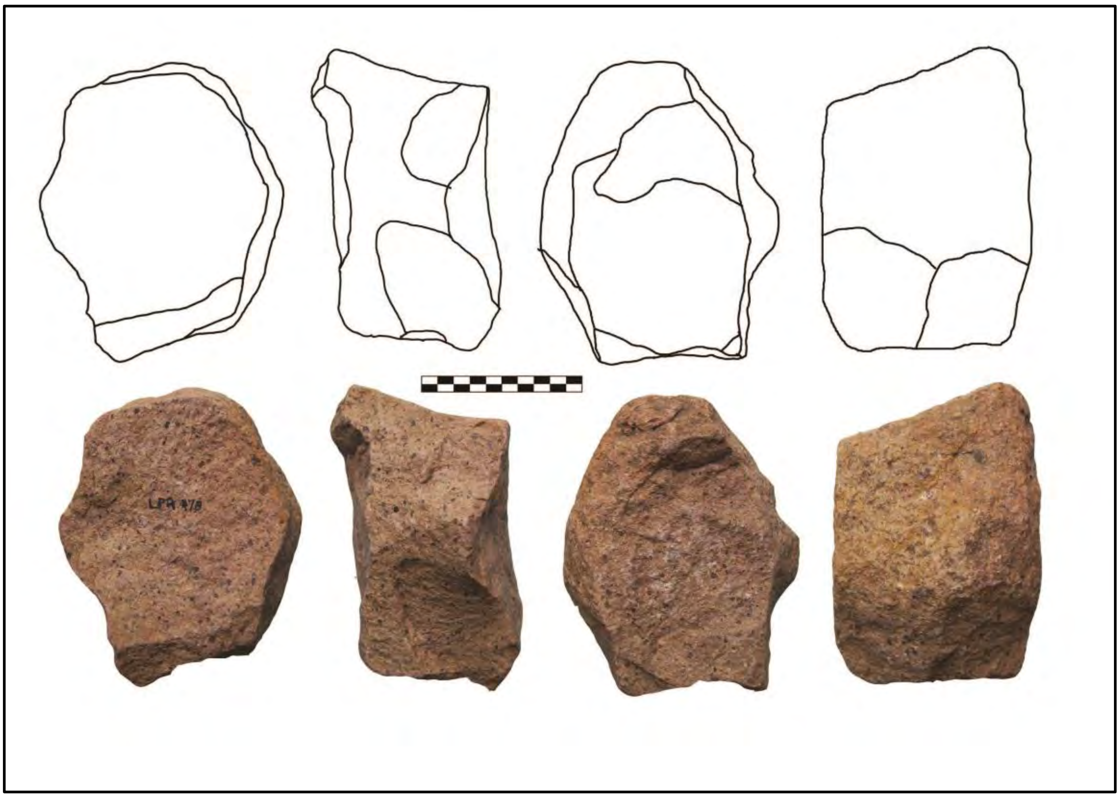


Fig. 5.15b: Multifacial Core from Lalitpur

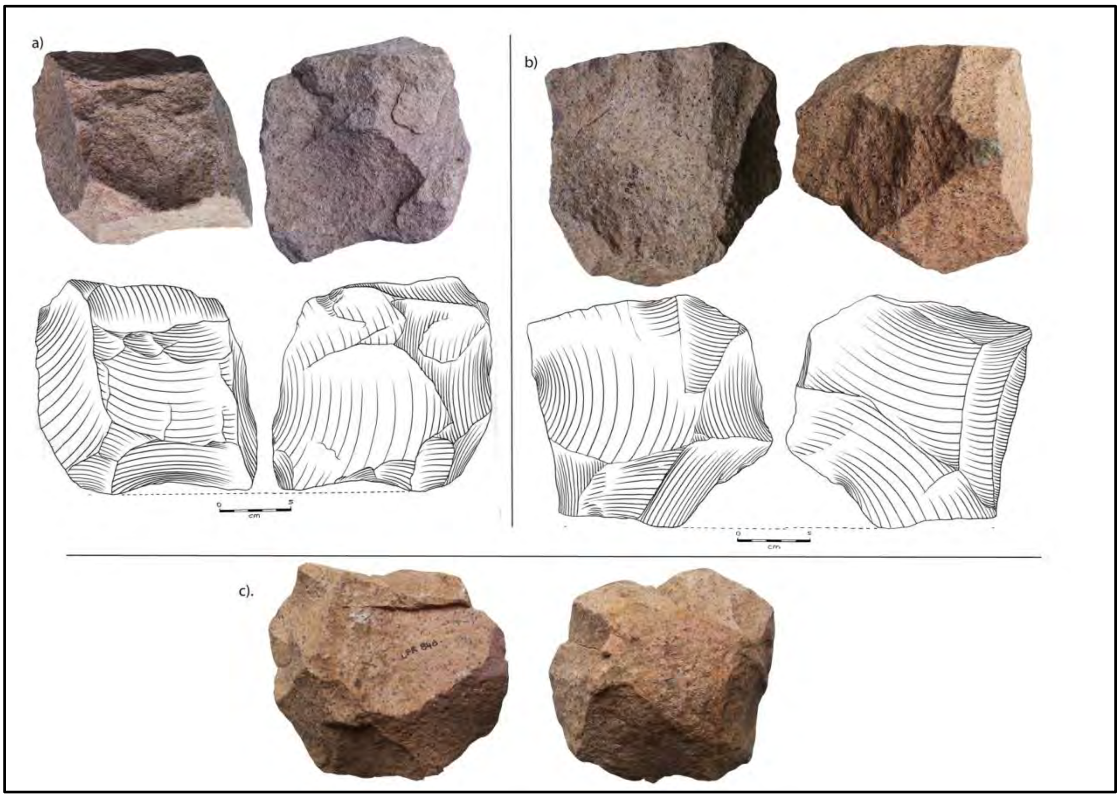


Fig. 5.16: Hierarchical Preferential cores with radial upper face and prefential scar

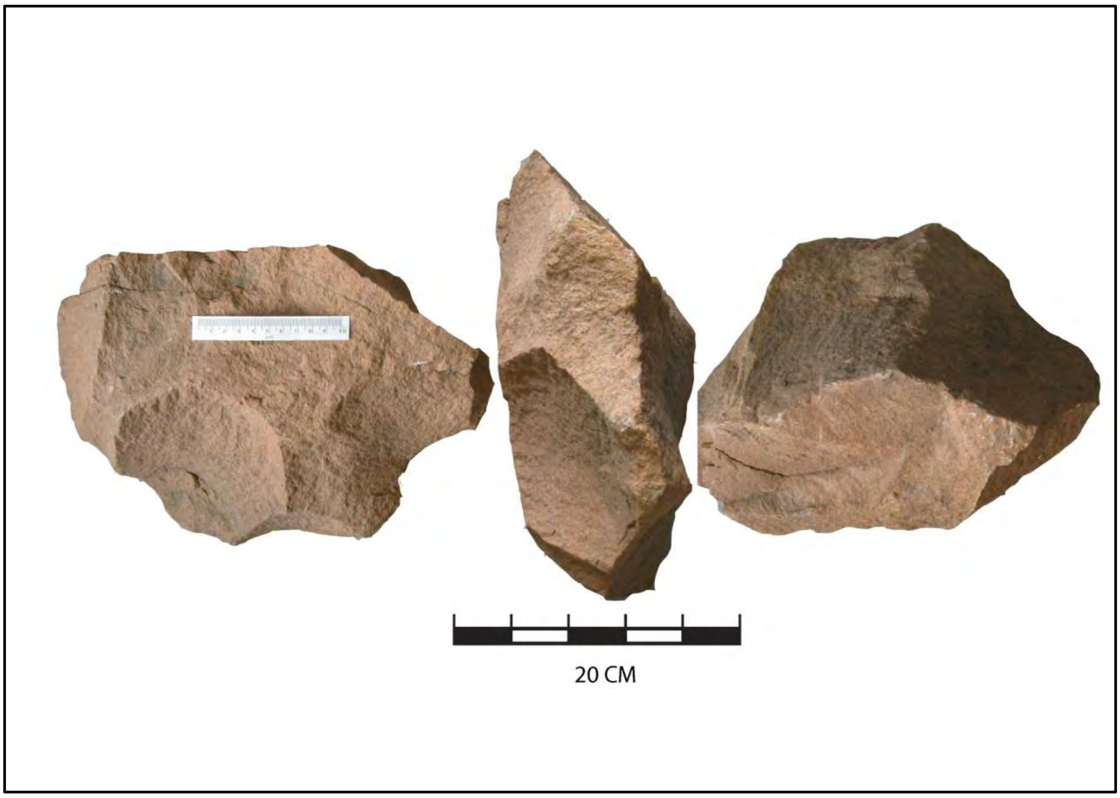


Fig. 5.17: Giant Core from Lalitpur

5.5 DEBITAGE

The flaking debitage is very informative as it can reveal important insights into the methods of tool production and core reduction and also about raw material economy, mobility behaviour, intentionality, predetermination and planning (Sullivan and Rozen 1985, Carr and Bradbury 2001, Andrefsky 2001; Bamforth 1991). Debitage, including flakes and flake fragments constitutes 51.27% of the entire assemblage. Of these complete flakes constitute 12.97%. More noteworthy is the near absence of small debitage (<1%). Here it may be mentioned that complete flakes with few secondary scars which do not cover much of the flake surface and have no clear pattern are also analysed here along with debitage flakes.

5.5.1 Size

Most flakes, unretouched and retouched, correspond to the large debitage *chaîne opératoire*. Flakes range in maximum length from 3.9 cm to 20.1 cm (Table 5.12). Quite interestingly, there is only one flake in the small size range (< 4.0 cm). Only 7.48% (8 pieces) of the flakes are < 6 cm in maximum length (Fig.5.18). Most flakes range in length from 8 to 12 cm. The maximum breadth for flakes ranges from 2.9 to 15.1 cm, with most flakes constrained within 6 to 9 cm. Most flakes fall in the thickness range of 2.8 to 4.4cm, though thickness is quite variable with minimum thickness at 1.2 cm and maximum thickness at 7 cm. In terms of mass, the flakes range from as low as 19 g to 1700 g, most flakes however falling in the range of 150 to 500 g (Table 5.12 & Fig 5.18 to 5.23).

Table 5.12: Size Dimensions of flaking debitage

	Maximum Length	Maximum Breadth	Maximum Thickness	Maximum Weight
Min	3.9	2.9	1.2	19
Median	10.5	7.5	3.7	335
Max	20.1	15.1	7	1700
Q1	8.05	5.95	2.8	157
Q3	12.1	9.1	4.4	501
SD	2.951	2.342	1.238	308.879
Variance	8.709	5.485	1.533	95406.31
Average	10.25	7.584	3.585	379.553

As suggested earlier, scar sizes on cores and flake sizes suggest the existence of two distinct *chaînes opératoires*, one geared towards large flake blank production which constitutes bulk of the assemblage recovered, another one is small flakes. Though the small debitage is scantily represented and most flakes fall in the size range of 8 – 12 cm, but the presence of a distinct reduction sequence meant for small flakes can be implied from the presence of cores meant exclusively for small flakes as inferred from the scar sizes on such cores.

Sizes of scars on cores and flakes when compared with the sizes of detached pieces suggest that the number of small flakes is much less than expected. This indicates a fragmented *chaîne opératoire* with underrepresentation of small flakes.

Near absence of small debitage can be explained by either anthropogenic or geogenic processes. Though some amount of winnowing could have occurred, but the presence of chips and small gravel suggests that fluvial sorting cannot fully explain the absence of small debitage. However, larger artefacts are more likely to survive longer and therefore it is possible that smaller artefacts are missing from the record. More probably however, it can be explained by anthropogenic processes. The sizes of scars on cores and flakes indicates their invasive or covering nature from which it can be implied that the manufacturing technique itself resulted in very little small debitage (2-4 cm).

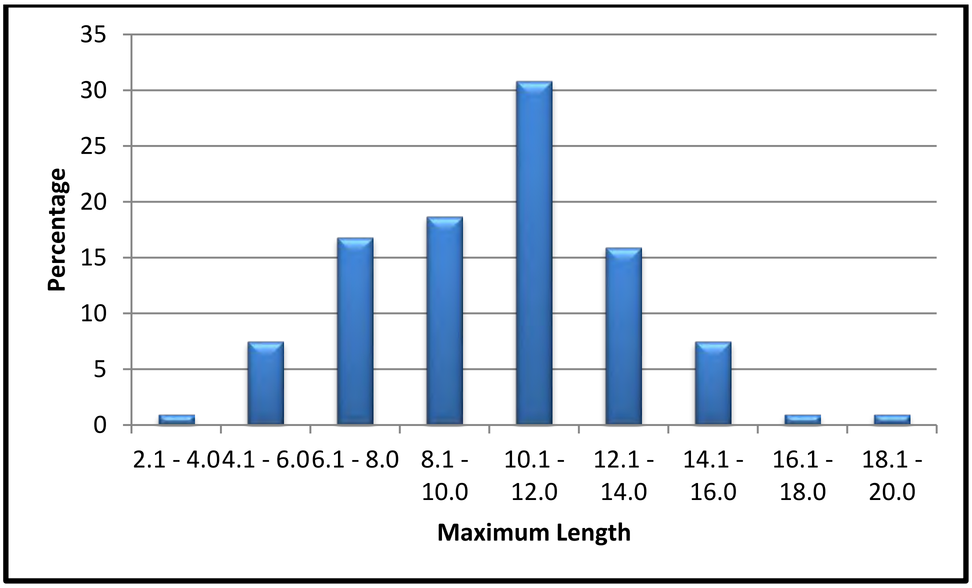


Fig. 5.18: Maximum Length for Flakes

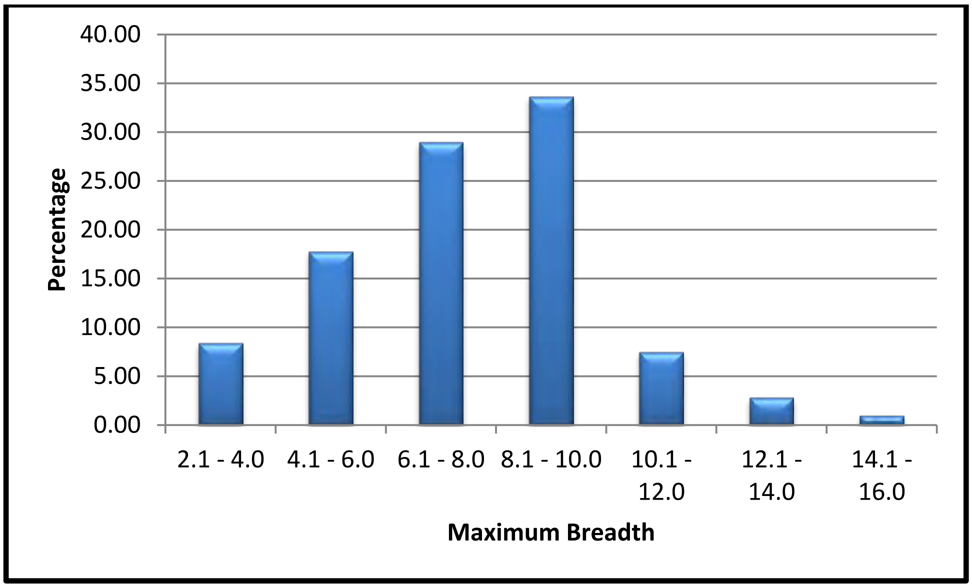


Fig. 5.19: Maximum Breadth for Complete Flakes

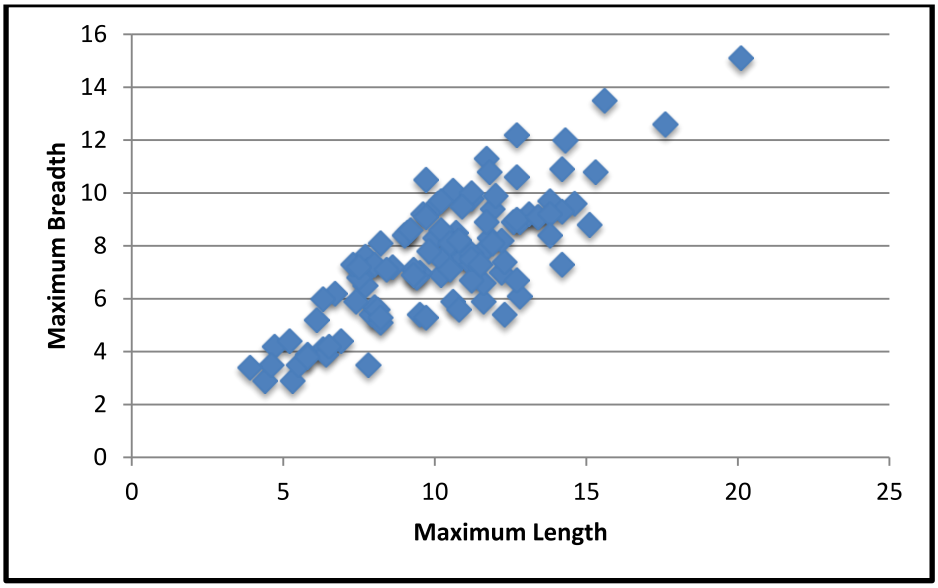


Fig. 5.20: Scatter Plot showing Length/Breadth for Flakes

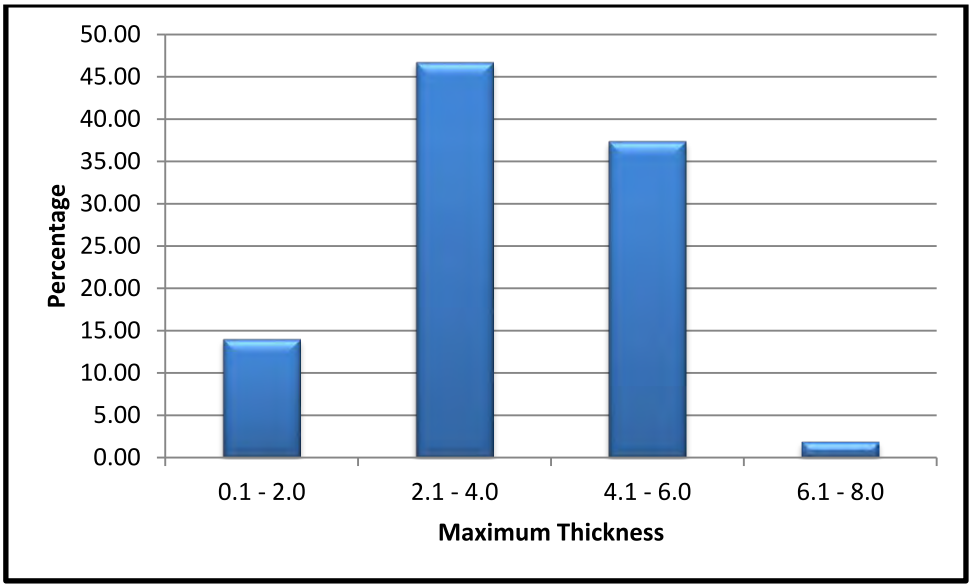


Fig. 5.21: Maximum Thickness for Flakes

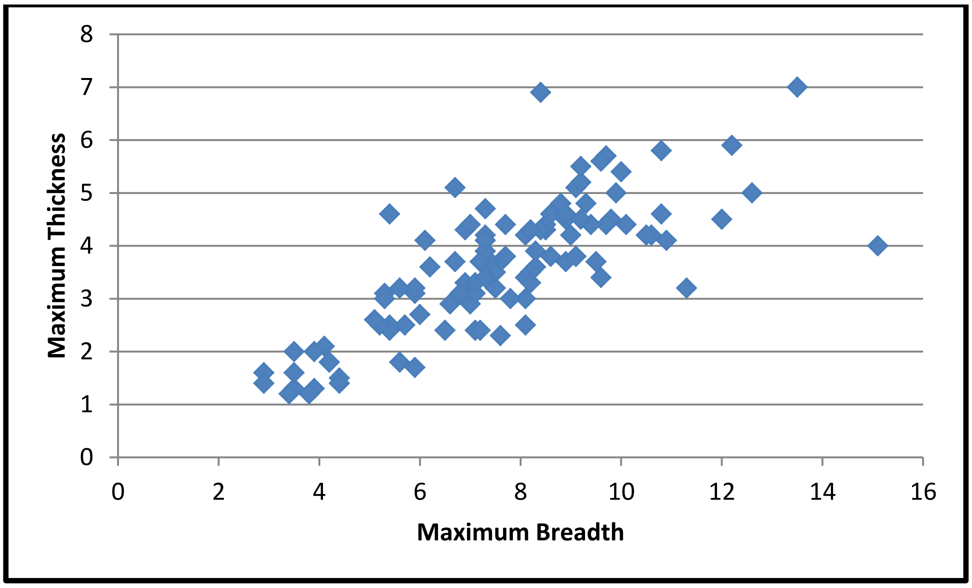


Fig. 5.22: Scatter Plot showing Breadth/Thickness for Flakes

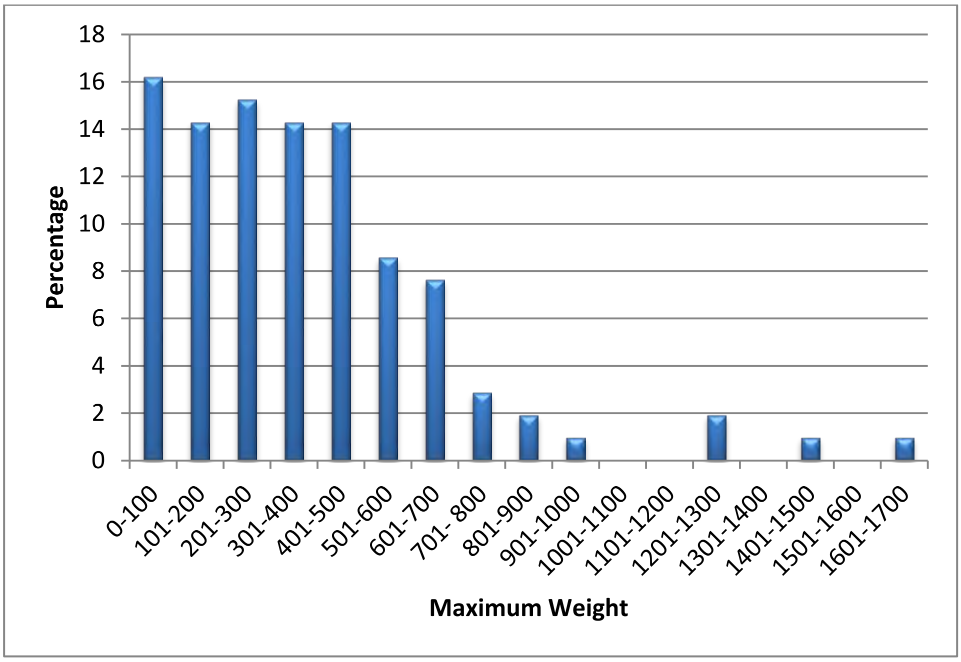


Fig. 5.23: Maximum Mass for Flakes

5.5.2 Flake Type and Cortex Cover

Notably, there is only one flake of Type 1 to 3 (Table 5.13 & Fig. 5.24). This means that there are virtually no flakes with cortical striking platform. This implies that before detaching the flakes, the weathered cortex was removed. However, such preparation flakes (which should have cortex on both dorsal surface and striking platform) are missing from the assemblage. This may be a result of faster weathering of cortical flakes. Such weathering of cortical flakes can happen if the cortex is quite weathered rendering it more prone to weathering. This would mean that the raw material used for knapping was mostly derived from the rock outcrop which had a highly weathered cortex as against river cobbles with a smooth and resistant cortex. Non cortical platforms also suggest bifacial rotation of cores (de la Torre 2011).

Further, a very low percentage of flakes with dorsal cortex (22.45%) may also be a result of fast weathering of cortical flakes (Table 5.14; Figs. 5.25 & 5.30). Alternatively, it is possible that the initial stages of core reduction were carried out elsewhere. This hypothesis is also supported by the low number of cores, a very high percentage of finished tools and a low number of small flakes and other debitage.

With regard to position of cortex, it is not found to be distributed in any specific part of the flake, and there also seems to be no preference for right or left sides (Table 5.15)

Table 5.13: Frequency and Percentage of Toth's Flake Types in the Assemblage

Toth's Flake Type	N	%
1		
2	1	1.02
3		
4	11	11.22
5	10	10.20
6	76	77.55
Indeterminate	9	

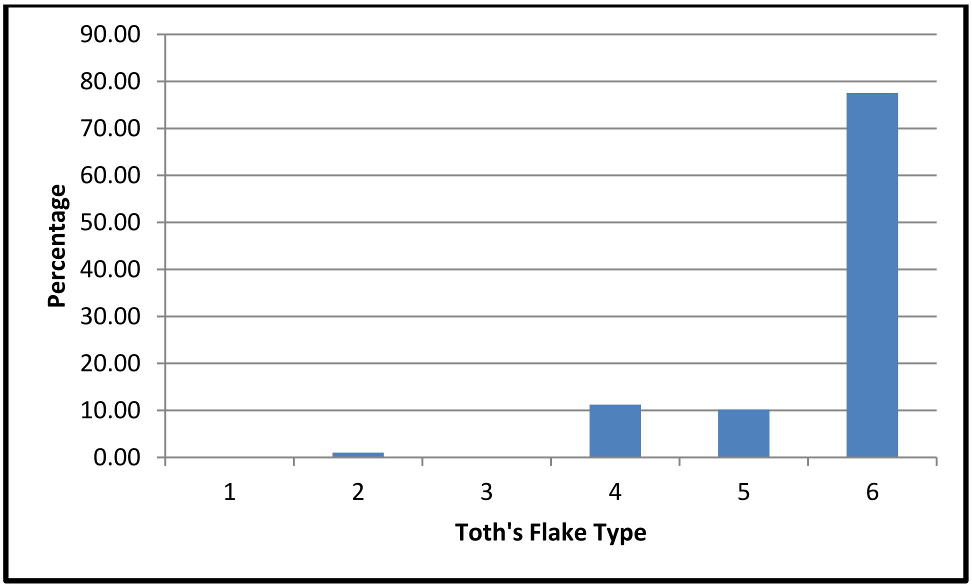


Fig. 5.24: Distribution of Toth's Flake Types in the Assemblage

Table 5.14: Frequency and Percentage of Cortex Cover on Flakes

Cortex Cover	N	%
Nil	76	77.55
1-25%	2	2.04
25 - 50%	5	5.10
50 - 75%	1	1.02
75 - 99%	2	2.04
100%	12	12.24
Indeterminate	9	
Total	107	

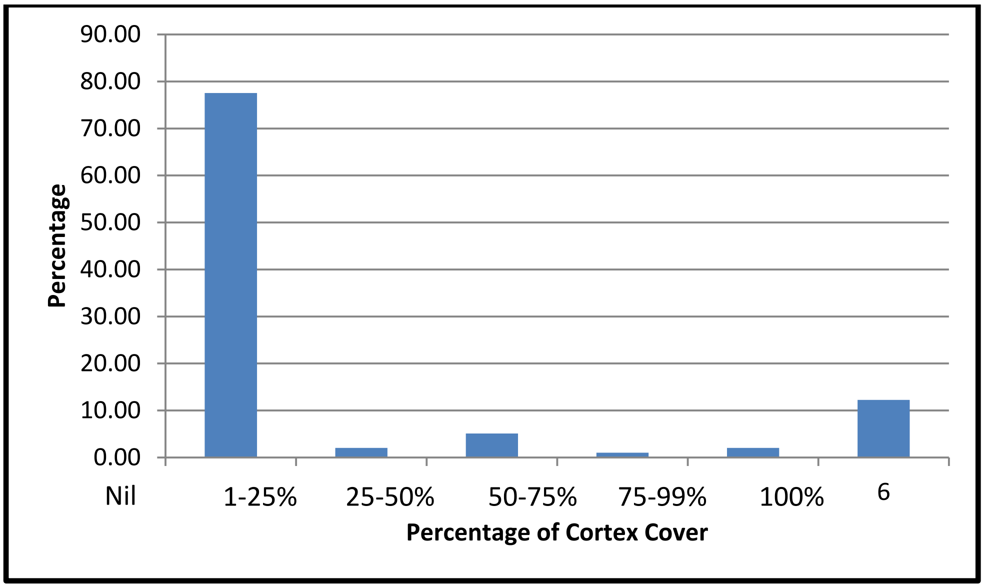


Fig. 5.25: Percentage of Cortex Cover on Complete Flakes

Table 5.15: Position of Dorsal Cortex on Complete Flakes

Position of Cortex	N	%
Distal	2	2.04
Mesial	5	5.10
Dorsal	11	11.22
Right	4	4.08
No Cortex	76	77.55
Indeterminate	9	
Total	107	

5.5.3 Flake Blow Direction

The flake blow directions indicate a clear preference for end-struck flakes (direction 5) with 68.87%. This is followed by side-struck (directions 3 and 7) flakes (~17%) and special side-struck (directions 4 and 6) flakes (~14%) (Table 5.16 & Fig. 5. 26).

Leader (2009) opines that slab like and tabular nature of the raw material makes it easier to exploit the largest surface for elongated flakes, resulting in more end struck products.

Table 5.16: Flake Blow Directions for Complete Flakes

Flake Blow Direction	N	%
1	0	0
2	0	0
3	10	9.43
4	6	5.66
5	73	68.87
6	9	8.49
7	8	7.55
8	0	0
Indeterminate	1	
Total	107	100

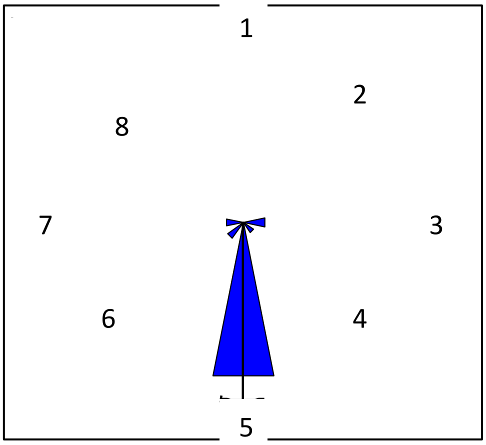


Fig. 5.26: Flake Blow Directions for Complete Flakes

5.5.4 Striking Platform

Most flakes have plain or dihedral platform. Only one flake has a facetted platform (Table 5.18 and Fig. 5.27). This implies negligible preparation of the core before detaching the flakes. Platform dimensions are highly variable with thickness ranging from 1 to 8 cm (Table 5.17).

Table 5.17: Striking Platform Dimensions for Complete Flakes

	Platform Thickness	Platform Breadth	Platform Angle
Min	0.8	1.9	90
Median	2.9	5.95	116
Max	8.1	14	135
Q1	2.1	4.125	110
Q3	3.675	7.475	122
SD	1.141	2.338	8.361
Variance	1.303	5.468	69.908

Table 5.18: Type of Striking Platform on Complete Flakes

Type of Striking Platform	N	%
Plain	84	83.17
Dihedral	16	15.84
Facetted	1	0.99
Indeterminate	6	
Total	107	

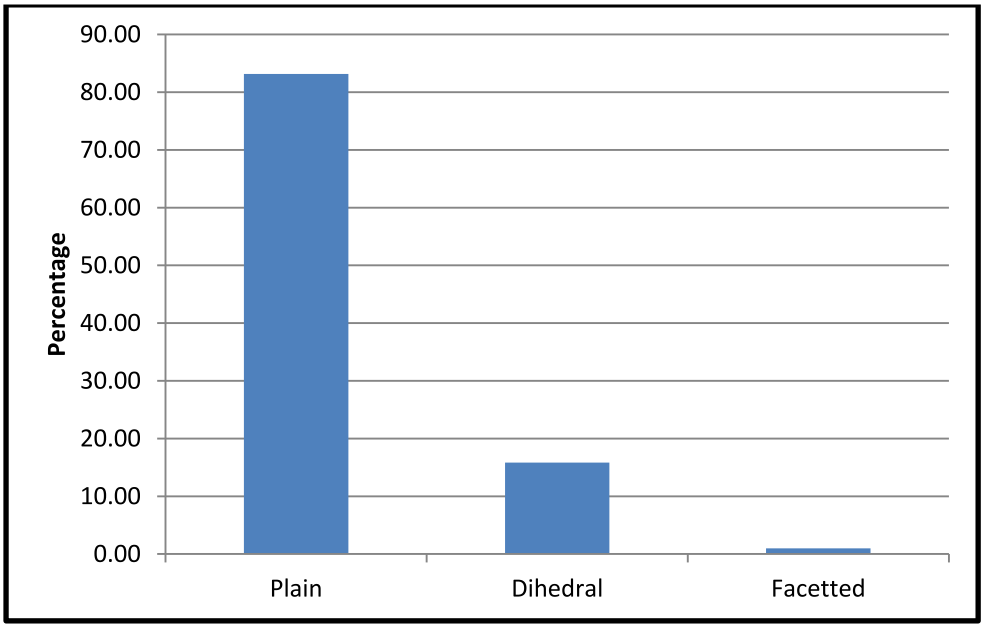


Fig. 5.27: Type of Striking Platform on Complete Flakes

5.4.5 Scar Count

The number of scars on flakes indicates an average of 2 previous scars per flake, with a maximum of 8 scars which is quite low (Table 5.19). This indicates non-intensive reduction. However, interestingly most flakes have some amount of secondary flaking. Only 25.74% have no secondary flaking at all. This means that most flakes were intended for use.

Table 5.19: Scar Count for Complete Flakes

	Previous scars
Min	0
Median	2
Max	8
Quartile 1	1
Quartile 3	3

5.4.6 Scar Pattern

Pattern of previous flake scars on the dorsal face are critical to understanding the knapping methods employed, particularly in the absence of cores and refitting. The scar pattern is mostly multidirectional suggesting a dynamic mechanism involving core rotation and alternation of surfaces (Table 5. 20 & Fig. 5.28).

Table 5.20: Dorsal Scar Pattern for Complete Flakes

Flake Scar Pattern	N	%
Cortical	12	17.91
Unidirectional	3	4.48
Bidirectional	14	20.90
Multidirectional	29	43.28
Convergent	2	2.98
Centripetal	3	4.48
Positive Flake Scar	4	5.97
Indeterminate	40	

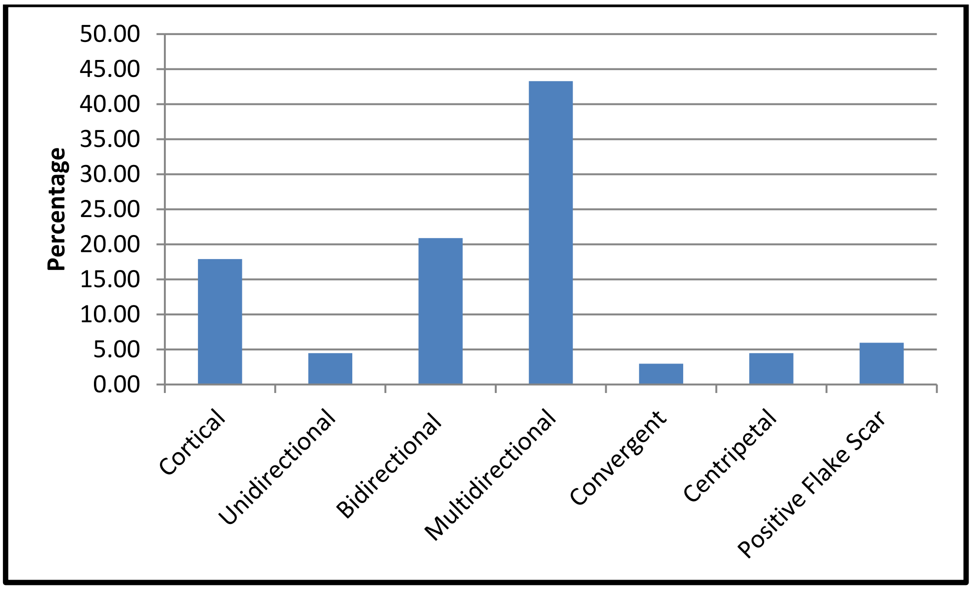


Fig. 5.28: Dorsal Scar Pattern for Complete Flakes

Low number of accidental breaks or bad flake terminations (step, hinge or plunging) indicates skilled knapping and understanding of stone fracture mechanics along with use of good quality raw material (Fig. 5.29).

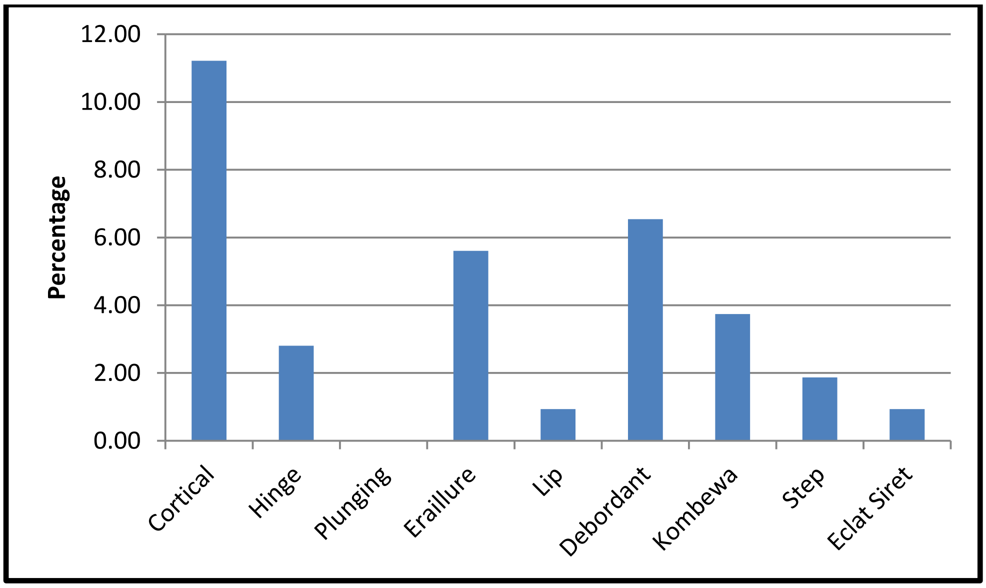


Fig. 5.29: Frequency of some technological features on flakes

The debitage attributes indicate non-intensive reduction indicated by low number of scars. Further, the debitage also has no morphological standardization. The nature of striking platforms, scar pattern and lack of cortex indicates that there was minimum preparation involving removal of cortex to obtain flakes. Most interesting however, is the presence of secondary scars on most flakes indicating intention of use (Figs. 5.30 to 5.35).

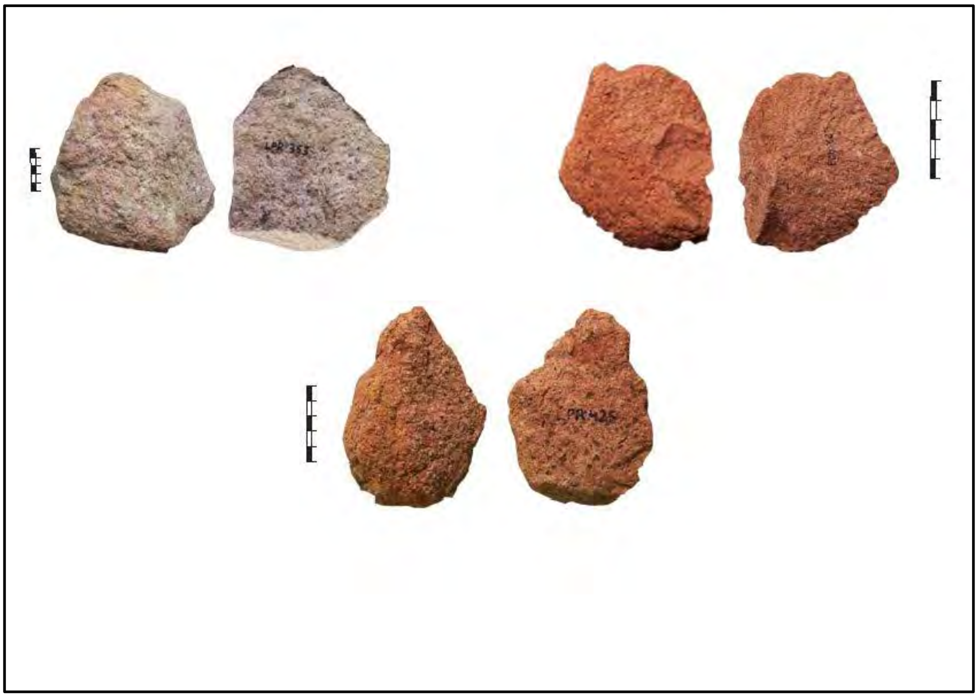


Fig. 5.30: Some Cortical Flakes from Lalitpur

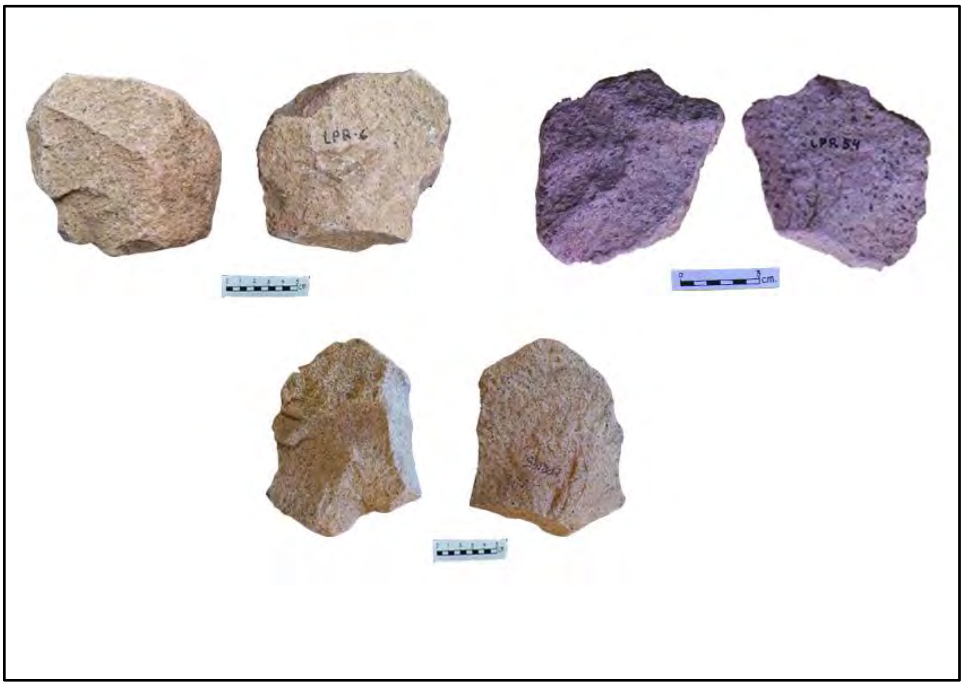


Fig. 5.31: Complete Unretouched Flakes from Lalitpur

Fig. 5.32: Complete Flakes from Lalitpur

Fig. 5.33: Some more Complete Flakes from Lalitpur

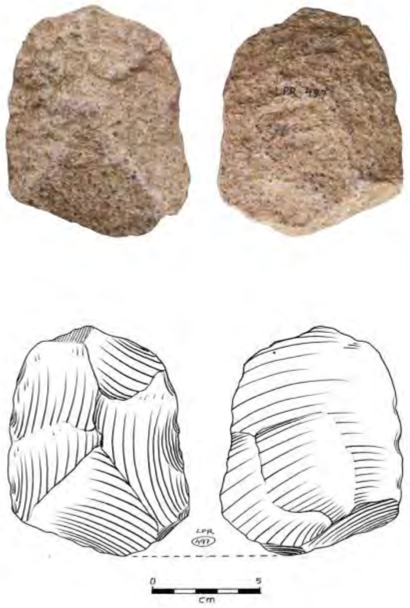


Fig. 5.34: A complete flake from Lalitpur

Fig. 5.35: a. Sandstone flakes, b.Radial Flake c. Kombewa flake from Lalitpur

5.6 LARGE CUTTING TOOLS

Large cutting tool (LCT) production was the main goal of stone knapping activities. LCTs constitute a fairly high 22.67 % of the total assemblage. These consist of 187 specimens.

Cleavers and cleaver flakes (88 pieces) together account for 47.06% of shaped tools and 10.67% of the total assemblage. Other LCTs including bifaces, unifaces, knives, scrapers, and retouched tools (99 pieces) form 12% of the total assemblage. For purposes of analysis, all LCTs other than cleavers have been grouped together, as they do not seem to constitute a distinct group (Sharon 2007, Isaac 1977) unlike cleavers which appear to have been intentionally prepared and are distinctive (Table 5.21 & Fig. 5.36).

The high frequency of LCTs indicates that perhaps they were introduced to the site from outside also. Further, isolated LCTs are found distributed at low densities across the landscape (Singh 1965), indicating they were carried away from manufacturing sites and sometimes abandoned at ephemeral activity locations. All this indicates long-distance transport. The typological bias towards LCTs reflected in the high frequency suggests that they were preferentially curated across the landscape.

Table 5.21: Frequency of different classes of Large Cutting Tools

Type	Granite (N)	Quartzite (N)	Quartz (N)	Total (N)	Total (%)	% LCTs
Cleaver	71	4		75	9.09	40.11
Cleaver Flakes	13			13	1.58	6.95
Subtotal	**84**	**4**		**88**	**10.67**	**47.06**
Unifaces	14	1		11	1.33	8.02
Bifaces	28	3	1	32	3.88	17.11
Knives	5	1		6	0.73	3.21
Scrapers	9	1		10	1.21	5.35
Others	36			36	4.36	19.25
Subtotal	**92**	**6**	**1**	**99**	**12.00**	**52.94**
Total	176	8		187	22.67	100

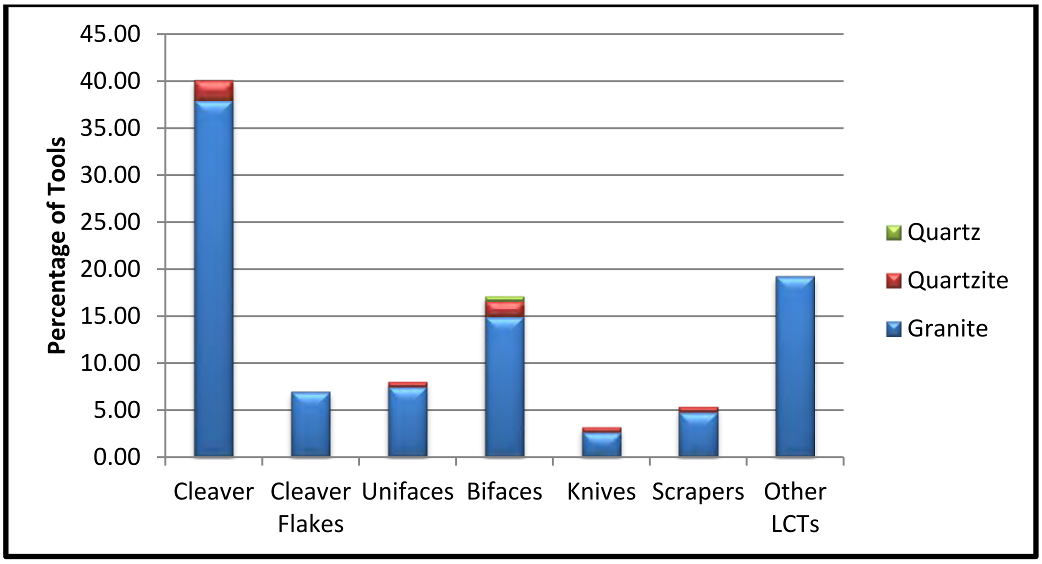


Fig. 5.36: Frequency of Shaped Tool Classes at Locality 1, Lalitpur

5.6.1 CLEAVERS

The assemblage from the excavation at Locality 1 in Lalitpur is dominated overwhelmingly by cleavers, which constitute 88artefacts making up 10.67% of the total artefact assemblage. This includes cleaver flakes also (Table 5.20 & Fig. 5.36).

The high percentage of cleavers at Lalitpur in comparison to other LFA sites as shown below (Table 5.22) could be arising from the differences in the criteria used to classify cleavers, handaxes and large flakes (outlined in Chapter III). However, even if we follow a strict definition of cleaver as followed by others (Roe 1994), the site of Lalitpur has a fairly high proportion of cleavers.

Such dominance of cleavers is also noted at Vaal River sites (78% of LCTs), Isimila (50% of all artefacts) Olorgesaillie (23% of all artefacts), Isenya and also at Ternifine (107 out of 126 bifaces). In Israel cleavers are found in a high proportion only at Gesher Benot Ya'aqov and also in Azraq, Jordan. At other sites they are found in very low proportion as in Ubeidiya (2%), Evron Quarry (3% of bifaces), Ma'ayan Barukh (2.2% of bifaces) and Latamne, Syria (2% of bifaces) (Ranov 2001) (see also Table 5.22 below).

In Spain, El Sartalejo also showed dominance of cleavers with cleaver:handaxe ratio being 1.84:1 (Table 5.22). At Torralba though cleavers as found in lesser proportion, but they still constitute a high frequency of 43 cleavers or 7.9%

and 57 handaxes or 10.1% of 544 artefacts. Ambrona has a similar proportion to Torralba of 10 cleavers or 1.5% and 14 handaxes or 2% of 682 artefacts (Ranov 2001).

Flake cleavers are found only south of the Pyrenees in Europe and distributed in considerable proportion in Tarn and Garonne valleys (Ranov 2001, Alimen 1975). Cleavers on flakes are rare in the British Lower Palaeolithic constituting 1-3% generally though in some assemblages the frequency may go to as high as 8-9% (Roe 1968).

In India, besides Lalitpur, Nagarjunakonda and Chirki also have a dominance of cleavers (Jayaswal 1978). In the neighbouring region of Lalitpur, Minarwala Kund near Raisen has a similarly high cleaver: handaxe ratio of 9.66:1 (Table 5.22). However at Bhimbetka we find that bifaces constitute a minor proportion (308 pieces or 1.65%) of 18721 Acheulean artefacts, with 93 handaxes (0.5%) and 215 cleavers (1.15%), but interestingly the proportion of cleavers to handaxes is 2.30:1 (Misra 1985) which is quite high and comparable to Raisen Complex and Lalitpur.

5.6.1.1 Raw Material

Out of 88, only 4 cleavers are made on quartzite while the rest are made on granite. Of these only four have been manufactured on slabs derived from granite outcrops, and one is made on a quartzite slab. Cleavers are as a rule made on flakes.

5.6.1.2 Size

Cleavers range in size from 9.9 cm to 19.9 cm in maximal length with an average of 13.19 cm. However, most cleavers cluster in the range of 11 to 15 cm (Table 5.23 & Fig. 5.37).

Width was more tightly constrained with most cleavers falling between 7.8 to 9.7 cm, and a minimum of 5.7 cm and maximum of 15.0 cm (Table 5.23 & Fig. 5.38).

Most cleavers fall in the thickness range of 3.8 to 4.9 cm, with the exception of a few thick cleavers. Minimum thickness was 3.0 cm and maximum 8.8 cm with an average of 4.46 cm (Table 5.23 & Fig. 5.41).

Table 5.22: Number of handaxes and cleavers at Acheulean sites around the world

Site	**Handaxes (N)**	**%**	**Cleavers (N)**	**%**	**Total**	**Reference**
South Africa						
Power's site	50	-	118	-	-	Sharon 2007
Pniel 6a	41	-	102	-	-	Sharon 2007
Riverview	47	-	76	-	-	Sharon 2007
Pniel 7b	40	-	100	-	-	Sharon 2007
Doornlaagte	381*	33	115	10	1153	Mason 1988
North Africa						
STIC	402[#]	39.5	16	1.6	1018	Biberson 1961
Tachenghit	44	36.1	42	34	122	Alimen 1978
Hassi Manda	19	17.1	72	65	111	Alimen 1978
East Africa						
Isimila K6	330	39.3	53	6.3	840	Howell *et al.* 1962
Isimila K14	48	6.71	93	13	715	Howell *et al.* 1962
Isimila K19	11	2.1	44	8.4	524	Howell *et al.* 1962
Isenya Niveau VI	418	6.24	948	15	6394	Roche *et al.* 1988
India						
Hunsgi V	40[$]	13.7	28	9.6	291	Paddayya 1982
Isampur	48	0.37	15	0.1	13043	Paddayya *et al.* 2006
Yediapur VI	21	2.98	28	4	704	Paddayya 2010
Chirki	564[@]	24.6	344	15	2290	Corvinus 1983
Attirampakkam	60	1.7	22	0.6	3528	Pappu 2011
Bhimbetka	93	0.5	215	1.15	18721	Misra 1985
Minarwala Kund (Raisen)	12	2	116	19	621	Jacobson 1985
Levant						
Ma'ayan Barukh	2503	66.3	-	-	3775	Gilead 1973
GBY NBA	171	-	93	-	-	Sharon 2007
GBY Layer II-6	325	-	136	-	-	Sharon 2007
Europe						
El Sartalejo	186	5.79	343	10.7	3213	Moloney 1992
Lanne Darre	40	2.77	73	5.05	1446	Mourre 2003

*Including pick, large knives and irregular bifaces; [#]Including trihedrals; [$]Including picks and knives; [@] Including picks, knives, scrapers and pickaxes.

Cleaver size data matches with the data available from many sites around the world which was taken here for purposes of comparison (Sharon 2007, Mourre 2003). However, when compared to the dataset from Isimila which is also made largely on granitic rocks, it was noticed that the mean length, width and thickness of Isimila bifaces is higher compared to Lalitpur. However, it matches well with Hunsgi V and Yediapur VI (Table 5.24) which also have a considerable number of tools on granitic rocks.

Cleavers are slightly larger than handaxes in maximal length. Most cleavers are wide giving them a broad cutting edge, though a high percentage of cleavers are also elongated (Figs. 5.39 & 5.40). However, a small number of cleavers have a narrow chisel ended cutting edge. This could be the result of different functional needs. Further, a high proportion of cleavers are fairly thick indicating lack of refinement and shaping (Figs. 5.42 & 5.43).

Table 5.23: Dimensions of Cleavers from Lalitpur, Locality 1 at Biana Nullah

	Length	Breadth	Thickness	L/B	B/T	Weight
Min	9.90	5.70	3.00	0.91	1.24	224
Median	12.75	8.70	4.30	1.45	2.04	482
Max	19.90	15.00	8.80	2.13	3.41	1750
Q1	11.20	7.80	3.88	1.34	1.69	384
Q3	14.70	9.70	4.90	1.61	2.45	645.8
SD	2.47	1.89	1.05	0.23	0.49	220.4
Variance	6.10	3.57	1.10	0.05	0.24	48563
Average	13.19	9.03	4.46	1.48	2.09	536.4
Skewness	13.10	8.97	4.39	1.48	2.08	523.2
Kurtosis	1.01	1.11	2.10	0.30	0.46	2.196

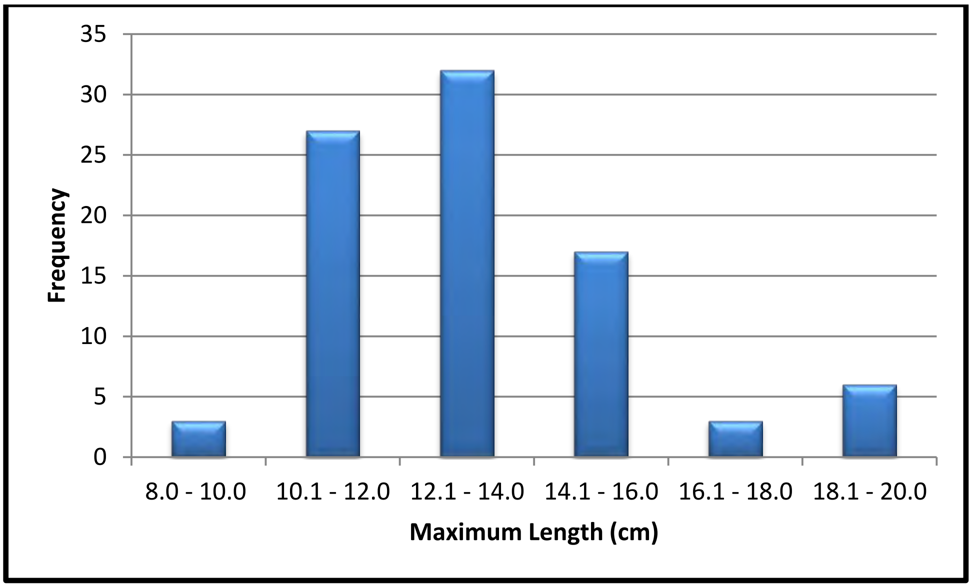


Fig. 5.37: Maximum Length for Cleavers

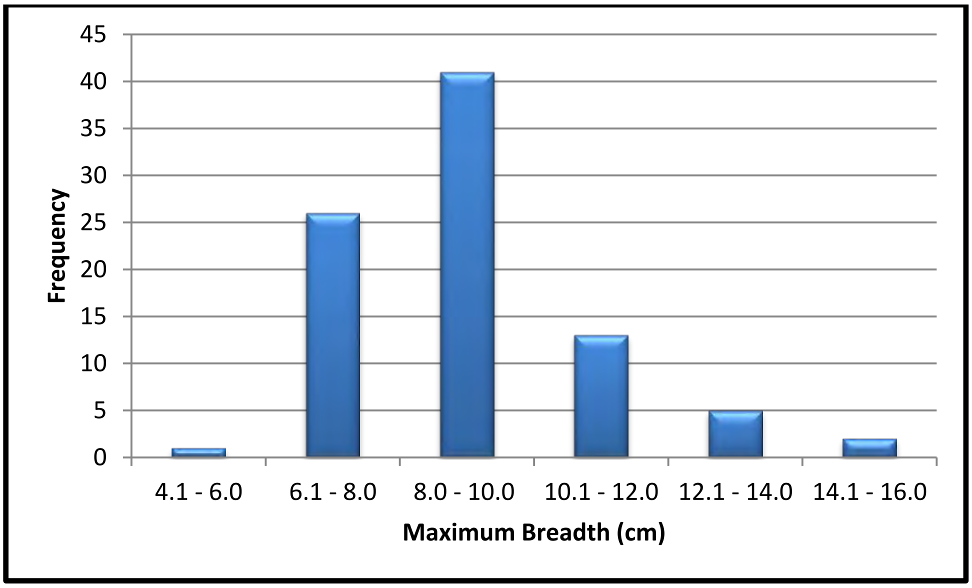


Fig. 5.38: Maximum Breadth for Cleavers

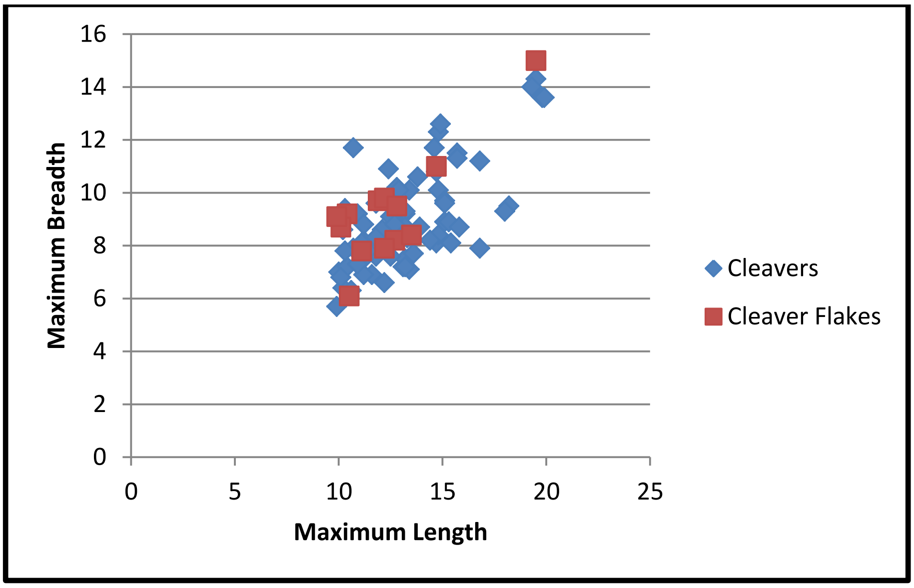


Fig. 5.39: Scatter plot showing Length/Breadth for Cleavers

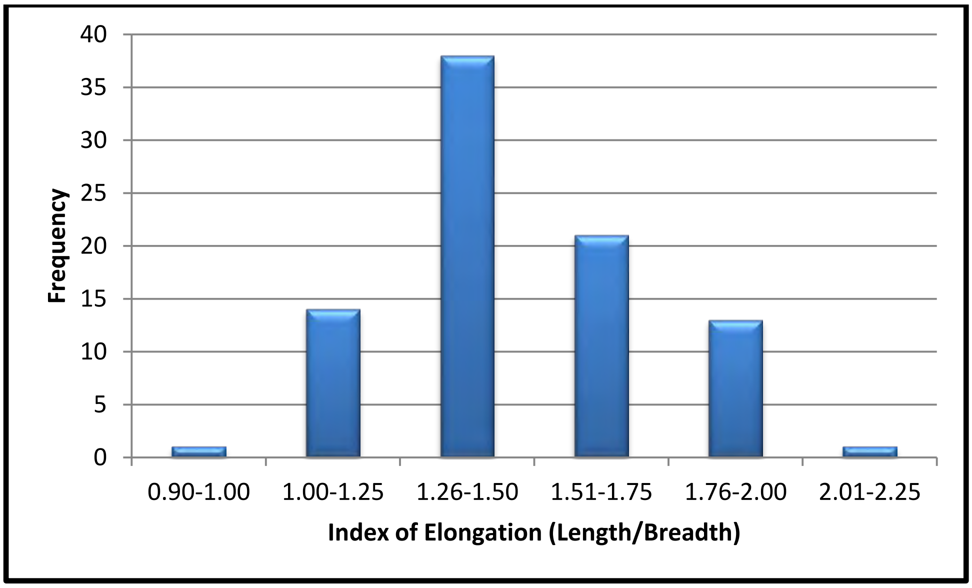


Fig. 5.40: Index of Elongation for Cleavers

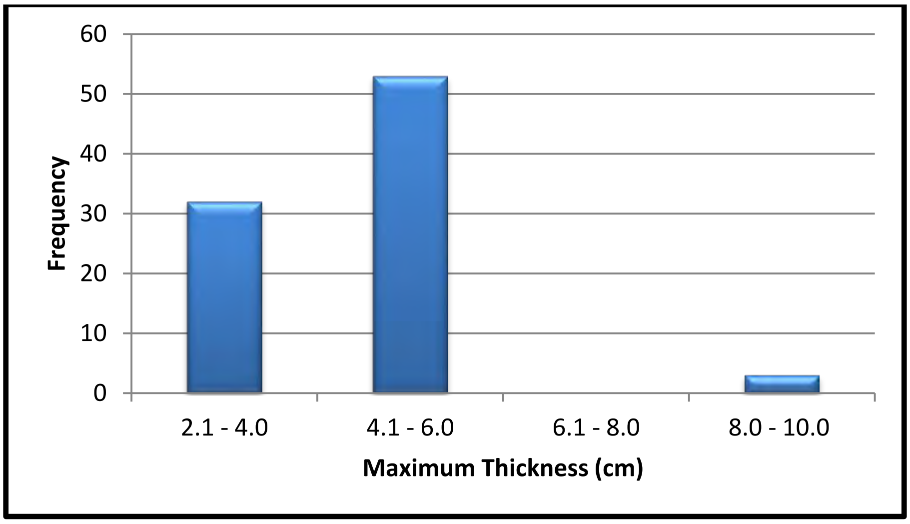


Fig. 5.41: Maximum Thickness for Cleavers

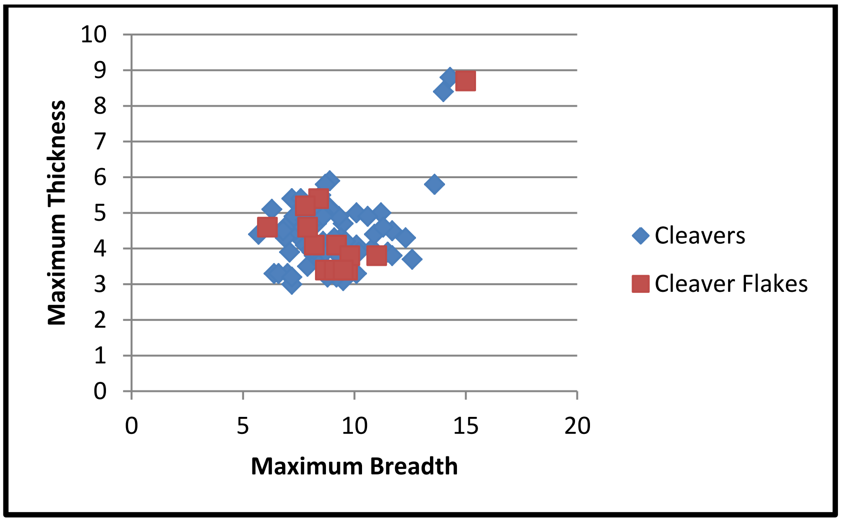


Fig. 5.42: Scatter Plot showing Breadth/Thickness for Cleavers

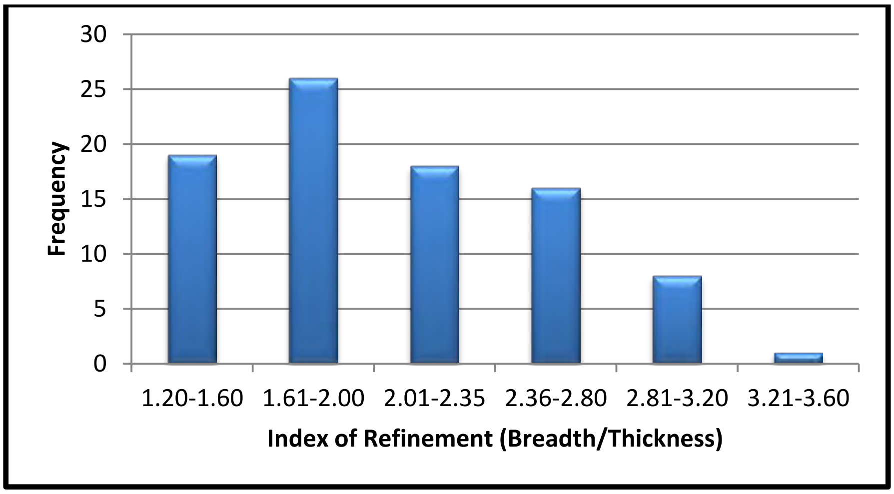


Fig. 5.43: Index of Refinement for Cleavers

Table 5.24: Cleaver size data from around the world

Site	N	Mean Length	Mean Width	Mean Thickness	Mean Weight	Reference
India						
Hunsgi	48	140	90	46		Sharon 2007
Yediyapur VI	11	137	84	38		Sharon 2007
Chirki	44	137	82	44		Sharon 2007
Bhimbetka	28	124.3929	73.0714	36.75		Sharon 2007
North Africa						
Erg Tihodaine	32	165.7	101	45.1	816.6	Mourre 2003
Tachenghit	147	147.3	96.2	36.1	566.1	Mourre 2003
HassiManda	60	140.5	105	32.4	522.4	Mourre 2003
STIC	5	179	106	47		Sharon 2007
Ternifine	41	144		42		Sharon 2007
Grotte des ours	9	128	80	44		Sharon 2007
South Africa						
Power's site	118	172	94	43		Sharon 2007
Pniel 6a	101	162	92	41		Sharon 2007
Riverview	75	160	97	45		Sharon 2007
Pniel 7b	99	150	88	41		Sharon 2007
Doornlaagte	13	170	102	48		Sharon 2007
Amanzi Springs	43	166	100	60		Sharon 2007
Elandsfontein 8364	27	162	93	51		Sharon 2007
East Africa						
Isimila K6	28	188	102	53		Sharon 2007
Isimila K14	52	195	105	46		Sharon 2007
Isimila K19	36	170	105	48		Sharon 2007
Olorgesailie DE89B	88	178	103	45		Sharon 2007
Isenya (VIb22)	41	172.9	105	46.3	823.6	Mourre 2003
Isenya (VIb1)	41	171.1	104.8	48	909.7	Mourre 2003
Isenya (Vb-Est)	39	175.3	100.9	46.3	895.1	Mourre 2003
Kamoa	63	144.8	95.4	42	645	Mourre 2003
Levant						
GBY NBA	80	140	93	33		Sharon 2007
GBY Layer II-6	104	138	83	35		Sharon 2007
Europe						
El Sartalejo	100	141.6	90.1	41.8	667.7	Mourre 2003
Valle d'Arros (B)	24	131	92.8	38.3	569.2	Mourre 2003
Valle d'Arros (M)	14	113.9	82.1	36.6	387.1	Mourre 2003
Lanne Darre	61	142.5	97	42.6	716	Mourre 2003
Campsas	48	120.6	85.6	36.8	465.9	Mourre 2003
Torralba	11	149.7	93.1	41.8	644.2	Mourre 2003
Ambrona	8	202	98.1	45.6	759.6	Mourre 2003

5.6.1.3 Cleaver Blank Type and Dorsal Scar Pattern

The type of blank is important in determining the technique of manufacture. The blank types have been here defined on the basis of dorsal scar pattern as Kombewa (single positive flake scar), multidirectional (with three or more scars in a multidirectional manner), or radial (with four or more scars in a centripetal manner). The scar patterns showed complete absence of cortical dorsal surface or unidirectional and bidirectional scar pattern. The blank type could not be determined for 21 cleavers, either because they were highly weathered or heavily retouched. Kombewa blank types were found in large percentage. Besides, a large number of multidirectional to radial blanks were found. Radial blanks indicate preparation of the dorsal face by removal of centripetal scars (Table 5.25 & Fig. 5.44).Multidirectional blanks are an intermediate strategy between Kombewa and radial blanks and do not form a distinct strategy of cleaver manufacture unlike Kombewa and radial blanks.

When compared with the global data, a high frequency of Kombewa blanks is also noted at Ternifine (Sharon 2007: Table 9, p. 47).

Table 5.25: Blank type for Cleavers

Blank Type	N	%
Kombewa	22	32.84
Radial	17	25.37
Multidirectional	28	41.79
Indeterminate	21	
Total	88	

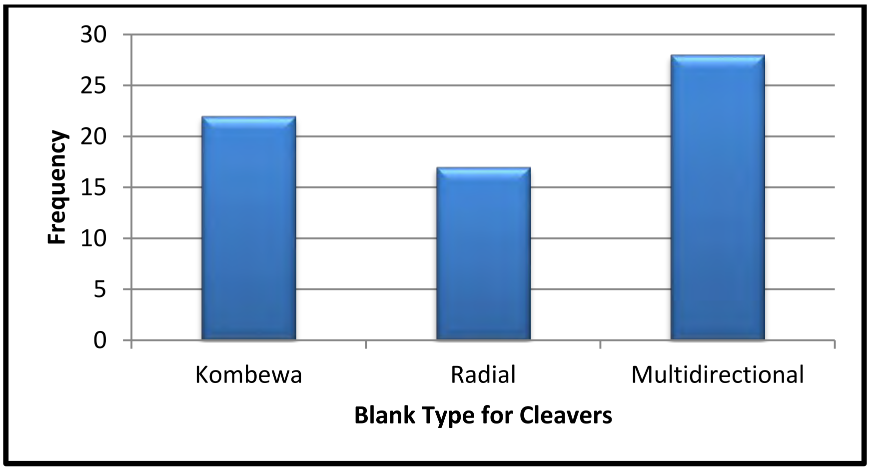


Fig. 5.44: Blank Type for Cleavers

5.6.1.4 Cleaver Blow Directions

Blow directions are significant in studying core organization and predetermination of blanks. In this study the blow directions have been defined following Goren-Inbar and Saragusti (1996) and Sharon (2007). Blow directions indicate use of all directions from 3 to 7 with a preference for end-struck flakes (direction 5), but if we club together side-struck (direction 3 and 7) and special side-struck or corner struck flakes (direction 4 and 6), then we find an almost equal proportion of both end-struck and side-struck flakes (Table 5.26 & Fig. 5.45) and also a considerable proportion of special side-struck or corner flakes. Blow directions 1, 2 and 8 were not found as this was the part of the active edge of the LCT blank. It may be noted here that blow direction could not be determined for 32 cleavers due to heavy weathering or extensive retouch, which means that only 56 cleavers have been considered here.

Table 5.26: Cleaver Blow Directions

Blow Directions	N
3	9
4	4
5	27
6	6
7	10
Indeterminate	32

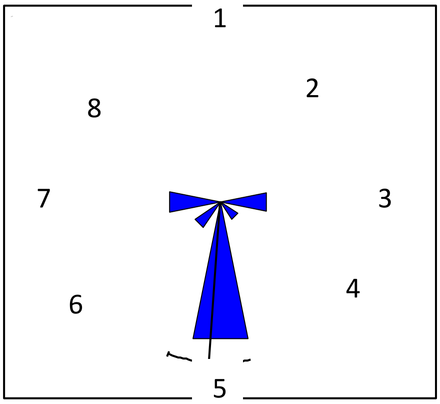


Fig. 5.45: Cleaver Blow Directions at Lalitpur

However, most Kombewa flakes have been flaked from direction 5 or end-struck, whereas cleavers on 'radial'and 'other' blanks do not show preference for any particular blow direction. (Table 5.27 and Fig. 5.46)

Table 5.27: Blow Direction for different cleaver blank types

	Blow Direction					
Blank Type	3	4	5	6	7	Total
Kombewa	1	2	11	1	2	17
Radial	2		3	2	3	10
Other	5	1	5	1	4	16
Total	8	3	19	4	9	43

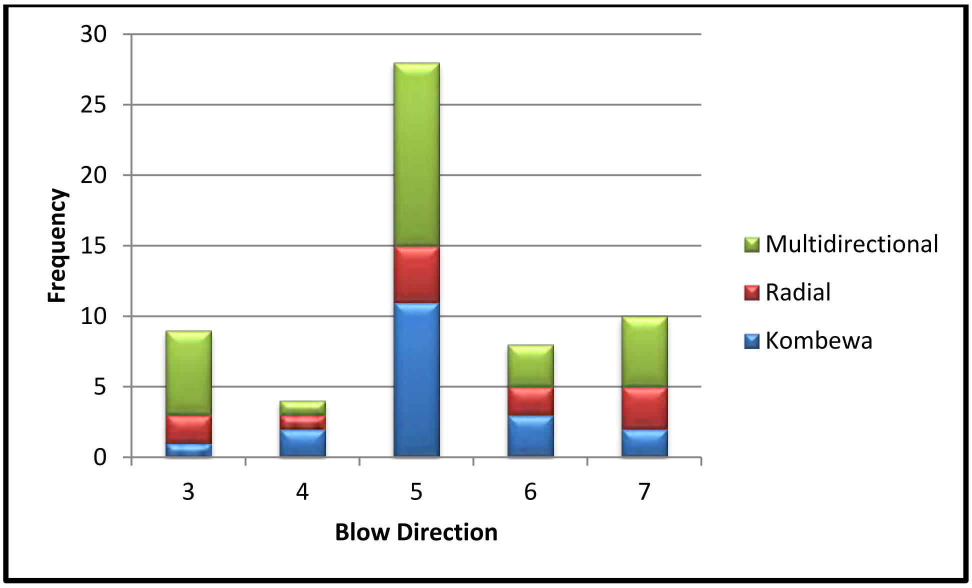


Fig. 5.46: Blow direction for different blank types

When we compare with the global data retrieved from Sharon (2007) and Mourre (2003) it shows a preference for side struck flakes (Table 5.28). Only at Ternifine which also displayed a dominance of Kombewa blanks like Lalitpur, a preference for end-struck flakes was noted while Tachengit and Isimila K6 displayed a preference for special side-struck or corner flakes. The Vaal River sites displayed a dominance of blow direction 3 while at GBY all blows directions 3 to 7 were found like at Lalitpur. Among the Indian sites Hunsgi and Chirki both displayed a preference for side-struck flakes though special side struck or corner flakes were also found in considerable proportion at Hunsgi.

Blow direction can be used as a strong indicator of the technique of manufacture as shown by strong preference for some blow directions (Sharon 2007). Preference for end-struck flakes at Lalitpur could be the result of predominant use of Kombewa method and also probably the use of tabular slabs which make it easier to exploit the largest surface for elongated flakes (Leader 2009).

At Tikoda in the Raisen Complex, S. Mishra (pers. comm.) observed that side flakes were mostly detached from the upper face of the cores, whereas end-struck flakes were detached from the sides of the core. Shipton *et al.* (2009) in their study of the core reduction at Isampur, call these flakes struck orthogonal to the bedding plane as perimeter flakes and those struck sub-parallel to the bedding plane as sectioning flakes. They also noted that alternate striking of perimeter and sectioning flakes created a bifacial edge which could be effectively used to knap large suitable flake blanks.

Table 5.28: Cleaver Blow Directions from Acheulean sites in the world (data derived from Sharon 2007, Mourre 2003)

Blow Direction	1		2		3		4		5		6		7		8		Indet		Total
Site	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N
Hunsgi	0	0	0	0	9	20	3	7	5	11	7	15	4	9	0	0	18	39	46
Yediyapur	0	0	0	0	2	17	1	8	2	17	0	0	0	0	0	0	7	58	12
Chirki	1	2	0	0	10	22	5	11	2	4	0	0	2	4	1	2	24	53	45
Power's site	0	0	0	0	42	40	3	3	12	11	3	3	4	4	0	0	42	40	106
Pniel 6a	0	0	0	0	36	39	2	2	2	2	2	2	9	10	0	0	42	45	93
Riverview	0	0	1	1	33	44	10	13	1	1	3	4	10	13	0	0	17	23	75
Pniel 7b	0	0	0	0	39	42	14	15	6	6	10	11	5	5	0	0	19	20	93
Doornlaagte	0	0	0	0	2	15	1	8	0	0	0	0	2	15	0	0	8	62	13
Isimila K6	1	4	0	0	0	0	6	24	0	0	2	8	2	8	0	0	14	56	25
Isimila K14	0	0	0	0	10	19	3	6	2	4	9	17	11	21	1	2	17	32	53
Isimila K19	0	0	1	3	8	21	3	8	3	8	1	3	13	34	1	3	8	21	38
GBY NBA	1	1	0	0	4	5	10	11	8	9	15	17	7	8	1	1	41	47	87
GBY L. II-6	0	0	0	0	11	9	15	12	19	15	22	17	23	18	0	0	38	30	128
Isenya (VIb22)	0	0	1	3.6	8	28.6	2	7.1	4	14.3	2	7.1	11	39.3	0	0	13		41
Isenya (VIb1)	0	0	1	3.6	8	28.6	2	7.1	6	21.4	5	17.9	6	21.4	0	0	13		41
Isenya (Vb-Est)	0	0	0	0	11	52.4	3	14.3	3	14.3	3	14.3	1	4.8	0	0	18		39
Kamoa	0	0	0	0	13	19.03	10	14.29	17	26.98	9	15.9	13	20.63	2	3.17	0		63
Ternifine	0	0	1	2	1	2	7	15	17	37	5	11	4	9	0	0	11	24	46
Erg Tihodaine	0	0	0	0	6	18.8	5	15.6	5	15.6	9	28.1	7	21.9	0	0	0		32
Tachengit	0	0	0	0	2	1.4	18	12.2	40	27.2	73	49.7	13	8.8	0	0	1		147
HassiManda	0	0	0	0	0	0	12	20.3	36	61	10	17	1	1.7	0	0			
El Sartalejo	0	0	0	0	21	21	17	17	19	19	16	16	25	25	1	1			
Valle d'Arros (B)	0	0	0	0	4	16.7	4	16.7	3	12.5	6	25	5	20.8	0	0	2		
Valle d'Arros (H)	0	0	0	0	1	7.1	3	21.4	8	57.1	2	14.3	0	0	0	0			
LanneDarre	0	0	1	1.6	10	16.4	16	26.2	20	32.8	8	13.1	5	8.2	1	1.6			
Campsas	0	0	0	0	4	8.3	17	35.4	5	10.4	16	33.3	5	10.4	0	0			
Torralba	0	0	0	0	1	9.1	5	45.5	1	9.1	3	27.3	1	9.1	0	0			11
Ambrona	0	0	1	13	4	50	2	25	1	12.5	0	0	0	0	0	0			8

5.6.1.5 Striking Platform

The striking platform dimensions show a mean thickness of 2.95 cm and a mean width of 6.09 cm with a mean platform angle of 119° (Table 5.29).

Table 5.29: Striking Platform Dimensions

	Platform thickness	Platform width	Platform angle
Minimum	1.90	2.90	96
Median	2.85	5.90	121
Maximum	4.90	11.20	132
Q1	2.48	4.43	115
Q3	3.40	7.10	124
SD	0.67	2.10	7.89
Variance	0.45	4.41	62.20

Striking platform frequencies with most flakes on plain or dihedral platforms indicates minimal core preparation (Table 5.30 & Fig. 5.47). However in many cases (48 pieces or 53.48% cleavers) the platform and the bulb has been trimmed or retouched to remove excess mass. Complete absence of cortical striking platforms is striking and suggests that initial core preparation was carried somewhere else and also that LCT blanks were detached after initial preparation of core comprising removal of cortex. The striking platform could not be determined for 2 cleavers due to weathering away of the platform.

Global data also shows predominance of plain or trimmed striking platforms as at Lalitpur (Sharon 2007: Table 17 p. 75).

In the case of Kombewa flakes, the striking platform of the earlier removal on the dorsal face has mostly been trimmed away for thinning the LCT. Such a pattern has also been noted in high frequencies (40 to 100%) for most sites analysed by Sharon (2007).

Table 5.30: Striking Platform Types for Cleavers

Striking Platform Types	Frequency
Plain	27
Dihedral	12
Facetted	1
Trimmed	46
Indeterminate	2
Total	88

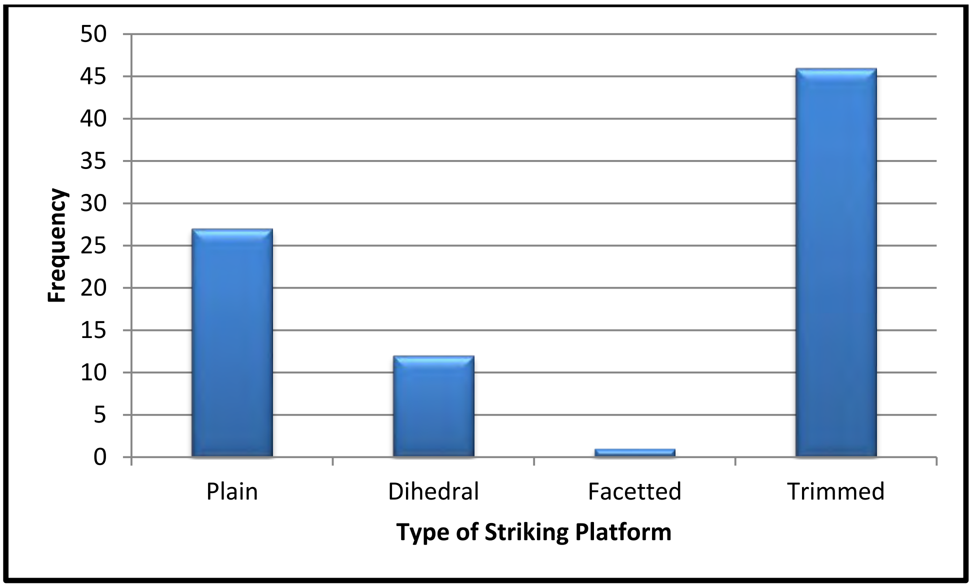


Fig. 5.47: Type of Striking Platform for Cleavers

5.6.1.6 Scar Count

Despite the difficulty in counting the scars, it was possible to generally note the number of scars on each face on a considerable number of pieces. The scar count and dorsal scar pattern proved to be important attributes helpful in highlighting important aspects of technological organization of large flake production.

Cleavers had very low number of ventral scars (Table 5.31) ranging generally from 0 -3, with a maximum of 12 scars because they were fashioned on flake blanks and therefore required minimal retouch of the ventral face to achieve a suitable edge which was in most cases already formed. The dorsal scars ranged from 1 to 16 with a median of 7 scars. The median number of total scars on both faces was 8.5, with a minimum of 2 and a maximum of 28 scars. The scar count could not be determined for 4 cleavers.

Though it was difficult to count previous scars on cleavers, but in cases where it was possible to count them, they ranged from a minimum of 1 to maximum 6 scars, with a median of 3 scars. It was not possible to count the previous scars on 8 cleavers where they were either heavily weathered or extensively retouched.

The scar count was high only for the four cleavers on quartzite where the total number of scars on both faces ranged from 14 to 28. The scar count was high on quartzite artefacts even for the dorsal face. On granite the scar count was lower with the total ranging from 2 to 20 and generally ranging from 7 to 11 scars. The scar count for ventral face was very low for granite artefacts compared to quartzite artefacts

(Figs. 5.110 - 5.114). However no significant difference was noted in the scar counts for the different blank types.

Table 5.31: Number of Scars on ventral and dorsal faces of Cleavers

	Previous Scars	**Secondary Scars**	**Ventral Scars**	**Dorsal Scars**	**Total Scars**
Min	1	0	0	1	2
Median	3	6	0	7	8.5
Max	6	27	12	16	28
Q1	1	4	0	6	7
Q3	4	9	3	10	11.25
SD	1.48	4.635	2.504	2.651	4.143
Variance	2.19	21.479	6.268	7.026	17.168

5.6.1.7 Cleaver Bit Characteristics

The cleaver bit morphology showed a predominantly straight delineation with a parallel morphology. A high proportion of convex and oblique bits were also found with divergent morphology. The cleaver bit shape could not be determined for 4 cleavers as the bit was heavily damaged either due to extensive use modification or weathering (Tables 5.32 & 5.33; Figs. 5.48 & 5.49).

Table 5.32: Delineation of Cleaver Bit

Delineation of Cleaver Bit	Frequency
Straight	39
Convex	11
Concave	0
Oblique	33
Convergent	1
Damaged	4
Total	88

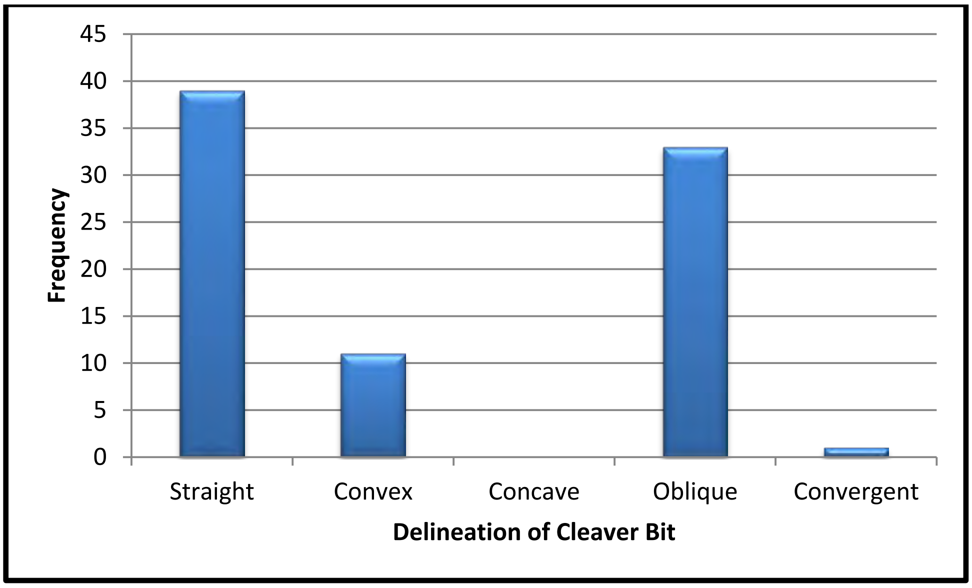


Fig. 5.48: Delineation of Cleaver Bit

Table 5.33: Shape of Cleaver Bit

Shape of Cleaver bit	Frequency
Convergent	16
Ultraconvergent	2
Divergent	23
Splayed	2
Parallel	45
Total	88

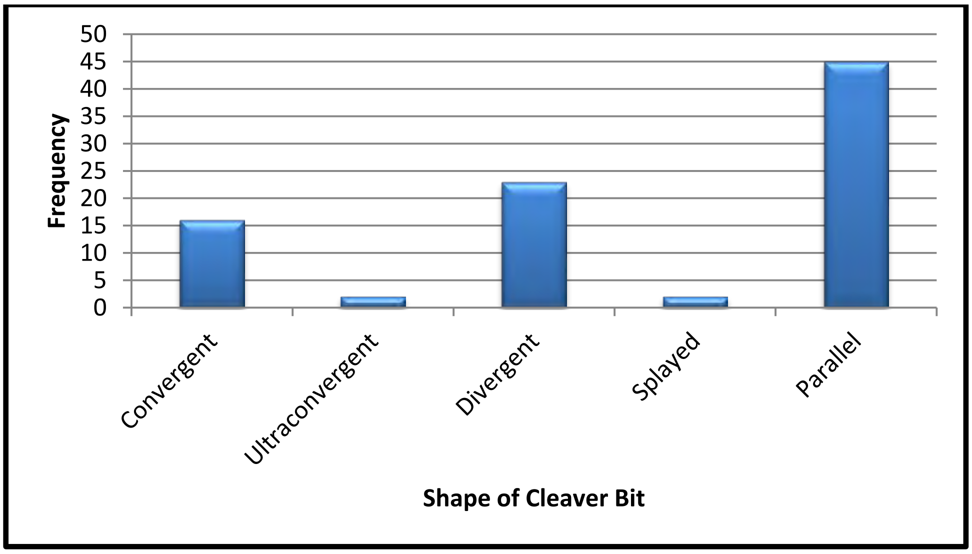


Fig. 5.49: Shape of Cleaver bit

The cleaver bit mostly results from a single predetermining scar. Only in 5 cases, it was determined by two scars (Table 5.34). The scar direction was predominantly from direction 1 or N with very few scars from directions 2, 3, 7, 8 (Table 5.35 & Fig. 5.50). It shows that simple organization was adopted for cleaver manufacture without any complexity in technique and methods.

Table 5.34: Number of Scars predetermining the cleaver bit

Number of Scars Predetermining the Tranchant	Frequency
1	80
2	5
➢ 2	0
Indeterminate	3
Total	88

Table 5.35: Direction of Scars predetermining the cleaver bit

Direction of Scars predetermining the tranchant	Frequency
1	44
2	2
3	2
7	3
8	7
Indeterminate	32

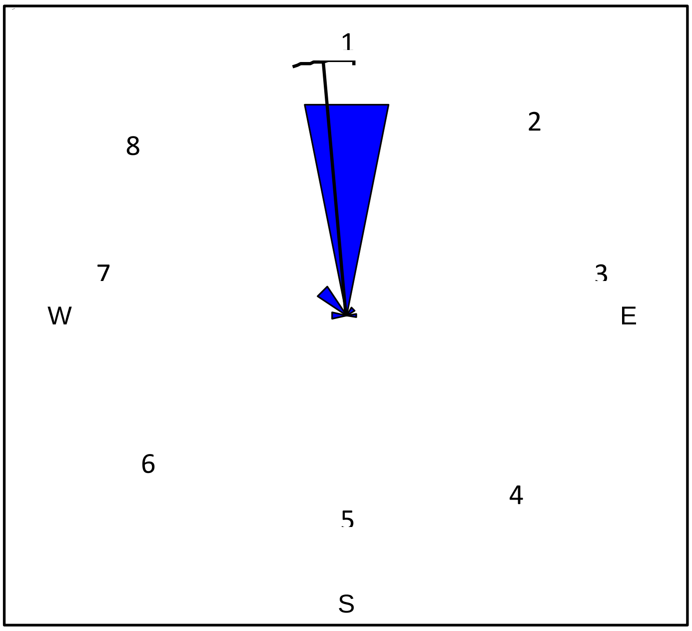


Fig. 5.50: Rose Diagram for direction of scars predetermining the cleaver bit

5.6.1.7 Cleaver Retouch Characteristics

It was observed that secondary retouch is mainly for reduction of volume or thinning of tools. The ventral surface of the flake blank was left largely intact indicating low reduction. Retouch was mostly confined to the dorsal face, but even on the dorsal face there was often very little or no retouch (Table 5.36 & Fig. 5.51). There is lesser amount of retouch on Kombewa blanks. Kombewa flakes served as highly efficient blanks for cleavers which needed no further modification to be used as tools. Minimal secondary flaking was done to shape the cutting edges of the tool (Fig. 5.52).

For resharpening generally steep retouch is employed while for thinning or gripping, alternate retouch is mainly used. Looking at the location of retouch, most of the retouch is confined to proximal and sides of the tool (Table 5.37 & Fig. 5.53). This is so because retouch was mostly related to thinning and blunting the tool for gripping purposes. Therefore most retouch was to remove the striking platform and bulb of percussion to remove the excess thickness and balance the tools' mass and regularize the edges. Very little standardization was noted in shapes with very little or no bifacial shaping. Further there is no attempt at symmetry, both bifacial and bilateral.

The secondary retouch on most cleavers was generally on the sides and base (Table 5.37 & Fig. 5.53), Retouch was predominantly abrupt or oblique lending a scraper like edge to most cleavers (Table 5.38; Figs. 5.54 & 5.66).

The intensity of retouch for the different blank production methods like Kombewa and radial cores is not much different (Figs. 5.59 – 5.62). However, the quartzite cleavers are more heavily modified with a higher scar count (Figs. 5.110 – 5.114) (also see section 5.8).

Though in most cases the cleaver edge was predetermined prior to blank detachment with no subsequent retouch to shape the edge, in only a small number of cases of quartzite cleavers, the cleaver edge was retouched (Figs. 5.69 a & b). Retouch of the cleaver edge has also been noted in a recent restudy of the Bhimbetka cleavers (S. Mishra pers. comm.). At Lalitpur the retouch of the cleaver edge on a few quartzite artefacts could be the result of heavy curation of imported raw material. In some cases the cleaver edge has been so heavily retouched that it has lost its typical cleaver characteristics and become more handaxe-like. There are no cases of cleaver edge formed by a tranchet blow.

Table 5.36: Face of Working of Cleavers

Face of Working	Frequency
Unifacial normal	45
Unifacial inverse	1
Bifacial	31

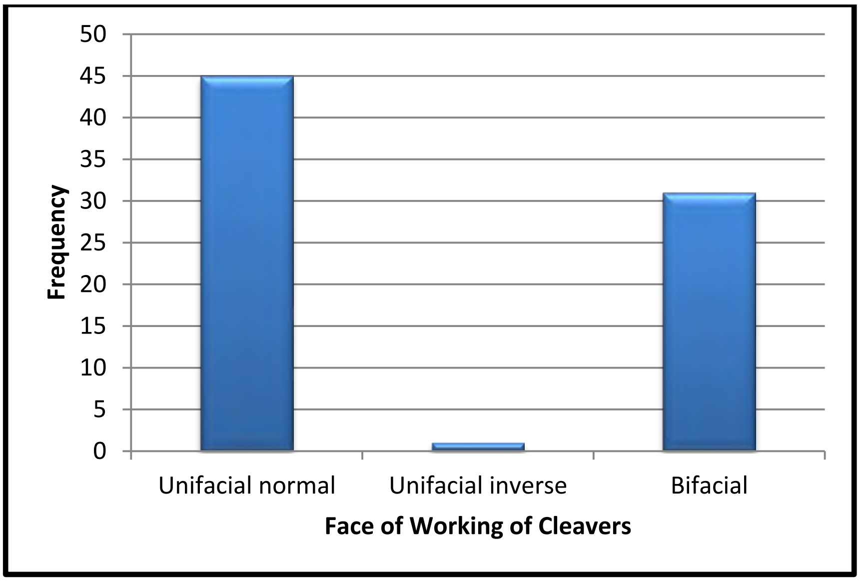


Fig. 5.51: Face of Working of Cleavers

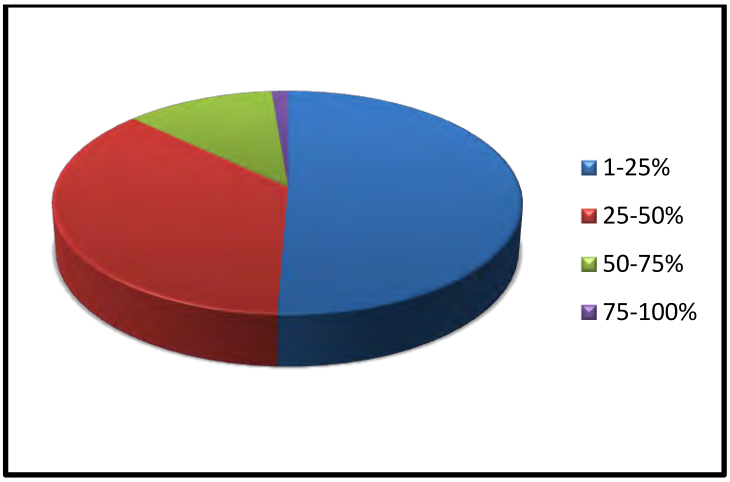


Fig. 5.52: Percentage of Retouch Distribution on both faces of Cleavers

Table 5.37: Location of Retouch for Cleavers

Location of Retouch	Frequency
Single side	7
Double sides	16
Side and end	46
All around	6
Indeterminate	2

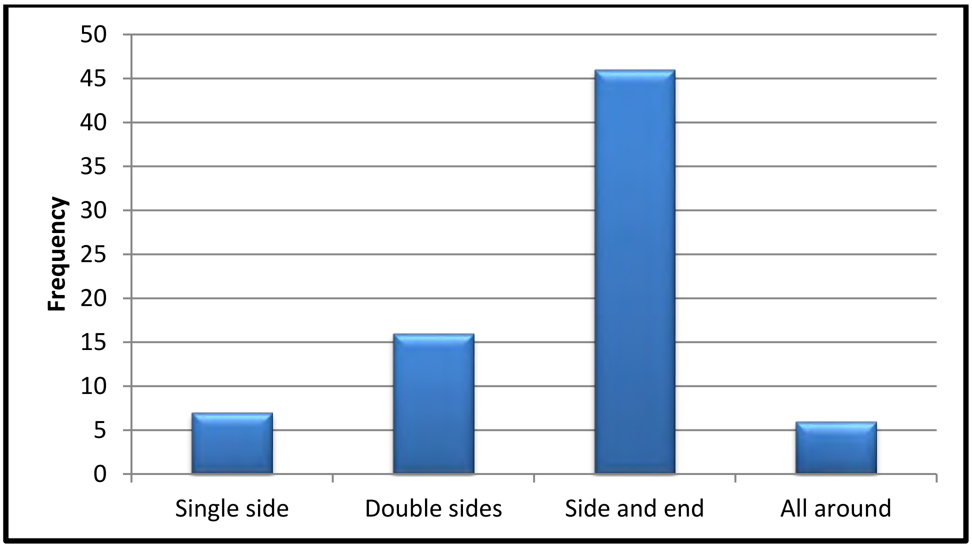


Fig. 5.53: Location of Retouch for Cleavers

Table 5.38: Inclination of Retouch for Cleavers

Inclination of retouch	Frequency
Flat	3
Oblique	34
Abrupt	40
Step	0

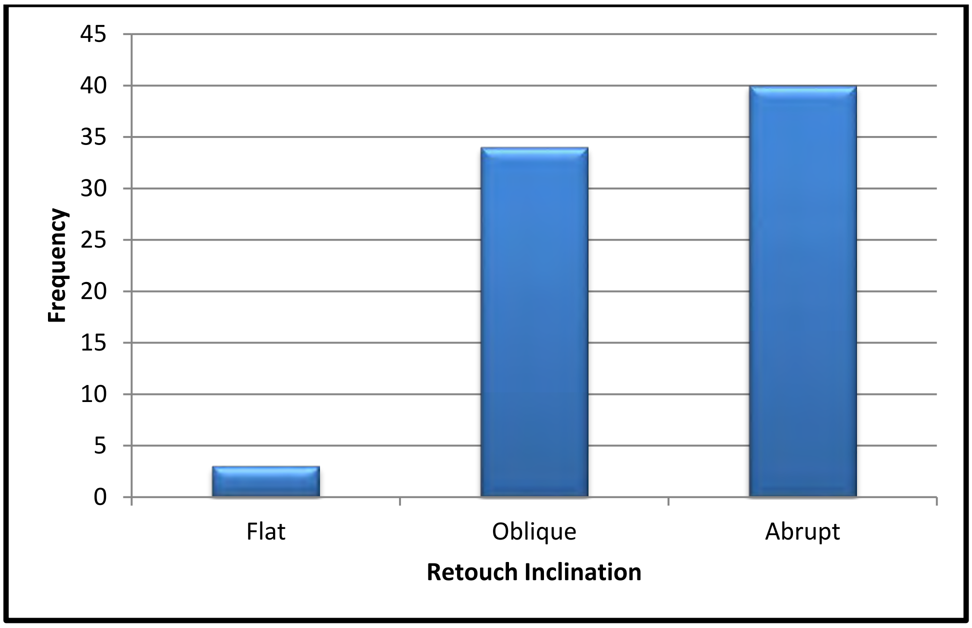


Fig. 5.54: Inclination of Retouch for Cleavers

5.6.1.7 Cleaver *Chaîne Opératoire*

Though the large cores from which cleaver blanks could have been detached are present in a very small proportion relative to the percentage of cleavers at the site. But some medium sized cores present large scars which could have been used as large flake blanks for LCTs (see section 5.4.6). Only one giant core was recovered from the ditch section at another nearby locality (see section 5.4.2). But a large number of cleaver flakes, scar pattern on dorsal face of cleavers, striking platform characteristics, cortex cover and other attributes recorded on cleavers as noted above have helped reveal the technique of manufacture of cleavers at the site of Lalitpur.

Most of the cleavers were made either by Kombewa method or from multidirectional or radially flaked cores.

Kombewa Method

The Kombewa method (Owen 1938) entails detaching a large flake from the ventral face of a previously extracted large flake. This means that the interior or flake surface of the first flake acts as the debitage surface and the resulting flake often retains a remnant of the platform of the original flake with both the surfaces having a flake surface. By using the convexity of the lower face of this first flake, the shape and thickness of a second flake (or several successive flakes) can be predetermined.

The flake so detached had a long sharp cutting edge which could be used without modification as a cleaver edge (Texier and Roche 1992). It presented plano-convex or biconvex section (Sharon 2007).

Use of the Kombewa method for making cleavers has been reported from a large number of other sites in India and Africa (Mishra *et al.*2010a; Pappu 2011; Corvinus 1983, Sharon 2007; Mourre 2003, Chavaillon and Piperno 2004; Haynes *et al.* 1997, 2001; Alimen *et al.*1978; Balout and Tixier 1957, Balout *et al.* 1967; Dauvois 1981; Newcomer and Hivernel-Guerre 1974)

Dag and Goren-Inbar (2001) have questioned the identification of all flakes with dorsally plain surfaces as inherently Kombewa. But, Sharon (2007) in his study of experimental bifacial cores showed that dorsally plain flakes larger than 10 cm do not result from bifacial core. Moreover, the present study shows that in most cases the second striking platform has been removed by secondary retouch, therefore we consider all flakes on which both ventral and dorsal surfaces are plain or scar free as Kombewa. Only two Kombewa cleavers are typified by two striking platforms on the same axis and two ventral surfaces, but even in this case the platform is partly trimmed. Only one Kombewa flake was found with an orthogonal platform. The rest all have dorsally plain surfaces which are typically Kombewa.

The presence of a high number of Kombewa flakes at Lalitpur (Figs. 5.64 a – c) demonstrates the ability to detach large flakes with desired edge and morphology by using simple methods of core organization and core volume management without complex core preparation. But definite predetermination is implied in the attainment of suitable sized flakes with ready to use large cutting edges. Such flakes required little or no retouch to be used as cleavers.

Radially Flaked Cleavers

A number of cleavers have been identified as having been made on radial flakes. These cleavers are typified by a radial scar pattern on their dorsal faces and very little or no secondary retouch. The organization of the scars, striking platform and retouch characteristics suggest that this was a special form of cleaver blank manufacture (Figs. 5.65a & b - 5.66 a & b)

The scar pattern and platform morphology suggest that the core was prepared by giving one or more blows to prepare the striking platform. Most cleavers on radial flakes have a plain or dihedral striking platform suggesting minimal preparation of the platform. Then the upper face of the core was flaked in a radial manner (resulting in more than 3 dorsal scars). Finally a blow was delivered resulting in the detachment of a cleaver blank with a sharp transverse cutting edge. The presence of a considerable number of radially flaked cleaver blanks with very little or no secondary retouch suggests predetermination of cleaver blanks so that they could be used without much further modification.

Few cores with a single large preferential scar also suggest that striking platform was prepared on one surface by just a few blows and then the upper face was prepared by radial flaking and finally the flake was detached with a sharp transverse cutting edge which could be used without little or no further modification as cleavers (Fig. 6.16).

However, this method resulted in varying cleaver morphology and the predetermination was not so much as in the classic Levallois method. However, very little secondary modification was done and that was also aimed at thinning the bulb and platform or shaping the lateral edges. This method is very similar to the Chirki cleaver core method (Corvinus 1983, Sharon 2007).

The method involved minimal core preparation but it does suggest the idea of a transverse sharp cutting edge which was obtained by simple core management. This resulted in very low mean number of dorsal scars.

Cleavers on Multidirectional Blanks

Apart from Kombewa and radial blanks, a considerable number of cleavers were made on blanks with multidirectional extractions on the dorsal face. However, such cleavers were perhaps a result of intermediate stage of cores between Kombewa blanks with a single previous scar and radial blanks with four to six previous scars. They were probably less carefully prepared and therefore involved more secondary modification than Kombewa and radial blanks. Multidirectional blanks do not form a clearly distinct strategy of cleaver manufacture unlike Kombewa and radial blanks.

Therefore, it may be surmised that the *chaîne opératoire* for cleavers at Lalitpur started with the simple strategy of obtaining Kombewa blanks from a previous large flake, which could be a split boulder, serving as core for detachment of the blank resulting in Kombewa flakes. As more and more blanks were detached from this core, the upper face had a multidirectional scar pattern and finally a radially prepared surface. It may be noted that very little or no secondary modification on cleavers made on radial blanks shows the intensive planning involved.

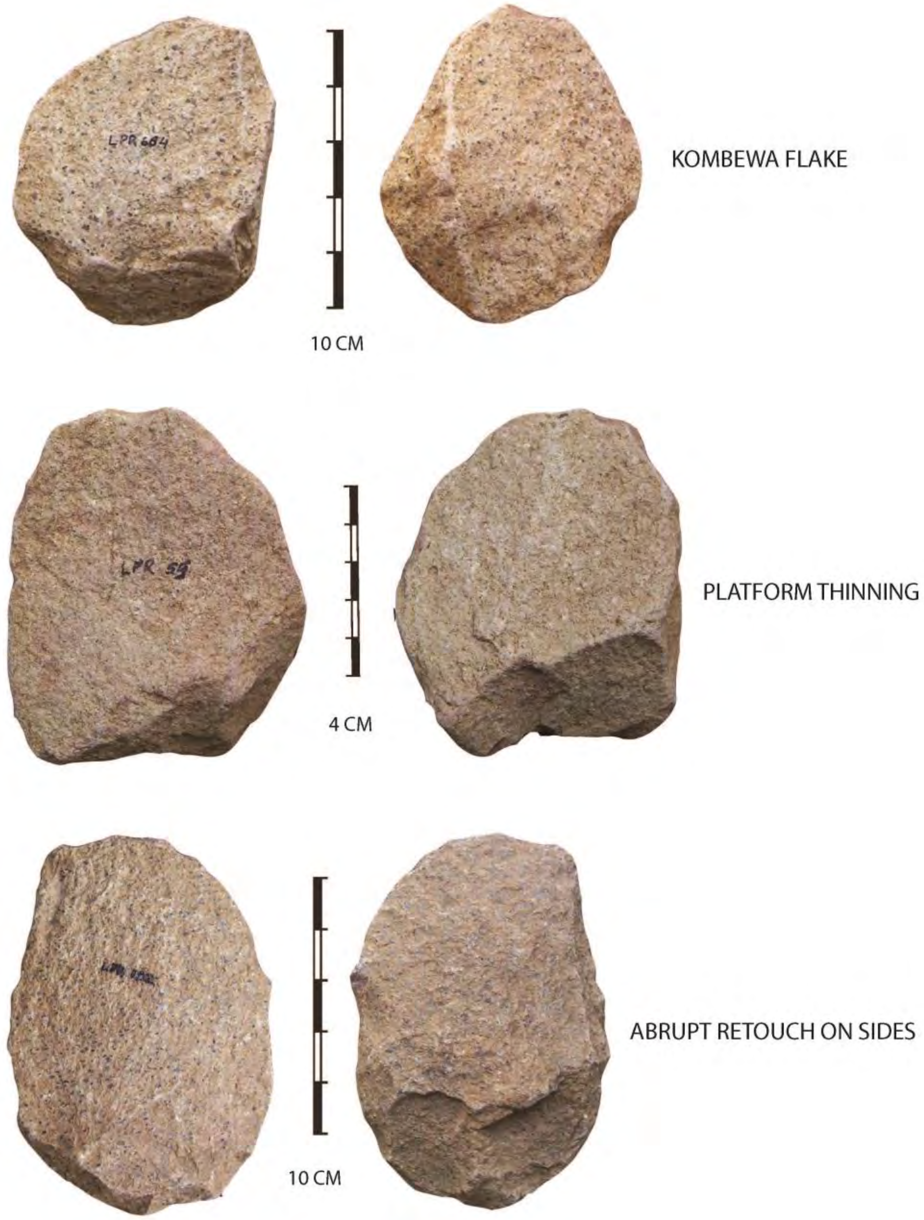


Fig. 5.55a: Cleaver *chaîne opératoire* for Kombewa Cleavers

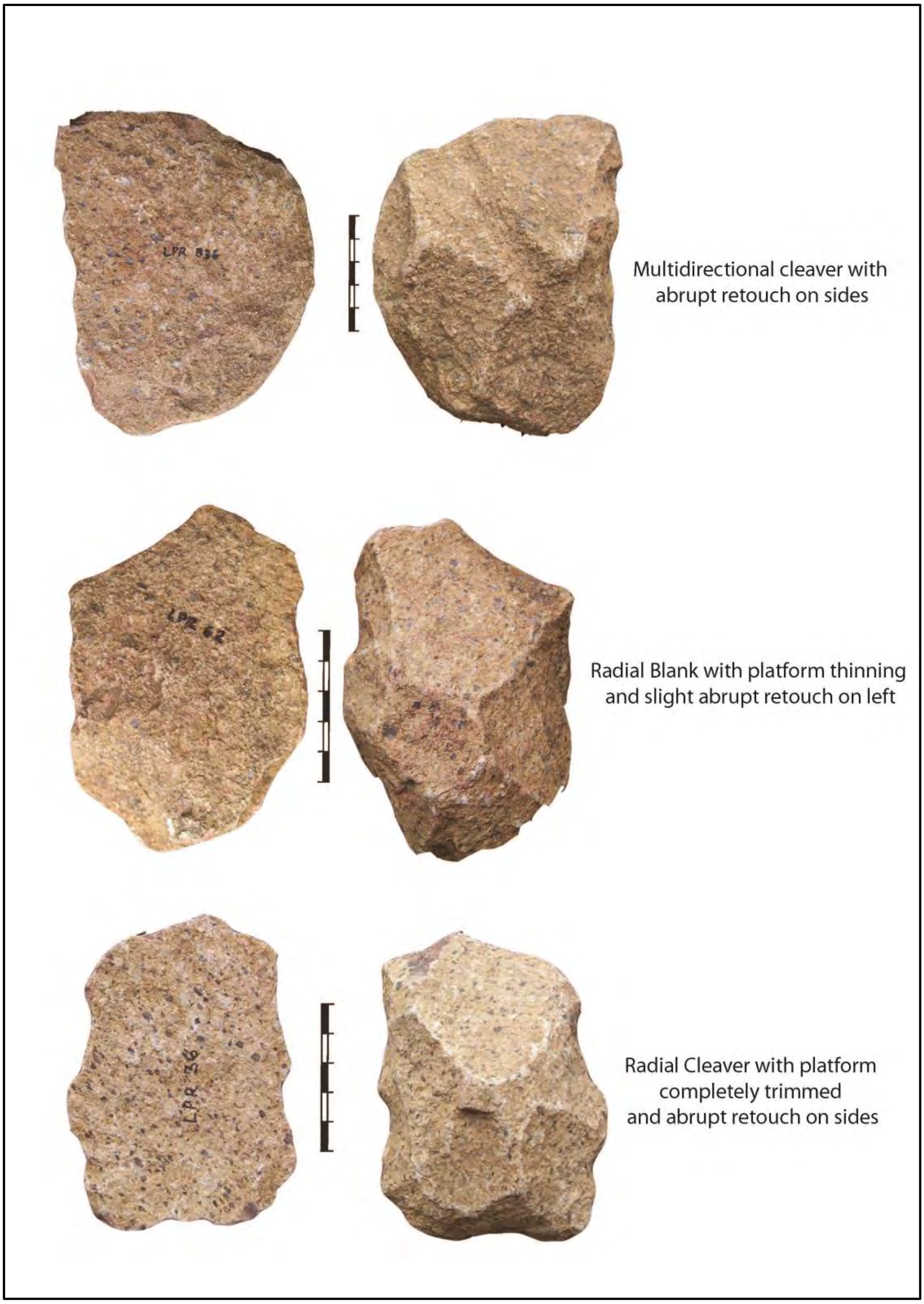


Fig. 5.55b: Cleaver *chaîne opératoire* for Multidirectional/Radial Cleavers

The nature of cortex cover, striking platform type, direction of blow, scar count and intensity of retouch for Kombewa, radial and multidirectional blanks does not show any striking differences in the cleaver blanks emerging from the core organization strategy (Figs. 5.56 – 5.63).

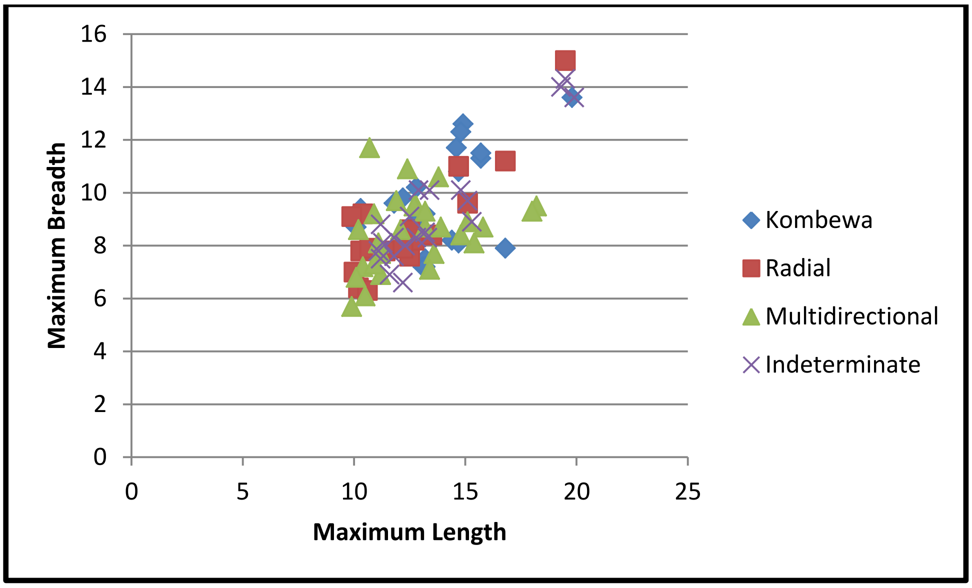


Fig. 5.56: Scatter Plot showing Length/Breadth for various blank types

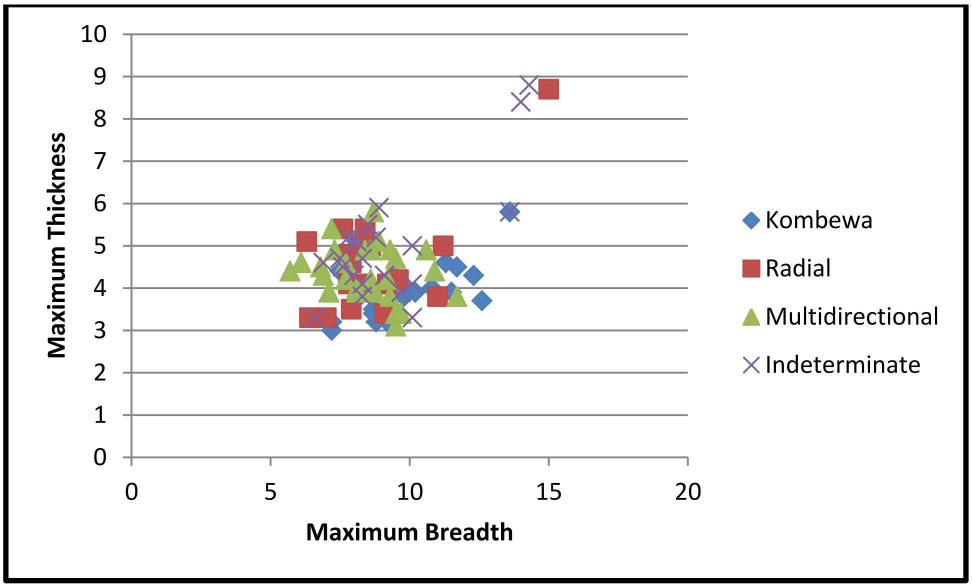


Fig. 5.57: Scatter plot showing Breadth/ Thickness for various blank types

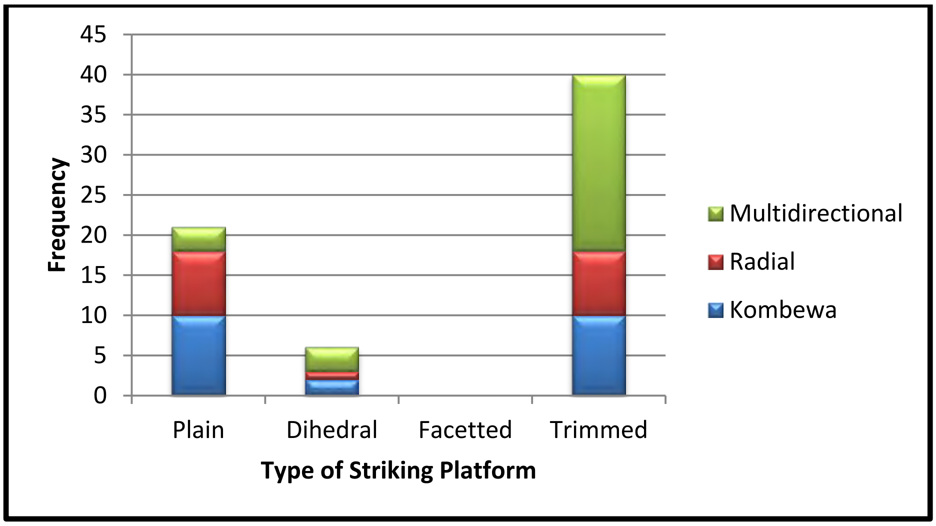


Fig. 5.58: Striking platform types for the different cleaver blank types

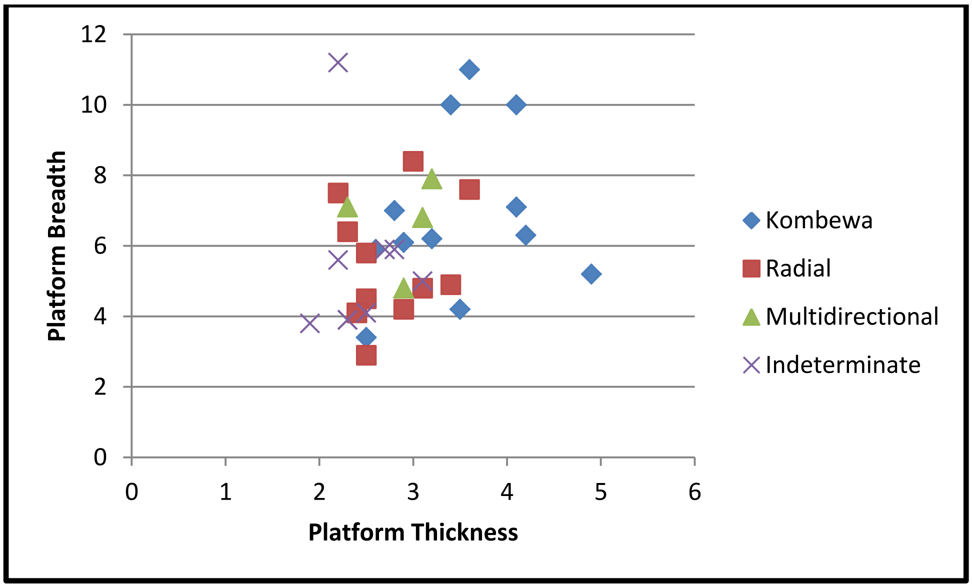


Fig. 5.59: Platform Thickness/Breadth for the different cleaver blank types

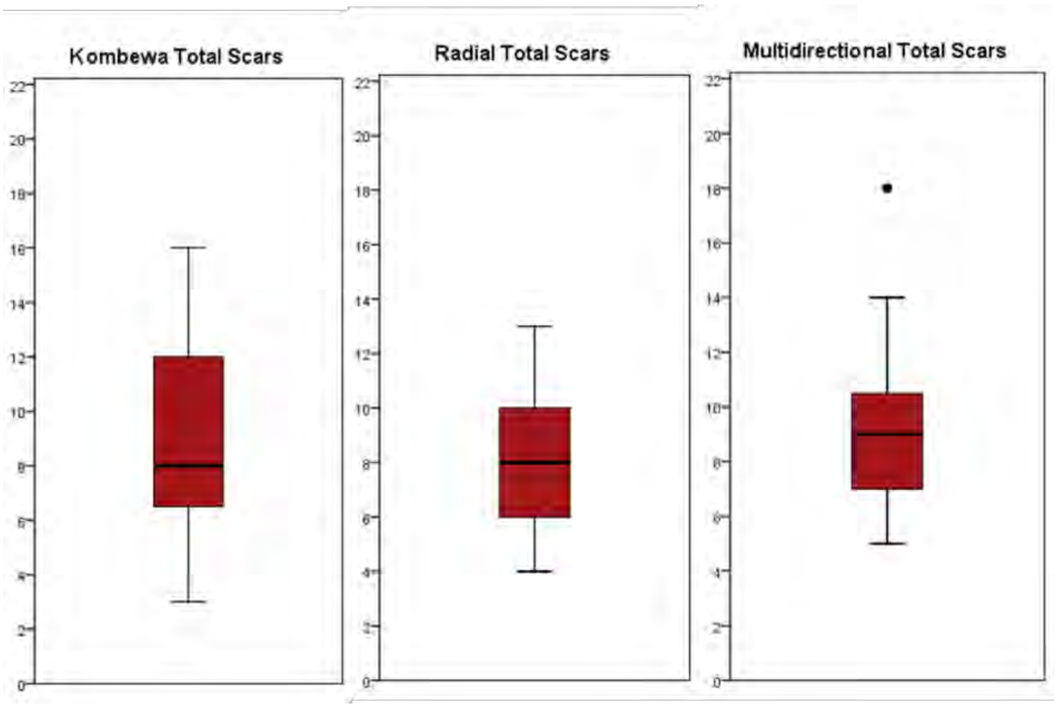


Fig. 5.60: Boxplot showing the total scar count for the different cleaver blank types (excluding cleavers on quartzite)

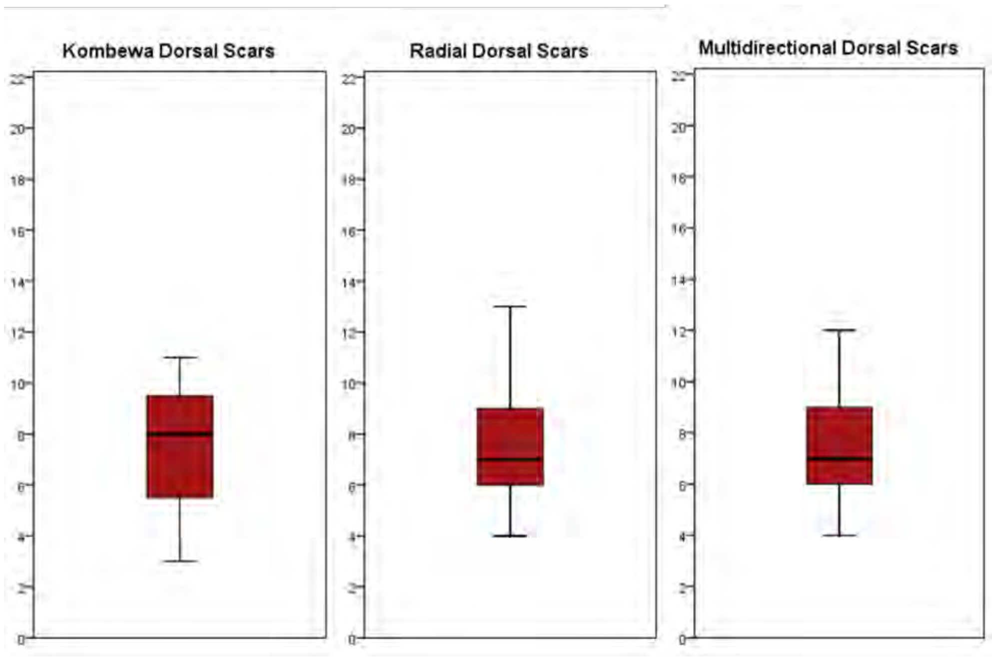


Fig. 5.61: Boxplot showing the dorsal scar count for the different cleaver blank types (excluding cleavers on quartzite)

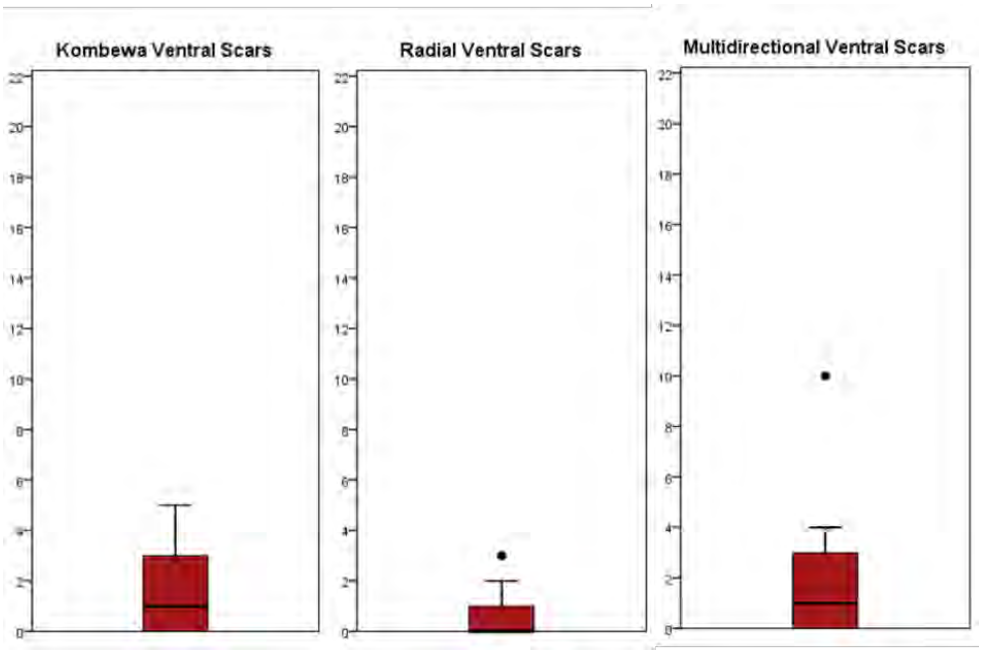


Fig. 5.62: Boxplot showing ventral scar count for the different cleaver blank types (excluding cleavers on quartzite)

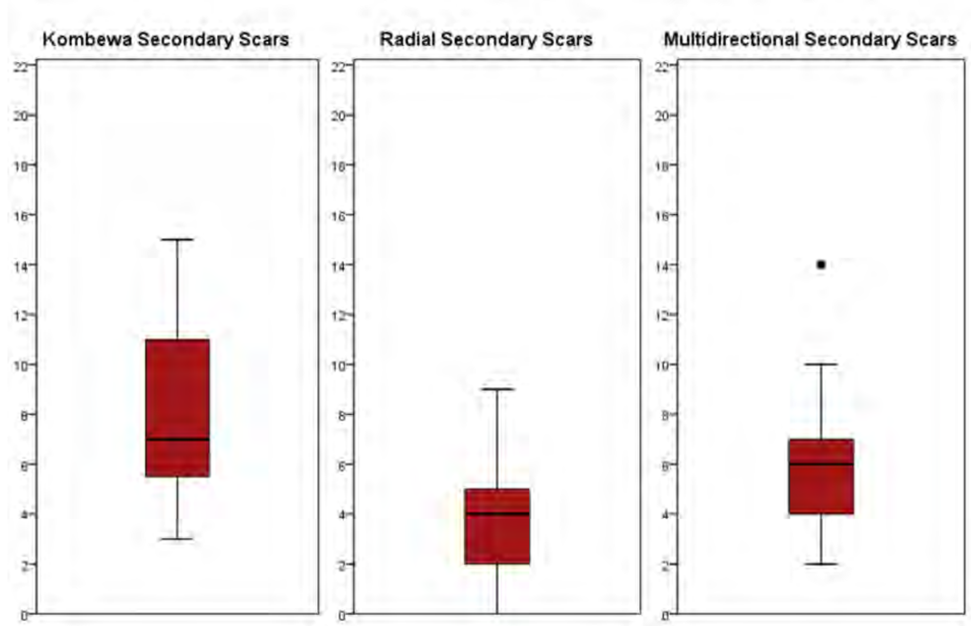


Fig.5.63: Boxplot showing secondary scar counts for the different cleaver blank types (excluding cleavers made on quartzite)

The cleavers at Lalitpur show a variable morphology from highly finished or well prepared cleavers (Figs. 5.68 &5.69 a & b) with a thin cross section and neatly prepared edges to minimally trimmed cleavers or cleaver flakes with no secondary modification (Figs. 5.65 a & b).

In this context it may be mentioned that a high frequency of cleaver flakes has been noted in many Indian and North African sites (Sharon 2007). The study of the cleaver flakes at Lalitpur show that they were made with core management strategies which were quite simple but involving sufficient predetermination resulting in a suitable cleaver edge morphology which needed no further modification. It may be noted that there appears to be no distinction in the sizes and morphology of the highly finished cleavers and cleaver flakes.

Further, if we follow a strict definition of cleavers as bifacially knapped tools, then most tools classified here as cleavers would be called cleaver flakes (Clark 2001: 49). However, we have classified all large flakes with a transverse cutting edge and any secondary working as cleavers, not necessarily bifacially shaped.

The study of cleavers and large flakes at Lalitpur shows that both cleavers and large flakes, unretouched or retouched, are actually found to be grading into each other and it is difficult and would be futile to keep them into water-tight compartments. Cleavers also grade into knives, scrapers and even handaxes. On few tools, it appears that a cleaver edge was later extensively trimmed and modified into handaxes or cleavers with narrow cutting edges. Similar trimming has been reported from Chirki (Corvinus 1983).

Most of the cleavers at Lalitpur have a predetermined unretouched cleaver edge. There are no cleavers made by tranchet removal or bifacial transverse edge. But a few ultraconvergent cleavers are also found.

A considerable number of cleavers have been found with moderate to extensive damage on their bits. However it was not possible to determine the nature of this damage due to heavy to moderate weathering on the cleavers.

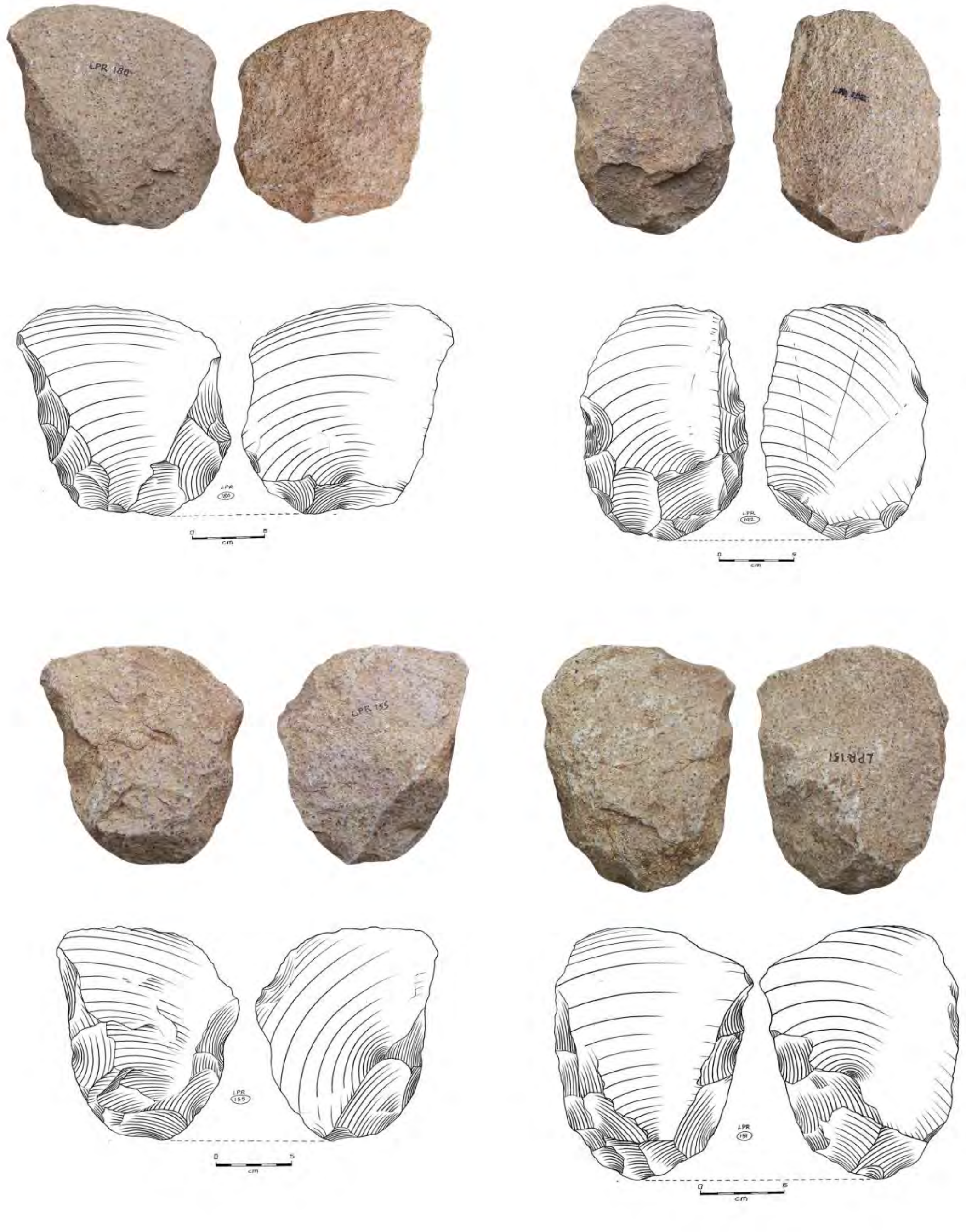


Fig. 5.64a: Cleavers on Kombewa Blanks

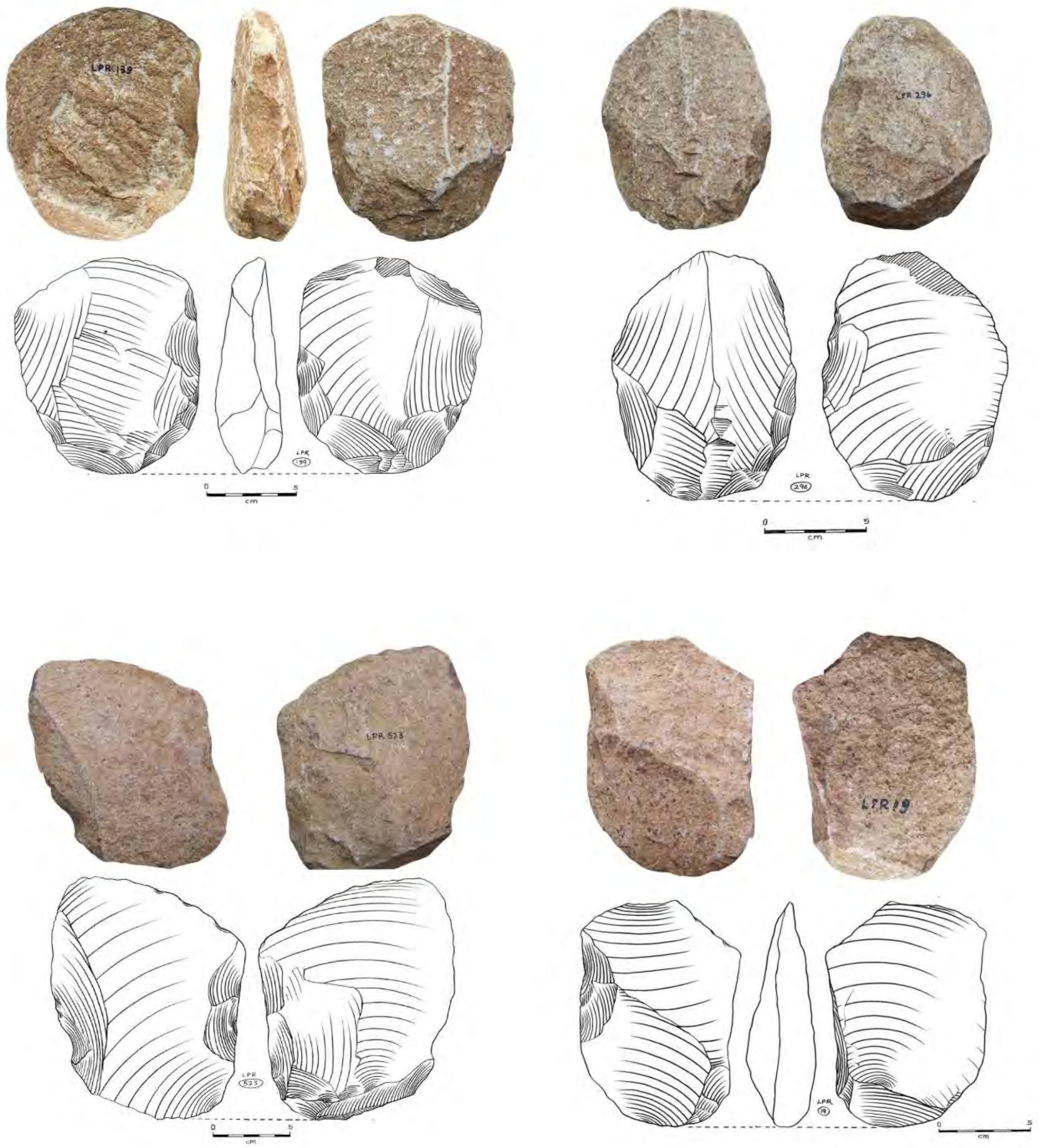


Fig. 5.64b: Cleavers on Kombewa Flakes

Fig. 5.64c: Cleavers on Kombewa Flakes

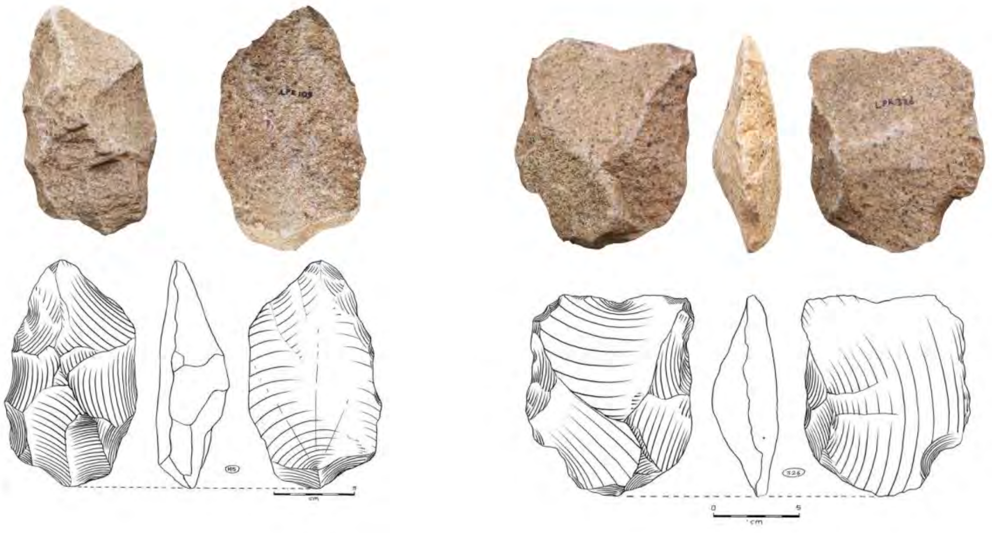


Fig. 5.65a: Cleaver flakes with radial scar pattern

Fig. 5.65b: Cleaver flakes with radial scar pattern

Fig. 5.66a: Cleavers with remnant of radial scar pattern

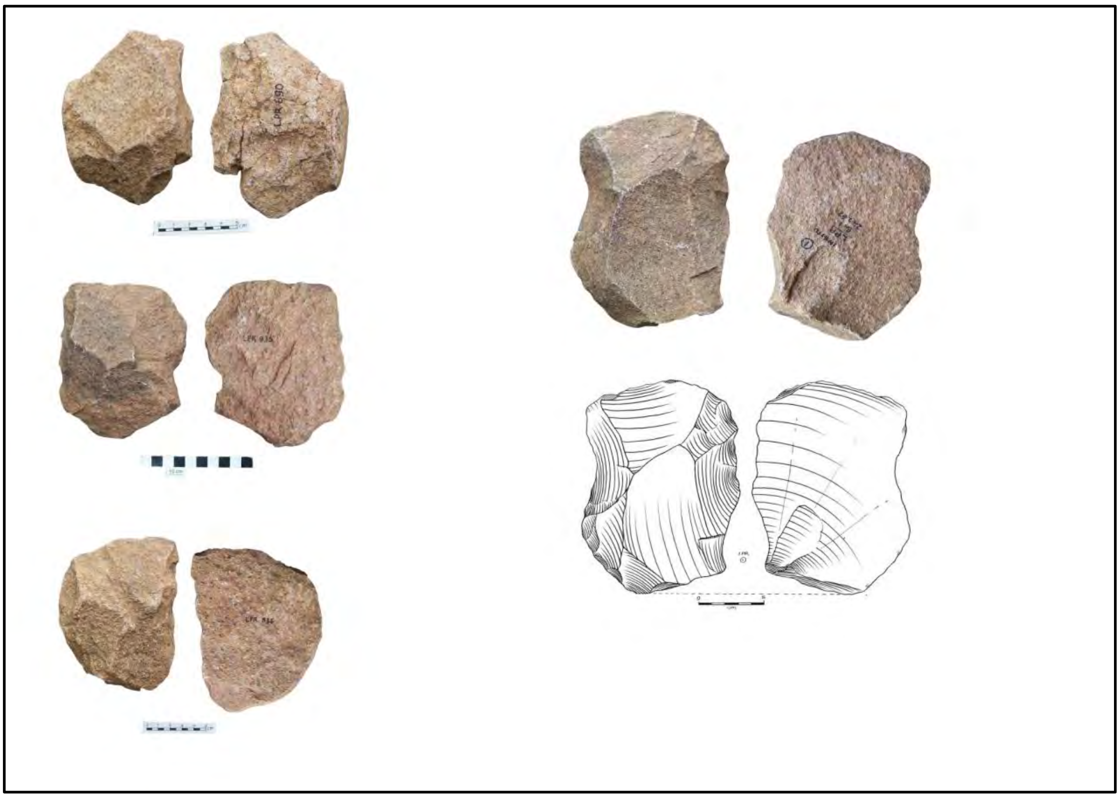


Fig. 5.66b: Cleavers with remnant of radial scar pattern

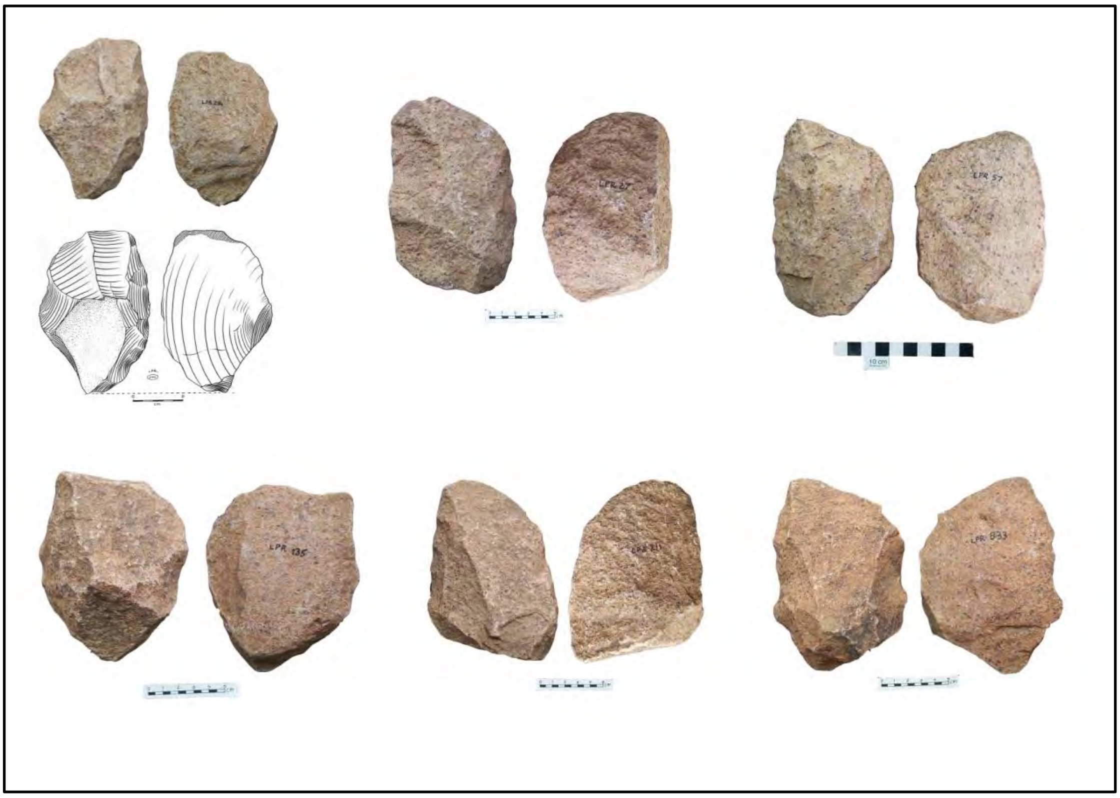


Fig. 5.67: Cleavers with abrupt retouch on lateral edges

Fig. 5.68: Finely trimmed cleavers

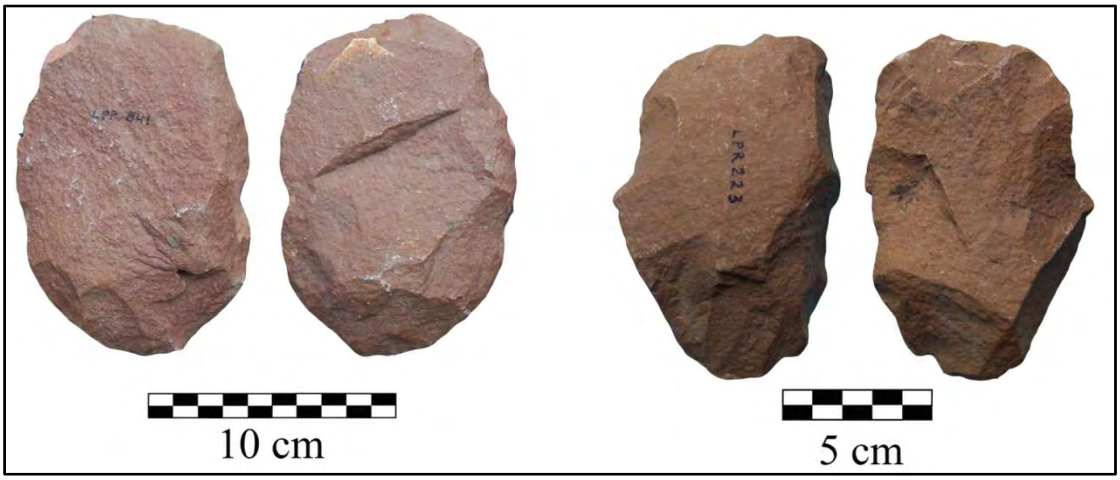


Fig. 5.69a: Finely trimmed quartzite cleavers

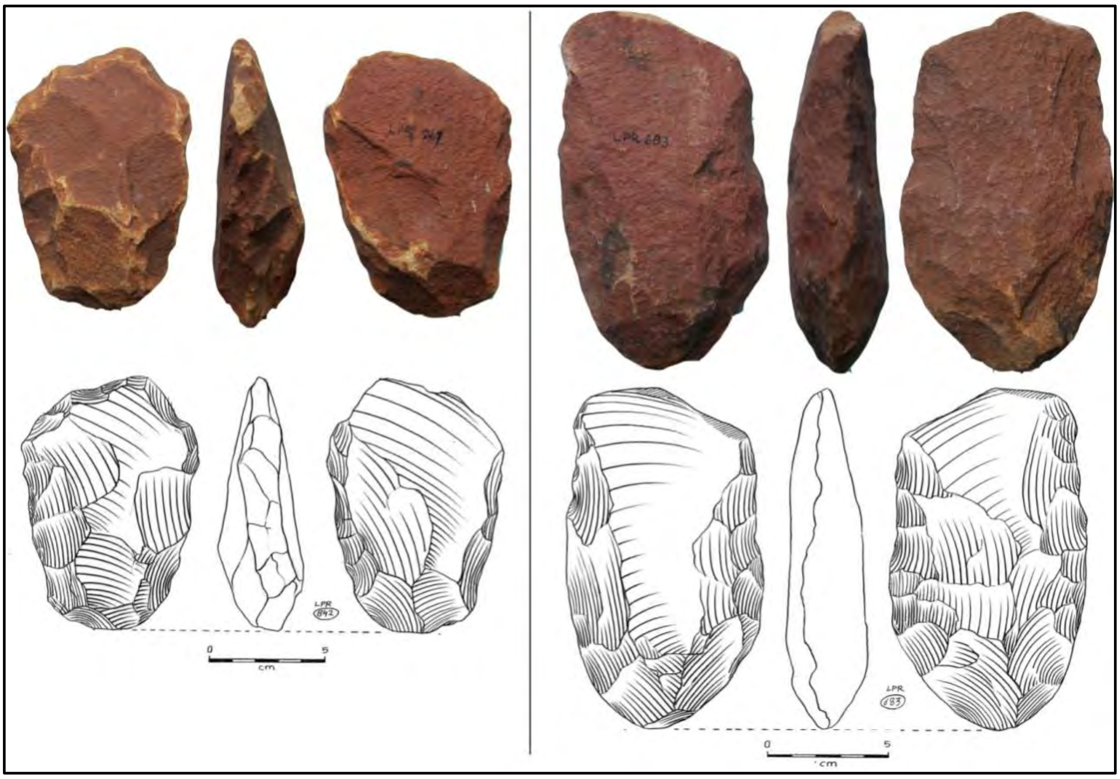


Fig. 5.69b: Finely trimmed quartzite cleavers (a). with modified cleaver bits

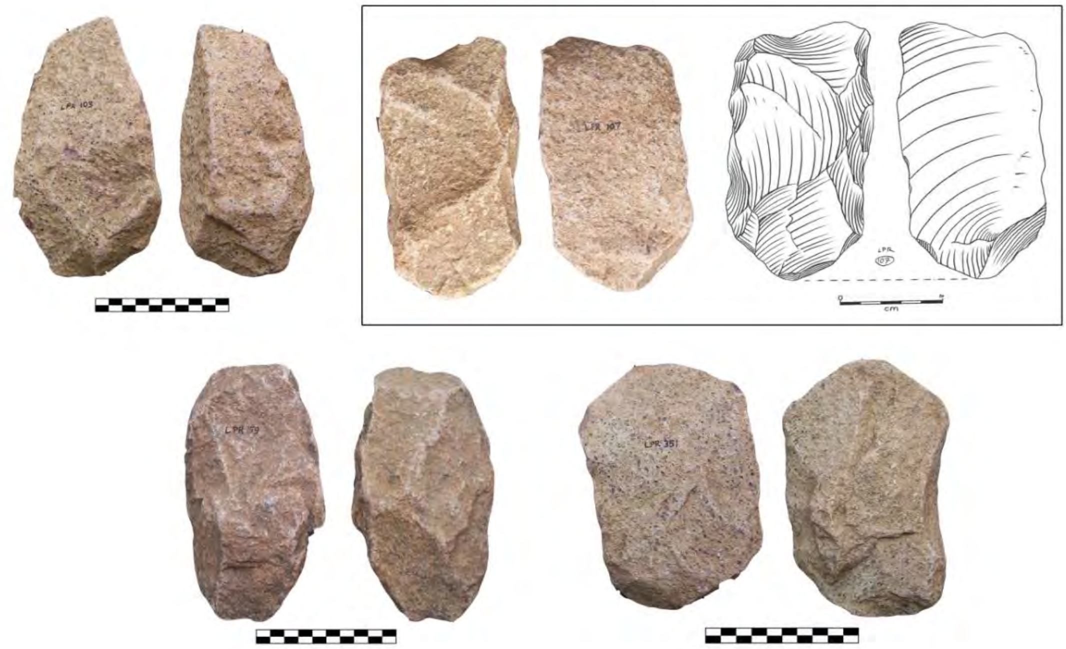


Fig. 5.70: Cleavers (am& c) with narrow cleaver bit; (d) with convergent bit

5.6.2 HANDAXES

As mentioned earlier, we have classified all large finished tool types apart from cleavers together. This was so because it was realized that these artefact classes, namely, bifaces, knives, and scrapers do not constitute a distinct class. Further, besides bifacially shaped 'true' handaxes which were not found in large numbers, we also we find a large percentage of unifacially flaked large pointed tools. Weathered tabular slabs were also occasionally exploited for expedient manufacture of pointed forms. These tabular slabs were probably easier to create a biface shape.

Besides, a considerable number of large flake blanks display retouch which is usually irregular and does not follow a standardized shape. It is often unifacial and abrupt, and invasive or covering but with low number of scars. There is no concept of symmetry. However, the character of retouch reflects considerable investment and intention to modify blanks into tools. Therefore, they are treated here along with 'handaxes'.

5.6.2.1 Dimensions

Handaxes range from 7.4 cm to 18.7 cm in maximal length with a median of 12.9 cm. However, most handaxes cluster in the range of 11 to 15 cm (Table 5.39). Less than 13% of the other LCTs are smaller than 10 cm (Fig. 5.71).

Most handaxes have a maximum width between 7.4 to 9.2 cm, with a minimum of 4.6 cm and maximum of 14.4 cm (Table 5.39 & Fig. 5.72). They fall in the thickness range of 3.8 to 4.8 cm. Minimum thickness was 2.2 cm and maximum 10 cm with a median of 4.2 cm (Table 5.39 & Fig. 5.75). Mass ranges from 94 to 1016 grams. with a median of 472 grams. (Fig. 5.78). In terms of breadth/thickness ratio, ~56% handaxes are thick (Figs. 5.76 & 5.77) while the length/width ratio indicates that ~50% are elongated (Figs. 5.73 & 5.74)

Interestingly the median values of bifaces, unifaces, knives, scrapers and other LCT forms are strikingly similar (Table 5.39) indicating selection of large and wide blanks for use as LCTs.

Table 5.37: Dimensions of Other LCTs (Handaxes) by type from Lalitpur, Locality 1

	Length			**Width**			**Thickness**			**Mass**			
Core Type	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**	**N**
Bifaces	7.4	12	18.7	4.6	8.05	14.4	2.2	4.6	10	94	449	1016	32
Unifaces	11.4	13.2	17.2	6.5	8.1	14.3	3.3	4.3	9.2	354	482	683	15
Knives	9.9	12.35	15.1	5.9	8.1	14	2.3	3.8	5.8	152	498.5	764	6
Scrapers	11	13.45	16.8	4.7	7.5	11.3	2.8	4.35	4.8	253	489	859	10
Retouched Tools	8.4	12.7	16.2	6.8	8.8	13.1	2.6	4.1	9.5	203	479	997	36
Total	7.4	12.9	18.7	4.6	8.3	14.4	2.2	4.2	10	94	472	1016	99

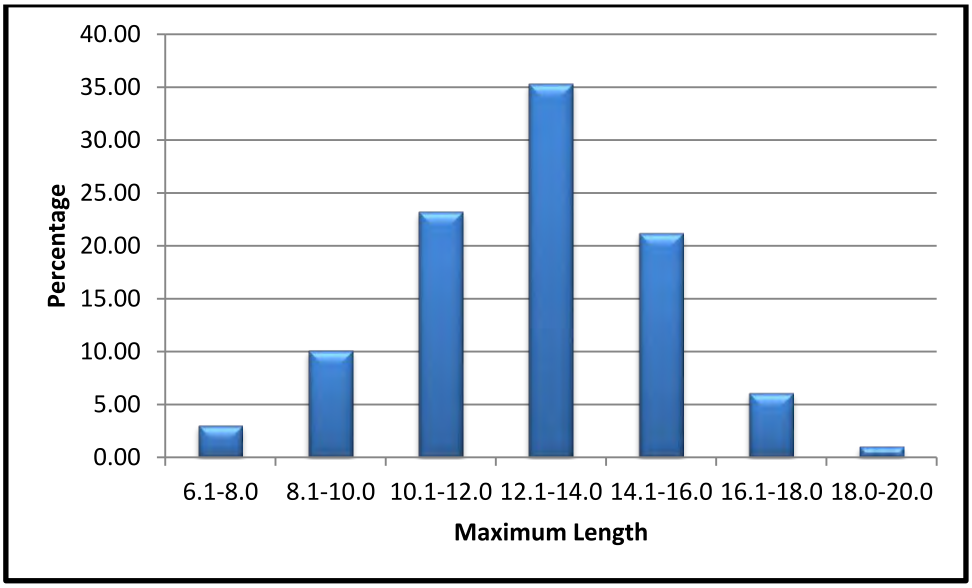


Fig. 5.71: Maximum Length for Handaxes

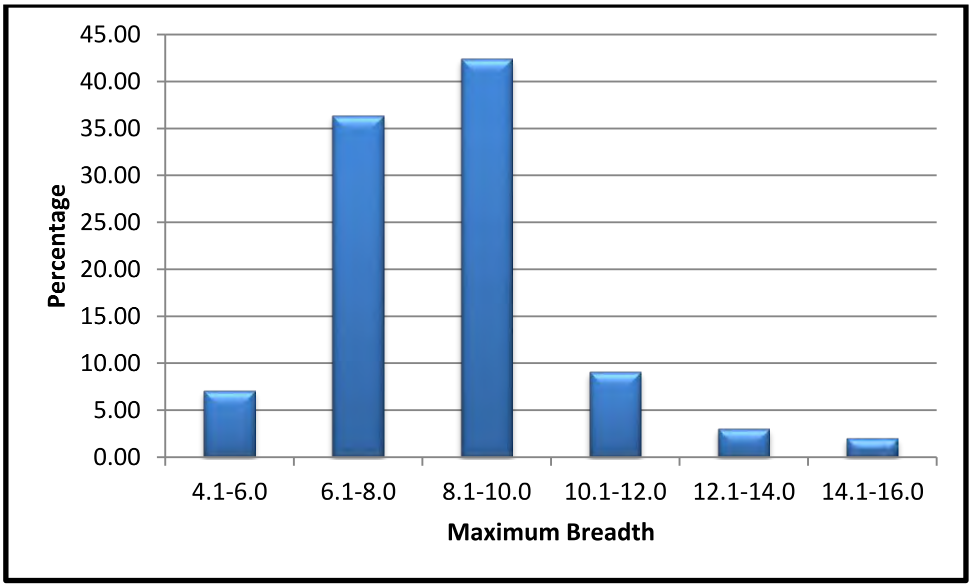


Fig. 5.72: Maximum Breadth for Handaxes

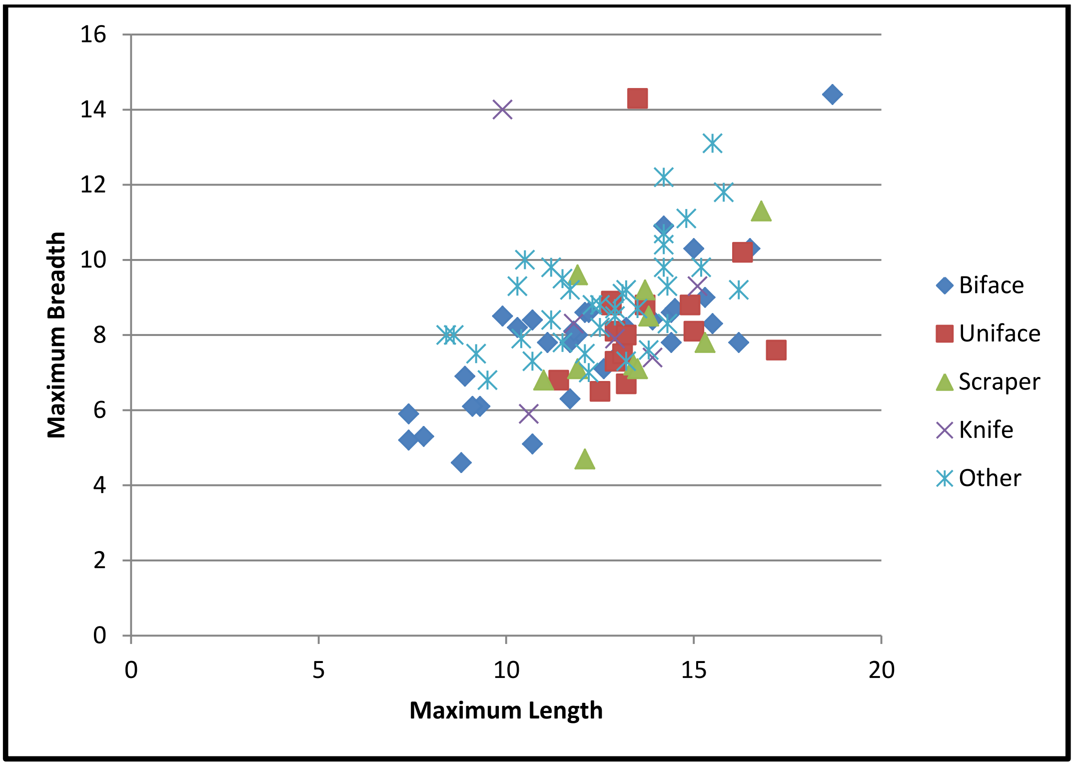


Fig. 5.73: Scatter Plot showing Length/Breadth for Other LCTs (Handaxes)

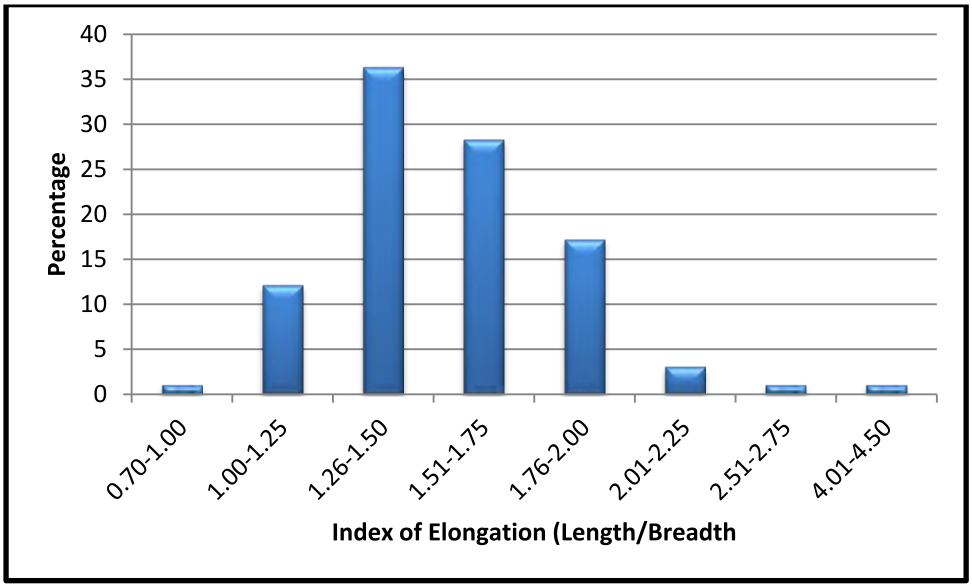


Fig. 5.74: Index of Elongation (Length/Breadth) for Handaxes

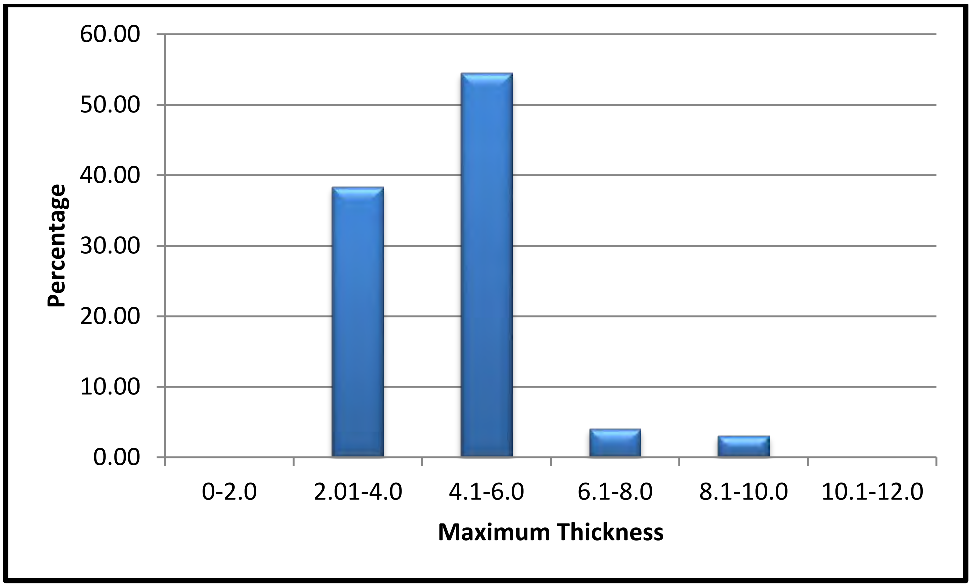


Fig. 5.75: Maximum Thickness for Handaxes

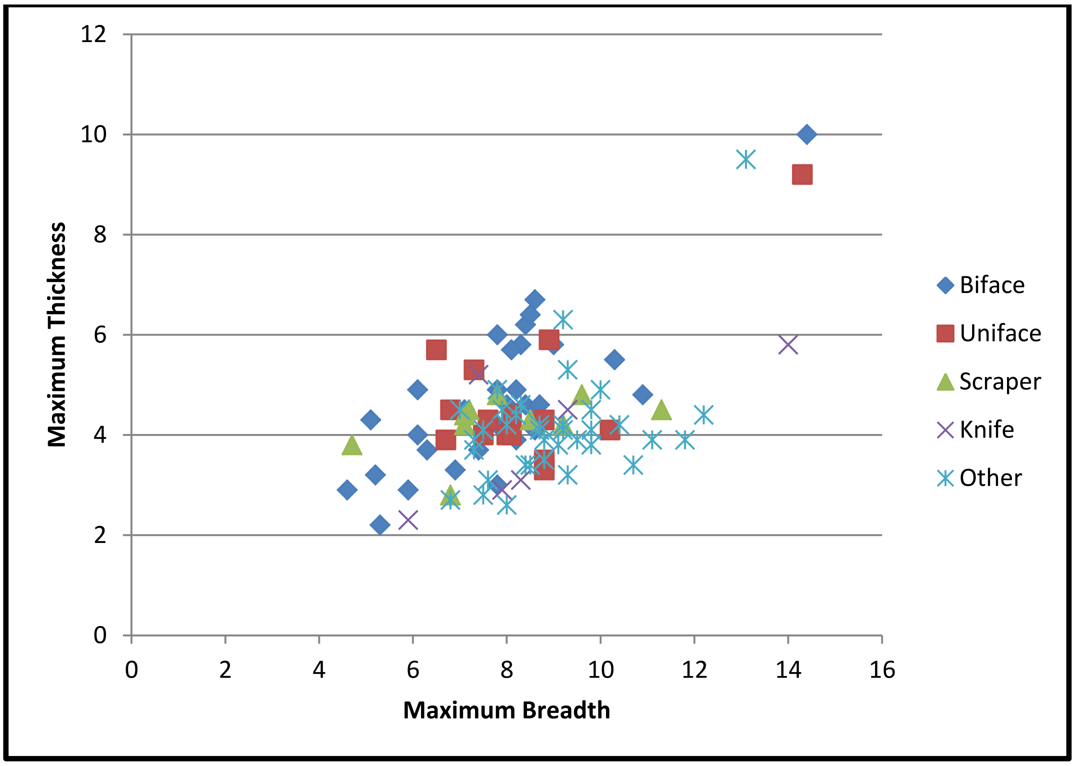


Fig. 5.76: Scatter Plot showing Breadth/Thickness for Other LCTs (Handaxes)

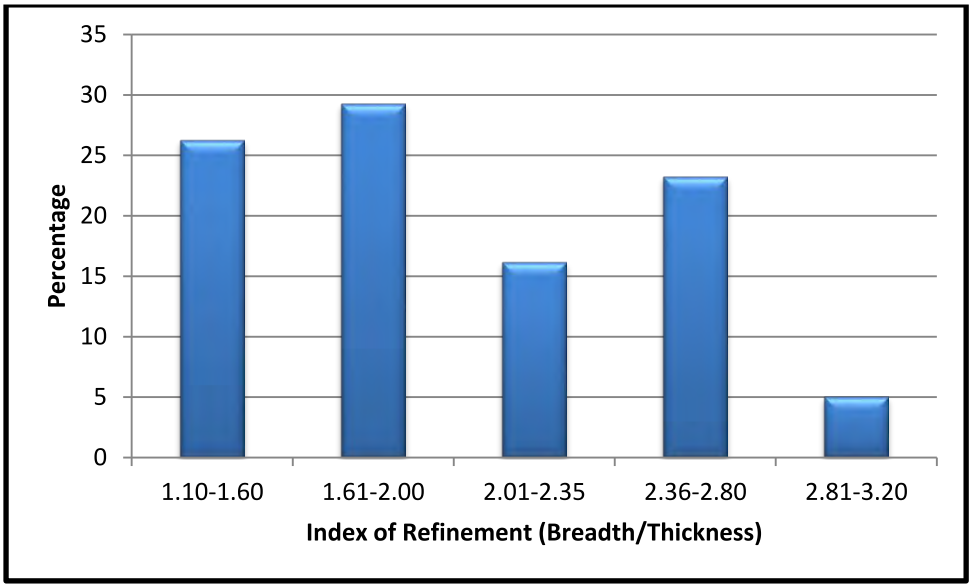


Fig. 5.77: Index of Refinement (Breadth/Thickness) for Handaxes

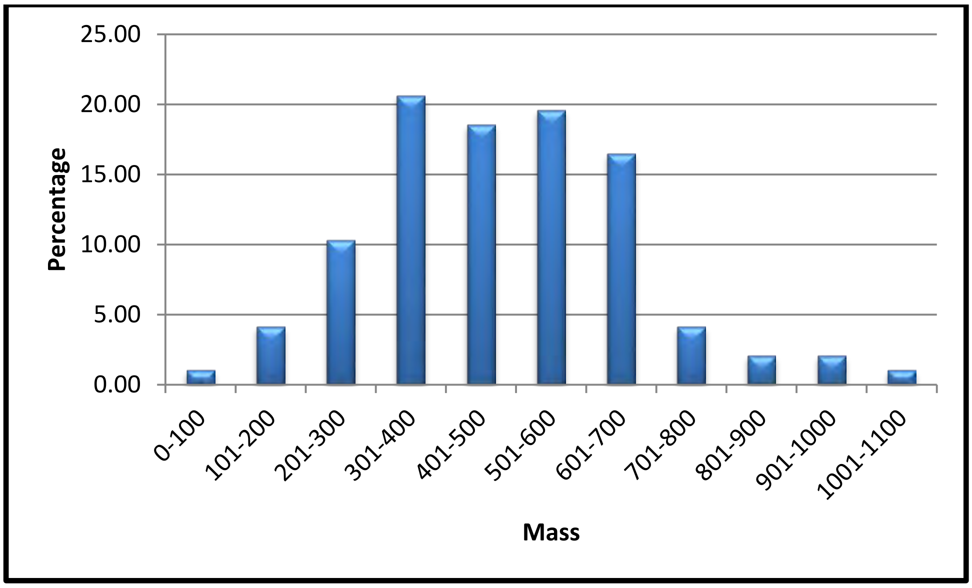


Fig. 5.78: Mass of Handaxes

The size data of these other LCTs (handaxes) matches very well with the sizes of cleavers from the site of Lalitpur. It also matches with the global data (Sharon 2007, Shipton 2010).

Cleavers are however slightly larger in maximal length, though with a similar range and mean length. Most cleavers are wide giving them a broad cutting edge, though a high percentage of cleavers are also elongated.

The size dataset for handaxes displays slightly more variability than cleavers which may be due to less strict control of knapping method in case of handaxes. This may also be because of greater variability in edge morphology which has been masked under the generic term 'handaxe'. In this study picks, knives, scrapers and all types of bifaces excluding cleavers have been grouped under handaxe type.

Few small sized handaxes on cobble blanks could also be the result of raw material constraints. Thicker handaxes are actually unfinished tools or roughouts.

No major differences are noted in the size of cleavers and handaxes made on granite and quartzite suggesting that raw material had no role in determining the size of handaxes. This goes well with the data analysed by Sharon (2007) who came to similar conclusion after a study of LCTs from 22 sites globally.

5.6.2.2 Raw Material

Only six of the handaxes are made on quartzite and one on quartz. Quartzite is a softer and finer grained raw material which is easier to flake and therefore the quartzite handaxes and cleavers are flatter and more refined (see section 5.8).

5.6.2.3 Type of Blank

Bifaces have mostly been extensively retouched barring observation on the type of blank resulting in a high number of indeterminates (18 pieces or 39.13%). Only five bifaces could be definitely said to have been made on flakes, one on a slab and one fashioned on a nodule. However, knives, scrapers, picks and unifaces are all made on flake blanks. The accidental biface forms are made on slabs for reasons outlined above (Fig. 5.79). The low number of cobble or slab blanks (5 pieces or 10.87%) compared to flake blanks is interesting.

Comparative data from Sharon and Mourre (2003) also shows a similar picture with a predominance of indeterminates. Once the indeterminates are excluded, the global data for the LFA shows a higher percentage of flake blanks compared to cobble or slab blanks.

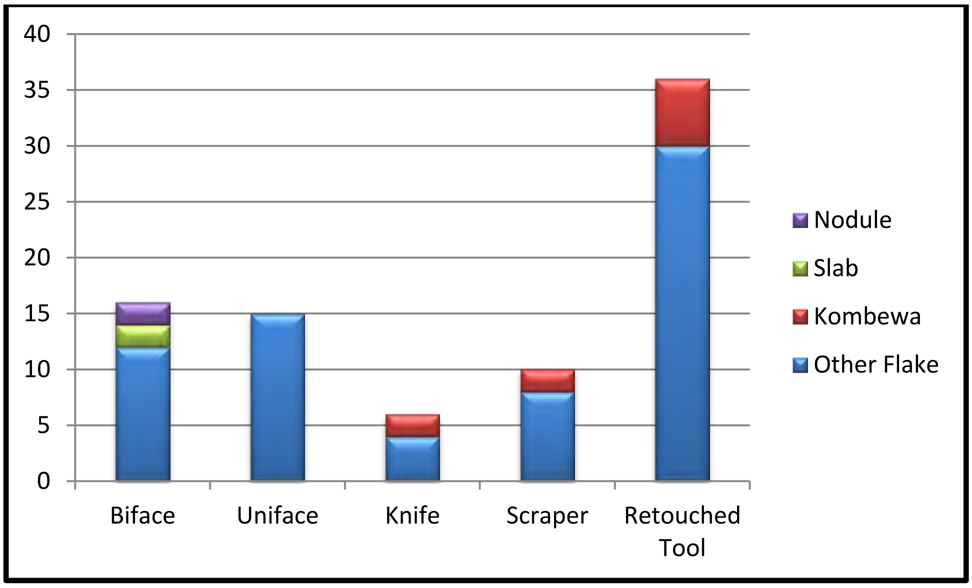


Fig. 5.79: Type of Blank for Handaxes

5.6.2.4 Direction of Debitage or Flake Blow

Most handaxes have been retouched to the extent that blow directions are not discernible. Blow directions could not be determined for 21 handaxes which makes 26.58% of handaxes, excluding handaxes made on cobble or slab blanks. But wherever blow directions could be seen, there is a clear preference for end-struck flakes for all kinds of handaxes (Table 5.40 & Fig. 5.80).

This is in contrast to the preference for side struck or special side struck flakes noticed earlier by Sharon (2007). It may be mentioned here that even for cleavers a large number of end struck flakes were noted.

Table 5.40: Flake Blow Direction for Handaxes

Flake Blow Directions	N	%
1	0	
2	0	
3	2	3.45
4	3	5.17
5	43	74.14
6	4	6.90
7	6	10.34
8	0	
Indeterminate	21	
Total	79	

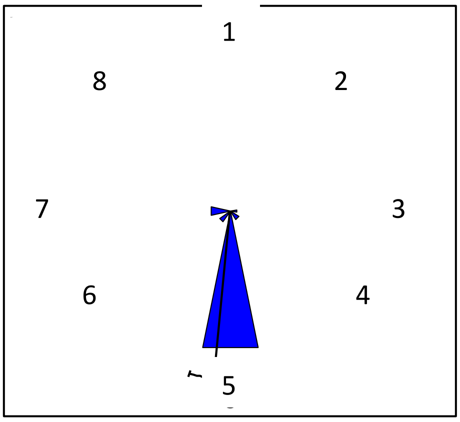


Fig. 5.80: Blow Direction for Handaxes

5.6.2.5 Striking Platform

The striking platform on most handaxes has been completely removed by deliberate breakage or secondary trimming in most cases. This has been done to remove excess mass and manage the volume of LCTs. However, it is possible to still discern the platform type on few handaxes. Plain platforms are more common, followed by dihedral platforms. There are no handaxes with facetted platforms (Fig. 5.81). A similar pattern was noted for the cleavers. Dominance of plain or dihedral platforms reveals lack of or negligible platform and core preparation and the use of previous negative scars as striking platforms for the removal of the next flake. Similarly high frequencies of plain platforms have been noted at other LFA sites except the Vaal River sites and Tachenghit documenting the Victoria West method and Tachenghit method respectively (Sharon 2007).

This suggests that the core preparation for detaching handaxes was similar to cleavers which was very simple and entailed removing only a few flakes from the sides of the core in order to remove the cortex and then preparing the upper face and finally detaching a large flake using the previous negative scar/scars on the sides of the core as a striking platform. This resulted in plain or dihedral platforms on LCTs.

Striking platform dimensions indicate a mean thickness of 5.1 cm and a mean width of 6.2 cm with a mean platform angle of 118° (Table 5.41).

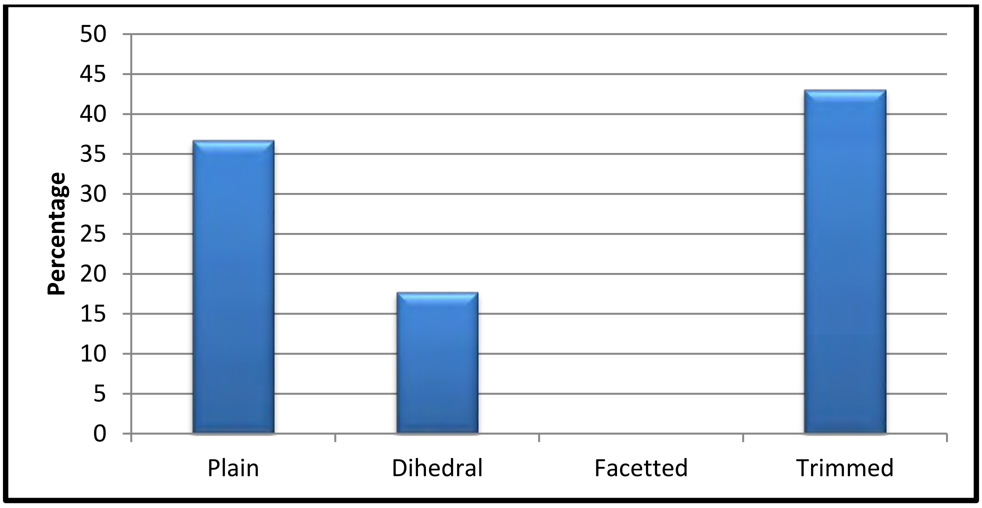


Fig. 5.81: Striking Platform types for Handaxes

Table 5.41: Striking Platform Dimensions for Handaxes

	Platform thickness	Platform width	Interior platform angle
Min	1.5	2.3	101
Median	3.1	6.2	118
Max	5.3	11.9	136
SD	0.789	2.035	7.364

5.6.2.6 Scar Count

Handaxes were found to have more number of scars than cleavers. Handaxes fashioned on slab or cobble blanks generally had a higher scar count due to more intensive shaping required for cobble blanks.

Handaxes at Lalitpur display a lower scar count on both faces when compared to global data (Table 5.42). However, a similar pattern was noted at other Indian sites of Chirki, Hunsgi and even Morgaon (S. Mishra pers. comm.). This may be attributed to a larger percentage of handaxes made on flake blanks which resulted in lesser need for retouch to shape the edge which was already configured before blank detachment.

A very high scar count was noted for the small number of LCTs on quartzite. Particularly intensive secondary retouch was noted on quartzite LCTs. This could be either due to differences in raw material properties or to more intense curation of quartzite which was an imported and hence precious raw material (see section 5.8). It is important however to mention here that Sharon (2007) did not find any differences in scar count emerging from raw material differences.

Table 5.42: Scar Count for Handaxes

	Previous Scars			Secondary Scars			Ventral scars			Dorsal Scars			Total Scars		
	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
Biface	2	3	5	3	7	11	0	5	9	5	8	17	8	13.5	25
Uniface	1	3.5	5	2	7	13	0	0	0	7	8	13	7	8	13
Knife	0	2	4	2	6	17	0	0	2	6	8	15	6	8	17
Scraper	1	1	4	6	9	21	0	0	6	8	10	15	8	10	21
Retouched Tool	1	2	7	3	6	17	0	0	6	0	7	13	4	8.5	17
Total	0	3	7	2	6	21	0	0	9	0	8	17	4	9	25

5.6.2.7 Scar pattern

Most handaxes have multidirectional to radial dorsal scar pattern. There is no clear preference for any particular reduction method being used for a specific LCT type. Only picks are preferably made on convergent blanks (Table 5.43 & Fig. 5.82).

Table 5.43: Scar Pattern for Handaxes

Flake Scar Pattern	N	%
Cortical	2	2.60
Unidirectional	0	0
Bidirectional Opposed	1	1.30
Multidirectional	27	35.06
Radial Convergent	30	38.96
Positive Flake Scar	9	11.69
Convergent	7	9.09
Other	1	1.30
Indeterminate	22	
Total	99	100

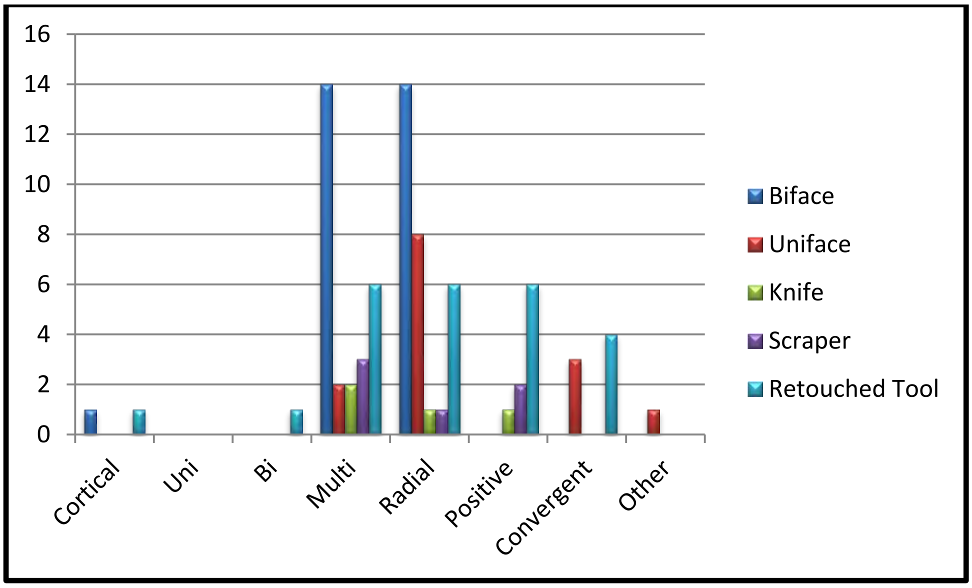


Fig. 5.82: Scar Pattern for Handaxes

5.6.2.8 Retouch

Most handaxes are minimally modified, with retouch mostly confined to trimming of the bulb and striking platform or at most minimal shaping of the edges (Figs. 5.87 – 5.101). The retouch is mostly made from the ventral side as a platform, giving it a clear unifacial character (Table 5.44 & Fig. 5.83). The retouch can be either in the form of one or few invasive to covering scars, when the intention is to reduce the volume or thinning of the bulb and platform. In other cases, they only modify the edge in a semi-invasive to marginal abrupt scraper like retouch (Table 5.46 & Fig. 5.85). Few of the handaxes display shaping of the tip with just a few blows from one or both lateral edges in order to create a pointed end, but even then retouch is unifacial in most cases (Table 5.45 & 5.47; Figs. 5.84 & 5.86). Very few LCTs display clear bifacial retouch with reduction of central volume and shaping of blanks resulting in biconvex sections (de la Torre *et al.* 2008) as they are mostly fashioned on flake blanks with flat ventral faces. There is a clear lack of emphasis on bifacial shaping and maintenance of bifacial and bilateral symmetry.

Retouch is mostly irregular, with no standardization of shapes, as there is minimal modification post blank detachment. The modification is confined to obtaining suitable edges or points or thinning of excess volumes in the butt and the bulb. Though some of these LCTs could be classified into tools with a pointed end (biface/uniface), sharp lateral edge (knife) or abrupt edge (scraper), yet most of them have unstandardized retouch (Table 5.44 – 5.47 & Figs. 5.83 – 5.86).

Table 5.44: Face of retouch for Handaxes

	Dorsal	Ventral	Partly Bifacial	Bifacial	Total
Biface				32	32
Uniface	15				15
Knife	6				6
Scraper	10				10
Retouched Tool	25	1	5	5	36

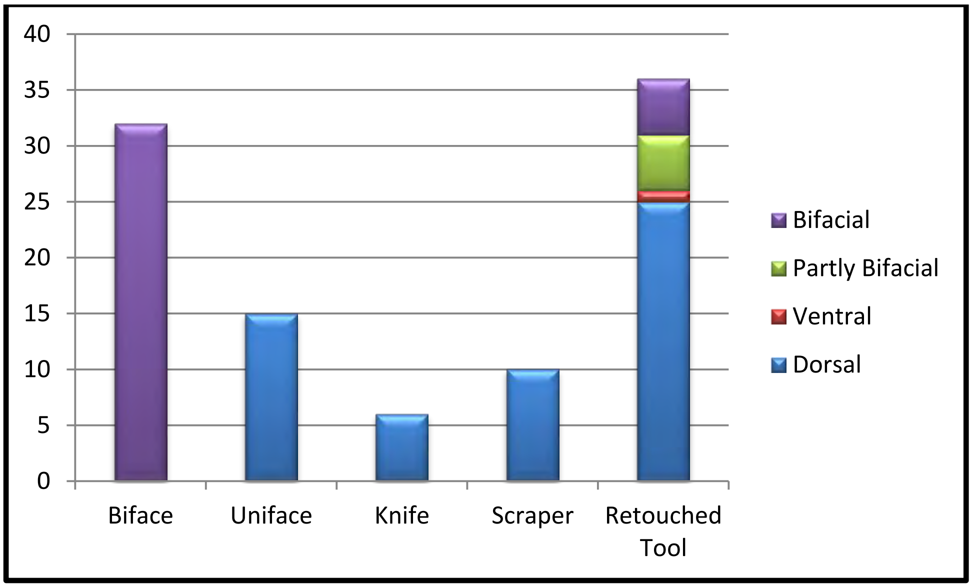


Fig. 5.83: Face of Retouch for Other LCTs (Handaxes)

Table 5.45: Location of Retouch for Handaxes

	Distal	Proximal	Single side	Both sides	Side &end	Proximal and side	All around	Total
Biface					3	5	4	12
Uniface					8	1	6	15
Knife			3	2			1	6
Scraper			1	6		3		10
Retouched Tool	1	3	2	7	1	16	6	36
Total	1	3	6	15	12	25	17	79

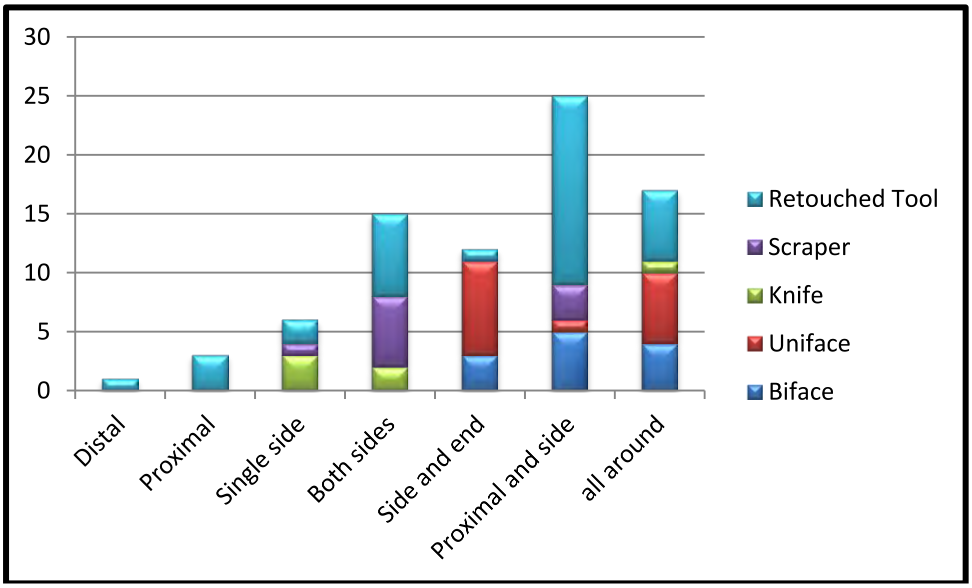


Fig. 5.84: Location of Retouch for Other LCTs (Handaxes)

Table 5.46: Inclination of Retouch for Handaxes

	Flat	Oblique	Abrupt	Step	Total
Biface		6	6		12
Uniface		4	11		15
Knife	1	2	3		6
Scraper			10		10
Retouched Tool		21	15		36

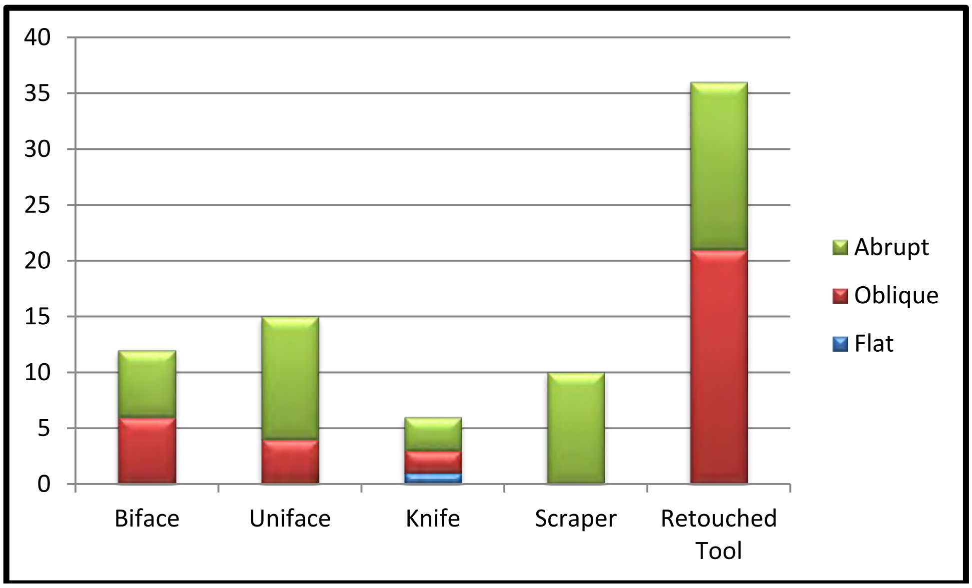


Fig. 5.85: Inclination of Retouch for Other LCTs (Handaxes)

Table 5.47: Extent and Distribution of Retouch on Handaxes

	Complete	Complete Marginal	Partial Marginal	Partial	Substantial	Total
Biface			2	6	4	12
Uniface			2	3	10	15
Knife		1	3	2		6
Scraper			6		4	10
Retouched Tool			15	11	10	36

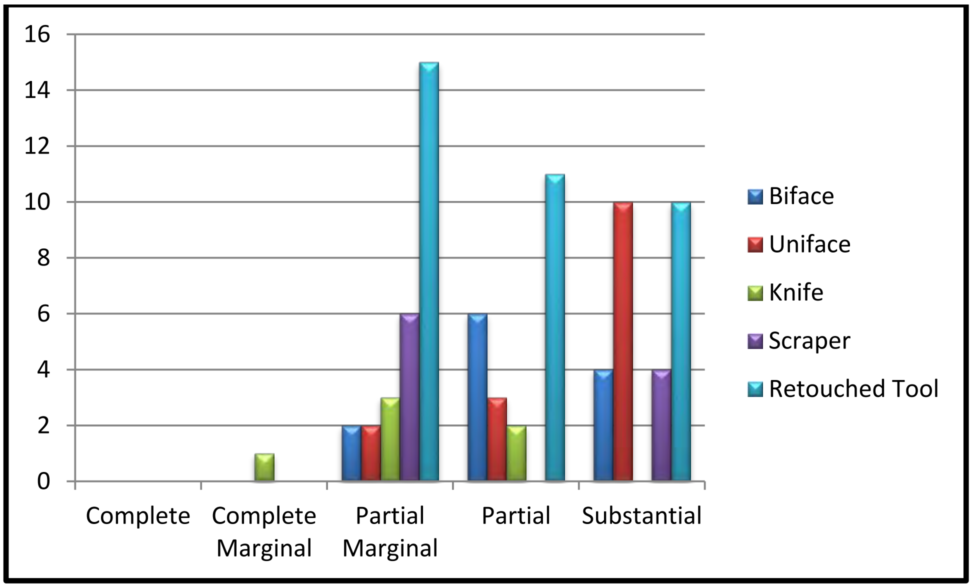


Fig. 5.86: Extent and Distribution of Retouch on Handaxes

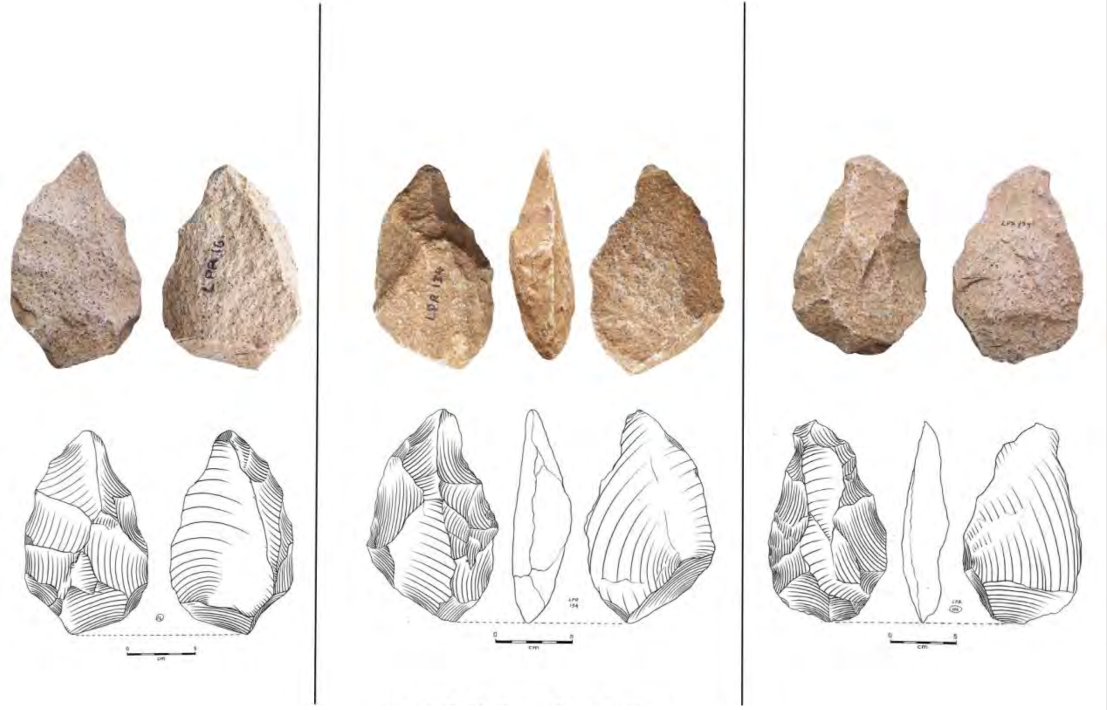


Fig. 5.87: Unifaces from Lalitpur

Fig. 5.88: Handaxes with platform deliberately removed

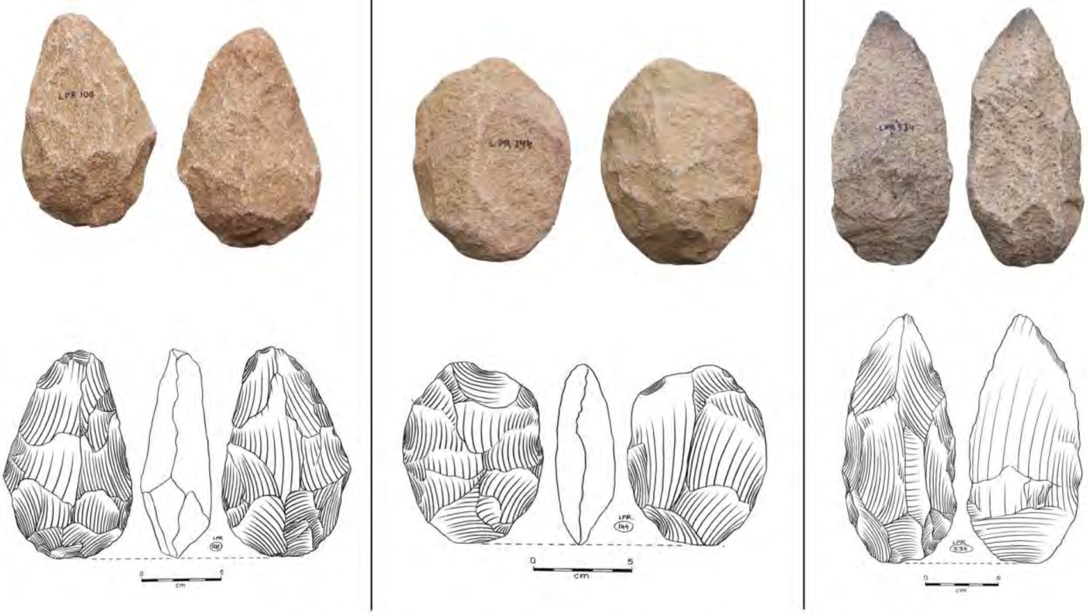


Fig. 5.89: Finely trimmed bifaces from Lalitpur

Fig. 5.90: Biface on prepared flake

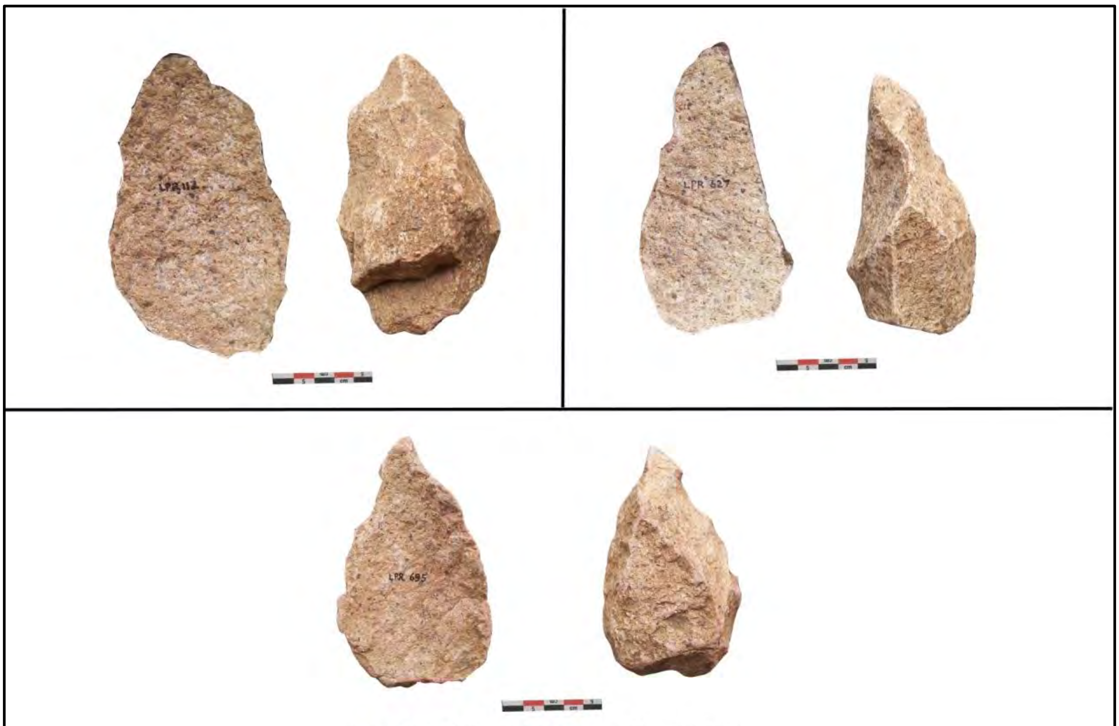


Fig. 5.91: Trihedral Handaxes from Lalitpur

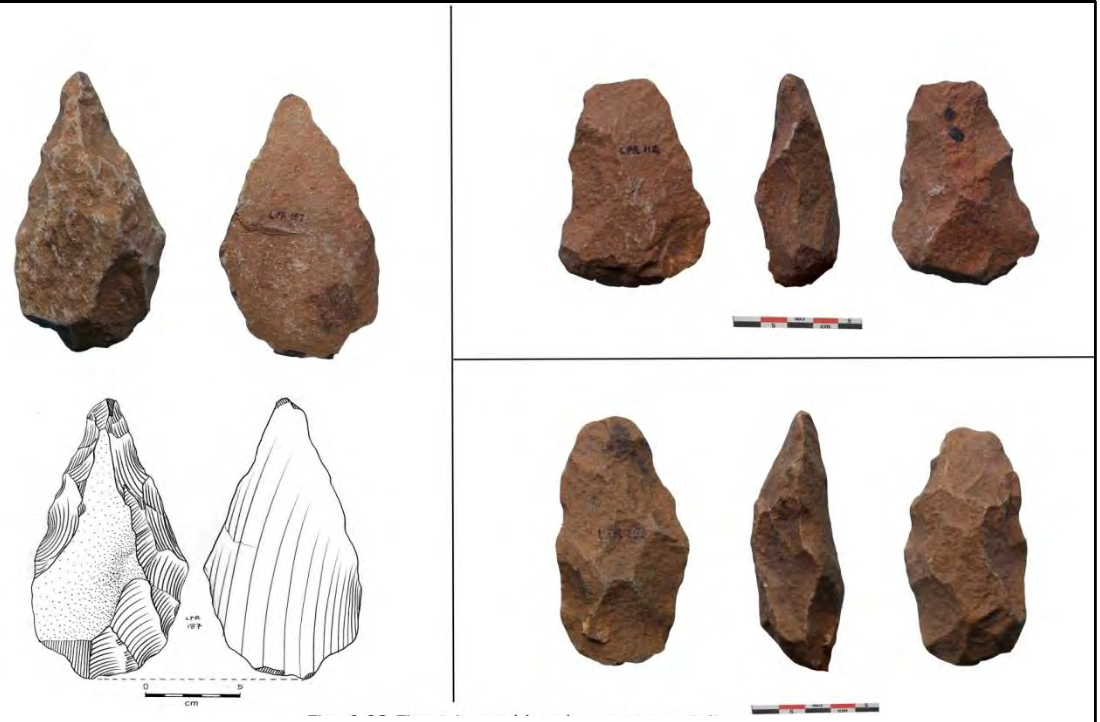


Fig. 5.92: Fine trimmed handaxes on quartzite

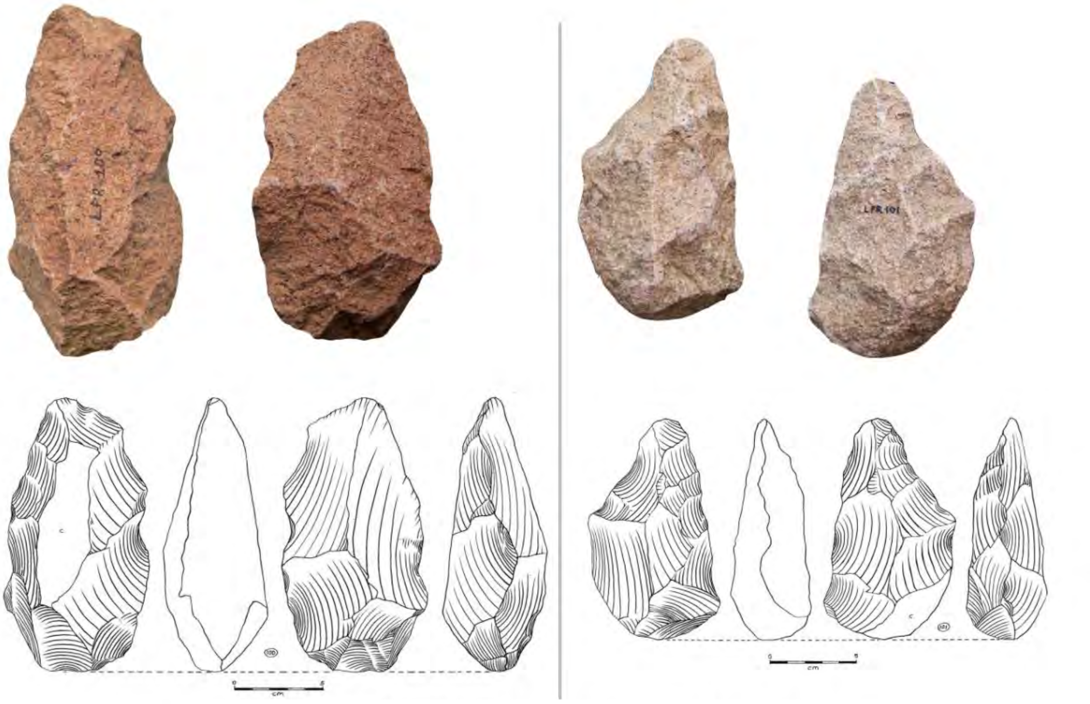


Fig. 5.93a: Bifaces shaped on slabs and nodules

Fig. 5.93b: Bifaces shaped on slabs and nodules

Fig. 5.94: Completely trimmed bifaces from Lalitpur

Fig. 5.95: A lone handaxe on quartz

Fig. 5.96: Roughly trimmed handaxes

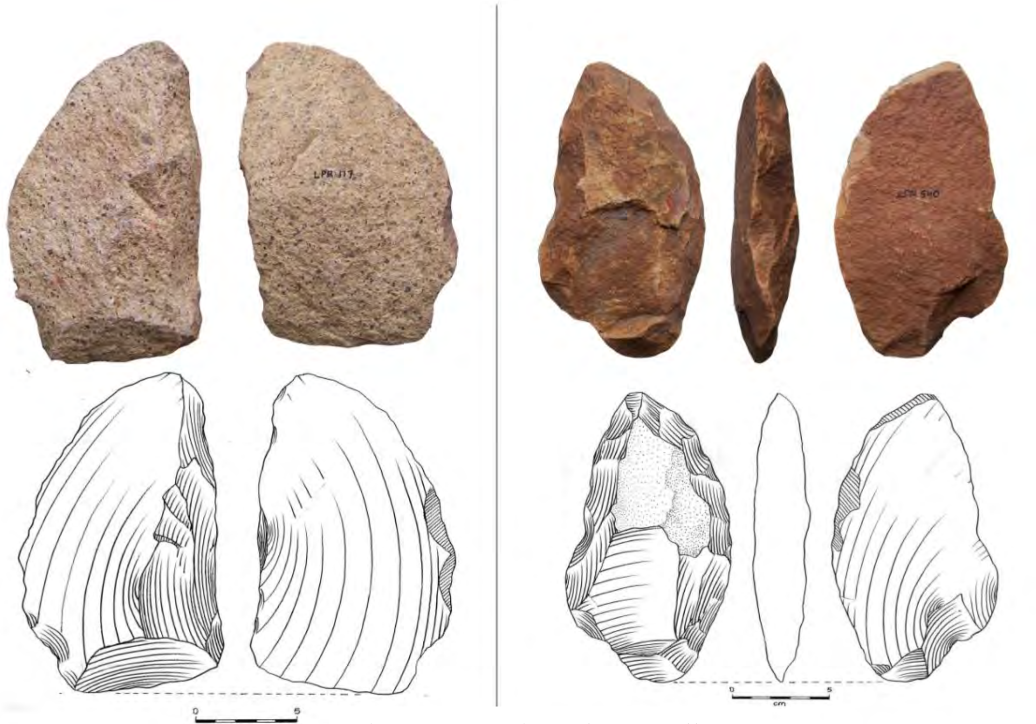


Fig. 5.97: Knives from Lalitpur

Fig. 5.98: Massive Scrapers from Lalitpur

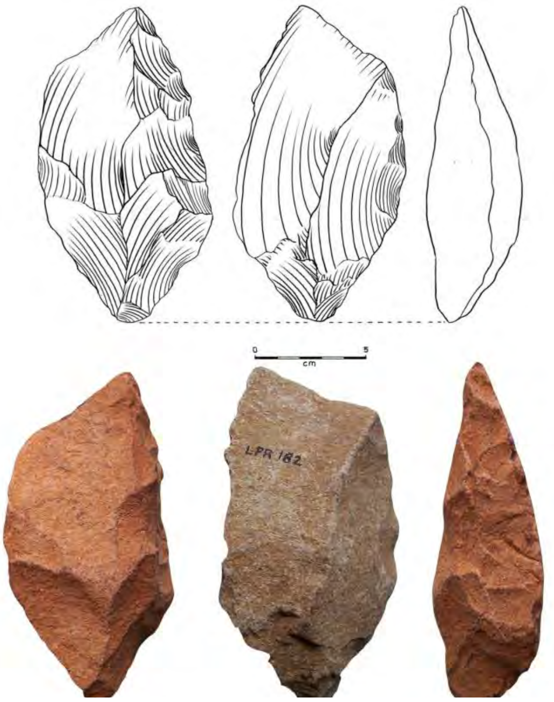


Fig. 5.99: Heavily resharpened Large Cutting Tool

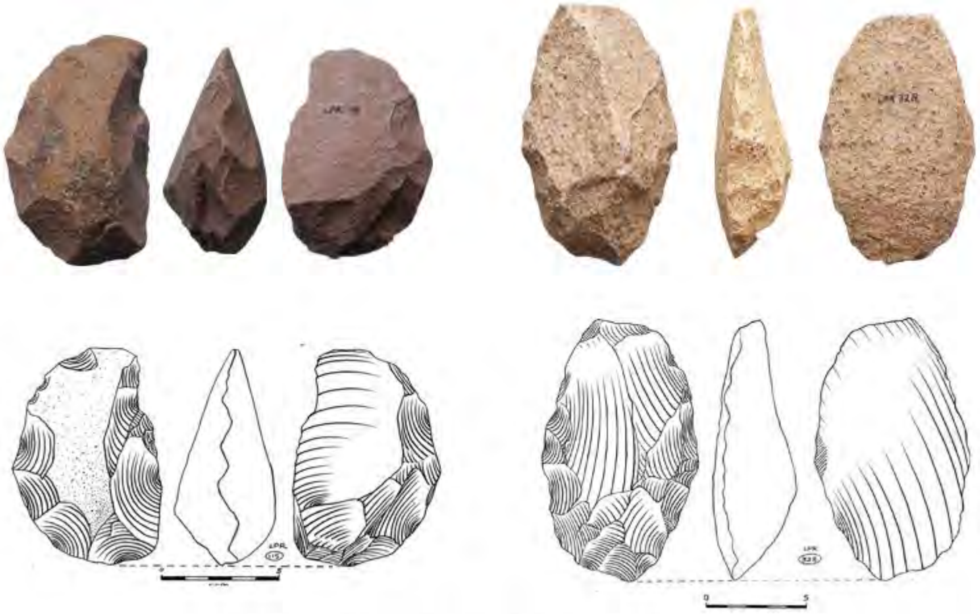


Fig. 5.100: Large Cutting Tools with abrupt retouch

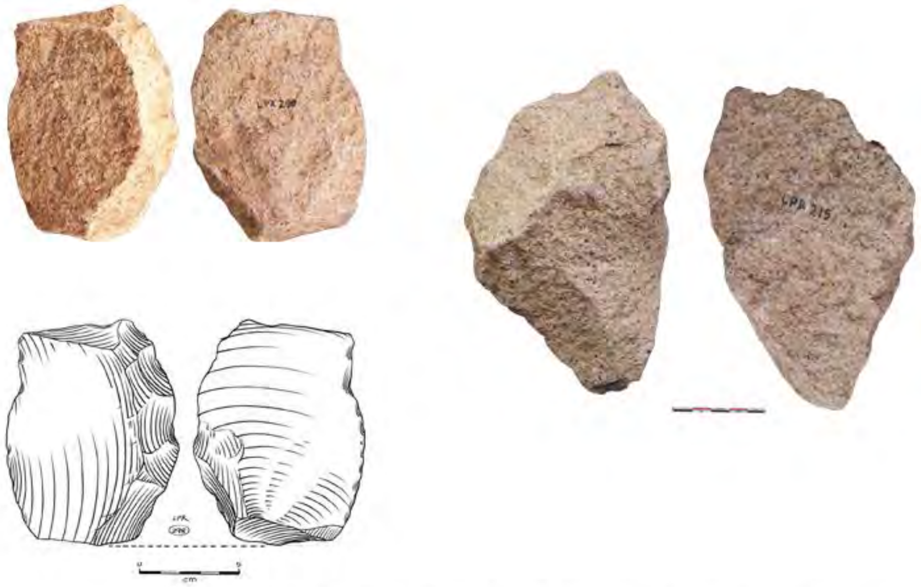


Fig. 5.101: Large Cutting Tools with abrupt retouch on edges

5.7 ARTEFACT SIZES

The dimensions of major artefact categories indicates clear unimodality of size with complete flakes, cleavers, handaxes and cores all having a mean length of 10 – 13 cm. However a minor proportion of small flakes (<8cm) also exists (25.23%). Cleavers are slightly larger, while a small number of handaxes (3 pieces) are smaller than 8 cm. Some of the cores are also small sized.

Table 5.48: Dimensions of major tool types

	Length	Breadth	Thickness	Weight
Unretouched Flakes				
Mean	10.25	7.584	3.59	379.55
SD	2.951	2.342	1.24	308.879
Cleavers				
Mean	13.9	9.03	4.46	536.43
SD	2.47	1.89	1.05	220.37
Other LCTs				
Mean	12.7	8.44	4.42	484.56
SD	2.262	1.848	1.3	190.585
Cores				
Mean	12.5	9.73	6.66	984.09
SD	3.4	3.06	2.56	746.08

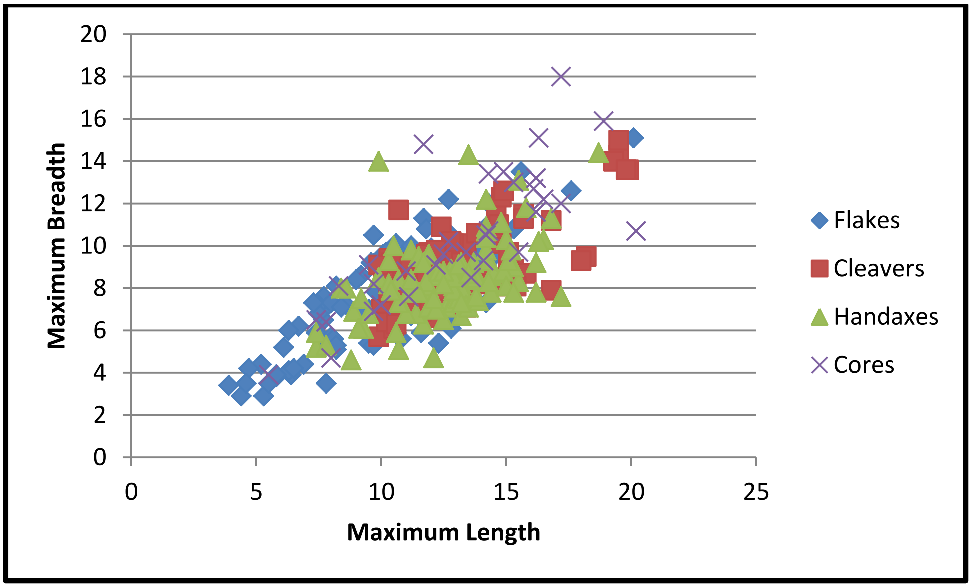


Fig. 5.102: Scatter Plot showing Length/Breadth for Artefact Types

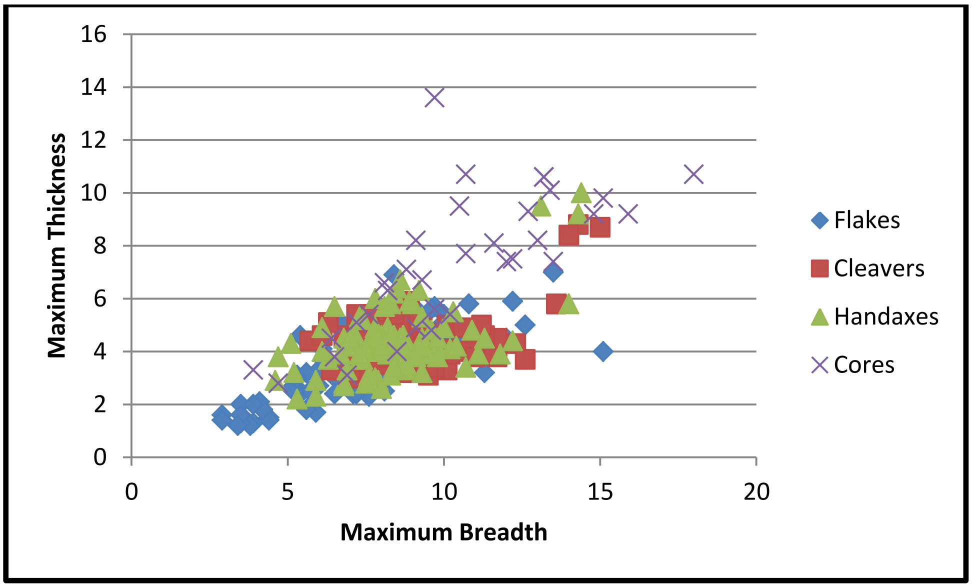


Fig. 5.103: Scatter Plot showing Breadth/Thickness for Artefact Types

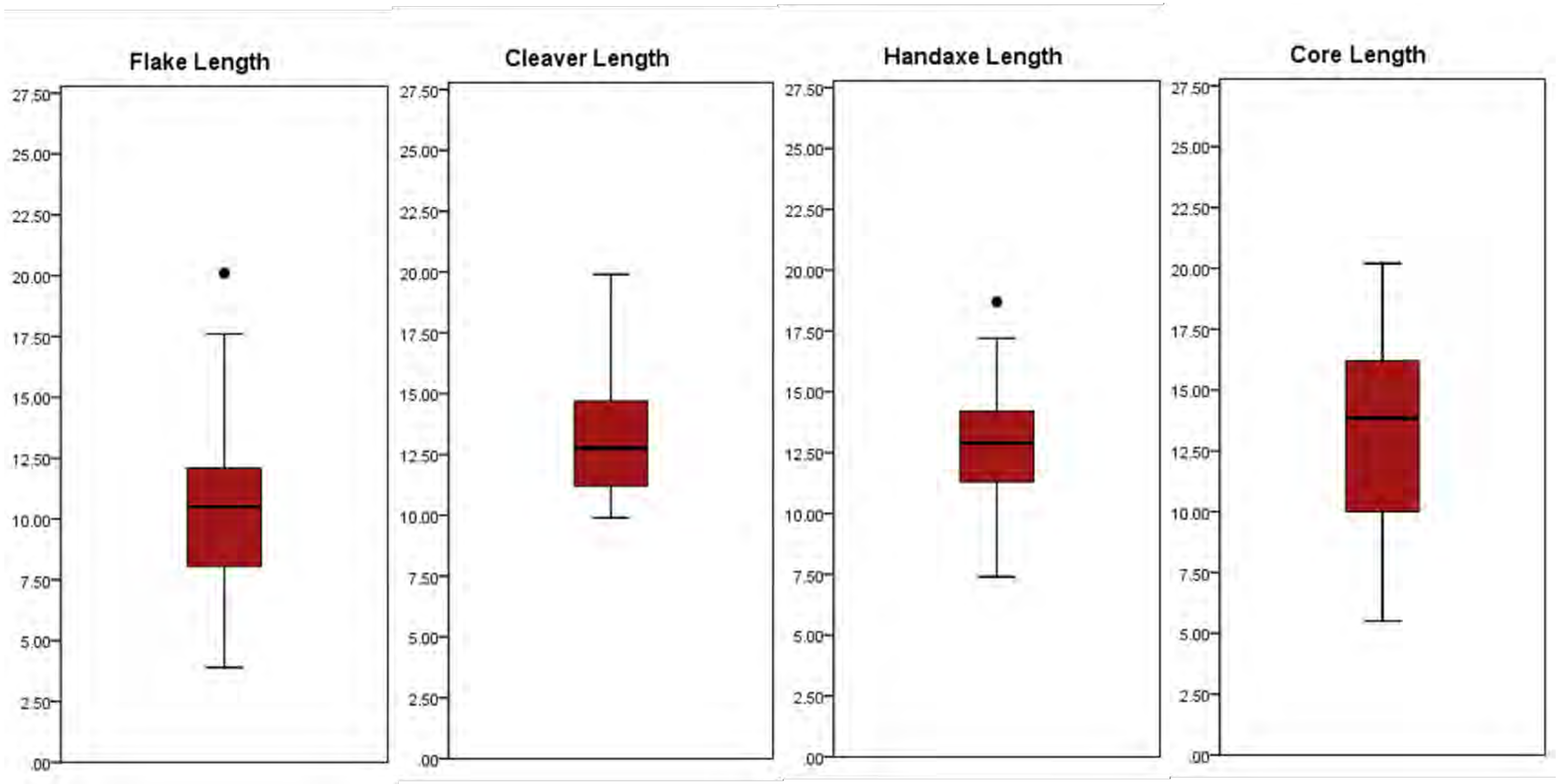


Fig. 5.104: Boxplot showing length for various artefact types

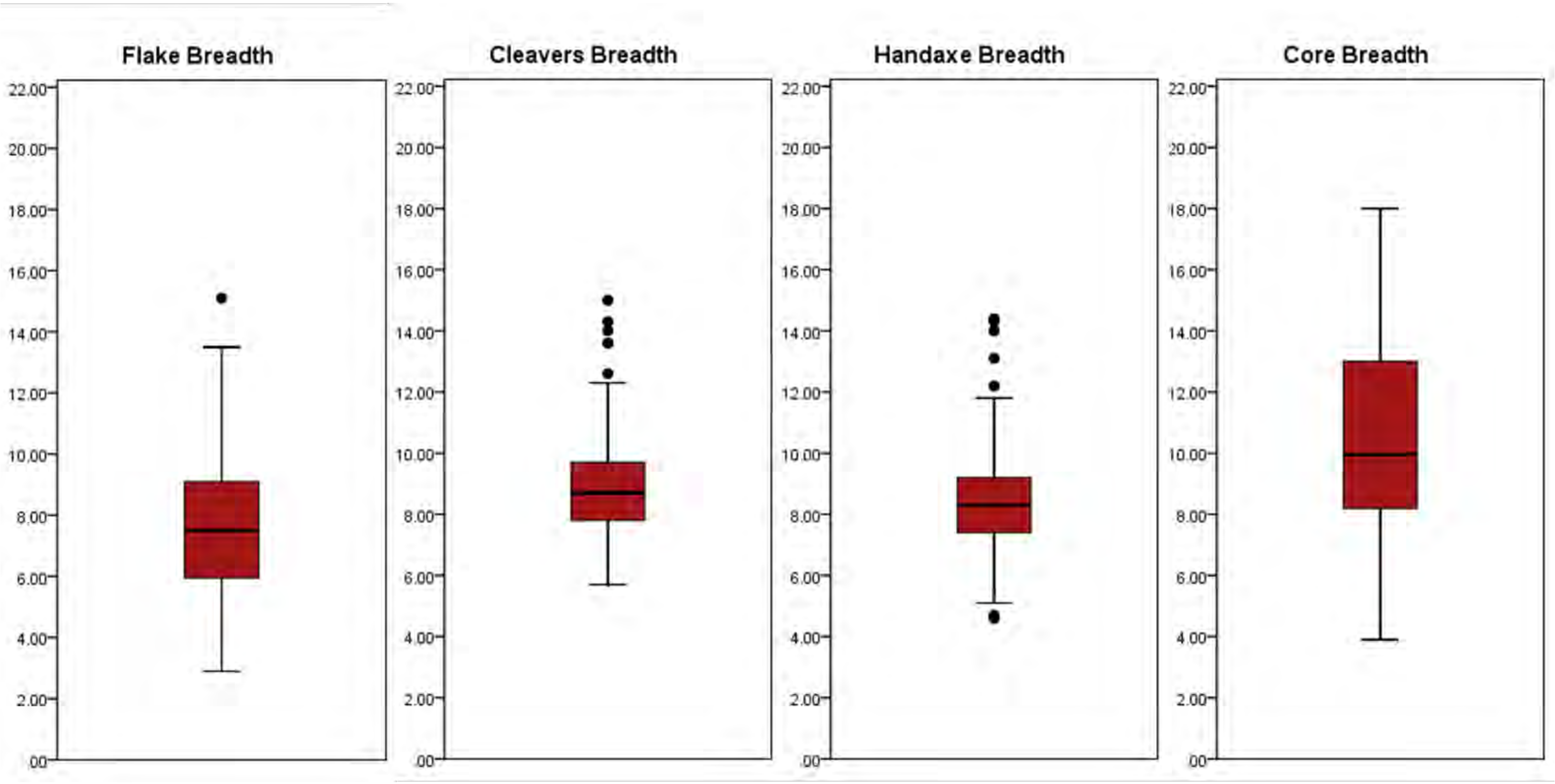


Fig. 5.105: Boxplot showing breadth for various artefact types

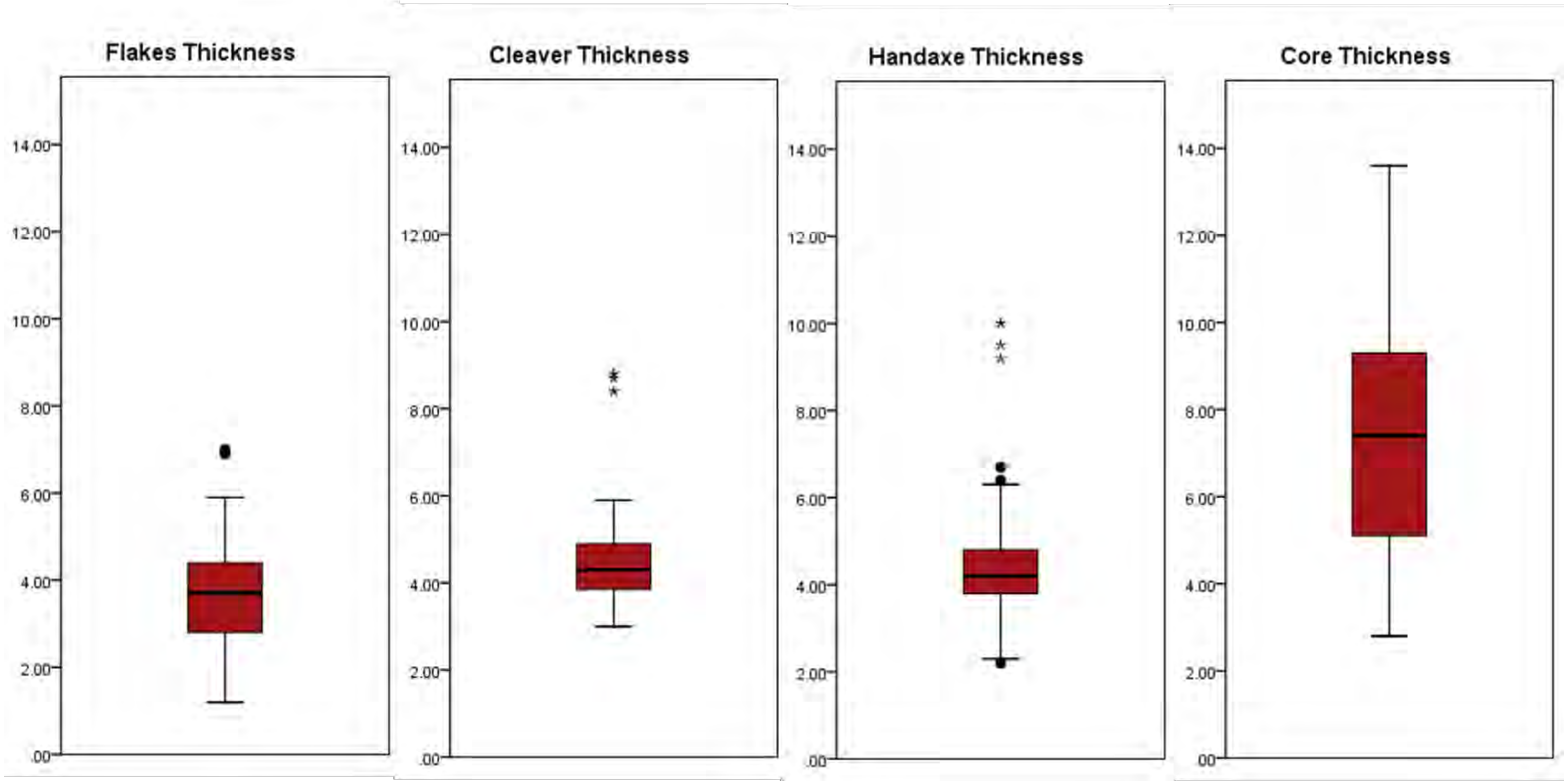


Fig. 5.106: Boxplot showing thickness for various artefact types

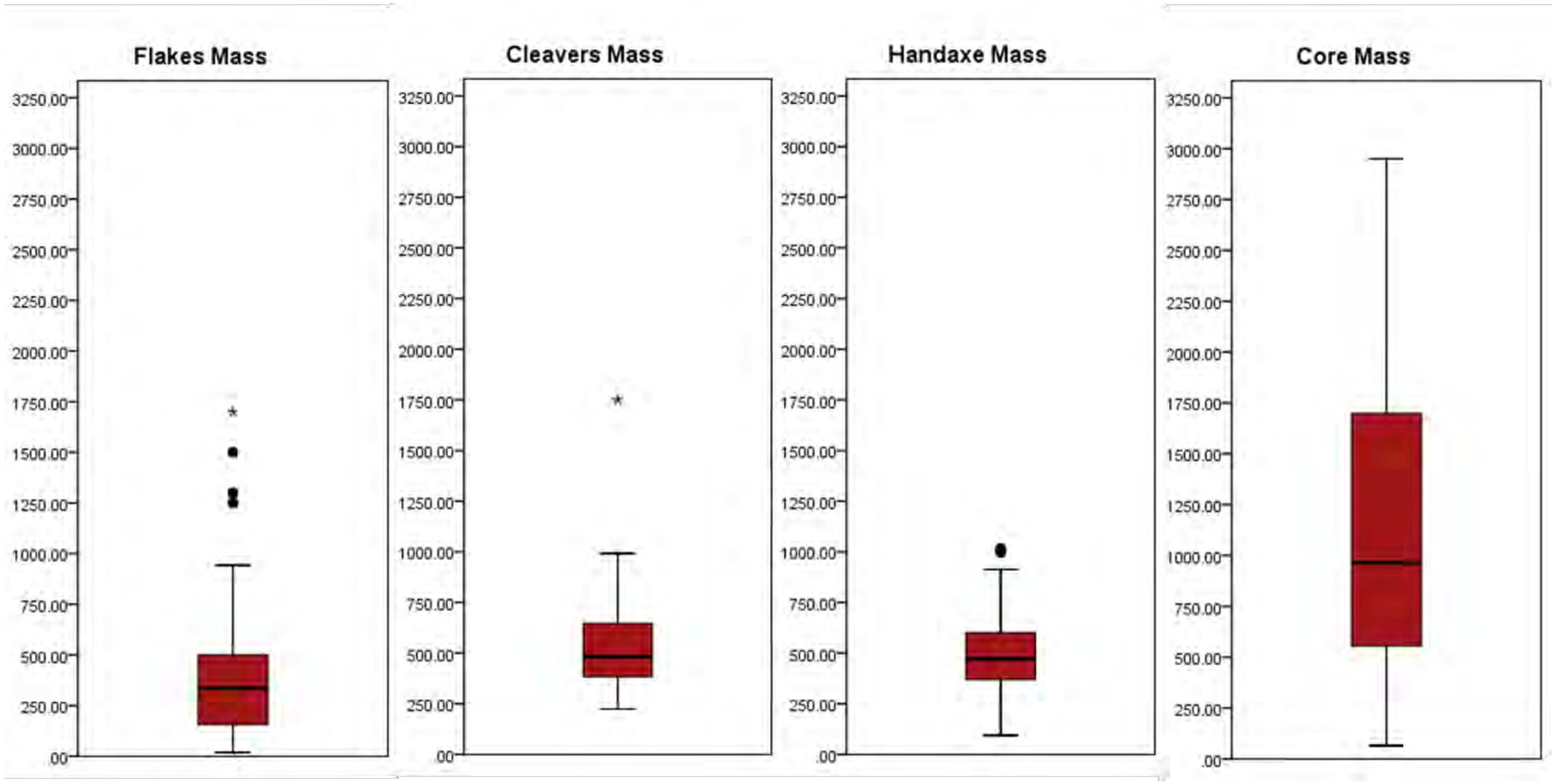


Fig. 5.107: Boxplot showing mass for various artefact types

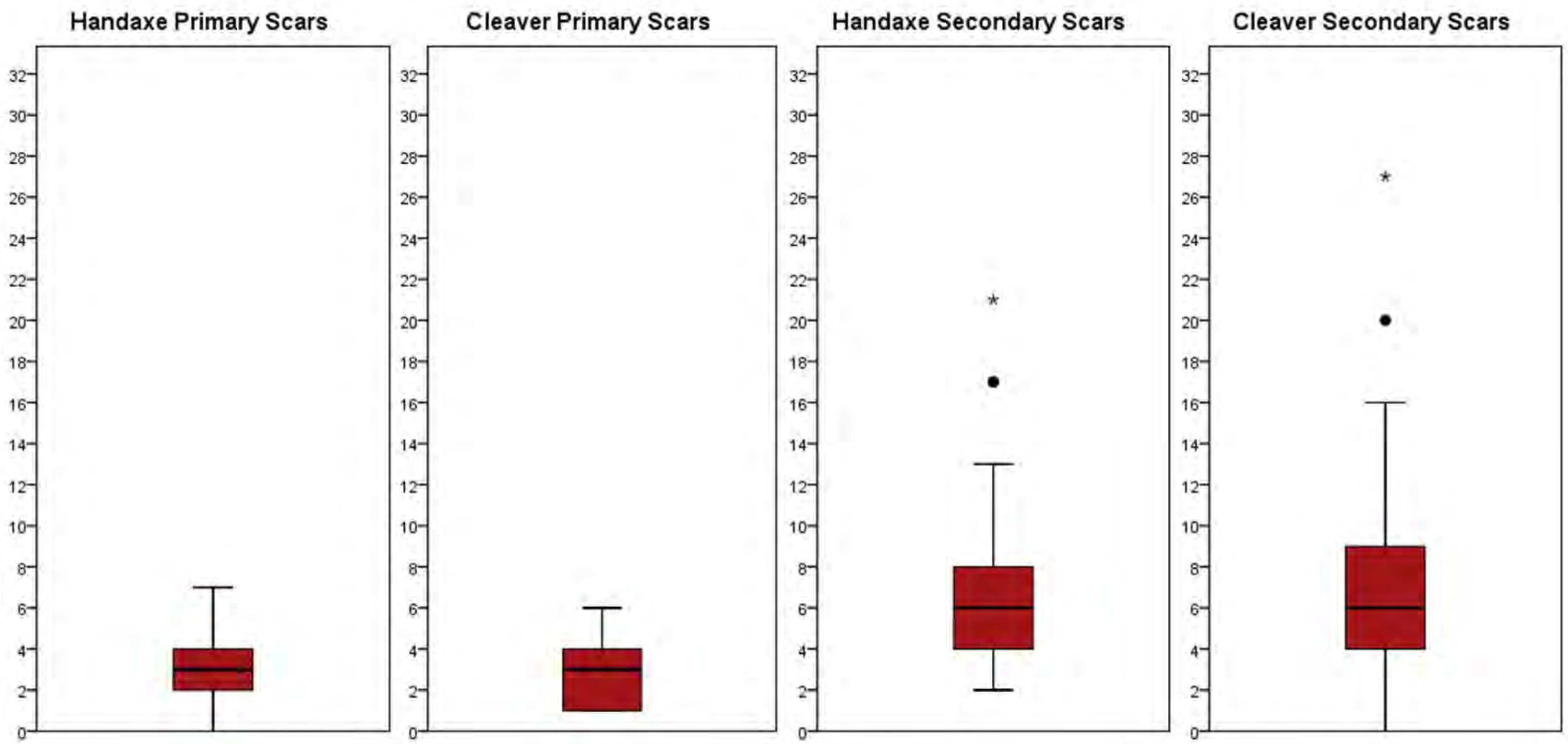


Fig. 5.108: Boxplot showing Primary and Secondary Scar Count for Cleavers and Handaxes

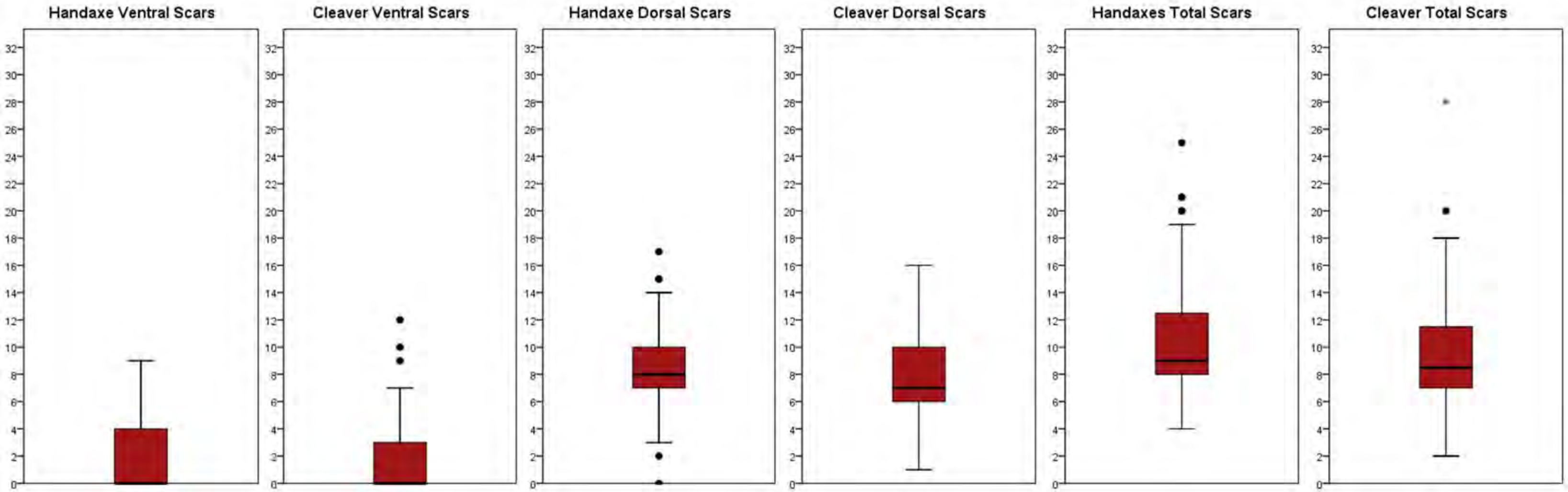


Fig. 5.109: Boxplot showing Scar Count for Cleavers and Handaxes

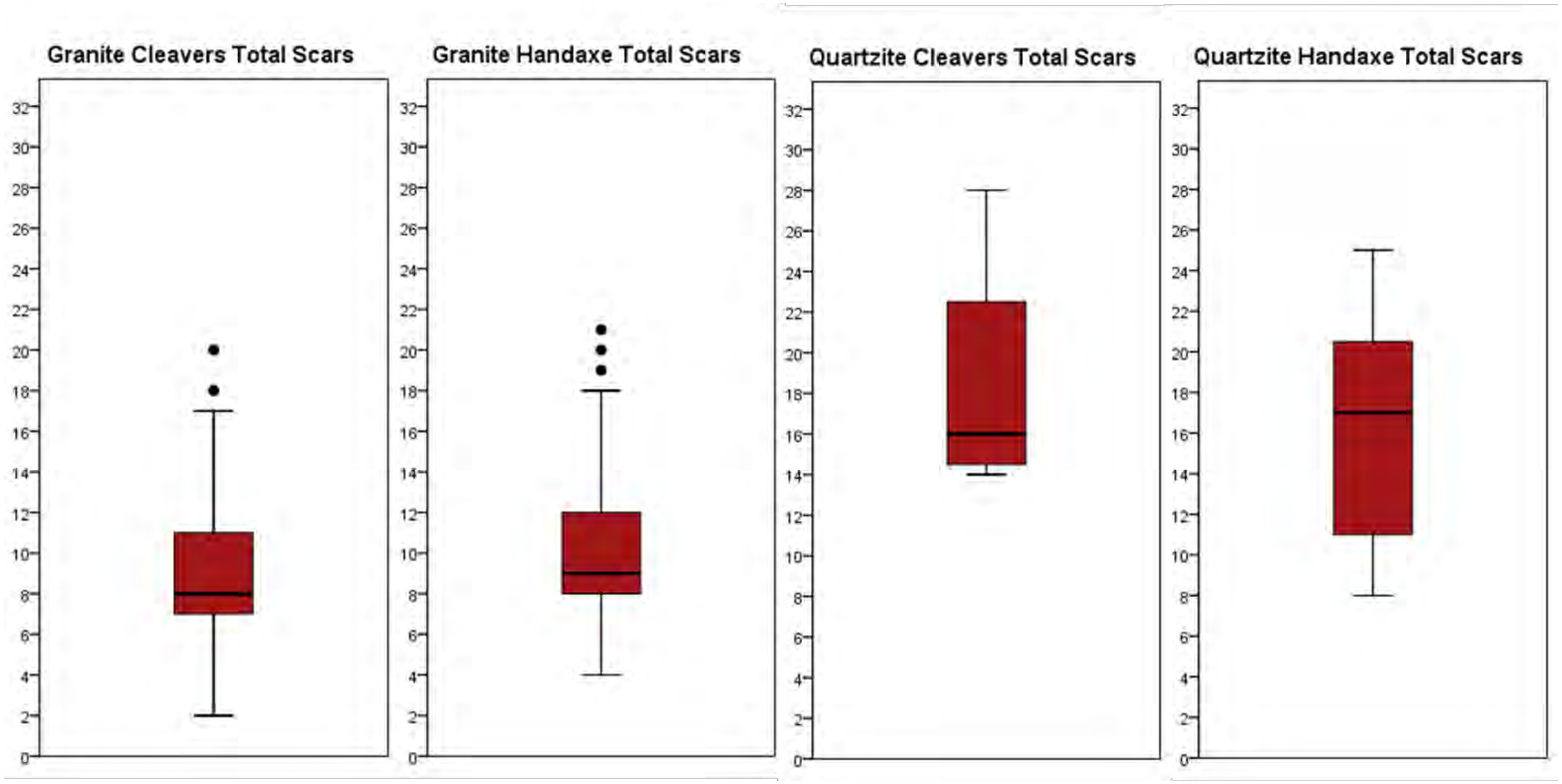


Fig. 5.110: Boxplot showing Total Scars for Cleavers and Handaxes on Quartzite and Granite

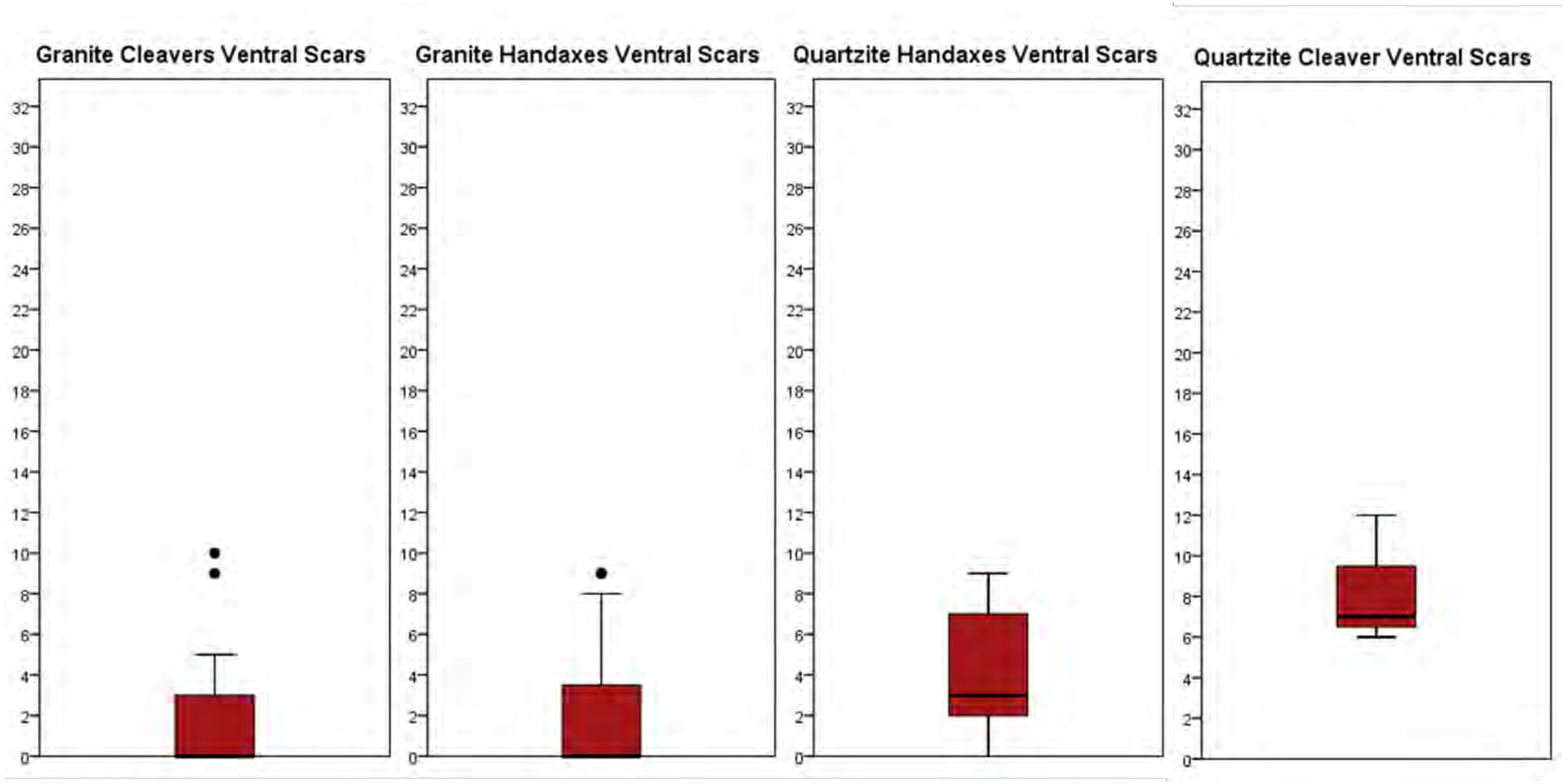


Fig. 5.111: Boxplot showing Ventral Scars for Cleavers and Handaxes on Quartzite and Granite

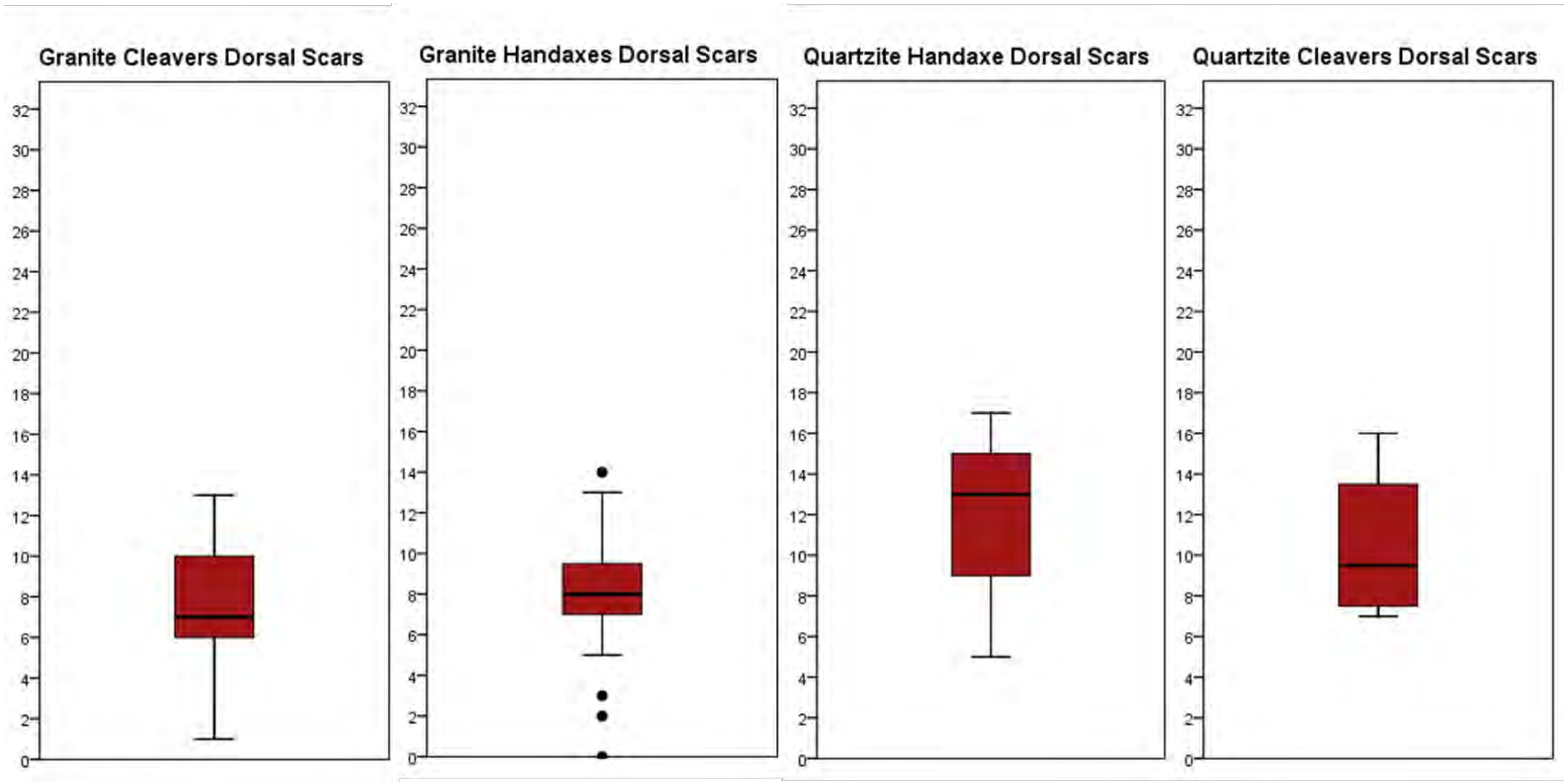


Fig. 5.112: Boxplot showing Dorsal Scars for Cleavers and Handaxes on Quartzite and Granite

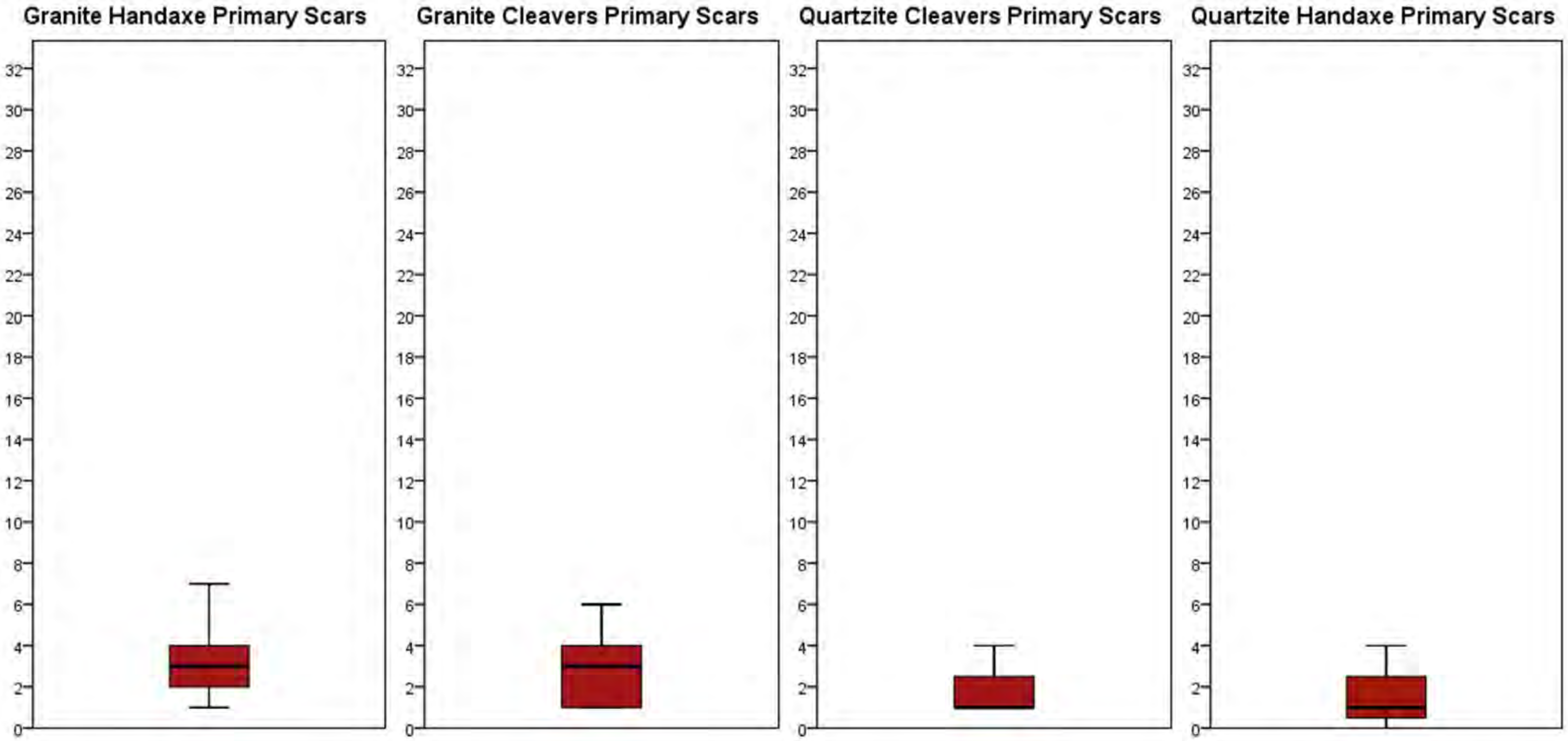


Fig. 5.113: Boxplot showing Primary Scars for Cleavers and Handaxes on Quartzite and Granite

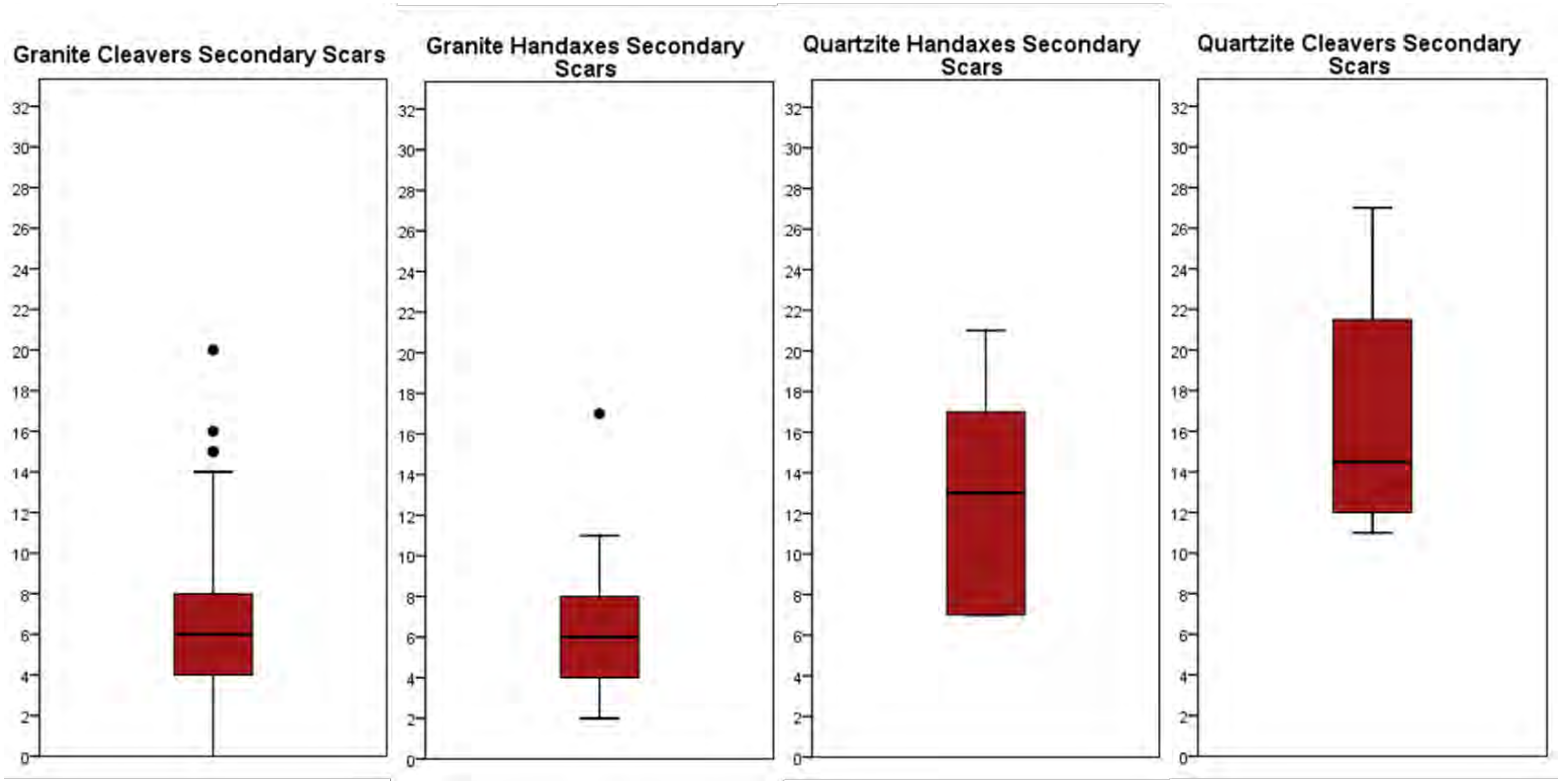


Fig. 5.114: Boxplot showing Secondary Scars for Cleavers and Handaxes on Quartzite and Granite

5.8 CURATION, MOBILITY AND TRANSPORT

Though very few artefacts are made on quartzite, but most of them display heavy retouch and resharpening. Such presence of more extensive retouch on quartzite artefacts at Locality 1 and also from LPR II raises certain questions. It could arise from the greater curation and resharpening of imported raw material. Differences in intensity of retouch between granite and quartzite artefacts (Figs. 6.110 – 6.114) could also arise from mechanical properties of rock making granite unsuitable for lighter secondary retouch. However, this proposition needs to be tested by more detailed experimentation and rock mechanical studies.

Absence of small flakes despite presence of cores for such flakes alongwith absence of large cores coupled with a fairly high number of large cutting tools indicates high mobility and transport of the tool kit by Acheulean hominins.

5.9 SUMMARY

On the basis of the above analysis we can deduce the characteristic features of the Acheulean assemblage at Lalitpur as:

I. Raw Material

1. Predominant use of local raw material available in the vicinity of the site in suitable sizes and morphology, namely granite. Use of granite as the principal raw material makes the assemblage unique as it has been earlier suggested that coarse grained multi-mineral rocks like granite are unsuitable for knapping. Only a few other Acheulean assemblages demonstrate use of granite, namely Isimila, Hunsgi and Yediapur.
2. Such predominant use of a single local raw material type has also been noticed at other LFA sites (Sharon 2007). A minor percentage of LCTs were made on quartzite and sandstone which are found in the nearby Vindhyan hills 8 – 15 km away. However, greater complexity is seen in raw material exploitation. The assemblage from another locality, LPR II in a similar geological terrain situated no more than 3 - 4 km away, demonstrates the exclusive use of quartzite for stone tool manufacture even when suitable granite outcropped in the vicinity. This shows the differences in raw material exploitation at two

nearby localities. Similar differences in raw material selection have also been noted at neighbouring sites of GBY and Ma'ayan Barukh (Sharon 2007) and also in the Hunsgi - Baichbal basin sites (Jhaldiyal 1997, 2006, Paddayya 1982). It is possible that the differential selection of rock type could be due either to chronological differences or to differential weathering, granite may be weathered more easily.

3. Raw Material Selection

The assemblage demonstrates clear evidence of deliberate raw material selection for fine grained quartzitic granitic even though coarse grained varieties also exist. Higher percentage of quartz made this particular granite type more suitable for flaking large flake blanks with a sharp cutting edge. It was not only finer grained but also more durable, and without foliations.

4. Raw Material Procurement
    a. Raw material procured is mainly in the form of weathered corestones abounding in the area, resulting from the weathering of the granite outcrop. Often tabular slabs are also used as they present suitable morphologies and angles to detach usable flakes with minimum effort. Even handaxes are often made on slabs with minimum flaking. Minimal use of river cobbles for either handaxes or flakes is observed.
    b. Weathered nodules or slabs from rock outcrops rather than river cobbles have also been used at the sites of Tikoda and Morgaon (pers. comm. S. Mishra; Joshi 1966). This is a typical feature of Indian Acheulean in contradistinction to the European Acheulean which is largely made on river cobbles.
5. Transport distances:

The site shows dominant utilization of locally available raw material within the site area, that is, granite; limited utilization of sandstones and quartzites occurring semi-locally 8 – 20 km south; rare use of distant raw materials like very fine grained quartzites.

However, abundance of tools in very high densities, compared to flakes and cores, absence of large cores, occurrence of off-sites with few LCTs indicate transport of both raw material and finished tools over small distances.

6. Variability due to raw material

More extensive retouch has been noticed on quartzite artefacts at Locality 1 and also from LPR II. This raises certain questions. It could arise from the greater curation and resharpening of imported raw material. Differences in intensity of retouch between granite and quartzite artefacts could also arise from mechanical properties of rock, making granite unsuitable for lighter secondary retouch. However, this proposition needs to be tested by more detailed experimentation and rock mechanical studies.

However, no differences have been noted in the size of large flake blanks between granite and quartzite at Lalitpur. Sharon (2007) also noted the lack of differences between LCTs made on different raw material. He also suggested that raw material size or technological constraints did not hamper the Acheulean knapper. This is also demonstrated at Lalitpur where LCTs on both quartzite and granite have uniform characteristics and are made by similar methods. Recently Eren *et al.* 2014 have also experimentally proven that raw material does not account for size and shape variability in artefacts.

II. Products:

7. Predominance of Large Flakes and tools on them

The assemblage is characterized by very high frequency of large flakes and LCTs on them, nearly 30%.

8. Abundance of Large Flakes but negligible presence of large cores

The cores for detaching the large flakes are found in very low numbers. Only one giant core was retrieved from the surface at Locality Bn5 during explorations in the area. Besides, out of the medium sized cores, the multifacial and hierarchical cores were also meant for LCT production (12.7% of the cores). However, the frequency of such cores is also low.

9. It is further characterised by the lack of small retouched tools and small flakes, but cores for small flakes (the bifacial partial, radial and discoid cores) are present. Almost 75% of the flakes are larger than 8 cm.
10. The presence of cores meant exclusively for the production of small flakes show that they constituted a minor component of the assemblage. These small flakes were not just a part of the debitage of LCT production, but an intentional and integral component of another parallel *chaîne opératoire*. Further these cores display considerable planning and organization in their

knapping sequence. This has also been demonstrated at other Acheulean assemblages in India (pers. comm. S. Mishra) and Africa (de la Torre 2011).

11. A small component of the battered pieces also exists at Lalitpur which present ellipsoidal flake scars emerging a little away from the edge and considerable pitting. The percentage of battered pieces could have been higher as indicated by the presence of a large number of quartzite cobbles which were actually removed from the artefact inventory (Singh 1965). These quartzite cobbles were definitely manuports as has been shown in the previous chapter. However the low percentage of flakes and tools on quartzite suggests that such a large percentage could not have been brought for the manufacture of tools. Alternatively they served a different purpose, probably as battered tools.

III. Technological characteristics

12. Low percentage of cortex

Virtual absence of Toth Types 1-4 and predominance of Type 6 shows cortex is mostly not present on flakes. This is not only a result of formation processes resulting in the faster weathering of cortical flakes probably, but also a result of the technology employed resulting in low number of cortical flakes and waste.

13. Absence of cortex on striking platforms, predominance of plain platforms, absence of facetted platforms with angles mostly in the range of 105 - 120°.
14. Low number of previous scars

The previous scars on most flakes and LCTs range from 1-3 with not more than 6-7 scars. As such they do not reveal any clear pattern unlike the flakes of the succeeding Middle Palaeolithic which have complex scar patterns (like unidirectional parallel, bidirectional opposed orthogonal and centripetal).

The study of previous scars, flake blanks and cores show that the continuing use of Kombewa flakes leads to 2-3 previous scars.

15. Low amounts of debitage and angular fragments
    a. All large flakes are actually tools with some amount of secondary modification
    b. Low amounts of debitage and angular fragments perhaps results from the flaking methods employed
16. Presence of cores, hammerstones and debitage attests to flaking activities at the site.

IV. Core Management

17. There is evidence of core organization but no real prepared cores in the sense of predetermining the size and shape of the flake. Core management and organization is aimed at mainly retrieving large flakes with long cutting edges.
18. Cleaver predetermination is only in obtaining a large flake with a broad cutting edge. The focus is on obtaining long sharp cutting edges through intersecting flake surfaces
19. The reconstruction of the *chaîne opératoire* from a study of technical attributes like presence and position of cortex and the number and pattern of previous scars shows that this is done in a simple manner. The weathered nodule is first split into two resulting in a very large Kombewa flake. This half of the nodule is then subject to further detachments resulting in Kombewa flakes with sharp broad cutting edges. The cutting edge results from the intersection of the two flaking surfaces. The large flake is a readymade tool which can be used without further modification.

    Further modification of this core results in flakes with 2 or more scars showing multidirectional or radial patterns. Thus Kombewa, multidirectional and radial blanks show a continuum of increasing utilization of the core resulting in more previous scars.
20. So, essentially the different methods seen in the production of LCTs are not actually different conceptual schemas but they show a continuum of increasing utilization of the core. The initial stage perhaps starts with a Kombewa and then as the core is more intensively reduced the number of flake scars increases, finally resulting in flakes with radial dorsal scar pattern.
21. Minimal core preparation which involves only decortication as seen in the flake scars on blanks and also striking platforms on cores which have only 1-2 scar facets and low cortex on flakes.
22. The core volume is also managed by simple methods of core rotation and bifacial centripetal reduction in many cases.
23. The scars are invasive, covering the entire flaking surface also suggesting good management of central volume thereby.
24. Predominantly simple strategies are used for flake detachment with the use of natural convexities.

25. Presence of organized hierarchical flaking strategies for LCT blank production.
26. As against the flakes which have little or no cortex, many cores retain some amount of cortex and the original shape of the nodule is still visible indicating short reduction sequences Though fairly reduced cores also exist, showing variability in flaking strategies.
27. The core strategies and LCT blanks show simple reduction strategies requiring minimal effort in detaching LCT blanks which needed little secondary modification. But the LCT blanks display considerable skill, planning and ability of the Acheulean hominins to produce suitable LCT blanks without complex preparation as seen in the remarkable homogeneity in the size of large flakes despite little investment in core preparation. This also indicates a fairly high degree of planning.

V. LCT Characteristics

28. LCTs constitute 22.7% of the total assemblage indicating a fairly high frequency. The large cutting tools mostly fall in two broad classes, one with a broad cutting edge typified by the cleaver which forms 47% of LCTs and the other with sharp lateral edges converging into a pointed end typified by the handaxe. But besides these two dominant forms, there is considerable variability reflected in the presence of knives, scrapers and other large retouched tools in low proportions. Isaac (1977) and de la Torre (2011) also recognized the existence of other forms of large retouched tools. Most early studies however ignored this morphological variability and emphasized on remarkable similarity in forms as they focused only on the study of bifaces or shaped tools.
29. Further it has also been seen that finished tools and large flakes grade into each other. It is difficult to establish clear-cut distinctions between different types of tools, such as handaxes, cleaver, knives and scrapers and also large flakes. This difficulty has also been mentioned by other researchers (Sharon 2007, Isaac 1977, Roe 2001). Isaac (1977: 120) aptly said that "… the sets of pieces classified into the named forms constitute a recurrent improbable combination of attribute states and that the field of morphological variation is consequently not random… in general, the form categories are not modes, but arbitrary zones within a structured continuum". On similar lines Roe (2001:

497) also pointed out that "Stone handaxes, cleaver, knives and core axes were individually made, not cast in a set of moulds for each tool class. The makers were committed to achieving functional effectiveness; it is the archaeologists who demand typological exclusiveness".

30. Most large flakes have some secondary modification suggesting that they were used.
31. The high frequency of LCTs and occurrence of isolated LCTs across the landscape suggest carrying and transport of tools. Further the typological bias towards LCTs shows that they were preferentially curated.
32. The scar pattern on LCTs is indicative of the choice of blanks. This suggests a very high frequency of Kombewa blanks (16%), followed by multidirectional and radial scar pattern.
33. Though all flake blow directions from 3 to 7 are found, there is a clear preference for end-struck flakes (direction 5), followed by side-struck (directions 3 and 7) for both cleavers and handaxes. Most Kombewa flakes are end struck, though radial blanks do not show any preferred blow direction.
34. The cleaver bit is almost always shaped by a single predetermining scar on the dorsal face intersecting with the flake margin.
35. The previous scars and platform all show simple core organization for cleaver manufacture without any complexity in methods and techniques.
36. Most handaxes are unifacial large pointed tools, mainly picks or crude bifaces. Bifacially shaped 'true' handaxes are found in very low frequencies. The retouch on handaxes is mostly unifacial, abrupt and semi-invasive to invasive with low number of scars and no regular pattern.

VI. Retouch characteristics

37. Very little secondary modification is seen on the tools. Many large flakes bear only 1-6 secondary scars. Secondary retouch present on the tools is mostly abrupt, semi-invasive confined to the lateral margins and proximal ends. It is not for shaping the working edge but only for regularizing the margins for suitable gripping and/or for thinning the thick proximal ends. Often the striking platforms on handaxes have been deliberately removed to get rid of the excess thickness and balance the tool mass. In very few cases, the distal end of the handaxes is secondarily modified to give it a shape.

38. Lack of secondary bifacial shaping of the edges. Most retouch is direct, only on the lateral margins and proximal ends of the dorsal faces. There is hardly any retouch on the ventral faces, with only a few LCTs showing ventral retouch. Very few LCTs display bifacial flaking, which is also mostly partial. Rarely, bifacial alternate flaking is seen on the tools.
39. Particularly, Kombewa flakes display very little retouches. They served as efficient tool blanks which required no further modification.
40. However, the quartzite cleavers and handaxes found in very low frequencies display heavy modification with a high scar count. The quartzite cleavers also display retouch of the edges, showing extensive resharpening. This could be the result of heavy curation of imported raw material.
41. Again handaxes on quartzite display fine working compared to granite.
42. Cleavers often display considerable damage on the cleaver bit which is related both to post-depositional processes and also use related modification.

VII. Shape and Standardization

43. Lack bifacial and bilateral symmetry
44. Lack of standardization

LCTs do not show much standardization in shape. However the cleavers fall mostly in the size range of 10-20 cm with the width and thickness tightly constrained. However there is no shape standardization seen in the tools.

Large flakes, cleavers, knives and scrapers and even handaxes grade into each other. Though cleavers form a distinct class of tools which is predetermined, all retouched large flakes actually form only one class of tools.

VIII. Behavioural Traits

45. Fragmentation of *chaîne opératoire*

The frequency of artefact types indicates fragmentation of the *chaîne opératoire* with presence of mostly large flakes and tools and the near absence of large cores and small flakes. Studies of artefact condition, granulometry and coarse clast analysis suggests that it may not be explained by geogenic fluvial sorting processes, as the size of natural clasts shows presence of both small and large clasts. The absence of small flakes may be explained by absence of screening of lithics during excavation, discard of small chips and quartz fragments (Singh 1965) and coarse nature of the sedimentary deposit. Some amount of winnowing and weathering cannot however be ruled out. Absence of small debitage may also be explained by the technique of manufacture itself resulting in very little small debitage. The absence of large cores is mainly anthropogenic (discussed further in Chapter VI).

46. Curation and transport

There is evidence for a fairly high degree of curation and transport (discussed further in Chapter VI)

47. Planning and Forethought

The technology reflects considerable planning and forethought as can be seen in the nature of LCTs which have suitable edges made so that little modification is required afterwards.

48. Socially Learned Tradition

The high degree of planning, skills and abilities displayed by the knappers evident from the large flakes and tools shows that it must have passed down generations as a socially learned tradition (discussed further in Chapter VI).

CHAPTER VI

CONCLUSIONS

This research focuses on the reconstruction of the lithic technological strategies, archeological site contexts and formation processes at the Acheulean site of Lalitpur, Central India. It has led to some interesting results pertaining to early hominin behaviour. The study of the technological organization of the Acheulean hominins at Lalitpur using a combination of the *chaîne opératoire* approach and attribute analysis, and focusing on the study of the entire assemblage including cores, flakes and tools as against the traditional approach focusing on shaped tools, has helped in deriving a comprehensive picture of the stone tool technological repertoire of the Acheulean hominins. It has helped redefine the Indian Acheulean and place it in global context. Further it has helped in clarifying the concept of 'Large Flake Acheulean' and the behavioural implications of this technology.

It has also highlighted the importance of 'surface' sites in the study of the Lower Palaeolithic, particularly in India and pointed out the importance of site formation studies in understanding the nature of Palaeolithic sites.

ACHEULEAN SITE CONTEXTS AND FORMATION PROCESSES

Geoarchaeological context of the Acheulean at Lalitpur was studied thoroughly. For this purpose intensive explorations were carried out in the site and also in the entire Betwa basin. Further remotely sensed imageries were used in a GIS platform to throw light on the fluvial dynamics and geotectonic context. This helped in understanding the geomorphic processes shaping the past landscape. Besides study of site stratigraphy, sedimentology, coarse clast analysis and artefact taphonomy were undertaken to understand the site contexts and formation processes at the Acheulean site of Lalitpur.

It has shown that the sites are located on low slopes in the granitic pediment and not disturbed by fluvial dynamics. Major processes affecting the landscape are weathering and small scale slope processes. The sites are found buried underneath a thin soil cover (15 - 30 cm) over gruss in granitic upland. This perhaps indicates lack of any net aggradation or incision since the Pliocene and consequent stable landscape which may be the result of rheological differences between the Archaean and younger continental crust (Westaway *et al.* 2003). The preservation of the sites underneath a thin silt cover and low degree of disturbance of the assemblage can be explained by recent erosion of a thicker silt cover.

The artefact spread shows that the assemblages are found as large concentrations of several thousand artefacts distributed over a large area. The artefact spreads are landscape wide features and not just confined to limited site areas. Further, concentration of sites in the small stretch of the interfluve between the Betwa and Shahzad Rivers only suggests differential preservation and exposure of Acheulean age sediments in that area. However, these are not the result of concentrated hominin activity only at those spots. Only they are found preserved in those locales (see also Mishra 2011, Deo *et al.* 2007). Wherever, the sediments associated with the Acheulean age are found exposed, the artefacts are found to occur. The rarity of the sites is however related to destructive processes, and it does not reflect population densities.

IMPORTANCE OF SURFACE SITES

Studies at Lalitpur indicate that it is not a surface site, but that the artefacts are only recently getting eroded from a previously buried context. Similar observations have been made at other sites including Tikoda in the Raisen Complex (Mishra *et al.* 2012), Hunsgi-Baichbal basin (Jhaldiyal 1997, 2006, Paddayya 2008) and others. During his researches in the Raisen area, Jacobson (1985) had earlier argued for the original presence of artefacts on the surface since actual discard. However it is difficult to imagine survival of the artefacts on the surface over a period of such long term exposure as considerable weathering would take place. Fresh nature of the artefacts, apart from high degree of weathering, rules out long term exposure. This leads into thinking that at least for the long timescale of the Lower Palaeolithic, there is no such thing as a surface site (Mishra *et al.* 2012).

Therefore, sites like Lalitpur can yield significant information about the technological strategies employed, even though chronological control is lacking.

THE CONCEPT OF LARGE FLAKE ACHEULEAN

Traditionally, the handaxe or biface is considered to be the iconic tool of the Acheulean with bifacial shaping as the distinctive feature of the Acheulean. Bifacial shaping and focus on bifacial bilateral symmetry and standardization has also prompted debates on 'mental templates'.

However, the study of the Acheulean assemblage at Lalitpur, and comparison with other well studied assemblages shows that the real innovation of the Acheulean is not in bifacial shaping but in the technology to manufacture large flakes and tools on them. These large flakes are distinctive characteristics of the Acheulean in India, and also in Africa and Southwest Asia (Sharon 2007, Mishra *et al.* 2010a, Kuman 2014, de la Torre 2011). This is in contradistinction to the Acheulean in Europe which focuses on bifacial shaping of river cobbles to achieve working edges (Santonja and Villa 2006, Barsky and de Lumley 2010, Moncel *et al.* 2013).

This distinction is quite marked and this unique nature of the technological organization at Early Acheulean sites in India, Africa, Southwest Asia in contradistinction to the European Acheulean has prompted many workers to moot the idea of this Early Acheulean as 'Large Flake Acheulean' (Mishra *et al.* 2010a, Sharon 2007, 2009). This was done because traditional understanding of the Acheulean largely based on the European Acheulean is misleading.

Sharon (2007, 2009) noted the major defining features of the LFA as:

- marked use of **large flakes**, larger than 10 cm;
- presence of cleavers made on large flakes with unretouched cutting edge and only **minimal bifacial cleavers** or retouched cleaver bits;
- notable presence of **cleaver flakes** among unretouched large flakes;
- **minimal retouch of the ventral face** with shaping that generally involved only thinning the bulb of percussion and platform though handaxes were more heavily retouched;
- predominance of **two basic types of cutting edge** - convergent pointed (handaxe) and broad edge (cleaver);
- use of a **variety of core knapping methods** which are well planned, systematic and predetermined adapted to raw material requirements;
- **predetermination of blank shape** prior to detachment;

- **variability in raw material exploitation** as against the exclusive use of flint in European Acheulean; and
- **preference for coarse-grained rocks** for detaching large flakes.
- He also noted that in the LFA, the handaxes have pointed tips, as against broad tipped ovate handaxes of the European Acheulean prompting a **cleaver-ovate dichotomy**.

In addition to the above, the present work based on the analysis of a complete assemblage from the site of Lalitpur and not just focusing on shaped tools and its comparison with well-studied assemblages in the European, African and Indian context has helped clarify the concept of 'Large Flake Acheulean' (LFA).

The defining features of LFA technology based on the present study are:

1. Raw Material Selection: As Sharon (2008) noted raw material is not a constraint on knapping and Acheulean knappers used all rock types, preferably coarse grained rocks facilitating the production of large flakes. However there is a clear **selection of suitable rocks** amenable to detaching large flakes.
2. Most Early Acheulean sites based on large flakes utilize weathered nodules (corestones) and tabular slabs resulting from the weathering of the rock outcrops. There is **minimal use of river cobbles** for either handaxes or flakes. This is a typical feature of the LFA in contradistinction to the European Acheulean which is largely made on river cobbles.
3. It is based largely on the production of **large flakes** and LCTs on them.
4. Small flake *chaîne opératoire*: The small flakes constitute a distinct *chaîne opératoire* within the Acheulean. However it **lacks the small retouched tools** like points, notches and scrapers found in the European Acheulean. Further the European Acheulean has a high percentage of small retouched tools unlike the LFA where the main technology is based on large flakes. At Caune de L'Arago for example, the small retouched tool component comprises 91% of the tools while bifaces comprise a minimal 7% of tools and just 0.4% of the entire assemblage (Barsky and de Lumley 2010, Ollé *et al.* 2013, Moncel *et al.* 2013, Garcia-Medrona *et al.* 2013).
5. The technology of the LFA is characteristic and diagnostic. Even the presence of few such flakes and tools may be marked as Acheulean. It is characterized by

i. **Low percentage of cortex**: There is virtual absence of Toth Types 1-4, predominance of Type 6. This contrasts the LFA with the earlier Oldowan which is comprised mainly of Toth types 1-3 (Barsky 2009, de la Torre *et al.* 2003).

ii. Absence of cortex on striking platforms, predominance of **plain platforms**, near absence of facetted platforms with angles mostly in the range of 105 - 120°.

iii. **Low number of previous scars**: The LCTs are characterized by low number of previous scars (mostly 1-3 scars).

iv. **Low amounts of waste flakes** and angular fragments: The LFA technology is distinctive in that it results in low amounts of waste flakes and angular fragments. This can be seen from the high number of finished tools, low frequencies of waste flakes, lack of core preparation, plain striking platforms, and LCT blank morphology with low number of invasive scars, and little secondary modification. Therefore, low amounts of small debitage may be explained by the nature of the knapping methods employed which resulted in very little debitage. This however needs to be proven experimentally.

6. **Low degree of secondary modification and lack of bifacial shaping**

   a. Most handaxes are unifacial large pointed tools, mainly picks or crude bifaces. Bifacially shaped 'true' handaxes are found in very low frequencies. The retouch on handaxes is mostly unifacial, abrupt and semi-invasive to invasive with low number of scars and no regular pattern. It is often restricted to the trimming of lateral margins (probably for gripping) and butt or proximal ends (for thinning and balancing of tool mass). Hardly any retouch is seen on the ventral faces. Very few LCTs display bifacial flaking. This indicates lack of secondary bifacial shaping which has till now been considered as the hallmark of Acheulean technology. Lack of bifacial shaping has been noticed by most works on Early Acheulean in Africa, Southwest Asia and India (McNabb *et al.* 2004, de la Torre 2011, Diez-Martin *et al.* 2014a & b, Sharon 2007, Beyenne *et al.* 2013, Kuman 2014).

7. **Lack of bifacial and bilateral symmetry** is another defining feature of LFA making it distinctive from the Late Acheulean in Europe and elsewhere (Beyenne *et al.* 2013).
8. **Lack of standardization**
   a. LCTs do not show much standardization in shape. However cleavers show considerably more standardization in size.
   b. Cleaver predetermination is only in obtaining a large flake with a broad cutting edge. The focus is on obtaining long sharp cutting edges through intersecting flake surfaces. Predetermination of shape and size seen in succeeding Levallois technology is not seen here.
   c. But there is no shape standardization seen in the tools. Large flakes, cleavers, knives and scrapers and even handaxes grade into each other.
9. **Core organization and management**: No complex preparation of cores like the succeeding Middle Palaeolithic which predetermines the size and shape of the flake. Despite being simple, the technology is not opportunistic, but sophisticated and intelligent as it involved effective and efficient planning and organization of the core with central volume management and control of guiding ridges resulting in the production of large flakes with either sharp cutting edges or pointed ends requiring little further investment effort in the modification of tools by secondary retouch.
10. **Fragmented *chaîne opératoire***

A marked characteristic of LFA is fragmented *chaîne opératoires* (Mishra *et al.* 2010a, de la Torre 2011). The frequency of artefact types indicates fragmentation of the *chaîne opératoire* with presence of mostly large flakes and tools and the near absence of large cores and small flakes. This is not an indication of low site integrity, as is often inferred from low ratio of cores to flakes and lack of refitting (seen in Lokalelei 2C, Dmanisi and other Oldowan sites). However it is an inherent behavior of Acheulean hominins, wherein they made, used and discarded tools at different locations. This makes the Acheulean significantly different from the earlier Oldowan technologies where tools were made, used and discarded mostly at the same locale.

11. Curation and Transport

The very high frequency of LCTs as against flakes and cores, alongwith occurrence of isolated LCTs across the landscape around many Acheulean localities suggest **carrying and transport of tools**. Further the typological bias towards LCTs shows that they were preferentially curated.

This carrying and transport of tools is a significant landmark in human evolution which has important behavioural implications. Carrying and transport of tools is seen in all post-Acheulean technologies.

12. Carrying Technology: It has been recently suggested that increase in fragmentation of *chaîne opératoires,* curation and transport of tools is a result of development of a carrying technology (Mishra *et al.* 2010a). The technology to carry objects was an important innovation triggering behavioural advances. This carrying technology aided collection of vegetable foods which further initiated developments in the technology to process vegetable foods like cooking over fire.

13. Planning and Forethought

Core strategies and LCT blanks show simple reduction strategies with minimal effort in detaching LCT blanks. But they point to considerable skill, planning, forethought and ability of the Acheulean hominins to produce suitable LCT blanks without complex preparation as seen in the remarkable homogeneity in the size of large flakes and production of flakes with suitable edges which required little further modification, despite little investment in core preparation. This also indicates a fairly high degree of planning and knowledge of fracture mechanics and efficient knapping skills (Jones 1994, Madsen and Goren-Inbar 2004, Sharon 2007).

14. Variability in Knapping Strategies: **Flexibility and Innovation**

Though there is considerable uniformity in size and morphology of tools at most Acheulean sites, considerable variability is seen in seen in raw material exploitation, strategies of exploitation, frequency of LCT types, large and small flake tools, and core management schemas adopted. This has been noted by earlier workers (Sharon 2007, Mourre 2003). This indicates flexibility and adaptation to needs and innovative capabilities of the Acheulean knapper.

15. Socially Learned Tradition

a. The high degree of planning, skills and abilities displayed by the knappers evident from the large flakes and tools shows that it must have passed down generations as a socially learned tradition

PROSPECTS FOR FUTURE RESEARCH

During the course of research focused on understanding the nature of site contexts and lithic technological organization at the Acheulean site of Lalitpur, many more questions were raised.

1. As pointed out earlier, predominant use of granite at Lalitpur affords an opportunity for studies related to raw material exploitation. Better understanding can be obtained in future through studies of granite fracture mechanics. Experiments can be designed to better understand the characteristics of granite fracture mechanics. Further more detailed petrographic and geochemical studies can be undertaken to understand aspects of raw material selection.
2. In particular, understanding of the site contexts and nature of the Acheulean occurrence was very limited. More detailed studies are needed to better understand the causes for the preservation and burial of artefacts. We need to establish the role of pedogenic, slope and denudational processes in the formation of the stonezone and the origin of fine sands capping the stone zone. Investigations are also required to establish whether laterite is formed in situ or it gets incorporated into the sediment.
3. Suitable experiments to replicate the technology based on understanding of the technology derived from the present study can help solve important questions pertaining to fracture mechanics in granite, and also reduction methods. It may be noted in this context that experiments designed to understand the Acheulean technology have probably not been able to replicate the technology completely as many discrepancies are noted between the archaeological assemblages and the experimental artefacts (Jones 1994, Toth 1982, 1985, Bradley and Sampson 1986, Sharon 2000, Madsen and Goren-Inbar 2004) in flake attributes, particularly in higher amounts of debitage and shatter, higher percentage of cortical flakes, crushed platforms. Further most experiments have been influenced by the bifacially shaped handaxes found in the European Acheulean.
4. More data on refinement, symmetry and standardization can be obtained by 3D geometric morphometrics.

5. We also need a better methodology for recording technological attributes like scar count, pattern and order suited to the LFA which can help in better understanding of the reduction sequence.
6. In future detailed studies may also be made of the many microlithic occurrences discovered during the course of explorations, both in terms of technological organization and also in terms of the nature of the site occurrences. These may have important implications for the dispersal of modern humans.

APPENDIX I

METHOD OF MORPHOMETRIC ANALYSIS

A. MORPHOMETRIC ANALYSIS

1. Basic Parameters

a. *Area (A)*: It is defined as the entire area between the divide line and the outfall with all sub- and inter-basin area (Garde 2006).

b. *Perimeter (P)*: It is the total length of the drainage basin boundary.

c. *Basin Length*: It is obtained by measuring the longest basin diameter between the mouth of the basin and most distinct point on the perimeter (Gregory and Walling 1973).

d. *Stream Order*: It is the determination of the hierarchical position of stream within a drainage basin (Strahler 1952).

e. *Stream Length*: It is the total length of streams of a particular order.

f. *Slope*: The basin slope was calculated by applying the following formula

$$Sb = \frac{H_{max} - H_{min}}{L}$$

Where, Hmax and Hmin are the maximum and minimum basin heights, respectively; L is the horizontal length of the basin.

2. Derived Parameters

a. *Bifurcation Ratio (Rb)*: It is the ratio of the number of streams of any given order (Nu) to the number in the next lower order (Nu+1). It is defined as:

$$Rb = \frac{Nu}{Nu + 1}$$

b. *Stream Length Ratio (Rl)*: It is calculated by following formula

$$Rl = \frac{Lu}{Lu - 1}$$

Where, Lu stream length of order u and Lu - 1 is the stream length of next lower order.

c. *Stream Frequency (Fs)*: It is defined as the ratio between the total number of stream segments of all orders in basin and the basin area (Horton 1945). It is expressed as:

$$Fs = \frac{\Sigma Nu}{A}$$

Where, Σ Nu is the total number of stream segments of all orders and A is the basin area. The general categories of stream frequency are very poor, poor, moderate, high and very high.

d. *Drainage Density (Dd)*: It is defined as the total length of streams per unit area (Horton 1945). It is expressed as:

$$Dd = \frac{\Sigma Lt}{A}$$

Where, Σ Lt is the total length of all order streams and A is area of the basin.

e. *Drainage Texture (T):* It is an expression of the relative channel spacing in a fluvial dissected terrain. It is expressed by the equation (Smith 1950):

$$T = Dd \times Fs$$

Where, Dd is the drainage density and Fs are the stream frequency.

f. *Basin Relief (R)*: It is the difference in elevation between the highest and lowest point of the basin.

$$R = H_{max} - H_{min}$$

Where, Hmax and Hmin are the maximum and minimum basin heights, respectively.

g. *Relief Ratio (Rr):* It is the ratio between the basin relief (R) and basin length (L) (Schumm 1963).

$$Rr = R / L$$

3. Shape Parameters

a. *Elongation Ratio (Re)*: It is defined by as the ratio between the diameter of a circle of the same area as the basin (D) and the basin length (L) (Schumm 1956).

$$Re = \frac{2}{\sqrt{\pi}}\sqrt{Ff} \quad \text{or} \quad Re = \sqrt{\frac{Ff4}{\pi}}$$

Where, Ff is the form factor. The values of elongation ratio varies from zero (highly elongated shape) to unity i.e. one (circular shape).

b. *Circularity Index (Rc)*: The circularity ratio (Miller 1953, Strahler 1964) of the basin is ratio of the basin area (A) and the area of a circle with same parameter as that of the basin (P)

$$Re = \frac{4\pi A}{P^2}$$

The values of circularity index varies from zero (a line) to unity i.e. one (a circle).

c. *Ellipticity Index (E)*: It is calculated by following formula:

$$E = \frac{\pi L^2}{4A}$$

Where, A is the basin area and L is the basin length. The value of ellipticity index varies from one to infinity.

d. *Form Factor (Ff)*: It is the ratio between the area of the basin (A) and the square of the basin length (L2) (Horton 1945).

$$Ff = \frac{A}{L^2}$$

The values of Form Factor varies from zero (highly elongated shape) to unity i.e. one (perfect circular shape).

B. GEOMORPHIC INDICES

1. River gradient was calculated by following formula:

   $\text{Gradient} = h1 - h2 / l2 - l1$

   Where: h = elevation, l = distance.

2. Stream gradient index were measured by the elevation change over a logarithmically normalized distance using the following formula (Rhea 1993):

   $\text{Gradient Index} = h1 - h2 / \ln l2 - \ln l1$

   Where: h = elevation, l = distance.

3. Valley Index was measured by calculating the ratio of valley floor width and valley width.

APPENDIX II

METHODS FOR SEDIMENTOLOGICAL ANALYSIS

A. TEXTURAL ANALYSIS OF SEDIMENTS

For conducting particle size analysis

1. A nest of clear screens was built from coarsest screen on top using the following subdivisions (8 mm, 2mm, 10, 18, 35, 60, 120 and 230 astm). A lid was placed on the top and a pan at the bottom.
2. Sediment (weighed nearest to 0.01 g) was poured onto the top screen in the nest and washed well until all fines were washed through the screen.
3. It was well shaken and then the contents of each sieve were poured on a high gloss paper by quickly inverting and slamming on the paper.
4. The sieve contents were dried in a 110º C oven under an infrared drying lamp.
5. Then the fraction in each sieve was weighed and recorded on form.
6. Sieve loss was determined and recorded

This simple method effectively served the principal aim of obtaining a general idea of the percentage of gravels, sands, silts and clays in Quaternary sediments.

Screen sizes Used

8 mm	64 - 4 mm – pebbles
2 mm	4 - 2 mm – granules
10 astm	2 – 1 mm – very coarse sand
18 astm	1 mm – 500 μ – coarse sand
35 astm	500 – 250 μ – medium sand
60 astm	250 – 125 μ – fine sand
120 astm	125 – 62 μ – very fine sand
230 astm	62 – 4 μ – silt
Pan	>4 μ – clay

B. PARAMETERS USED FOR COARSE CLAST ANALYSIS

1. Size of Clasts
    a. Maximum length along long axis
    b. Breadth (perpendicular to length)
    c. Mass
2. Lithology
3. Rounding

    a. Angular (1)
    b. Subangular (2)
    c. Subrounded (3)
    d. Rounded (4)
    e. Well rounded (5)
4. State of weathering
    a. Fresh (1)
    b. Slightly weathered (2)
    c. Moderately weathered (3)
    d. Highly weathered (4)
5. Abrasion
    a. Unabraded
    b. Slightly abraded
    c. Moderately abraded
    d. Highly abraded
6. Type of weathering
    a. Granular disintegration
    b. Pitting
    c. Cracking
    d. Exfoliation
    e. Etching
    f. Weathering rind
    g. Calcrete encrustation
7. Rolling
    a. None
    b. Slight
    c. Moderate
    d. Heavy
8. Patination: Color
9. Breakage
    a. None
    b. Chipping
    c. Broken

APPENDIX III

ATTRIBUTES FOR LITHIC ANALYSIS

Site and Locality Name, Artifact Number, Date of Collection

A. COMMON TAPHONOMIC ATTRIBUTES

1) Raw material
    i) Granite (variety of granite)
    ii) Sandstone
    iii) Quartz
    iv) Quartzite

2) Source of Raw Material
    i) Slab
    ii) Nodule
    iii) Fluvially transported (pebble, cobble)
    iv) Indeterminate

3) State of preservation
    i) Fresh
    ii) Slightly weathered
    iii) Moderately weathered
    iv) Highly weathered

4) Patination
    i) No patina
    ii) Patinated
    iii) Double patinated

5) Degree of patination (on both ventral/dorsal faces)
    i) None
    ii) Slight
    iii) Moderate
    iv) Heavy

6) Type of patination (on both dorsal/ventral faces)
    i) None
    ii) Carbonate crust
    iii) Dust film
    iv) Lithobiontic coating
    v) Oxide film
    vi) Manganese staining

7) Other weathering features (on both dorsal/ventral faces)
    i) None
    ii) Granular disintegration
    iii) Exfoliation
    iv) Cracking
    v) Weathering rind
    vi) Pitting
    vii) Other

8) Degree of rounding (on both ventral/dorsal faces and edges)
    i) Sharp
    ii) Slightly rounded
    iii) Moderately rounded
    iv) Heavily rounded

9) Complete
    i) Yes
    ii) No

10) Breakage location (if incomplete)
    i) None
    ii) Lateral (side edge)
    iii) Distal (tip)
    iv) Mid-section
    v) Proximal (base)
    vi) Lateral & distal
    vii) Distal & proximal
    viii) Proximal & lateral
    ix) Indeterminate

11) Type of breakage
    i) None
    ii) Old
    iii) Fresh
    iv) Indeterminate

12) % of dorsal cortex
    i) Nil
    ii) < 25%
    iii) 25 – 50%
    iv) 50-75%
    v) 75-99%
    vi) 100%
    vii) Indeterminate

13) Cortex side
    - i) No cortex
    - ii) Striking platform
    - iii) Dorsal
    - iv) Left
    - v) Right
    - vi) Distal
    - vii) Mesial
    - viii) Proximal

14) Edge Damage
    - i) Yes
    - ii) No

15) Type of edge damage
    - i) Very little
    - ii) Continuous along a sector
    - iii) Extensive
    - iv) Entire edge

16) Position of edge damage
    - i) Single side
    - ii) Double sides
    - iii) Proximal end
    - iv) Distal end
    - v) Side and apex
    - vi) All edges

B. CORES

1) Dimensions
    i) Maximum Linear Dimension (along the longest axis)
    ii) Maximum Breadth
    iii) Maximum Thickness
    iv) Mass

2) Number of surfaces/planes worked

3) Number of scars on each surface

4) Scar pattern
    i) Unidirectional irregular
    ii) Unidirectional convergent
    iii) Unidirectional parallel
    iv) Bidirectional irregular
    v) Bidirectional opposed
    vi) Bidirectional orthogonal
    vii) Multidirectional
    viii) Centripetal
    ix) Irregular

5) Length of largest flake scar

6) Width of largest flake scar

7) Core type

    i) Casual Slab Core
    ii) Bifacial Partial Chopper Core
    iii) Bifacial Core
    iv) Multifacial Core
    v) Preferential Core
    vi) Core on Flake
    vii) Core Fragment

8) Core shape
    i) Globular
    ii) Prismatic
    iii) Pyramidal
    iv) Conical
    v) Polyhedral
    vi) Amorphous
    vii) Exhausted indefinable
    viii) Other

9) Degree of exhaustion of the core (based on % of cortex and degree of flaking)
    i) Exhausted
    ii) Minimally worked
    iii) Medium

C. FLAKES

1) Flake type (following Toth 1982)
    i) Cortical striking platform, totally cortical dorsal surface
    ii) Cortical striking platform, partly cortical dorsal surface
    iii) Cortical striking platform, non-cortical dorsal surface
    iv) Non-cortical striking platform, totally cortical dorsal surface
    v) Non-cortical striking platform, partly cortical dorsal surface
    vi) Totally non-cortical

2) Dimensions
    i) Length
    ii) Breadth
    iii) Thickness
    iv) Mass
    v) Platform thickness
    vi) Platform Width
    vii) Platform angle

3) Direction of blow: 1 to 8, indeterminate (9)

4) Flake scar pattern
    i) Cortical
    ii) Unidirectional parallel
    iii) Unidirectional convergent
    iv) Unidirectional irregular
    v) Bidirectional opposed
    vi) Bidirectional Perpendicular
    vii) Multidirectional
    viii) Centripetal
    ix) Positive flake scar
    x) Irregular
    xi) Indeterminate

5) Type of striking platform
    i) Cortical
    ii) Plain
    iii) Dihedral
    iv) Facetted
    v) Trimmed
    vi) Broken
    vii) Completely Removed

6) Number of previous flake scars

7) Secondary flake scars
    i) Yes
    ii) No

8) Number of secondary scars

9) Number of flake scars (on both faces)

10) Curvature of ventral face
    i) Straight
    ii) Convex
    iii) Concave
    iv) Irregular
    v) Indeterminate

11) Bulb
    i) Prominent
    ii) Diffused
    iii) Trimmed
    iv) Absent

12) Technological Features
    i) Outrepassé (Plunging)
    ii) Hinge
    iii) Step
    iv) Debordant
    v) Kombewa
    vi) Éclat siret
    vii) Lip
    viii) Eraillure
    ix) Lip & eraillure

D. LARGE CUTTING TOOL

1) Type
    - i) Cleaver
    - ii) Other LCT
        - a) Unifacial handaxe
        - b) Bifacial handaxe
        - c) Knife
        - d) Scraper
        - e) Large Retouched tool

2) Blank type
    - i) Kombewa Flake
    - ii) Multidirectional Flake
    - iii) Radial flake
    - iv) Slab
    - v) Nodule
    - vi) Indeterminate

3) Dimensions
    - i) Length
    - ii) Breadth
    - iii) Thickness
    - iv) Weight

4) Face of working
    - i) Unifacial normal (dorsal)
    - ii) Unifacial Inverse (ventral)
    - iii) Bifacial
    - iv) Partly Bifacial

5) Number of flake scars on each face (dorsal and ventral)

6) Edge working
    - i) Single side
    - ii) Double sides
    - iii) End (Distal)
    - iv) Side and end
    - v) Convergent
    - vi) All around
    - vii) All tool's face
    - viii) Butt (Proximal)
    - ix) Proximal & sides

7) Location of edge
    - i) All around
    - ii) All around except base
    - iii) All around except striking platform
    - iv) Side
    - v) Tip
    - vi) Tip and sides
    - vii) Indeterminate

8) Form of edge
    - i) Straight
    - ii) Convex
    - iii) Concave
    - iv) Convergent
    - v) Wavy
    - vi) Denticulate
    - vii) Notched
    - viii) Indeterminate

9) Inclination of retouch
    - i) Flat
    - ii) Oblique
    - iii) Abrupt
    - iv) Step

10) Character of Retouch Distribution
    - i) Complete
    - ii) Complete marginal
    - iii) Partial marginal
    - iv) Partial
    - v) Substantial
    - vi) Marginal

11) Extent of retouch
    - i) Marginal
    - ii) Invasive
    - iii) Semi-invasive
    - iv) Covering

12) Shape of butt end
    - i) Squared base
    - ii) Pointed
    - iii) Rounded

13) Butt
    - i) Untrimmed
    - ii) Only 1 – 2 scars removed
    - iii) Partly trimmed, bulb removed
    - iv) Partly trimmed, bulb still present
    - v) Trimmed all over, bulb removed
    - vi) Removed
    - vii) Indefinable

14) Technological Features
    i) Outrepassé
    ii) Hinge
    iii) Debordant
    iv) Kombewa
    v) Steps
    vi) Éclat siret
    vii) Lip
    viii) Eraillure
    ix) Lip & eraillure
    x) Thinning of bulb

For Cleavers

15) Shape of cleaver edge
    i) Splayed
    ii) Parallel-sided
    iii) Convergent
    iv) Ultraconvergent
    v) Shouldered
    vi) Divergent
    vii) Indeterminate

16) Delineation of cleaver trenchant
    i) Straight
    ii) Convex
    iii) Concave
    iv) Convergent
    v) Oblique

17) Number of scars predetermining the trenchant (negative or positive)
    i) 0 (cortical)
    ii) 1, 2, 3, 4, >4

18) Direction of scar/scars predetermining the trenchant: 1, 2, 3, 4, 5, 6, 7, 8, indeterminate

For Handaxes

19) Tip shape
    i) Markedly convergent
    ii) Convergent with squared tip
    iii) Convergent with oblique tip
    iv) Convergent with generalized tip
    v) Wide or divergent
    vi) Wide with oblique tip
    vii) Wide convex tip

E. MISCELLANEOUS

1) Artifact type
    i) Flake fragment
    ii) Core fragment
    iii) Angular chunk
    iv) Indeterminate

2) Dimensions
    i) Length
    ii) Breadth
    iii) Thickness
    iv) Weight

REFERENCES

Abbas, R. 2006. *Prehistoric investigations in the Parbati Basin*. Unpublished Ph. D. Dissertation, Pune: Deccan College.

Acharyya, S.K. and P.K. Basu. 1993. Toba ash on the Indian subcontinent and its implications for correlation of late Pleistocene alluvium. *Quaternary Research* 40: 10–19

Agarwal, K.K., I.B. Singh, M. Sharma and S. Sharma. 2002. Extensional tectonic activity in the cratonward parts (peripheral bulge) of the Ganga Plain foreland basin, India. *International Journal of Earth Science* 91: 897–905.

Agarwal, N. 2008. *Microwear analysis of experimental granite tools.* Unpublished Masters Dissertation, Universitat Rovira i Virgili, Tarragona, Spain.

Agustí, J. and D. Lordkipanidze. 2011. How 'African' was the early human dispersal out of Africa? *Quaternary Science Reviews 30* (11): 1338-1342.

Agustí, J., H.A. Blain, G. Cuenca-Bescós, and S. Bailon. 2009. Climate forcing of first hominid dispersal in Western Europe. *Journal of Human Evolution 57*(6): 815-821.

Agustí, J., O. Oms, M. Garcés and J.M. Parés. 1996. Calibration of the late Pliocene–early Pleistocene transition in the continental beds of the Guadix-Baza Basin (southeastern Spain). *Quaternary International* 40: 93–100

Ahler, A.S. 1989. Mass analysis of flaking debris: studying the forest rather than the trees. In *Alternative Approaches to Lithic Analysis*, eds. D.O. Henry and G.H. Odell. Archaeological Papers of the American Anthropological Association 1: 85-118.

Alam, M.S. 2001. *Palaeolithic industries of Bhimbetka, central India: a morphometric study.* Dhaka: Bangla Academy.

Alam, M.S. 1990. *Morphometric study of Palaeolithic industries of Bhimbetka*, Central India, Unpublished Ph. D. Dissertation, University of Pune, Pune.

Alimen, M.H. 1975. Les "isthmes" Hispano-Marocains et Siculo-Tunisiens aux temps Acheuléens. *L'Anthropologie* 79 (3): 399-436.

Alimen, M.H. 1972. Considérations sur l'évolution des hachereaux au Sahara Nord-Occidental. *VIème Congrès Panafricain de Préhistoire*, Dakar 1967, pp. 95-101.

Alimen H., J. Zuate and Y. Zuber. 1978. *L'évolution de l'Acheuléen au Sahara Nord-Occidental (Saoura-Ougarta-Tabelbala).* Paris: Centre National de la Recherche Scientifique.

Alperson-Afil, N. 2008. Continual fire-making by hominins at Gesher Benot Ya'aqov, Israel. *Quaternary Science Reviews 27*(17): 1733-1739.

Amick, D. S. and R. P. Mauldin (eds.). 1989. *Experiments in lithic technology*. British Archaeological Reports International Series 528. Oxford: Archaeopress.

Andrefsky Jr, W. 2005. *Lithics: macroscopic approaches to analysis*. Cambridge: Cambridge University Press.

Andrefsky, Jr. W. 2001. Emerging directions in debitage analysis. In *Lithic Debitage: Context, form, Meaning,* ed. W. Andrefsky, Jr. 1-14. Salt Lake City: University of Utah Press.

IAR: *Indian Archaeology: A Review*. 1953-54 to 2002-2003. New Delhi: The Director General, Archaeological Survey of India (Volumes mentioned in the text).

Archer, W. and D.R. Braun. 2010. Variability in bifacial technology at Elandsfontein, western cape, South Africa: a geometric morphometric approach. *Journal of Archaeological Science* 37: 201-209.

Armand, J. 1985. The emergence of the handaxe tradition in Asia with special reference to India. In *Recent Advances in Indo-Pacific Prehistory*, eds. P. Bellwood and V.N. Misra, 3–8. Delhi: Oxford & IBH Publishing.

Arunkumar. 1989. A metrical analysis of handaxes and cleavers from the Acheulean site at Gangapur, Nasik District, Maharashtra. *Man and Environment* XIII: 49 – 64.

Arunkumar. 1985. *Quaternary studies of the upper Godavari Valley: a study in Environmental Archaeology.* Unpublished Ph.D. Dissertation, University of Poona, Pune.

Arzarello, M. and C. Peretto. 2010. Out of Africa: The first evidence of Italian peninsula occupation. *Quaternary International* 223-224: 65-70.

Arzarello, M., F. Marcolini, G. Pavia, M. Pavia, C. Petronio, M. Petrucci, L. Rook and R. Sardella. 2007. Evidence of earliest human occurrence in Europe: the site of Pirro Nord (southern Italy). *Naturwissenschaften* 94: 107-112.

Asfaw, B., Y. Beyenne, G. Suwa, R.C. Walter and T.D. White. 1992. The earliest Acheulian from Konso Gardula. *Nature* 360: 732-735.

Ashton, N. and S.G. Lewis. 2012. The environmental contexts of early human occupation of northwest Europe: The British Lower Palaeolithic record. *Quaternary International* 271: 50-64

Ashton, N., S.G. Lewis, I. De Groote, S.M. Duffy, M. Bates, R. Bates, P. Hoare, M. Lewis, S.A. Parfitt, S. Peglar, C. Williams and C. Stringer. 2014. Hominin footprints from early Pleistocene deposits at Happisburgh, UK. *PloS one 9* (2): e88329.

Ashton, N. and M. White. 2003. Bifaces and raw materials: flexible flaking in the British early Paleolithic, In *Multiple Approaches to the Study of Bifacial Technology*, eds. M. Soressi and H. Dibble, 109–124. University Museum Monograph 115. Philadelphia: University of Pennsylvania Museum of Archaeology and Anthropology.

Athreya, S. 2007. Was *Homo heidelbergensis* in South Asia? A test using the Narmada fossil from Central India. In *The Evolution and History of Human Populations in South Asia,* eds. M.D. Petraglia and B. Allchin, 137–170. Dordrecht: Springer.

Auden, J.B. 1933. Vindhyan sedimentation in the Son Valley, Mirzapur District. *Memoirs of the Geological Survey of India* 62: 141–250.

Badam, G.L. 1979. *Pleistocene fauna of India*. Pune: Deccan College Postgraduate and Research Institute.

Bajpai, V.N. 1989. Surface and subsurface evidence of neotectonics and the aquifer disposition in central Gangetic alluvial terrain of Kanpur-Unnao region in Uttar Pradesh, India. *Photonirvachak-Journal of the Indian Society of Remote Sensing* 17 (2): 47-53.

Bajpai, V.N. and H. Kumar. 1988. Aquifer disposition and palaeochannel morphology in Kanpur-Unnao region of central Ganga plain, India. In *Geomorphology and Environment*, eds. S. Singh and R.C. Tiwari, 142-152. Allahabad: Geographical Society.

Balout, L. 1967 Procèdes d'analyse et questions de terminologie dans l'étude des ensembles industriels du Paléolithique Inférieur en Afrique du Nord. In *Background to Evolution in Africa*, eds. W.W. Bishop and J.D. Clark, 701–735. Chicago: University of Chicago Press.

Balout, L. and J. Tixier. 1957. L'Acheuléen de Ternifine. In *Congrès préhistorique de France – Compte rendu de la XVème session – Poitiers-Angoulème, 15–22 juillet 1956*: 214–218.

Balout, L., P. Biberson and J. Tixier 1967 L'Acheuléen de Ternifine (Algérie), gisement de l'Atlanthrope. *L'Anthropologie* 71(3-4): 230–237.

Barsky, D. 2009. An overview of some African and Eurasian Oldowan sites: evaluation of hominin cognition levels, technological advancement and adaptive skills. In *Interdisciplinary Approaches to the Oldowan.* eds. E. Hovers and D. Braun, 39-47. Netherlands: Springer.

Barsky, D. and H. de Lumley. 2010. Early European Mode 2 and the stone industry from the Caune de l'Arago archaeostratigraphical levels "P". *Quaternary International 223*: 71-86.

Bamforth, D.B. 1991. Technological organization and hunter-gatherer land-use: a California example. *American Antiquity* 56: 216-234.

Bannerjee, I. 1974. Barrier coastline sedimentation model and the Vindhyan example - Contributions to the Earth and Planetary Sciences Golden Jubilee Volume. *Quarterly Journal of Geological, Mining and Meteorological Society* 46: 101–127.

Bar-Yosef, O. 1994. The Lower Palaeolithic of the Near East. *Journal of World Prehistory* 8: 211-265.

Bar-Yosef, O.and P. Van Peer. 2009. The c*haîne opératoire* approach in Middle Paleolithic archaeology. *Current Anthropology* 50: 103-131.

Bar-Yosef, O., N. Goren-Inbar and I. Gilead. 1993. *The lithic assemblages of Ubeidiya: a Lower Palaeolithic site in the Jordan Valley*. Qedem 34. Jerusalem: Institute of Archaeology, Hebrew University of Jerusalem.

Baskaran, M., A.R. Marathe, S.N. Rajaguru and B.L.K. Somayajulu. 1986. Geochronology of Palaeolithic cultures in the Hiran Valley, Saurashtra, India. *Journal of Archaeological Science* 13: 505–514.

Basu, A.K. 1986. Geology of parts of the Bundelkhand Granite Massif, central India. *Records of the Geological Survey of India* 117 (2): 61-124.

Benito del Rey, L. 1986. De cómo estudiamos un hendidor, útil del Paleolítico inferior y medio: ficha y comentarios. *Studia Zamorensia (Historica)* VII: 221-254.

Benito del Rey, L. 1972-73. Los hendidores de la capa musteriense 'Alfa' de la Cueva del Castillo (Santander)- Estudio tipológico. *Zephyrus* XXIII-XXIV: 269-290.

Berger, G.W., A. Pérez-González, E. Carbonell, J.L. Arsuaga, J.M. Bermúdez de Castro and T.L. Ku. 2008. Luminescence chronology of cave sediments at the Atapuerca paleoanthropological site, Spain. *Journal of Human Evolution* 55: 300–311

Bergman, C. A., and M.B. Roberts. 1988. Flaking technology at the Acheulean site of Boxgrove (West Sussex, England). *Revue archéologique de Picardie* 1(1): 105-113.

Bermúdez de Castro, J.M., M. Martinón-Torres, A. Gómez-Robles, L. Prado-Simón, L. Martín-Francés, M. Lapresa, A. Olejniczak and E. Carbonell. 2011. Early Pleistocene human mandible from Sima del Elefante (TE) cave site in Sierra de Atapuerca (Spain): a comparative morphological study. *Journal of Human Evolution* 61 (1): 12–25

Bermúdez de Castro, J.M., M. Martinón-Torres, A. Gómez Robles, L. Prado and E. Carbonell. 2010. New human evidence of the early Pleistocene settlement of Europe, from Sima del Elefante site (Sierra de Atapuerca, Burgos, Spain). *Quaternary International* 223–224: 431–433

Beyenne, Y., Y. Zeleke and K. Uzawa. 1997. The Acheulean at Konso-Gardula: Results from Locality GA4-A2. In *Ethiopia in Broader Perspective: Papers of the XIIIth International Conference of Ethiopian Studies, Kyoto* eds. K. Fukui, E. Kurimoto and M. Shigeta. Kyoto: Book Sellers.

Beyenne, Y., S. Katoh, G. WoldeGabriel, W.K. Hart, K. Uto, M. Sudo, M. Kondo, M. Hyodo, P.R. Renne, G. Suwa, and B. Asfaw. 2013. The characteristics and chronology of the earliest Acheulean at Konso, Ethiopia. *Proceedings of the National Academy of Sciences* **110**(5), 1584-1591.

Bianchini, G. 1973. Gli "hachereaux" nei giacimenti paleolitici della Sicilia Sud Occidentale - Nota preliminare, In *Atti della XV riunione scientifica dell'Istituto italiano di Preistoria e Protoistoria,* Verona-Trento, 27-29 ottobre 1972: 11-25.

Biberson, P. 1961. *Le Paléolithique inférieur du Maroc Atlantique*. Rabat: Service des Antiquités du Maroc.

Biberson, P. 1954. Le hachereau dans l'Acheuléen du Maroc Atlantique. *Libyca* T. II: 39-61.

Binford, L.R. 2001. *Constructing frames of reference: an analytical method for archaeological theory building using ethnographic and environmental data sets.* Berkeley: University of California Press.

Binford, L.R. 1983. *In pursuit of the past: decoding the archaeological record*. London: Thames and Hudson.

Binford, L.R. 1980. Willow smoke and dogs' tails: hunter-gatherer settlement systems and archaeological site formation. *American Antiquity* 45:4-20.

Bischoff, J.L., R.W. Williams, R.J. Rosenbauer, A. Aramburu, J.L. Arsuaga, N. García and G. Cuenca-Bescós. 2007. High-resolution U-series dates from the Sima de los Huesos hominids yields 600 ± 66 kyrs: implications for the evolution of the early Neanderthal lineage. *Journal of Archaeological Science* 34 (5): 763–770

Bleed, P. 2001. Trees or chains, links or branches: conceptual alternatives for consideration of stone tool production and other sequential activities. *Journal of Archaeological Method and Theory* 8(1): 101-128.

Boëda, E., C. Griggo, Y. Hou, W.B. Huang and M. Rasse. 2011. Données stratigraphiques, archéologiques et insertion chronologique de la séquence de Longgupo {Stratigraphy, archaeology and chronological insertion of the Longgupo sequence}. *L'anthropologie* 115: 40-77.

Boëda, E., J.M. Geneste and L. Meignen, 1990. Identification de chaînes opératoires lithiques du Paléolithique ancien et moyen, *Paléo: Revue d'Archeologie Prehistorique* 2: 43-80.

Bordes, F. 1961. *Typologie du Paléolithique ancien et moyen*. Paris: CNRS.

Bordes, F. 1950. Principes d'une méthode d'étude des techniques de débitage et de la typologie du Paléolithique ancien et moyen. *L'anthropologie*, *54*(1-2), 19-34.

Brace, W.F. 1961. *Dependence of fracture strength of rocks on grain size: Proceedings of the fourth symposium on rock mechanism*, University Park, Pennsylvania: 99-103.

Bradbury, A.P. and P. J. Carr. 1999. Examining stage and continuum models of flake debris analysis: an experimental approach. *Journal of Archaeological Science* 26:105–116

Bradley, B. and C.G. Sampson. 1986. Analysis by replication of two Acheulean artefact assemblages from Caddington, England. In *Stone Age Prehistory: Studies in Memory of Charles McBurney*, eds. G.N. Bailey and P. Callow, 29-46. Cambridge: Cambridge University Press.

Bretzke, K. and N.J. Conard. 2012. Evaluating morphological variability in lithic assemblages using 3D models of stone artifacts. *Journal of Archaeological Science* 39: 3741-3749.

Buchanan, B. 2006. An analysis of Folsom projectile point resharpening using quantitative comparisons of form and allometry. *Journal of Archaeological Science* 33, 185-199.

Buchanan, B. and C. Mark. 2010. A geometric morphometric-based assessment of blade shape differences among Paleoindian projectile point types from western North America. *Journal of Archaeological Science* 37, 350-359.

Burroni, D., R.E. Donahue and A.M. Pollard. 2002. The surface alteration features of flint artifacts as a record of environmental processes. *Journal of Archaeological Science* 29: 1277–1287.

Butt, C.M. 1985. Granite weathering and silcrete formation on the Yilgarn Block, western Australia. *Australian Journal of Earth Sciences* 32: 415-33

Cachel, S. and J.W.K. Harris. 1998. The lifeways of *Homo erectus*, In *Early Human Behaviour in Global Context,* eds. M.D. Petraglia and R. Korisettar. London: Routledge.

Cahen, D. and P. Martin. 1972. *Classification formelle automatique et industries lithiques:* i*nterprétation des hachereaux de la Kamoa*. Tervuren: Musée Royal de l'Afrique Centrale.

Callahan, E. 1979. The basics of biface knapping in the eastern fluted point tradition: a manual for flintknappers and lithic analysts. *Archaeology of Eastern North America* 7, 1-172.

Cameron, D., R. Patnaik and A. Sahni. 2004. The phylogenetic significance of the Middle Pleistocene Narmada hominin. *International Journal of Osteoarchaeology* 14: 419–447.

Carbonell, E., J.M., Bermudez De Castro, J.M., Pares, A. Perez-Gonzalez, G. Cuenca-Bescos, A. Ollé, M. Mosquera, R. Huguet, J. Van Der Made, A. Rosas, R. Sala, J. Vallverdu, N. Garcia, D. E. Granger, M. Martinon-Torres, X. P. Rodriguez, G. M. Stock, J.M. Verges, E. Allue, F. Burjachs, I. Caceres, A. Canals, A. Benito, C. Diez, M. Lozano, A. Mateos, M. Navazo, J. Rodriguez, J. Rosell and J.L. Arsuaga. 2008. The first hominin of Europe. *Nature* 452: 465-469.

Carbonell, E., J.M. Bermúdez de Castro, J.L. Arsuaga, J.C. Díez, A. Rosas, G. Cuenca-Bescós, R. Sala, M. Mosquera and X.P. Rodríguez. 1995. Lower Pleistocene hominids and artifacts from Atapuerca-TD6 (Spain). *Science* 269 (1995), pp. 826–830

Carr, P.J. and A.P. Bradbury. 2001. Flake debris analysis, levels of production, and the organisation of technology. In *Lithic Debitage*: C*ontext, Form and Meaning,* ed. W. Andrefsky Jr., 126-146. Salt Lake City: University of Utah Press.

Champault, B. 1966. *L'Acheuléen évolué au Sahara Occidental – Notes sur l'homme au Paléolithique Ancien*. Unpublished Ph. D. Dissertation, Faculté de Lettres, Paris. 2 vol., 1068 p.

Champault, B. 1953. L'industrie de Tachenghit. In *A.F.A.S., 70ème Congrès de l'Association Française pour l'Avancement des Sciences III* : 123–130.

Chauhan, P.R. 2010a. The Indian subcontinent and 'Out of Africa I', In *Out of Africa I: The First Hominins of Eurasia*, eds. J. Fleagle, J. Shea and R. Leakey, 145-164. Kluwer-Academic Press, Paleobiology and Paleoanthropology Series.

Chauhan, P.R. 2010b. Comment on 'Lower and Early Middle Pleistocene Acheulian in the Indian subcontinent' by Gaillard *et al.* (2009) (Quaternary International). *Quaternary International* 223-224: 248-259.

Chauhan, P.R. 2009. The Lower Paleolithic of the Indian subcontinent. *Evolutionary Anthropology* 18: 62-78.

Chauhan, P.R. 2008. Soanian lithic occurrences and raw material exploitation in the Siwalik frontal zone, northern India: a geoarchaeological perspective. *Journal of Human Evolution* 54 (5): 591-614.

Chauhan, P.R. 2007. Soanian cores and core-tools from Toka, northern India: towards a new typo-technological organization. *Journal of Anthropological Archaeology* 26: 412-44.

Chauhan, P.R. 2004. A review of the early Acheulian evidence from South Asia. *Assemblage - The Sheffield Graduate Journal of Archaeology* 8: http://www.shef.ac.uk/assem/ issue8/chauhan.html.

Chavaillon, J. 1965. Les pièces à tranchant terminal - essai de classification, *Revista de Faculdade de Letras de Lisboa* III (9) : 3-11.

Chavaillon, J. and M. Piperno (eds). 2004. *Studies on the Early Paleolithic site of Melka Kunture, Ethiopia*. Florence: Istituto Italiano di Preistoria e Protostoria.

Chazan, M., H. Ron, A. Matmon, N. Porat, P. Goldberg, R. Yates, M. Avery, A. Sumner and L.K. Horwitz. 2008. Radiometric dating of the Earlier Stone Age sequence in excavation I at Wonderwerk cave, South Africa: preliminary results. *Journal of Human Evolution* 55: 1-11.

Chen, T.M., Q. Chen, Q. Yang and Y.Q. Hu. 2001. The problems in ESR dating of tooth enamel of early Pleistocene and the age of Longgupo hominid, Wushan, China. *Quaternary Science Reviews* 20: 1041–1045.

Clark, J.D. 1994. The Acheulian industrial complex in Africa and elsewhere. In *Integrative Paths to the Past: Paleoanthropological Advances in Honor of F. Clark Howell*, eds. R.S. Corruccini and R.L. Ciochon, 451-469, New Jersey: Prentice Hall.

Clark, J.D. 2001. Variability in primary and secondary technologies of the Later Acheulian in Africa, In *A Very Remote Period Indeed: Papers on the Palaeolithic Presented to Derek Roe,* eds. S. Milliken and J. Cook. Oxford: Oxbow books.

Clark, J.D. and M.R. Kleindienst. 2001. The Stone Age cultural sequence: terminology, typology and raw material. In *Kalambo Falls Prehistoric Site,* vol. III, ed. J.D. Clark, 34–65. Cambridge: Cambridge University Press.

Clark, J.D. and M.R. Kleindienst. 1974. The Stone Age cultural sequence: terminology, typology and raw material. In *Kalambo Falls Prehistoric Site*, ed. J.D. Clark, 71–106. Vol. II. Cambridge: Cambridge University Press.

Clarke, J.J. 1966. Morphometry from map, *Essays in Geomorphology,* 235-274. New York: Elsevier Publishing Company.

Cole, G.H. and M.R. Kleindienst. 1974. Further reflections on the Isimila Acheulian. *Quaternary Research* 4: 346–355.

Corvinus, G. 2004 *Homo erectus* in East and Southeast Asia, and the questions of the age of the species and its association with stone artifacts, with special attention to handaxe-like tools. *Quaternary International* 117: 141-151.

Corvinus, G. 1983. *A survey of the Pravara River system in western Maharashtra, India. Vol 2: The excavation of the Acheulian site of Chirki-on-Pravara, India.* Tubingen: Institut für Urgeschichte der Universität Tübingen.

Costa, A.G., 2010. A geometric morphometric assessment of plan shape in bone and stone Acheulean bifaces from the Middle Pleistocene site of Castel di Guido, Italy, In *New Perspectives on Old Stones. Analytical Approaches to Paleolithic Technologies*, eds. S.J. Lycett and P.R. Chauhan, 23-42. New: York: Springer.

Couzens, R.A. 2012. *An analysis of the symmetry of large cutting tools within the South African Acheulean.* Unpublished Masters Dissertation, University of the Witwatersrand, Johannesburg. wiredspace.wits.ac.za/jspui/handle/10539/11896

Crabtree, D. E. and B. R. Butler. 1964. Notes on experiments on flint knapping. 1. Heat treatment of silica materials. *Tebiwa* 7:1–6.

Cranshaw, S. 1983. *Handaxes and cleavers: selected English Acheulian industries*. British Archaeological Reports British Series 113, Oxford.

Crochet, J.Y., J.L. Welcomme, J. Ivorra, G. Ruffet, N. Boulbes, R. Capdevila, J. Claude, C. Firmat, G. Métais, J. Michaux and M. Pickford. 2009. Une nouvelle faune de vertébrés continentaux, associée à des artefacts dans le Pléistocène inférieur de l'Hérault (Sud de la France), vers 1,57 Ma. *Comptes Rendus Palevol* 8 (8): 725–736

Crompton, R.H. and J.A.J. Gowlett. 1993. Allometry and multidimensional form in Lower Palaeolithic bifaces from Kilombe. *Journal of Human Evolution* 25: 175–199.

Dag, D. and N. Goren-Inbar. 2001. An actualistic study of dorsally plain flakes: a technological note. *Lithic Technology* 26(2): 105– 117.

Dauvois, M. 1981. de la simultanéité des concepts Kombewa et Levallois dans l'Acheuléen du Maghreb et du Sahara Nord-Occidental. In *Préhistoire Africaine – Mélanges offerts au doyen Lionel Balout*, eds. C. Roubet, H.J. Hugot and G. Souville, 313–321. Paris: Ed. ADPF.

Davidson, I. 2002. The finished artefact fallacy: Acheulean handaxes and language origins. In *The Transition to Language*, ed. A. Wray, 180–203. Oxford: Oxford University Press.

de la Torre, I. 2011. The Early Stone Age lithic assemblages of Gadeb (Ethiopia) and the Developed Oldowan/Early Acheulean in East Africa. *Journal of Human Evolution* 60: 768-812.

de la Torre I, R. Mora and J. Martınez-Moreno. 2008. The early Acheulean in Peninj (Lake Natron, Tanzania). *Journal of Anthropological Archaeology* 27: 244-64.

de la Torre I and R. Mora. 2005. *Technological strategies in the Lower Pleistocene at Olduvai Beds I & II.* Liege: ERAUL 112.

de la Torre, I., R. Mora, M. Dominguez-Rodrigo, L. de Luque and L. Alcala. 2003. The Oldowan industry of Peninj and its bearing on the reconstruction of the technological skills of Lower Pleistocene hominids. *Journal of Human Evolution* 44: 203-224.

de Lumley, H. and A. Sonakia. 1985. Contexte stratigraphique et archéologique de l'homme de la Narmada, Hathnora, Madhya Pradesh, Inde. *L' Anthropologie* 89: 3–12.

de Lumley, H., D. Lordkipanidze, G. Feraud, T. Garcia, C. Perrenoude, C. Falgueres, J. Gagnepain, T. Saos and P. Voinchet. 2002. Datation par la methode 40A/39A de la couche de cendres volcaniques (couche VI) de Dmanissi (Georgie) qui a livre des restes d'hominides fossiles de 1.81 Ma. *Comptes Rendu Palevol* 1: 181-189.

Deacon, H.J. and J. Deacon. 1999. *Human beginning in South Africa*. Cape Town: David Philip Publishers.

Debénath, A. and H.L. Dibble. 1994. *Handbook of Paleolithic typology Vol. 1: Lower and Middle Paleolithic in Europe.* Philadelphia: University Museum, University of Pennsylvania.

Deino, A.L., M. Domínguez-Rodrigo and L. Luque, 2006. ^{40}Ar/^{39}Ar dating of the Pleistocene Peninj group, Lake Natron, Tanzania. *EOS, Transactions, American Geophysical Union* 87:52.

Dennell, R.W. 2011. An earlier Acheulian arrival in South Asia. *Science* 331: 1532-1533.

Dennell, R.W. 2004a. *Early hominin landscapes in northern Pakistan: Investigations in the Pabbi Hills* (with contributions from M. Anwar, M. Beech, R. Coard, L. Hurcombe, H. Rendell, and A. Turner). British Archaeological Reports International Series 1265. Oxford: Archaeopress.

Dennel, R.W. 2004b. Hominid dispersals and Asian biogeography during the Lower and Early Middle Pleistocene, c. 2.0-0.5 Mya. *Asian Perspectives* 43: 205-226.

Dennell, R.W. 2003. Dispersal and colonisation, long and short chronologies: how continuous is the Early Pleistocene record for hominids outside East Africa? *Journal of Human Evolution* 45: 421-440.

Dennell, R.W. 1995. The Early Stone Age of Pakistan: A methodological review. *Man and Environment* 20: 21–28.

Dennell, R.W. and W. Roebroeks. 2005. Out of Africa: An Asian perspective on early human dispersal from Africa. *Nature* 438: 1099-1104.

Dennell, R.W., H.M. Rendell and E. Hailwood. l988a. Early tool-making in Asia: two million year old artefacts in Pakistan. *Antiquity* 62: 98-106.

Dennell, R.W., H.N. Rendell and E. Hailwood 1988b. Late Pliocene artefacts from Nothern Pakistan. *Current Anthropology* 29: 495-498.

Dennell, R.W., R. Coard and A. Turner. 2006. The biostratigraphy and magnetic polarity zonation of the Pabbi Hills, northern Pakistan: An Upper Siwalik (Pinjor Stage) Upper Pliocene-Lower Pleistocene fluvial sequence. *Palaeogeography, Palaeoclimatology, Palaeoecology* 234: 168-185.

Deo, S.G., S. Mishra, and S.N. Rajaguru. 2007a. Palaeoclimatic studies at Deccan College 1940-2005: a geoarchaeological approach. *Bulletin of the Deccan College Postgraduate and Research Institute* 64/65: 209-228.

Deo, S.G., S. Mishra, S.N. Rajaguru and S. Ghate. 2007b. Antiquity of Acheulian culture in upland Maharasthra: a geoarchaeological Approach. In *Genome and People of India*, ed. A.R. Sankhyan, 292–308. Calcutta: Concept Publishers.

Despriée, J., P. Voinchet, H. Tissoux, J.J. Bahain, C. Falguères, G. Courcimault, J. Dépont, M.H. Moncel, S. Robin, M. Arzarello, R. Sala, L. Marquer, E. Messager, S. Puaud and S. Abdessadok. 2011. Lower and Middle Pleistocene human settlements recorded in fluvial deposits of the Middle Loire River Basin, Centre Region, France. *Quaternary Science Reviews* 30: 1474-1485.

Despriée, J., P. Voinchet, H. Tissoux, M.-H. Moncel, M. Arzarello, S. Robin, J.-J. Bahain, C. Falguères, G. Courcimault, J. Dépont, R. Gageonnet, L. Marquer, E. Messager, S. Abdessadok and S. Puaud. 2010. Lower and Middle Pleistocene human settlements in the Middle Loire River Basin, Centre Region, France. *Quaternary International* 223-224: 345–359.

Dewey, J.F., R.M. Shackleton, C. Chenfa and S. Yiyin. 1988. The tectonic evolution of the Tibetan Plateau. *Philosophical Transactions of the Royal Society*, *London* 327: 379–413.

Dewey, J.F., S. Cande and W.C. Pitman. 1989. Tectonic evolution of the India/Eurasia collision zone (Evolution Tectonique de la Zone de Collision Inde/Eurasie). *Eclogae Geologicae Helvetiae* 82 (3): 717-734.

Dibble, H. L. and S. McPherron. 2006. The missing Mousterian. *Current Anthropology* 47: 777–803.

Dibble, H.L., U.A. Schurmans, R.P. Iovita and M.V. McLaughlin. 2005. The measurement and interpretation of cortex in lithic assemblages. *American Antiquity* 70 (3): 545-560.

Diez-Martin, F. and M.I. Eren. 2012. The Early Acheulean in Africa: past paradigms, current ideas, and future directions. In *Stone Tools and Fossil Bones: Debates in the Archaeology of Human Origins*. ed. M. Dominguez-Rodrigo, 310-358. Cambridge: Cambridge University Press.

Diez-Martín, F., P. Sánchez Yustos, D. Gómez de la Rúa, J.A. Gómez González, L. de Luque, L. and R. Barba. 2014a. Early Acheulean technology at ES2-Lepolosi (ancient MHS-Bayasi) in Peninj (Lake Natron, Tanzania). *Quaternary International 322:* 209-236.

Diez-Martín, F., P. Sánchez Yustos, J.A. Gómez González, L. Luque, D. Gómez de la Rúa, and M. Domínguez-Rodrigo. 2014b. Reassessment of the Early Acheulean at EN1-Noolchalai (Ancient RHS-Mugulud) in Peninj (Lake Natron, Tanzania). *Quaternary International 322:* 237-263.

Diez-Martín, F., F. Cuartero, P.S. Yustos, J. Baena, M. Domínguez-Rodrigo, and D. Rubio. 2012. Testing cognitive skills in Early Pleistocene hominins: An analysis of the concepts of hierarchization and predetermination in the lithic assemblages of Type Section (Peninj, Tanzania). In *Stone Tools and Fossil Bones: Debates in the Archaeology of Human Origins*. ed. M. Dominguez-Rodrigo, 245-309. Cambridge: Cambridge University Press.

Domínguez-Rodrigo, M., I. Torre, L. Luque, L. Alcalá, J. Serrallonga and V. Medina. 2002. The ST site complex at Peninj, West Lake Natron, Tanzania: implications for early hominid behavioural models. *Journal of Archaeological Science* 29: 639–665.

Dominguez-Rodrigo, M., J. Serrallonga, J. Juan-Tresserras, L. Alcalá and L. Luque. 2001. Woodworking activities by early humans: A plant residue analysis on Acheulian stone tools from Peninj (Tanzania). *Journal of Human Evolution* 40: 289–299.

Domínguez-Rodrigo, M., L. Alcalá and L. Luque (eds.). 2009. *Peninj - a research project on the archaeology of human origins (1995-2005).* Cambridge: Oxbow.

Dong, W. 2006. Récentes découvertes de restes d'hominidés fossiles en Chine du Sud. (Recent discoveries of hominid fossils in southern China). *L'anthropologie 110:* 241-257.

Dubey, V.S. and S. Merh. 1991. Diamondiferous plug of Majhgawan in Central India. *Quarterly Journal of Geological, Mining and Meteorological Society, India* 21(1): 1-5.

Duval, M., D. Moreno, Q. Shao, P. Voinchet, C. Falguères, J.J. Bahain, J. García and K. Martínez. 2011. Datación por ESR del yacimiento arqueológico del Pleistoceno inferior de Vallparadís (Terrassa, Cataluña, España) *Trabajos de Prehistoria* 68: 7–24.

Eren, M.I. and S.J. Lycett. 2012. Why Levallois? A morphometric comparison of experimental 'preferential' Levallois flake versus debitage flakes. *PLoS ONE* 7: e29273.

Eren, M. I., C.I. Roos, B. Story, N. von Cramon-Taubadel and S.J. Lycett. 2014. The role of raw material differences in stone tool shape variation: an experimental assessment. *Journal of Archaeological Science*.49: 472-487

Falguères, C., J.J. Bahain, Y. Yokoyama, J.L. Bischoff, J.L. Arsuaga, J.M. Bermúdez de Castro, E. Carbonell and J.M. Dolo. 2001. Datation par RPE et U-Th des sites Pléistocènes d'Atapuerca: Sima de los Huesos, Trinchera Dolina et Trinchera Galería: bilan géochronologique. *L'Anthropologie* 105 (1): 71–81

Falguères, C., J.J. Bahain, Y. Yokoyama, J.L. Arsuaga, J.M. Bermúdez de Castro, E. Carbonell, J.L. Bischoff and J.M. Dolo. 1999. Earliest humans in Europe: the age of TD6 Gran Dolina, Atapuerca, Spain. *Journal of Human Evolution* 37 (3/4): 343–352

Farooqui, A. and B. Sekhar. 2011. Climate change and vegetation succession in Lalitpur area, Uttar Pradesh (India) during late Holocene. *Tropical Ecology* 52(1): 69-77.

Feblot-Augustins, J. 1997. *La circulation des matières premières au Paléolithique: synthèse des données, perspectives comportementales.* Études et Recherches Archéologiques de l'Université de Liège, N° 75, Liège: Universite de Liège, 2 Volumes, 275 p.

Fermor, L.L. and C.S. Fox, 1916. The Deccan trap flows of Linga, Chhindwara District, Central Provinces. *Records of the Geological Survey of India* XLVII: 88-110.

Gabunia, L. and A. Vekua, 1995. A Plio-Pleistocene hominid from Dmanisi, East Georgia, Caucasus. *Nature* 373: 509-512.

Gabunia, L., A. Vekua, D. Lordkipanidze, C.C.I. Swisher, C.R. Ferring, A. Justus, M. Nioradze, M. Tvalchrelidze, S.C. Anton, G. Rosinski, O. Joris, H. de Lumley, G.M. Majsuradze and A. Mouskhelishvili. 2000. Earliest Pleistocene hominid cranial remains from Dmanisi, Republic of Georgia: taxonomy, geological setting, *Science* 288: 1019-1025.

Gaillard, C. 2006. Les premiers peuplements d'Asie du Sud: vestiges culturels. *Comptes Rendus Palevol* 5: 359–369.

Gaillard, C. 1996. Processing sequences in the Indian Lower Palaeolithic: examples from the Acheulian and the Soanian. *Bulletin of the Indo-Pacific Prehistory Association (Chiang Mai Papers, vol. 1),* 14: 57-67.

Gaillard, C. 1995. An Early Soan assemblage from the Siwaliks: a comparison of processessing sequences between this assemblage and an Acheulian Assemblage from Rajasthan. In *Quaternary Environments and Geoarchaeology of India,* eds. S. Wadia, R. Korisettar and V.S. Kale. Bangalore: Memoir of the Geological Society of India.

Gaillard, C. and S. Mishra. 2001. The Lower Palaeolithic in South Asia, In *Origin of Settlements and Chronology of the Paleolithic Cultures in SE Asia: Colloque International de la Fondation Singer Polignac*, eds. F. Semah, C. Falgueres, D. Grimaund-Herve, and A.M. Semah, 73-92. Semenanjuang and Paris.

Gaillard, C. and M.L.K. Murty. 1988. Typo-technological comparison of two Acheulian assemblages at Renigunta, south India. *Man and Environment* 12: 125-133.

Gaillard, C., S. Mishra, M. Singh, S. G. Deo, and R. Abbas. 2010. Lower and Early Middle Pleistocene Acheulean in the Indian subcontinent. *Quaternary International* 223-224: 234-241.

Gaillard, C., M. Singh, K.K. Rishi and V. Bhardwaj. 2010. Atbarapur (Hoshiarpur district, Punjab), the Acheulian of the Siwalik Range within the South Asian context. *Comptes Rendus Palevol* 9: 237-243.

Gaillard, C., M. Singh, K.K. Rishi. 2008. Technological analysis of the Acheulian assemblage from Atbarapur in the Siwalik Range (Hoshiarpur District, Punjab). *Man and Environment* 33, 1-14.

Gaillard, C., V.N. Misra and M.L.K. Murty. 1990. Comparative study of three series of handaxes: one from Rajasthan and two from Andhra Pradesh. *Bulletin of the Deccan College Research Institute* 49: 137-144.

Gaillard, C., D.R. Raju, V.N. Misra and S.N. Rajaguru. 1986. Handaxe assemblages from Didwana Region, Thar Desert, India: a metrical analysis. *Proceedings of the Prehistoric Society* 52: 189-214.

Gallotti, R. 2013. An older origin for the Acheulean at Melka Kunture (Upper Awash, Ethiopia): techno-economic behaviours at Garba IVD. *Journal of Human Evolution 65*(5): 594-620.

Gallotti, R., J.P. Raynal, D. Geraads, and M. Mussi. 2014. Garba XIII (Melka Kunture, Upper Awash, Ethiopia): A new Acheulean site of the late Lower Pleistocene. *Quaternary International*. In Press.

http://dx.doi.org/10.1016/j.quaint.2014.04.039.

Gao, X., Q. Wei, C. Shen and S. Keates, 2005. New light on the earliest hominid occupation in East Asia. *Current Anthropology (Suppl.)* 46: 115–120.

Garcia, J., K. Martinez, and E. Carbonell, 2011. Continuity of the first human occupation in the Iberian Peninsula: closing the archaeological gap. *Comptes Rendus Palevol* 10: 279-284.

Garde, R.J. 2006. *River Morphology*, New Age International (P) Limited, Publishers (formerly Wiley Eastern Limited), 479 pp.

Géraads, D., J.J. Jaeger, H. Tong, S. Sen and P. Toubeau. 1986. The Pleistocene hominid site of Ternifine, Algeria: new results on the environment, age, and human industries. *Quaternary Research 25*(3): 380-386.

Ghosh, D. 1974. The nature of the Narmada-Son lineament. In *International Seminar on Tectonics and Metallogeny of Southeast Asia and Far East*, ed. Murthy, Geological Survey of India, Calcutta. p. 45.

Ghosh, R. and G. Ray. 1964. A technological study of the cleavers of Mayurbhanj. *Man in India* 44**:** 50-74.

Gibbon, R.J., D.E. Granger, K. Kuman and T.C. Partridge. 2009. Early Acheulean technology in the Rietputs Formation, South Africa, dated with cosmogenic nuclides. *Journal of Human Evolution* 56: 152-160.

Gibert, J., L. Gibert and E. Maestro. 1998. Two 'Oldowan' Assemblages in the Plio-Pleistocene deposits of the Orce region, southeast Spain. *Antiquity* 72: 17-25.

Gibert, J., L. Gibert, C. Ferrandez-Canadell, A. Iglesias and F. Gonzalez. 2001. Venta Micena, Barranco Leon-5 and Fuentenueva-3: three archaeological sites in the Early Pleistocene deposits of Orce, southeast Spain. In *A Very Remote Period Indeed: Papers on the Palaeolithic Presented to Derek Roe,* eds. S. Milliken and J. Cook. Oxford: Oxbow Books.

Gibling, M.R., S.K. Tandon, R. Sinha, and M. Jain. 2005. Discontinuity-bounded alluvial sequences of the southern Gangetic Plains, India: aggradation and degradation in response to monsoonal strength. *Journal of Sedimentary Research* 75: 369-385.

Gilead, D. 1973. Cleavers in Early Paleolithic industries in Israel. *Paléorient* 1: 73–86.

Goodwin, A.J.H. 1953. *Method in Prehistory* (2nd ed). Claremont, Cape Town: The South African Archaeological Society.

Goodwin, A.J.H. 1934. Some developments in technique during the Earlier Stone Age. *Transactions of the Royal Society of South Africa* 21(2): 109–123.

Goodwin, A.J.H. and C. van Riet Lowe. 1929. *The Stone Age cultures of South Africa. Annals of the South African Museum* XXVII. Edinburgh: Neill and Co.

Goodwin, A.J.H. 1929. The Victoria West industry. *Annals of the South African Museum* 27:53–69.

Goren-Inbar, N. and I. Saragusti. 1996. An Acheulian biface assemblage from Gesher Benot Ya'aqov, Israel: indications of African affinities. *Journal of Field Archaeology* 23: 15–30.

Goren-Inbar, N., I. Zohar and D. Ben-Ami. 1991. A new look at old cleavers - Gesher Benot Ya'aqov. *Journal of the Israel Prehistoric Society* 24**:** 7-33.

Goren-Inbar, N., L. Grosman and G. Sharon. 2011. The technology and significance of the Acheulian giant cores of Gesher Benot Ya'aqov, Israel. *Journal of Archaeological Science* 38: 1901-1917.

Goren-Inbar, N., N. Alperson-Afil, M.E. Kislev, O. Simchoni, Y. Melamed, A. Ben-Nun and E. Werker. 2004. Evidence of hominin control of fire at Gesher Benot Ya'aqov, Israel. *Science 304*(5671): 725-727.

Goren-Inbar, N., S. Belitzky, Y. Goren, R. Rabinovitch and I. Saragusti. 1992. Gesher Benot Ya'aqov – the 'Bar': an Acheulian assemblage. *Geoarchaeology* 7(1): 27–40.

Gowlett, J.A.J. 2006. The elements of design form in Acheulian bifaces: Modes, modalities, rules and language. In *Axe Age: Acheulian Tool-making from Quarry to Discard*, eds. N. Goren-Inbar and G. Sharon, 203–222. London: Equinox.

Gowlett, J.A.J. and R.H. Crompton, 1994. Kariandusi: Acheulean morphology and the question of allometry. *The African Archaeological Review* 12: 3-42.

Gowlett, J.A.J., R.H. Crompton and L. Yu. 2001. Allometric comparisons between Acheulean and Sangoan large cutting tools at Kalambo Falls. In *Kalambo Falls Prehistoric Site, Vol. 3: the Earlier Cultures: Middle and Earlier Stone Age*, ed. J.D. Clark, 612–619. Cambridge: Cambridge University Press.

Gregory, K.J. and D.E. Walling. 1973. *Drainage basin form and process: a geomorphological approach*. London: Edward Arnold (Publishers) Limited, 458 pp.

Grosman, L., Y. Goldsmith, and U. Smilansky. 2011. Morphological analysis of Nahal Zihor handaxes: a chronological perspective. *PaleoAnthropology* 203-215.

Grosman, L., O. Smikt and O. Smilansky. 2008. On the application of 3-D scanning technology for the documentation and typology of lithic artifacts. *Journal of Archaeological Science* 35: 3101–3110.

Hajiabdolmajid, V. and P. Kaiser. 2003. Brittleness of rock and stability assessment in hard rock tunneling. *Tunnelling and Underground Space Technology* 18: 35-48.

Haldar, D. and D.B. Ghosh 1981. A discussion on the uncertainties in the dating of the Vindhyan and Bijawar rocks. In *Proceedings of the Symposium on Vindhyans of Central India*, Anonymous. Miscellaneous Publication – Geological Survey of India. 50: 223-228.

Haslam, M., R.G. Roberts, C. Shipton, J.N. Pal, J.L. Fenwick, P. Ditchfield, N. Boivin, A.K. Dubey, M.C. Gupta and M. Petraglia. 2011. Late Acheulean hominins at the Marine Isotope Stage 6/5e transition in north-central India. *Quaternary Research* 75: 670-682.

Hay, R.L. 1992. Potassium-Argon dating of Bed I, Olduvai Gorge, 1961-1972. *Quaternary International* 13: 31-36.

Hay, R.L. 1976. *Geology of the Olduvai Gorge: a study of sedimentation in a semi-arid basin.* Berkeley: University of California Press.

Haynes, C.V., T.A. Maxwell, A.E. Hawary, K.A. Nicoll and S. Stokes. 1997. An Acheulian site near Bir Kiseiba in the Darb el Arba'in desert, Egypt. *Geoarchaeology: An International Journal* 12(8): 819–832.

Haynes, C.V.J., T.A. Maxwell, D.L. Johanson and A. Kilani. 2001. Research note: Acheulian sites near Bir Kiseiba in the Darb el Arba'in desert, Egypt: New Data. *Geoarchaeology* 16(1): 143–150.

Heron, A.M.H. 1953. Geology of Central Rajputana. *Memoir of the Geological Survey of India.*

Herries, A.I.R. 2011. A chronological perspective on the Acheulian and its transition to the Middle Stone Age in Southern Africa: the question of the Fauresmith. *International Journal of Evolutionary Biology* 2011: 1-25.

Horn, P., D. Mzuller-Sohnius, D. Storzek and L. Zoller. 1993. K-Ar, fission-track, and thermoluminescence ages of Quaternary volcanic tuffs and their bearing on

Acheulian artifacts from Bori, Kukdi Valley, Pune District, India. *Zeitschrift der Deutschen Geologischen Gesellschaft* 144: 326-329.

Horton, R.E. 1945. Erosional development of streams and their drainage basin: hydrological approach to quantitative morphology. *Geological Society of America Bulletin* 56: 275–370.

Hosfield, R. 2011. The British Lower Palaeolithic of the early Middle Pleistocene. *Quaternary Science Reviews* 30 (11–12): 1486-1510.

Hou, Y., R. Potts, B. Yuan, Z. Guo, A. Deino, W. Wang. J. Clark, G. Xie and X. Huang 2000. Mid Pleistocene Acheulean-like stone technology of the Bose Basin, south China. *Science* 287: 1622-1626.

Hou, Y.M. and L.X. Zhao. 2010a. New archeological evidence for the earliest hominin presence in China. In *Out of Africa I,* eds. J.G. Fleagle, J.J. Shea, F.E. Grine, A.L. Baden and R.E. Leakey. Netherlands: Springer.

Hou, Y.M. and L.X. Zhao. 2010b. An archeological view for the presence of early humans in China, *Quaternary International* 223–224: 10-19.

Hovers, E. 2009. *The lithic assemblages of Qafzeh cave*. Oxford: Oxford University Press.

Howell, F.C., G.H. Cole, M.R. Kleindienst and E.G. Haldemann. 1962. Isimila - an Acheulian occupation site in the Iringa Highlands, Southern Highlands Province, Tanganyika. In *Actes du IVème Congrès Panafricain de Préhistoire et de l'etude du Quaternaire*, ed. G. Mortelmans, Tervuren: Musée Royal de l'Afrique Centrale N° 40.

Huang, W.B., R. Ciochon, Y. Gu, R. Larick, Q. Fang, H.P. Schwarcz, C. Yonge, J. de Vos and W.J. Rink. 1995. Early Homo and associated artifacts from Asia. *Nature* 378: 275–278.

Inizan, M.L., M. Reduron-Ballinger, H. Roche and J. Texier 1999 *Technology and terminology of knapping stone*. Préhistoire de la Pierre Taillée 5. Nanterre: CREP.

Iovita, R. 2009. Ontogenetic scaling and lithic systematics: method and application. *Journal of Archaeological Science* 36: 1447-1457.

Iovita, R. 2010. Comparing stone tool resharpening trajectories with the aid of eliptical fourier analysis, in: *New Perspectives on Old Stones. Analytical Approaches to Paleolithic Technologies* eds. S.J. Lycett and P.R. Chauhan, 235-254. New York: Springer.

Iovita, R. 2011. Shape variation in Aterian tanged tools and the origins of projectile technology: a morphometric perspective on stone tool function. *PLoS ONE* 6: e29029.

Iovita, R. and S.J.P. McPherron. 2011. The handaxe reloaded: A morphometric reassessment of Acheulian and Middle Paleolithic handaxes. *Journal of Human Evolution* 61: 61-74.

Isaac, G. 1981. Stone Age visiting cards: approaches to the study of early land-use patterns. In *Patterns of the Past*, eds. G. Isaac and N. Hammond, 131-155. Cambridge: Cambridge University Press.

Isaac, G. 1977. *Olorgesailie: archaeological studies of a Middle Pleistocene lake basin in Kenya*. Chicago: University of Chicago Press.

Isaac, G. 1968. *The Acheulean site complex at Olorgesailie, Kenya: a contribution to the interpretation of Middle Pleistocene culture in East Africa.* Unpublished Ph. D. thesis, University of Cambridge, Cambridge.

Isaac, G.L. and G.H. Curtis, 1974. Age of Early Acheulian industries from the Peninj Group, Tanzania. *Nature* 249: 624 - 627.

Isaac, G.L., J.W.K. Harris and E.M. Kroll. 1997. The stone artefact assemblages: a comparative study. In *Koobi Fora Research Project- Plio-Pleistocene Archaeology*, Vol. 5, ed. G.L. Isaac, 262-362. Oxford: Oxford University Press.

Jacobson, J. 1985. Acheulian surface sites in Central India. In *Recent Advances in Indo-Pacific Prehistory*, eds. P. Bellwood and V.N. Misra, 49-58. Delhi: Oxford & IBH Publishing.

Jacobson, J. 1976a. Acheulian surface sites in Central India, Paper Presented at *Recent Advances in Indo-Pacific Prehistory*, Pune.

Jacobson, J. 1976b. Evidence for prehistoric habitation patterns in eastern Malwa. In *Ecological Backgrounds of South Asian Prehistory*, eds. K.A.R. Kennedy and G.L. Possehl, 1-16. Ithaca: Cornell University South Asia Occasional Papers and Theses, 4.

Jacobson, J. 1975. Early Stone Age habitation in eastern Malwa. *Proceedings of the American Philosophical Society* 119: 280–297.

Jacobson, J. 1974. Early Stone Age habitation patterns in Raisen District, Madhya Pradesh. Paper Presented at the *Seminar on Indian Prehistory and Protohistory*, Deccan College, Poona. June 25-29.

Jacobson, J. 1970. On Palaeolithic occupation floors in India. *Current Anthropology* 11: 483.

Jain, V. and R. Sinha. 2005. Response of active tectonics on the alluvial Baghmati River, Himalayan foreland basin, eastern India. *Geomorphology* 70 (3-4): 339-356.

Jansen, F.J. 1926. A new type of stone implement from Victoria West. *South African Journal of Science* XXIII: 818– 825.

Jayaswal, V. 1978. *Palaeohistory of India (A study of prepared core techniques of the Palaeolithic cultures of India).* Delhi: Agam Kala Prakashan.

Jhaldiyal, R. 1997. *Formation processes of the prehistoric sites in the Hunsgi and Baichbal Basins, Gulbarga District, Karnataka.* Unpublished Ph. D. Thesis. University of Pune, Pune.

Jhaldiyal, R. 2006. *Formation processes of the Lower Palaeolithic record in the Hunsgi and Baichbal Basins, Gulbarga District, Karnataka.* Kolkata: Centre for Archaeological Studies and Training, Eastern India.

Jhingran, A.G. 1958. The problem of Bundelkhand Granites and Gneisses. Presidential Address, *Proceedings of Indian Science Congress 45th Session*, Madras, 48-120.

Jiménez-Arenas, J.M., M. Santonja, M. Botella and P. Palmqvist. 2011. The oldest handaxes in Europe: fact or artefact? *Journal of Archaeological Science* 38, 3340-3349.

Jin C. Z., L. Zheng, W. Dong, J. Liui, Q.Q. Xu,, L. Han, J.J. Zheng, G.B. Wei and F. Wang. 2000. The Early Pleistocene deposits and mammalian fauna from Renzidong, Fanchang, Anhui Province, China. *Acta Anthropologica Sinica* 19(3):184-198.

Jones, P.R. 1994. Results of experimental work in relation to the stone industries of Olduvai Gorge. In *Olduvai Gorge -Vol 5: Excavations in Beds III, IV and the Masek Beds, 1968-1971*, eds. M.D. Leakey and D.A. Roe, 254-98. Cambridge: Cambridge University Press.

Jones, P. R. 1981. Experimental implement manufacture and use: a case study from Olduvai Gorge, Tanzania. *Philosophical Transactions of the Royal Society of London. B, Biological Sciences 292*(1057): 189-195.

Joshi, D.D. and S.P. Bhartiya. 1991. Geomorphic history and lithostatigraphy of a part of eastern Gangetic Plain, Uttar Pradesh. *Journal of Geological Society of India* 37: 569-76.

Joshi, R.V. and A.R. Marathe. 1985. A comparative study of metrical data on handaxes and their cultural interpretations. In *Recent Advances in Indo-Pacific Prehistory*, eds. V.N. Misra, and P. Bellwood. New Delhi: Oxford and IBH.

Joshi, R.V. and A.R. Marathe. 1977. Correlation analysis of handaxes and cleavers and the functional interpretation. *Bulletin of the Deccan College Postgraduate and Research Institute* 37: 48- 60.

Joshi, R.V. and A.R. Marathe. 1976. Metrical analysis of handaxes from Chirki-on-Pravara, W. Maharashtra, India. *Puratattva* 8**:** 3-12.

Kailath, A.J., T.K.G. Rao, R.P. Dhir, K.S.V. Nambi, V.D. Gogte and A.K. Singhvi. 2000. Electron spin resonance characterization of calcretes from Thar Desert for dating applications. *Radiation Measurements* 32: 371 - 383.

Keates, S.G. 2002. Movius Line: fact or fiction? *Bulletin of the Indo-Pacific Prehistory Association* 22: 17-24.

Kennedy, K.A.R., A. Sonakia, J. Chiment and K.K. Verma. 1991. Is the Narmada hominid an Indian *Homo erectus*. *American Journal of Physical Anthropology* 86: 475–496.

Khan, K.F., A.D. Shamim and S.A. Khan. 2012. Geochemistry of phosphate bearing sedimentary rocks in parts of Sonrai Block, Lalitpur District, Uttar Pradesh, India. *Chemie der Erde - Geochemistry* 72 (2): 117-125.

Khatri, A.P. 1963. Mahadevian: An Oldowan pebble culture of India. *Asian Perspective* 6: 186–197.

Klein, R. 2000. The Earlier Stone Age of Southern Africa. *South African Archaeological Bulletin* 55: 107-122.

Kleindienst, M.R. 1962. Components of the East African Acheulian assemblage: an analytic approach. In *Actes du IVème Congrès Panafricain de Préhistoire et de l'Etude du Quaternaire,* vol. 40, ed. G. Mortelmans, 81–105. Tervuren: Musée Royal de l'Afrique Centrale.

Kleindienst, M. R. 1961. Variability within the Late Acheulian assemblage in Eastern Africa. *The South African Archaeological Bulletin* 16 (62): 35-52.

Kleindienst, M.R. and C.M. Keller. 1976. Towards a functional analysis of handaxes and cleavers: the evidence from Eastern Africa. *Man*, New Series 11(2): 176-187.

Korisettar, R. and S.N. Rajaguru. 1998. Quaternary stratigraphy, palaeoclimate and the Lower Palaeolithic of India. In *Early Human Behavior in Global Context: The Rise and Diversity of the Lower Palaeolithic Record*, eds. M.D. Petraglia and R. Korisettar, 304–342. New York: Routledge.

Krishnan, M.S. 1960. *Geology of India and Burma*. 4th Ed. Madras: Higginbothams.

Kuman, K. 2014. Acheulean Industrial Complex. In *Encyclopedia of Global Archaeology,* ed. C. Smith, New York: Springer.

Kuman, K. and R.J. Gibbon. 2007. The early Acheulean of South Africa: Sterkfontein Valley and the Vaal River Basin. Paper presented at 'Colloque International *Les Cultures à Bifaces du Pléistocene Inferieur et Moyen dans le Monde.* Émergence du Sens de l'Harmomie. Tautavel, France.

Kuman, K. and R.J. Clarke. 2000. Stratigraphy, artefact industries and hominid associations for Sterkfontein, Member 5. *Journal of Human Evolution* 38: 827-847.

Kumar, G. 2005. *Geology of Uttar Pradesh and Uttaranchal*. Bangalore: Geological Society of India.

Kumar, G., P.C. Khanna and S. Prasad. 1996. Sequence stratigraphy of the foredeep and evolution of Indo-Gangetic Plain, Uttar Pradesh. *Proceedings of Symposium on NW Himalaya and Foredeep* 21: 173–207.

Kumar, S. and I.B. Singh. 1978. Sedimentological study of Gomti River sediments, Uttar Pradesh, India - example of a river in alluvial plain. *Senckenbergiana Marit* 10(4/6): 145-211.

Leader, G.M. 2013. *New excavations at Canteen Kopje, Northern Cape Province, South Africa: A techno-typological comparison of three earlier Acheulean assemblages with new interpretations on the Victoria West phenomenon.* Unpublished PhD Dissertation, University of the Witwatersrand, Johannesburg.

Leader, G.M. 2009. *Early Acheulean in the Vaal River Basin, Rietputs Formation, Northern Cape Province, South Africa.* Unpublished Masters Dissertation, University of the Witwatersrand, Johanessburg. http://wiredspace.wits.ac.za/bitstream/handle/10539/8135/LEADER%202009%20MSc%20dissertation.pdf?sequence=2

Leakey, M. 1971. *Olduvai Gorge: Excavations in Beds I & II 1960–1963*. Cambridge: Cambridge University Press.

Lefèvre, D., J.P. Raynal, G. Vernet, G. Kieffer and M. Piperno. 2010. Tephrostratigraphy and the age of ancient southern Italian Acheulean settlements: The sites of Loreto and Notarchirico (Venosa, Basilicata, Italy. *Quaternary International 223:* 360-368.

Lepre, C.J. and D.V. Kent. 2010. New magnetostratigraphy for the Olduvai subchron in the Koobi Fora Formation, northwest Kenya, with implications for early Homo. *Earth and Planetary Science Letters* 290: 362–374.

Lepre, C., H. Roche, D.V. Kent, S. Harmand, R.L. Quinn, J.P. Brugal, J.P. Texier, A. Lenoble and C. Feibel. 2011. An earlier origin for the Acheulian. *Nature* 477: 82 – 85.

Leroi-Gourhan, A. 1943. *L'Homme et la matière*. Paris: Albin Michel.

Lewarch, D.E. and M.J. O'Brien. 1981 The expanding role of surface assemblages in archaeological research. In *Advances in Archaeological Method and Theory,* ed. M.B. Schiffer, 4: 297-342. New York: Academic Press.

Lin, S.C.H., M.J. Douglass, S.J. Holdaway and B. Floyd. 2010. The application of 3D laser scanning technology to the assessment of ordinal and mechanical cortex quantification in lithic analysis. *Journal of Archaeological Science* 37: 694-702.

Lordkipanidze, D., T. Jashashvili, A. Vekua, M. Ponce de Léón, C.P.E. Zollikofer, G.P. Rightmire, H. Pontzer, C.R. Ferring, O. Oms, M. Tappen, M. Bukhsianidze, J. Agustí, R. Kahlke, G. Kiladze, B. Martínez-Navarro, A. Mouskhelishvili and M. Nioradze. 2007. Postcranial evidence of early Homo from Dmanisi, Georgia. *Nature* 449: 305-310.

Lordkipanidze, D., A. Vekua, C.R. Ferring, G.P. Rightmire, J. Agusti, G. Kiladze, A. Mouskhelishvili, M. Nioradze, M. Ponce de Leon, M. Tappen and C.P.E. Zollikofer 2005. The earliest toothless hominin skull. *Nature* 434: 717-718.

Lycett, S. J. 2007. Is the Soanian techno-complex a Mode 1 or Mode 3 phenomenon? A morphometric assessment. *Journal of Archaeological Science 34*(9): 1434-1440.

Lycett, S.J. and M.I. Eren. 2013. Levallois economics: an examination of 'waste' production in experimentally produced Levallois reduction sequences. *Journal of Archaeological Science* 40: 2384-2392.

Lycett, S.J. and N. von Cramon-Taubadel. 2013. A 3D morphometric analysis of surface geometry in Levallois cores: patterns of stability and variability across regions and their implications. *Journal of Archaeological Science* 40: 1508-1517.

Lycett, S. and C. Bae. 2010. The Movius Line controversy: the state of the debate. *World Archaeology* 42: 521-544.

Lycett, S. J., and J.A. Gowlett. 2008. On questions surrounding the Acheulean 'tradition'. *World Archaeology*, *40* (3): 295-315.

Lycett, S. J., N. von Cramon-Taubadel, and J.A. Gowlett. 2010. A comparative 3D geometric morphometric analysis of Victoria West cores: implications for the origins of Levallois technology. *Journal of Archaeological Science 37*(5): 1110-1117.

Lycett, S. J., N. von Cramon-Taubadel, and R.A. Foley. 2006. A crossbeam co-ordinate caliper for the morphometric analysis of lithic nuclei: a description, test and empirical examples of application. *Journal of Archaeological Science 33*(6): 847-861.

Machin, A.J., R.T. Hosfield and S.J. Mithen, 2007. Why are some handaxes symmetrical? Testing the influence of handaxe morphology on butchery effectiveness. *Journal of Archaeological Science* 34: 883-893.

Madsen, B. and N. Goren-Inbar. 2004. Acheulian giant core technology and beyond: An archaeological and experimental case study. *Eurasian Prehistory* 2(1): 3–52.

Magne, M. and D. Pokotylo. 1981. A pilot study in bifacial lithic reduction sequences. *Lithic Technology 10 (2/3):* 34-47.

Mallet, F.R. 1869. On the Vindhyan Series exhibited in Northwestern and Central Provinces of India. *Memoirs of the Geology Survey of India* 7(1): 1–129.

Marathe, A.R. 2006. Acheulian cave at Susrondi, Konkan, Maharashtra. *Current Science* 90: 1538–1544.

Marathe, A.R. 1981. *Geoarchaeology of the Hiran Valley, Saurashtra, India*. Pune: Deccan College Postgraduate and Research Institute.

Marshall, G.D., C.G. Gamble, D.A. Roe and D. Dupplaw. 2002. *Acheulian biface database.* York: Archaeological Data Service.
http://ads.ahds.ac.uk/catalogue/specColl/bifaces/index.cfm.

Martínez, K., J. García, E. Carbonell, J. Agustí, J.J. Bahain, H.A. Blain, F. Burjachs, I. Cáceres, M. Duval, C. Falgueres, M. Gómez and R. Huguet. 2010. A new Lower Pleistocene archeological site in Europe (Vallparadís, Barcelona, Spain). *Proceedings of the National Academy of Sciences* 107 (13): 1–6

Martınez a arro, ., A. Turq, J.A. Ballester and O. Oms. 1997. Fuente Nueva-3 (Orce, Granada, Spain) and the first human occupation of Europe. *Journal of Human Evolution 33*(5): 611-620.

Mason, R.J. 1988. The Doornlaagte Early Stone Age Late Acheulian camp, Kimberley District. In *Cave of Hearths, Makapansgat Transvaal*, ed. R. Mason, 623–626. Occasional Papers 21. Johannesburg: University of the Witwatersrand, Archaeological Research Unit.

Mathur, P.C. 1954. A note on the granitisation of quartzites in Bundelkhand. *Science and Culture* 20: 242-243.

Mauldin, R. P. and D.S. Amick. 1989. Investigating patterning in debitage from experimental bifacial core reduction. *Experiments in lithic technology*, 67-88.

McBrearty, S. and C.A. Tryon. 2005. From Acheulean to Middle Stone Age in the Kapthurin Formation, Kenya, In *Transitions before the Transition: Evolution and Stability in the Middle Palaeolithic and Middle Stone Age*, eds. E. Hovers and S. Kuhn. New York: Springer.

McNabb, J. 2001. The shape of things to come: a speculative essay on the role of the Victoria West phenomenon at Canteen Koppie, during the South African Stone Age. In *A Very Remote Period Indeed: Papers on the Palaeolithic Presented to Derek Roe*, eds. S. Milliken and J. Cook, 37–46. Oxford: Oxbow Books.

McNabb, J., F. Binyon and L. Hazelwood. 2004. The large cutting tools from the South African Acheulean and the question of social traditions. *Current Anthropology* 45(5): 653–677.

McPherron, S.P. 2006. What typology can tell us about Acheulian handaxe production. In *Axe Age: Acheulian Tool-making from Quarry to Discard*, eds. N. Goren-Inbar and G. Sharon, 267–286. London: Equinox.

McPherron, S.P. 2000. Handaxes as a measure of the mental capabilities of early hominids. *Journal of Archaeological Science* 27: 655–663.

McPherron, S.P. 1999. Ovate and pointed handaxes assemblages: two points make a line. *Préhistoire Européenne* 14: 9 - 32.

McPherron, S.P. 1994. *A reduction model for variability in Acheulian biface morphology*. Unpublished Ph.D. Dissertation, University of Pennsylvania.

Medlicott, H.B. 1860. Vindhyan rocks and their associates in Bundelkhand. *Memoirs of the Geology Survey of India,* 2.

Miller, V.C. 1953. *A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee*. Technical report, 3, Office of Naval Research. Department of Geology, Columbia University, New York.

Mishra, R.C. and R.P. Sharma. 1975. New data on the Geology of the Bundelkhand Complex of Central India. In *Recent Researches in Geology*, ed. V.K. Verma, Delhi: Hindustan Publishing Corporation.

Mishra, S. 2011. Comparing the Earliest Stone Tools from Africa, Europe, China and India: implications for the timing of "Out of Africa 1" *Suyanggae International Symposium*, 14-21 August 2011, Yangyan County, South Korea.

Mishra, S. 2010a. The Indian subcontinent: One of mankind's original homelands. Paper presented at the Colloque international "*Les premiers peuplements prehistoriques sur les different continents"* Centenary Celebrations for the Institute of Human Palaeontology, 2-6 June 2010, Paris France.

Mishra, S. 2010b. http://sheilamishra.wordpress.com/2010/08/, Revising the Indian Palaeolithic Sequence.

Mishra, S. 2006-2007. The Indian Lower Palaeolithic. *Bulletin of the Deccan College Post-Graduate and Research Institute* 66-67: 47-94.

Mishra, S. 1995. Chronology of the Indian Stone Age: the impact of recent absolute and relative dating attempts. *Man and Environment* 20: 11–16.

Mishra, S. 1994. The South Asian Lower Palaeolithic. *Man and Environment* 19: 57–72.

Mishra, S. 1992. The age of the Acheulian in India: New Evidence. *Current Anthropology* 33: 325-328.

Mishra, S. 1986. Archaeological assemblages and basalt weathering: a re-evaluation of the Nevasian. *Man and Environment* 10: 91-96.

Mishra, S. 1982. On the effects of basalt weathering on the distribution of Lower Palaeolithic sites in the Deccan. *Bulletin of the Deccan College Postgraduate and Research Institute* 41**:** 107-115.

Mishra, S. and S.N. Rajaguru. 1996. Comment on "New geochemical evidence for the Youngest Toba tuff in India." *Quaternary Research* 46: 340–341

Mishra, S., S. Deo and S.B. Ota. 2012. Are there any surface Acheulian sites? Lessons from Tikoda. Paper presented at the *International Seminar on Art & Archaeology of Madhya Pradesh and Adjoining Region* jointly organized by Society of South Asian Archaeology and the Directorate of Archaeology, Archives and Museum, Government of Madhya Pradesh in Bhopal from 13th – 14th March 2012.

Mishra, S., C. Gaillard, S.G. Deo, M. Singh, R. Abbas, N. Agrawal and S.N. Rajaguru, 2010a. Large Flake Acheulean in India: implications for understanding Lower Pleistocene human dispersals. *Quaternary International* 223-224: 271-272.

Mishra, S., C. Gaillard, C. Hertler, A.-M. Moigne, and H.T. Simanjuntak. 2010b. India and Java: contrasting records, intimate connections. *Quaternary International* 223-224: 265-270.

Mishra, S., S. Deo, and S.N. Rajaguru. 2007. Some observations on laterites developed on Deccan Trap: implications for post-Deccan Trap denudational history. *Journal of the Geological Society of India* 70: 521-525.

Mishra, S., S.G. Deo, R. Abbas, S. Naik, G. Shete, N. Agrawal and S.N. Rajaguru. 2009. Excavations at the Early Acheulian site of Morgaon, Maharashtra (2000-2007). In *Recent Research Trends in South Asian Archaeology,* eds. K. Paddayya, P.P. Joglekar, K.K. Basa and R. Sawant, 121-137. Pune: Deccan College Postgraduate and Research Institute.

Mishra, S., T.R. Venkatesan, S.N. Rajaguru and B.L.K. Somayajulu. 1995. Earliest Acheulian industry from Peninsular India. *Current Anthropology* 36: 847-851.

Mishra, M.N., R.N. Srivastava, M.C. Upadhyaya and M.P. Srivastava. 1994. Quaternary geology and morphotectonic evolution of the Lower Sind Basin, Marginal Gangetic Plains, MP and UP. *Journal of the Geological Society of India* 43(6): 677-684.

Misra, V.N. 1995. Geoarchaeology of the Thar Desert, northwest India. In *Quaternary Environments and Geoarchaeolgy of India,* eds. S. Wadia, R. Korisettar and V.S. Kale, 210–230. Bangalore: Geological Society of India.

Misra, V.N. 1989. Stone Age India: an ecological perspective. *Man and Environment* 14: 17–64.

Misra, V. N. 1987. Middle Pleistocene adaptations in India. In *The Pleistocene Old World*, ed. O. Soffer, 99-119. New York: Plenum Press.

Misra V.N. 1985. The Acheulian succession at Bhimbetka, Central India. In *Recent Advances in Indo-Pacific Prehistory*, eds. V.N. Misra and P. Bellwood, 35-48. New Delhi: Oxford – IBH.

Misra, V.N. 1978a. The Acheulian industry of rockshelter IIIF-23 at Bhimbetka, Central India. *Australian Archaeology* 8: 63-106.

Misra, V.N. 1978b. The Acheulian industry of rockshelter IIIF-23 at Bhimbetka, Central India: a preliminary study. *Puratattva* 8: 12-36.

Misra, V.N. 1967. *Pre and Proto-History of the Berach Basin, south Rajasthan,* Poona: Deccan College.

Misra, V.N. and S.N. Rajaguru. 1986. Environnement et culture de l'Homme pre´ historique dans le désert du Thar, Rajasthan, Inde. *L'Anthropologie* 90 (3): 407–438.

Misra, V.N., S.N. Rajaguru, D.R. Raju, H. Raghavan and C. Gaillard. 1982. Acheulian occupation and evolving landscape around Didwana in the Thar Desert, India. *Man and Environment* 6: 72–86.

Mohindra, R. and B. Parkash. 1994. Geomorphology and neotectonic activity of the Gandak megafan and adjoining areas, Middle Gangetic Plains. *Journal of the Geological Society of India* 43: 149–157.

Mohindra, R., B. Parkash and J. Prasad. 1992. Historical geomorphology and pedology of the Gandak megafan, Middle Gangetic Plains, India. *Earth Surface Processes and Landforms* 17: 643–662.

Moncel, M.H., J. Despriée, P. Voinchet, H. Tissoux, D. Moreno, J.J. Bahain, G. Courcimault and C. Falguères. 2013. Early Evidence of Acheulean Settlement in northwestern Europe - La Noira Site, a 700 000 Year-Old Occupation in the Center of France. *PLoS ONE* **8**(11): e75529.

Moncel, M. H. and J. Combier. 1990. L'exploitation de l'espace au Pleistocene moyen: l'approvisionnement en matières premières lithiques. L'exemple du site d'Orgnac 3 (Ardèche, France). *Bulletin de la Société préhistorique de France* 87**(**10-12**):** 299-314.

Mondal, M.E.A. and S.M. Zainuddin. 1997. Geochemical characteristics of the granites of Bundelkhand Massif, Central India. *Journal of Geological Society of India* 50: 69-74.

Mondal, M.E.A., J.N. Goswami, M.P. Deomurari and K.K. Sharma. 2002. Ion microprobe 207Pb/206Pb zircon ages of zircons from the Bundelkhand Massif, northern India: implications for crustal evolution of the Bundelkhand-Aravalli protocontinent. *Precambrian Research* 117: 85-100.

Moloney, N. 1992. Lithic production and raw material exploitation at the Middle Pleistocene site of El Sartalejo, Spain. *Papers from the Institute of Archaeology* 3: 11-22.

Mosquera, M., A. Ollé and X.P. Rodríguez. 2013. From Atapuerca to Europe: tracing the earliest peopling of Europe. *Quaternary International* 295: 130-137

Mourre, V. 2003 *Implications culturelles de la technologie des hachereaux*. Unpublished Ph.D. Dissertation, Université de Paris X, Nanterre.

Movius, H.L. 1948. The Lower Palaeolithic Cultures of Southern and Eastern Asia. *Transactions of the American Philosophical Society*, New Series 38: 329–420.

Mukherji, A.B. 1963. Alluvial morphology of the Upper Ganga-Yamuna doab. *The Deccan Geographer* 2: 1–36.

Muttoni, G., G. Scardia, D.V. Kent, E. Morsiani, F. Tremolada, M. Cremaschi and C. Peretto. 2011. First dated human occupation of Italy at ~0.85 Ma during the late Early Pleistocene climate transition. *Earth and Planetary Science Letters* 307 (3–4): 241–252.

National Atlas Organization. 1959. NAO Lucknow Physical Plate.

Newcomer, M.H. and F. Hivernel-Guerre. 1974. Nucléus sur éclat: technologie et utilisation par differéntes cultures préhistoriques. *Bulletin de la Société Préhistorique Française* 71(4): 119–127.

Noll, M.P. 2000. *Components of Acheulian lithic assemblage variability at Olorgesailie, Kenya*. Unpublished Ph.D. Dissertation, University of Illinois at Urbana-Champaign.

Norton, C.J. and K. Bae. 2008. The Movius Line sensu lato: further assessed and defined. *Journal of Human Evolution* 55: 1148-1150.

Nowell, A. and M. White. 2010. Growing up in the Middle Pleistocene: life history strategies and their relationship to Acheulian industries. In *Stone Tools and the Evolution of Human Cognition*, eds. A. Nowell and I. Davidson. 67-82, Colorado: University Press of Colorado.

Odell, G. H. 1989. Experiments in lithic reduction. *Experiments in lithic technology*, *528*, 163-198.

Oldham, R.D. 1917. The structure of Himalayas and the Gangetic Plain as elucidated by geodetic observations in India. *Memoir of Geological Society of India* 42: 1–153.

Ollé, A., M. Mosquera, X.P. Rodríguez, A. de Lombera-Hermida, M.D. García-Antón, P. García-Medrano, L. Peña, L. Menéndez, M. Navazo, M. Terradillos, A. Bargalló, B. Márquez, R. Sala and E. Carbonell. 2013. The Early and Middle Pleistocene technological record from Sierra de Atapuerca (Burgos, Spain). *Quaternary International* 295: 138–167.

Ollier, C.D. and S.N. Rajaguru. 1989. Laterite of Kerala, India. *Geografia Fisica e Dinamica Quarternaria* 12: 27-33

Oms, O., J.M. Pares, B.J. Martinez-Navarro, I. Agusti, G. Toro, G. Martinez-Fernandez and A. Turq. 2000. Early human occupation of Western Europe: Paleomagnetic dates for two Paleolithic sites in Spain. *Proceedings of the National Academy of Sciences* 97: 10666-10670.

Oms, O., J. Dinares-Turell, J. Agustí and J.M. Parés. 1999. Refinements of the European mammal chronology from the magnetic polarity record of the plio-Pleistocene Zújar section, Guadix-Baza Basin, SE Spain. *Quaternary Research* 51: 94–103.

Onodera, T.F. and H.M. Asoka Kumara. 1980. Relation between texture and mechanical properties of crystalline rocks. *Bulletin of International Association of Engineering Geology* 22: 173-177.

Ota, S.B. and S.G. Deo. 2014. Investigation of Acheulian Localities TKD-I and TKD-II at Tikoda, District Raisen, Madhya Pradesh (2010-12). In *Recent Advances in Acheulian Culture Studies in India, eds.* K.Paddayya and S.G. Deo, 57-66, Pune: Indian Society for Prehistoric and Quaternary Studies

Ota, S.B., S. Deo and S. Mishra. 2012. *Acheulian site at Tikoda, District Raisen, Madhya Pradesh: geoarchaeological investigations.* Paper presented at the International Seminar on Art & Archaeology of Madhya Pradesh and Adjoining Region jointly organized by Society of South Asian Archaeology and the Directorate of Archaeology, Archives and Museum, Government of Madhya Pradesh in Bhopal from 13th – 14th March, 2012.

Owen, W.E. 1938. The Kombewa culture, Kenya Colony. *Man* 38: 203–205.

Paddayya, K. 2010. Excavation at Acheulian Locality VI near Yediyapur in Baichbal Valley, Gulbarga district, Karnataka. *Bulletin of the Deccan College Postgraduate and Research Institute* 68/69: 31-69.

Paddayya, K. (ed.) 2008. *Site formation processes.* Pune: Deccan College.

Paddayya, K. 2006–2007. Evolution within the Acheulian in India: a case study from the Hunsgi and Baichbal Valleys, Karnataka. *Bulletin of Deccan College Postgraduate Research Institute* 66–67: 95–111.

Paddayya, K. 1987. Excavation of an Acheulian occupation site at Yediyapur, Peninsular India. *Anthropos* 82: 610-614.

Paddayya, K. 1982 *The Acheulian culture of the Hunsgi Valley (Peninsular India): a settlement system perspective*. Pune: Deccan College.

Paddayya, K. and M.D. Petraglia. 1995. Natural and cultural formation processes of the Acheulian sites of the Hunsgi and Baichal Valleys, Karnataka. In *Quaternary Environments and Geoarchaeology of India,* eds. S. Wadia, R. Korisettar and V.S. Kale, 333-351. Bangalore: Memoirs of the Geological Society of India.

Paddayya, K. and M.D. Petraglia. 1993. Formation processes of Acheulean localities in the Hunsgi and Baichbal Valleys, Peninsular India. In *Formation Processes in Archaeological Context,* eds. P. Goldberg, D.J. Nash and M.D. Petragia, 61-82. Madison: Prehistory Press.

Paddayya, K., R. Jhaldiyal and M.D. Petraglia. 2006. The Acheulian quarry at Isampur, Lower Deccan, India. In *Axe Age: Acheulean Toolmaking from Quarry to Discard*, eds. N. Goren-Inbar and G. Sharon, 45–74. London: Equinox.

Paddayya, K., B.A.B. Blackwell, R. Jhaldiyal, M.D. Petraglia, S. Fevrier, D.A. Chaderton II, J.I.B. Blickstein and A.R. Skinner. 2002. Recent findings on the Acheulian of the Hunsgi and Baichbal Valleys, Karnataka, with special reference to Isampur Excavation and its Dating. *Current Science* 83: 641-647.

Pandey, S.K. 1969. *Painted rockshelters of Madhya Pradesh with special reference to Mahakoshal*. Unpublished Ph. D. Dissertation, Saugor University, Saugor.

Pant, P.C. 1982. *Prehistoric Uttar Pradesh: a study of Old Stone Age).* Delhi: Agam Kala Prakashan.

Pappu, R.S. 2001. *Acheulian culture in Peninsular India: an ecological perspective*. New Delhi: D.K. Printworld.

Pappu, R.S. 1985. The geomorphic setting of Acheulian sites in Peninsular India, In *Recent Advances in Indo-Pacific Prehistory*, eds. P. Bellwood and V.N. Misra, 9–18. Delhi: Oxford & IBH Publishing.

Pappu, R. S. 1974. *Pleistocene studies in the Upper Krishna Basin.* Unpublished Ph.D. Dissertation, Deccan College, Poona.

Pappu, R.S. and S.G. Deo 1994. *Man-land relationships during Palaeolithic times in the Kaladgi Basin, Karnataka*. Pune: Deccan College Postgraduate and Research Institute.

Pappu, S., Y. Gunnell, K. Akhilesh, R. Braucher, M. Taieb, F. Demory and N. Thouveny. 2011. Early Pleistocene presence of Acheulian hominins in south India. *Science* 331: 1596-1600.

Pappu, S., G. Yanni and M. Taieb. 2003. Excavations at the Palaeolithic site of Attirampakkam, south India: preliminary findings. *Current Anthropology* 44: 591-598.

Parfitt, S.A. , N.M. Ashton, S.G. Lewis, R.L. Abel, G.R. Coope, M.H. Field, R. Gale, P.G. Hoare, N.R. Larkin, M.D. Lewis, V. Karloukovski, B.A. Maher, S.M. Peglar, R.C. Preece, J.E. Whittaker and C.B. Stringer. 2010. Early Pleistocene human occupation at the edge of the boreal zone in northwest Europe. *Nature* 466: 229–233.

Parfitt, S.A., R. Barendregt, M. Breda, I. Candy, A. Matthew, J. Collins, G.R. Coope, P. Durbidge, M.H. Field, J.R. Lee, A.M. Lister, R. Mutch. K.E.H. Penkman, R.C. Preece, J. Rose, C. Stringer, R. Symmons, J.E. Whittaker, J.J. Wymer and A.J. Stuart. 2005. The earliest record of human activity in northern Europe. *Nature* 438: 1008-1012.

Parkash, B., S. Kumar, M.S. Rao, S.C. Giri, S.C. Kumar, S. Gupta and P. Srivastava. 2000. Holocene tectonic movements and stress fields in the western Gangetic Plain. *Current Science* 78: 438–449.

Parés, J.M. and A. Pérez-González. 1999. Magnetochronology and stratigraphy at Gran Dolina section, Atapuerca (Burgos, Spain). *Journal of Human Evolution* 37 (3/4): 325–342

Parés, J.M., A. Pérez-González, A. Rosas, A. Benito, J.M. Bermúdez de Castro, E. Carbonell and R. Huguet. 2006. Matuyama-age lithic tools from the Sima del Elefante site, Atapuerca (northern Spain). *Journal of Human Evolution* 50: 163–169

Pascoe, E.H. 1950. *A manual of the Geology of India and Burma*, 3rd ed., Vol. 1. Calcutta: Geological Survey of India.

Patnaik, R., P.R. Chauhan, M.R. Rao, B.A.B. Blackwell, A.R. Skinner, A. Sahni, M.S. Chauhan and H.S. Khan. 2009. New geochronological, palaeoclimatological and

Palaeolithic data from the Narmada Valley hominin locality, Central India. *Journal of Human Evolution* 56: 114-133.

Pelcin, A. 1997. The effect of indentor type on flake attributes: evidence from a controlled experiment. *Journal of Archaeological Science* 24: 613-621.

Pelegrin, J. 1990. Prehistoric lithic technology: some aspects of research. *Archaeological review from Cambridge 9*(1): 116-125.

Pelegrin, J., C. Karlin and P. Bodu. 1988. *"Chaîne Opératoire": un outil pour le prehistorien.* Technologie Prehistorique. Notes et Monographies Techniques. Editions du CNRS, Paris, 55-62.

Perlès, C. 1992. In search of lithic strategies: A cognitive approach to prehistoric chipped stone assemblages, In *Representations in Archaeology*, eds. J.C. Gardin and C.S. Peebles, 223-247. Bloomington: Indiana University Press.

Petraglia, M.D. 2006. The Indian Acheulean in global perspective. In *Axe Age: Acheulean toolmaking from quarry to discard*, eds. N. Goren-Inbar and G. Sharon, 389–414. London: Equinox.

Petraglia, M.D. 2001. The Lower Palaeolithic of India and its behavioural significance. In *Human roots: Africa and Asia in the Middle Pleistocene*, eds. K. Robson-Brown and L. Barham, 217–233. Bristol: Western Academic & Specialist Press.

Petraglia, M.D. 1998. The Lower Palaeolithic of India and its bearing on the Asian record. In *Early Human Behavior in Global Context: The Rise and Diversity of the Lower Palaeolithic Record*, eds. M.D. Petraglia and R. Korisettar, 343–90. New York: Routledge.

Petraglia, M.D. and C. Shipton. 2008. Large cutting tool variation west and east of the Movius line. *Journal of Human Evolution* 55: 962-966.

Petraglia, M.D., P. LaPorta and K. Paddayya. 1999. The first Acheulian quarry in India: stone tool manufacture, biface morphology and behaviors. *Journal of Anthropological Research* 55: 39–70.

Pigeot, N. 1988. *Apprendre a debiter des lames: un cas d'education tehcnique chez des magdaleniens d'Etiolles.* Technologie Prehistorique. Notes et Monographies Techniques. Editions du CNRS, Paris, pp. 63-70.

Piperno, M. and A. Tagliacozzo. 2001. The elephant butchery area at the Middle Pleistocene site of Notarchirico (Venosa, Basilicata, Italy). *The World of Elephants – International Congress*, Rome: 230–236.

Piperno, M., D. Lefèvre, J.P. Raynal and A. Tagliacozzo. 1998. Notarchirico. An early Middle Pleistocene site in the Venosa Basin. *Anthropologie 36*(1-2): 85-90.

Pope, M., K. Russel and K. Watson. 2006. Biface form and structured behaviour in the Acheulean. *Lithics 27*: 44-57.

Porat, N., M. Chazan, R. Grun, M. Aubert, V. Eisenmann, and K.L. Horwitz. 2010. New radiometric ages for the Fauresmith industry from Kathu Pan, Southern Africa: implications for the earlier to Middle Stone Age transition. *Journal of Archaeological Science* 37*:* 269-283.

Potts, R., P. Shipman and E. Ingall. 1988. Taphonomy, paleoecology, and hominids of Lainyamok, Kenya. *Journal of Human Evolution* 17(6): 597-614.

Potts, R. 1984. Home bases and early hominids: how old is the earliest campsite? *American Scientist* 72: 338-47.

Prakash, R., J.N. Singh and P.N. Saxena. 1970. *A geology of the pyrophyllite and diaspore deposits of Jhansi District, Uttar Pradesh*. Lucknow: Directorate of Geology and Mining.

Prakash, R., J.N. Singh and P.N. Saxena. 1975. Geology and mineralization in the southern parts of Bundelkhand in Lalitpur District, Uttar Pradesh. *Journal of Geological Society of India* 16(2): 143-156.

Prasad, B. 1984. Geology, sedimentation and paleogeography of the Vindhyan Supergroup, southeastern Rajasthan. *Memoirs of the Geological Survey of India* 116(1): 1–102.

Preece, R.C. and S.A. Parfitt. 2012. The Early and early Middle Pleistocene context of human occupation and lowland glaciation in Britain and northern Europe. *Quaternary International* 271: 6-28.

Prentiss, W.C. 1998. The reliability and validity of a lithic debitage typology: implications for archaeological interpretation. *American Antiquity* 63: 635-650.

Raghavan, H., S.N. Rajaguru and V.N. Misra. 1989. Radiometric dating of a Quaternary dune section, Didwana, Rajasthan. *Man and Environment* 13: 19–22.

Rahman, A. and S.M. Zainuddin. 1993. Bundelkhand granites: An example of collision-related Precambrian magmatism and its relevance to the evolution of Central Indian Shield. *Journal of Geology* 101: 413-419.

Rai, R.K. 1980. *Geomorphology of the Sonar-Bearma Basin*. New Delhi: Concept Publishing.

Raju, D.R. 1985. Handaxe assemblages from the Gunjana Valley, Andhra Pradesh: a metrical analysis. *Bulletin of the Indo-Pacific Prehistory Association* 6: 10 – 26.

Raju, D.R. 1983. Palaeolithic cultures and ethnography of the Gunjana Valley, Andhra Pradesh. *Bulletin of the Indo-Pacific Prehistory Association* 4**:** 10-17.

Raju, D.R. 1988. *Stone Age hunter-gatherers: an ethnoarcheaology of Cuddapah Region, southeast India.* Pune: Ravish Publishers.

Raju, D.R. 1989. The Lower Palaeolithic culture in the Gunjana Valley on the southeast coast of India. *Bulletin of the Deccan College Postgraduate and Research Institute* 47/48: 283- 300.

Ranov, V.A. 2001. Cleavers: their distribution, chronology and typology. In *A Very Remote Period Indeed: Papers on the Palaeolithic Presented to Derek Roe*, eds. S. Milliken and J. Cook, 105–113. Oxford: Oxbow Books.

Rao, M.B.R. 1973. The subsurface geology of Indo-Gangetic Plains. *Journal of the Geological Society of India* 14: 217–242.

Rao, V.V.M. 1983. Metrical analysis of Acheulian tools from the Paleru Valley, Coastal Andhra. In *Rangavalli - Recent Researches in Indology,* eds. A.V.N. Murty and B.K. Gururaj Rao. Delhi: Sundeep Prakashan.

Rao, V.V.M. 1979. Discovery of Stone Age sites in the Paleru Valley, coastal Andhra Pradesh. *Current Science* 48: 349 - 350.

Rao, V.D., M.V. Subba Rao and N.N. Murthy. 1999. Granite forming events and their role in crust formation of the Indian Shield. *Revista Brasileira de Geociências* 29(1): 33-40.

Raynal, J. P., F.Z. Sbihi Alaoui, D. Geraads, L. Magoga and A. Mohi. 2001. The earliest occupation of North-Africa: the Moroccan perspective. *Quaternary International 75*(1): 65-75.

Rendell H.M., R.W. Dennell and M.A. Halim. 1989. *Pleistocene and Palaeolithic investigations in the Soan Valley, northern Pakistan*. British Archaeolgical Mission to

Pakistan Series 2, vol. 544. Oxford: British Archaeological Reports International Series.

Rendell, H. and R.W. Dennell. 1985. Dated Lower Palaeolithic artefacts from northern Pakistan. *Current Anthropology* 26: 393.

Rendell, H.M., E.A. Hailwood and R.W. Dennell. 1987. Magnetic polarity stratigraphy of Upper Siwalik Sub-Group, Soan Valley, Pakistan: implications for early human occupancy of Asia. *Earth Planetary Science Letter* 85: 488–496.

Reuter H.I, A. Nelson and A. Jarvis. 2007. An evaluation of void filling interpolation methods for SRTM data, *International Journal of Geographic Information Science* 21 (9): 983-1008.

Rhodes, E.J., J.S. Singarayer, J.P. Raynal, K.E. Westaway and F.Z. Sbihi-Alaoui. 2006. New age estimates for the Palaeolithic assemblages and Pleistocene succession of Casablanca, Morocco. *Quaternary Science Reviews 25*(19): 2569-2585.

Roche, H. 1980. *Premiers outils taillés d'Afrique*, Vol. 1. Société d'éthnographie.

Roche, H. and M. Kibunjia. 1996. Contribution of the West Turkana sites to the Archaeology of the Lower Omo/Turkana Basin. *Kaupia* 6: 27–30.

Roche, H. and M. Kibunjia. 1994. Les sites archéologiques pliopléistocènes de la formation de Nachukui, West Turkana, Kenya. *Comptes Rendus de l'Académie des Sciences de Paris, Série II* 318: 1145–1151.

Roche, H. and P.J. Texier. 1995. Evaluation of technical competence of *Homo erectus* in East Africa during the Middle Pleistocene. In *Evolution and Ecology of Homo erectus*, eds. J.R.F. Bower and S. Sartono, 153–167. Leiden: Royal Netherlands Academy of Arts and Sciences. Pithecanthropus Centennial Foundation.

Roche, H. and P.J. Texier. 1991. La notion de complexité dans un ensemble lithique: application aux séries Acheuléenes d´Isenya (Kenya). In: *25 Ans d´études Technologiques en Préhistoire,* 99–108. APDCA, Juanles- Pins.

Roche, H., J.P. Brugal, D. Lefevre, S. Ploux and P.J. Texier. 1988. Isenya: état des recherches sur un nouveau site Acheuléen d'Afrique orientale. *African Archaeological Review* 6(1):27-55.

Roche, H., J.P. Brugal, A. Delagnes, C. Feibel, S. Harmand, M. Kibunjia, S. Prat and P.J. Texier. 2003. Les sites archéologiques Plio-Pléistocènes de la formation de Nachukui, Ouest-Turkana, Kenya: bilan synthétique 1997-2001. *Comptes Rendus Palevol* 2: 663-673.

Rodríguez, J., F. Burjachs, G. Cuenca-Bescós, N. García, J. Van Der Made, A. Pérez González, H.A. Blain, I. Expósito, J.M. López-García, M. García Antón, E. Allué, I. Cáceres, R. Huguet, M. Mosquera, A. Ollé, J. Rosell, J.M. Parés, X.P. Rodríguez, C. Díez, J. Rofes, R. Sala, P. Saladié, J. Vallverdú, M.L. Bennasar, R. Blasco, J.M. Bermúdez De Castro and E. Carbonell, 2011. One million years of cultural evolution in a stable environment at Atapuerca (Burgos, Spain). *Quaternary Science Reviews* 30: 1396-1412.

Roe, D.A. 2006. Some thoughts about Acheulean cleavers. In *Axe Age: Acheulian Tool-making from Quarry to Discard*, eds. N. Goren-Inbar and G. Sharon. London: Equinox.

Roe, D.A. 2001. The Kalambo Falls large cutting tools: a comparative metrical and statistical analysis, In *Kalambo Falls Prehistoric Site III; the Earlier Cultures: Middle and Earleir Stone Age,* ed. J.D. Clark, 492-599. Cambridge: Cambridge University Press.

Roe, D.A. 1994. A metrical analysis of selected sets of handaxes and cleavers from Olduvai Gorge. In *Olduvai Gorge*, vol. 5, eds. M.D. Leakey and D.A. Roe, 146–234. Cambridge: Cambridge University Press.

Roe, D.A. 1978. Hlalakahle Early Stone Age site (Acheulian), In *Hlalakahle/Kufika - Stone Age sites in northwestern Swaziland*, eds. W.D. Price and N.E. Lindsey, 21-44. Report to the Swaziland National Trust Commission, Swaziland Archaeological Research Association - Preliminary Series 1.

Roe, D.A. 1968. British Lower and Middle Palaeolithic handaxe groups. *Proceedings of the Prehistoric Society* 34: 1–82.

Roe, D.A. 1964 The British Lower and Middle Paleolithic: some problems, methods of study and preliminary results. *Proceeding of the Prehistoric Society* 30: 245–267.

Ronen, A. 2006. The oldest human groups in the Levant. *Comptes Rendus Palevol* 5: 343-351.

Rosas, A., A. Pérez-Gonzàlez, E. Carbonell, J. van der Made, A. Sánchez, C. Laplana, G. Cuenca-Bescós, J.M. Parés and R. Huguet. 2001. Le gisement pléistocène de la Sima del Elefante (Sierra de Atapuerca, Espagne). *L'Anthropologie* 105: 301–312.

Roy, M., A.K. Bagchi, E.V.S.S.K. Babu, B. Mishra and P. Krishnamurthy. 2004. Petromineragraphy and mineral chemistry of bituminous shale-hosted uranium mineralization at Sonrai, Lalitpur district, Uttar Prdaesh. *Journal of Geolological Society of India* 63: 291-298.

Ruff, C. B., E. Trinkaus and T.W. Holliday. 1997. Body mass and encephalization in Pleistocene Homo. *Nature*, *387* (6629): 173-176.

Sahnouni, M. 2012. Lower Palaeolithic settlements in the Maghreb: current state of knowledge and perspectives in the framework of the World Heritage Convention. In *Human origin sites and the World Heritage Convention in Africa,* ed. N. Sanz, *33* (12): 128. UNESCO.

Sahnouni, M., S. Semaw and M. Rogers. 2013. The African Acheulean. In *The Oxford Handbook of African Archaeology* eds. P. Mitchell and P.J. Lane, 307-323. Oxford: Oxford University Press.

Salahuddin, R.K. Ganjoo, G.L. Badam and S.N. Rajaguru. 1986–1987. On the archaeological association of the fossil hominid from Hathnora, Madhya Pradesh, India. *Asian Perspective* 27: 193–204.

Sangode, S.J., S. Mishra, S. Naik and S.G. Deo. 2007. Magnetostratigraphy of the Quaternary sediments associated with some Toba tephra and Acheulian artefact bearing localities in western and central India. *Gondwana Magazine, Special Volume* 10: 111-121.

Sankhyan, A.R. 1997. A new human fossil from the Central Narmada Basin and its chronology. *Current Science* 73: 1110–1111.

Sankhyan, A.R. 2005. New fossils of Early Stone Age man from Central Narmada Valley. *Current Science* 88: 704–707.

Santonja, M. and A. Perez-Gonzalez. 2010. Mid-Pleistocene Acheulean industrial complex in the Iberian Peninsula. *Quaternary International* 223–224: 154–161.

Santonja M. and P. Villa. 2006. The Acheulian of Western Europe. In *Axe Age. Acheulian Toolmaking from Quarry to Discard,* eds. N. Goren-Inbar and G. Sharon, 429-478. Oxford: Equinox Publishers.

Santonja, M., J. Panera, S. Rubio-Jara, A. Pérez-González, D. Uribelarrea, M. Domínguez-Rodrigo, A.Z.P.Mabulla, H.T. Bunn and E. Baquedano. 2014. Technological strategies and the economy of raw materials in the TK (Thiongo Korongo) lower occupation, Bed II, Olduvai Gorge, Tanzania. *Quaternary International 322:* 181-208.

Saragusti, I., A. Karasik, I. Sharon and U. Smilansky. 2005. Quantitative analysis of shape attributes based on contours and section profiles in artifact analysis. *Journal of Archaeological Science* 32(6): 841– 853.

Saragusti, I., I. Sharon, O. Katzenelson and D. Avnir. 1998. Quantitative analysis of the symmetry of artefacts: Lower Paleolithic handaxes. *Journal of Archaeological Science* 25: 817-825.

Sarkar, A., D.K. Paul and P.J. Potts. 1995. Geochronology and geochemistry of the Mid - Archaean trondhjemitic gneisses from the Bundelkhand Craton, Central India. In *Recent Researches in Geology and Geophysics of the Precambrians (RRG)*, ed. A.K. Saha, Vol. 16, 76–92. Bangalore: Geological Society of India.

Sastri, V.V., L.L. Bhandari, A.T.R. Raju and A.K. Dutta. 1971. Tectonic framework and subsurface stratigraphy of the Ganga Basin. *Records of the Geological Society of India* 12: 222–233.

Saxena, M.N. 1966. Revision of the term Bundelkhand Gneiss (Granite). *Rajasthan Current Science* 35(10): 156-157.

Saxena, M.N. 1961. Bundelkhand granites and associated rocks from Kabrai and Mauranipur area of Hamirpur and Jhansi District, Uttar Pradesh. *Research Bulletin (N.S.). Punjab University* 12(1-2): 85–107.

Saxena, M.N. 1957. *Bundelkhand Granites and associated rocks*. Unpublished Ph. D. Dissertation, Lucknow University, Lucknow.

Schick, K.D. and J.D. Clark. 1994. The Movius line reconsidered: perspectives on the Earlier Paleolithic of Eastern Asia, In *Integrated Paths to the Past: Palaeoanthropological Advances,* eds. R.S. Corruccini and R.L. Ciochon, 569-96. New Jersey: Prentice Hall.

Schmidt, P.W., V. Prasad and P.K. Raman. 1983. Magnetic ages of some Indian laterites. *Palaeogeography, Palaeoclimatology, Palaeoecology* 44: 185-202.

Schumm, S.A. 1963. Sinuosity of alluvial rivers of Great Plains. *Geological Society of America Bulletin* 74: 1089–1100.

Schumm, S.A. 1956. Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Geological Society of America Bulletin* 67: 597–646.

Scott, G.R. and L. Gibert. 2009. The oldest hand-axes in Europe. *Nature* 461, 82-85.

Searle, M.P., J.R. Elliott, R.J. Phillips and S.L. Chung. 2011. Crustal-lithospheric structure and continental extrusion of Tibet. *Journal of the Geological Society of London* 168: 633-672.

Searle, M.P., R.F. Weinberg and W.J. Dunlap. 1998. Transgressional tectonics along the Karakoram Fault Zone, northern Ladakh: constraints on Tibetan extrusion. *Geological Society Special Publication* 307-326.

Sellet. F. 1993. *Chaîne opératoire*: the concept and its applications. *Lithic Technology* 18(1-2): 106 - 112.

Semans, C.A. 1981. Analysis of an Acheulian collection from Peerah Nullah, Narmada Valley, India. *Man and Environment* 5: 13-31.

Semaw, S., M.J. Rogers and D. Stout. 2009. The Oldowan-Acheulian transition: Is there a 'Developed Oldowan' artifact tradition? In *Sourcebook of Paleolithic Transitions,* eds. M. Camps and P.R. Chauhan, 173-193. Springer.

Shane, P.A.R., J.A. Westgate, M.A.J. Williams and R. Korisettar. 1995. New geochemical evidence for the Youngest Toba tuff in India. *Quaternary Research* 44: 200–204

Sharma, K.K. 1998. Geological evolution and crustal growth of Bundelkhand craton and its relict in the surrounding regions, north Indian shield. In *The Indian Precambrian,* ed. B.S. Paliwal, 33–43. Jodhpur: Scientific Publishers.

Sharon G. 2010. Large flake Acheulian. *Quaternary International* 223-224:226-33.

Sharon, G. 2009. Acheulian giant core technology: a worldwide perspective. *Current Anthropology* 50 (3): 335-367.

Sharon, G. 2008. The impact of raw material on Acheulian large flake production. *Journal of Archaeological Science* 35: 1329-1344.

Sharon, G. 2007. *Acheulian large flake industries: technology, chronology and significance.* BAR International Series 1701. Oxford: Archaeopress.

Sharon, G. 2000. *Acheulian basalt tools of Gesher Benot Ya'aqov: experimental and technological study*. Unpublished M.A. Dissertation, Hebrew University, Jerusalem.

Sharon, G., N. Alperson-Afil and N. Goren-Inbar. 2011. Cultural conservatism and variability in the Acheulian sequence of Gesher Benot Ya'aqov. *Journal of Human Evolution* 60: 387-397.

Shchelinsky, V.E., A.E. Dodonov, V.S. Baigusheva, S.A. Kulakov, A.N. Simakova, A.S. Tesakov and V.V. Titov. 2010. Early Paleolithic sites on the Taman Peninsula (Southern Azov Sea region, Russia): Bogatyri/Sinyaya Balka and Rodniki. *Quaternary International* 223–224: 28–35.

Shipton, C. 2013. *A million years of hominin sociality and cognition: Acheulean bifaces in the Hunsgi-Baichbal Valley, India*. Archaeopress.

Shipton, C., M.D. Petraglia and K. Paddayya. 2009. Stone tool experiments and reduction methods at the Acheulean site of Isampur Quarry, India. *Antiquity* 83: 769-785.

Shipton, C., S. Mishra, K. Paddayya, S.G. Deo, J.N. Pal, N. Roseboom, C. Gaillard, M.C. Gupta and Y. Hou. 2014. Empirical differences between the Earlier and Later Acheulian in India. In *Recent Advances in Acheulian Culture Studies in India,* eds. K.Paddayya and S.G. Deo, 23-36. Pune: Indian Society for Prehistoric and Quaternary Studies.

Shott, M.J. 2003. *Chaîne opératoire* and reduction sequence. *Lithic Technology* 28(2): 95-105.

Shott, M.J. 1994. Size and form in the analysis of flake debris: review and recent approaches. *Journal of Archaeological Method and Theory* 1(1): 69-110.

Shukla, R.S. Raju, D.P. Singh and S.S. Hasan. 1995. Geology of the area around Babina, Nathikhera, Kuraicha and Madaura, Jhansi and Lalitpur Districts, Uttar Pradesh. *Records of the Geological Survey of India* 128 (8): 161-165.

Singh, I.B. 2002. Late Quaternary evolution of Ganga Plain and proxy records of climate change and anthropogenic activity. *Pragdhara* 12: 1–25.

Singh, I.B. 2001. *Proxy records of neotectonics, climate change and anthropogenic activity in the Late Quaternary of Ganga Plain*. Geological Survey of India Special Publication 65(1): XXXIII–L.

Singh, I.B. 1999. Tectonic control on sedimentation in Ganga Plain foreland basin: constrained on Siwalik sedimentation models. In *Geodynamics of the NW Himalaya*, eds. A.K. Jain and R.M. Manickavasagam, 247–262. Gondwana Research Group Memoir 6.

Singh, I.B. 1996. Geological evolution of Ganga Plain: An Overview. *Journal of the Palaeontological Society of India* 41: 99–137.

Singh, I.B. and D.K. Ghosh. 1994. Geomorphology and neotectonic features of Indo-Gangetic Plain. In *India: Geomorphological diversity*, eds. K.R. Dikshit, V.S. Kale and M.N. Kaul, 270–286.

Singh, I.B. and V.N. Bajpai. 1989. Significance of syndepositional tectonics in the facies development of the Gangetic alluvium near Kanpur, Uttar Pradesh. *Journal of the Geological Society of India* 34: 61–66.

Singh, I.B. and S.P. Rastogi. 1973. Tectonic framework of Gangetic alluvium with special reference to Ganga River in Uttar Pradesh. *Current Science* 42: 305–307.

Singh, I.B., M.K. Jaiswal, A.K. Singhvi and B.K. Singh. 2003. Rapid subsidence of western Ganga Plain during Late Pleistocene: evidence from optical dating of subsurface samples. *Current Science* 84: 451-455.

Singh, I.B., S. Sharma, M. Sharma, P. Srivastava and G. Rajagopalan. 1999. Evidence of human occupation and humid climate of 30 ka in the alluvium of southern Ganga Plain. *Current Science* 76(7): 1022-1026.

Singh, I.B., A.A. Ansari, R.S. Chandel and A. Misra. 1996. Neotectonic control on drainage system in Gangetic Plain, Uttar Pradesh. *Journal Geological Society of India* 47: 599–609.

Singh, I.B., V.N. Bajpai, A. Kumar and M. Singh. 1990. Changes in the channel characteristics of Ganga River during Late-Pleistocene-Holocene. *Journal of the Geological Society of India* 36: 67- 73.

Singh, R. 1965. *Palaeolithic industries of northern Bundelkhand.* Unpublished Ph. D Dissertation, Deccan College, Pune.

Singh, V. 1987. *Rock art of Sagar District, Madhya Pradesh*. Unpublished Ph. D. Dissertation, Deccan College, Pune.

Sinha, R. 1995. Sedimentology of Quaternary alluvial deposits of the Gandak- Kosi interfan, north Bihar Plains. *Journal of Geological Society of India* 46: 521-532.

Sinha, R., M. Khanna, V. Jain and S.K. Tandon. 2002. Mega-geomorphology and sedimentation history of parts of the Ganga- Yamuna Plains. *Current Science* 82(5): 562-566.

Sinha, R., P.F. Friend and V.R. Switsur. 1996. Radiocarbon dating and sedimentation rates in the Holocene alluvial sediments of the northern Bihar plains, India. *Geological Magazine* 133: 85–90.

Sinha, R., V. Jain, G.P. Babu and S. Ghosh. 2005. Geomorphic characterization and diversity of the fluvial systems of the Gangetic Plains. *Geomorphology* 70: 207–225.

Sirakov, N., J.L. Guadelli, S. Ivanova, S. Sirakova, M. Boudadi-Maligne, I. Dimitrova, P.H. Fernandez, C. Ferrier, A. Guadelli, D. Iordanova, N. Iordanova, M. Kovatcheva, I. Krumov, J.C. Leblanc, V. Miteva, V. Popov, R. Spassov, S. Taneva and T. Tsanova. 2010. An ancient continuous human presence in the Balkans and the beginnings of human settlement in western Eurasia: a Lower Pleistocene example of the Lower Palaeolithic levels in Kozarnika cave (north-western Bulgaria). *Quaternary International* 223–224: 94–106

Smith, K.G. 1950. Standards for grading texture of erosional topography. *American Journal of Science* 248: 655–668.

Sonakia, A. 1984. The skull cap of early man and associated mammalian fauna from Narmada Valley alluvium, Hoshangabad area, Madhya Pradesh, India. *Record of Geological Survey of India* 113: 159–172.

Sonakia, A. and S. Biswas. 1998. Antiquity of the Narmada *Homo erectus*, the early man of India. *Current Science* 75: 391–393.

Soni, M.K., S. Chakraborty and V.K. Jain. 1987. Vindhyan Supergroup: a review. In *Purana Basins of Peninsular India (Middle to Late Proterozoic),* ed. B.P. Radhakrishna, 87-138. Bangalore: Geological Survey of India Memoir 6.

Soressi, M. and J.M. Geneste. 2011. Reduction sequence, c*haîne opératoire*, and other methods: the history and efficacy of the c*haîne opératoire* approach to lithic analysis: studying techniques to reveal past societies in an evolutionary perspective. Paleoanthropology, 334-350.

Spate, O.H.K. 1954. *India and Pakistan: a general and regional geography*. London: Methuen.

Srivastava P., U.K. Shukla, M. Sharma, S. Sharma, P. Mishra, I.B. Singh and A.K. Singhvi. 2000. Luminescence chronology and facies development of Bhur sands in the interfluve region of Central Ganga Plain, India. *Current Science* 78: 498–503.

Srivastava, P., B. Parkash, J.L. Sehgal and S. Kumar, 1994. Role of neotectonics and climate in development of the Holocene geomorphology and soils of the Gangetic Plains between the Ramganga and Rapti Rivers. *Sedimentary Geology* 94: 129-151.

Srivastava, P., I.B. Singh, M. Sharma and A.K. Singhvi. 2003. Luminescence chronometry and Late Quaternary geomorphic history of the Ganga Plain, India. *Palaegeology, Palaeoclimate and Palaeoecogy* 197: 15-41.

Stoops, G., H.J. Altemuller, E.B.A. Bisdom, J. Delvigne, V.V. Dobrovolsky, E.A. Fitzpatrick, G. Paneque and J. Sleeman. 1979. Guidelines for the description of mineral alterations in soil micromorphology. *Pedologie* 29: 121-135.

Stahle, D.W. and J.E. Dunn. 1982. An analysis and application of the size distribution of waste flakes from the manufacture of bifacial tools. *World Archaeology* 14: 84-97.

Stout, D., J. Apel, J. Commander, and M. Roberts, M. 2014. Late Acheulean technology and cognition at Boxgrove, UK. *Journal of Archaeological Science 41:* 576-590.

Strahler, A.N. 1952. Hypsometric (area-altitude) analysis of erosional topography. *Geological Society of America Bulletin* 63: 1117–1142.

Strahler, A.N. 1964. Quantitative geomorphology of drainage basin and channel network, In *Handbook of Applied Hydrology*, ed. V.T. Chow, 4–76. New York: McGraw Hill Book Co.

Straus, L.S. 1983. Review of K. Paddayya's "The Acheulian culture of the Hunsgi Valley (Peninsular India): a settlement system perspective". *Journal of Anthropological Research* 39: 447-449.

Sullivan, III, A.P. and K.C. Rozen. 1985. Debitage analysis and archaeological interpretation. *American Antiquity* 50 (4): 755-779.

Supekar, S.G. 1985. Some observations on the Quaternary stratigraphy of the Central Narmada Valley, In *Recent Advances in Indo-Pacific Prehistory*, eds. P. Bellwood and V.N. Misra, 19–27. Delhi: Oxford & IBH Publishing.

Swisher, C.C.I., G.H., Curtis, T. Jacob, A.G. Getty and S.A. Widiasmoro. 1994. Age of the earliest known hominids in Java, Indonesia. *Science* 263: 118-21.

Szabo, B.J., C. Makinney, T.S. Dalbey and K. Paddayya. 1990. On the age of the Acheulian culture of the Hunsgi-Baichbal Valleys, Peninsular India. *Bulletin of the Deccan College Postgraduate and Research Institute* 50: 317-321.

Tandon, S.K., M.R. Gibling, R. Sinha, V. Singh, P. Ghazanfari, A. Dasgupta, M. Jain and V. Jain. 2006. Alluvial valleys of the Gangetic Plains, India: causes and timing of incision. In *Incised Valleys in Time and Space*. SEPM Special Publication 85: 15-35.

Tandon, S.K., R. Sinha, M.R. Gibling, A.S. Dasgupta and P. Ghazanfari. 2008. Late Quaternary evolution of the Ganga Plains: myths and misconceptions, recent developments and future directions. *Memoir of the Geological Society of India* 66: 259-299.

Texier, P.J. and H. Roche. 1995. Polyèdre, sub-sphéroïde, sphéroïde et bola: des segments plus ou moins longs d'une même chaîne opératoire. *Cahier Noir* 7: 31-40.

Texier, P.J. and H. Roche. 1992. The impact of predetermination on the development of some Acheulian *chaînes opératoires.* In *Evolución Humana en Europa y los Yacimientos de la Sierra de Atapuerca,* Vol 2., eds. J.M. Bermúdez de Castro, J.L. Arsuaga and E. Carbonell, 403–420. Valladolid: Junta de Castilla y León.

Texier, P.J. 1995. The Oldowan assemblage from NY 18 Site at Nyabusosi (Toro-Uganda). *Comptes Rendus de l'Academie des Sciences Paris* 320: 647–653.

Thompson, E. 2009. Acheulean artifact accumulation and early hominin land use, Garden Route Casino Road, Pinnacle Point, South Africa.*Geoarchaeology 24* (4): 402-428.

Tixier, J., 1978. Methode pour l'etude des outillages lithiques : notice sur les travaux scientifiques de J. Tixier. Universite de Paris X Nanterre.

Tixier, J. 1956. Le hachereau dans l'Acheuléen Nord-Africain: notes typologiques. In *Congrès préhistorique de France – Compte-rendu de la XVème session,* 15–22 July*,* 914–923. Poitiers: Angoulême.

Tixier, J., M.L. Inizan and H. Roche. 1980. *Prehistoire de la pierre taillee 1: Terminologie et Technologie.* Cercle de Recherches et d'Etudes Prehistoriques, Valbonne.

Toro-Moyano, I., D. Barsky, D. Cauche, V. Celiberti, S. Grégoire, F. Lebegue, M.H. Moncel and H. de Lumley. 2011. The archaic stone tool industry from Barranco León and Fuente Nueva 3, (Orce, Spain): evidence of the earliest hominin presence in southern Europe. *Quaternary International* 243 (1): 80-91.

Toth, N. 1987. Behavioral inferences from early stone artifact assemblages: an experimental model. *Journal of Human Evolution 16*(7): 763-787.

Toth, N. 1985. The Oldowan reassessed: a close look at Early stone artifacts. *Journal of Archaeological Science* 12: 101-20.

Toth N. 1982. *The stone technologies of Early Hominids at Koobi Fora, Kenya: an experimental approach*. Unpublished Ph. D. Dissertation, University of California, Berkeley.

Tryon, C.A. and S. McBrearty. 2002. Tephrostatigraphy and the Acheulean to Middle Stone Age transition in the Kapthurin Formation, Kenya. *Journal of Human Evolution* 42: 211–35.

Tryon, C.A. and R. Potts. 2011. Approaches for understanding flake production in the African Acheulean. *Paleoanthropology* 376−389.

Tugrul, A. and I.H. Zarif. 1999. Correlation of mineralogical and textural characteristics with engineering properties of selected granitic rocks from Turkey. *Engineering Geology* 51: 303-317.

Upadhyaya, T.P., S. Raju and D.P. Singh. 1993. Second generation mapping of Bundelkhand granites and Bijawar group of rocks in parts of Lalitpur district, U.P. *Records of the Geological Survey of India* 126 (8): 44-48.

Utrilla, P. and C. Mazo. 1996. Non-flint raw materials in La Rioja: a tentative interpretation. In *Non-flint Stone Tools and the Palaeolithic Occupation of the Iberian Peninsula*, eds. N. Moloney, L. Raposo and M. Santonja, 63–80. Oxford: Tempus Reparatum, BAR International Series 649.

Vallverdú, J., P. Saladié, L. Bennàsar, D. Cabanes, E. Mancha, L. Menéndez, H. Blain, A. Ollé, J. Vilalta, M. Mosquera, I. Cáceres, I. Expósito, M. Esteban, R. Huguet, A. Rosas, À. Solé, L. López-Polín, J. Martinell, A. García-Garbo, B. Martínez-Navarro, J. Agustí, S. Ros-Montoya, E. Carbonell and R. Capdevila. 2009. El barranc de la Boella de la Canonja (Tarragonès) revisitat en la intervenció arqueològica preventiva de l'any 2007. *Tribuna D'Arqueologia* 2008–2009:7–28.

van Riet Lowe, C. 1945. The evolution of the Levallois technique in South Africa. *Man* 45: 49–59.

Vaughan, C.D. 2001. A million years of style and function: regional and temporal variation in Acheulean handaxes. In *Style and Function: Conceptual Issues in Evolutionary Archaeology*, eds. T.D. Hurt and G.F.M. Rakita, 141-163. Westport, Connecticut: Bergin & Garvey.

Vekua, A., D. Lordikipanidze, G.P. Rightmire, J. Agusti, R. Ferring, G. Maisuradze, A. Mouskhelishvili, M. Nioradze, M. Ponce De Leon, M. Tappen, M. Tvalchrelidze, and C.P.E. Zollikofer. 2002. A new skull of Early Homo from Dmanisi, Georgia. *Science* 297: 85-89.

Vredenburg, E. 1906. Geology of the state of Panna, principally with reference to the diamond-bearing deposits. *Records of the* Geological *Survey of India* 33: 261–314.

Wadia, D.N. 1961. *Geology of India*. London: Macmillan.

Wakankar. V.S. 1975. Bhimbetka: the prehistoric paradise. *Prachya Pratibha* 3 (2): 7-29.

Wakankar, V.S. 1973. Bhimbetka excavations. *Journal of the Indian History* LI (1): 23-32.

Wakankar. V.S. 1962. Painted rock-shelter of India. *Revista di Science Prehistorische* 17: 132.

Wakankar, V.S. and R.R.R. Brooks. 1976. *Stone Age paintings in India.* Cambridge: University of Cambridge.

Walker, M. J., M. López-Martínez, J.S. Carrión-García, T. Rodríguez-Estrella, M. San-Nicolás del-Toro, J.L. Schwenninger, A. López-Jiménez, J. Ortega-Rodrigáñez, M. Haber-Uriarte, J.L. Polo-Camacho, J. García-Torres, M. Campillo-Boj, A. Avilés-Fernández and W. Zack. 2012. Cueva Negra del Estrecho del Río Quípar (Murcia, Spain): A late Early Pleistocene Hominin site with an 'Acheulo-Levalloiso-Mousteroid' Palaeolithic Assemblage. *Quaternary International,* 294: 135-159

Walker, M. J., T. Rodriguez Estrella, J.S. Carrion Garcia, M.A. Mancheno Jimenez, J.L. Schwenninger, M. Lopez Martinez, A. Lopez Jimenez, M. San Nicolas del Toro, M.D. Hills and T. Walkling. 2009. Cueva Negra del Estrecho del Río Quípar (Murcia, southeast Spain): an Acheulian and Levalloiso-mousteroid assemblage of Paleolithic artifacts excavated in a Middle Pleistocene faunal context with hominin skeletal remains. *Eurasian Prehistory,* 4: 3-42.

West, W.D. and V.D. Choubey. 1964. Geomorphology of the country around Sagar and Katangi, M.P.: An example of superimposed drainage. *Journal of the Geological Society of India* 5: 41–55.

Westaway, R. 2011. A re-evaluation of the timing of the earliest reported human occupation of Britain: the age of the sediments at Happisburgh, eastern England. *Proceedings of the Geologists' Association* 122 (3): 383-396

Westaway, R., D.R. Bridgland and S. Mishra. 2003. Rheological differences between Archaean and younger crust can determine rates of Quaternary vertical motions revealed by fluvial geomorphology. *Terra Nova* 15: 287–298.

Westaway, R., S. Mishra, S. Deo and D.R. Bridgland. 2011. Methods for determination of the age of Pleistocene tephra, derived from eruption of Toba, in central India. *Journal of Earth System Science* 120: 503-530.

Westgate, J. A., P.A.R. Shane, N.J.G. Pearce, W.T. Perkins, R. Korisettar, C.A. Chesner, M.A.J. Williams and S.K. Acharyya. 1998. All Toba tephra occurrences across Peninsular India belong to the 75,000 yr BP eruption. *Quaternary Research* 50 (1): 107-112.

White, M. 1995. Raw materials and biface variability in southern Britain: a preliminary examination. *Lithics* 15: 1–20.

White, M. 2006. Axeing cleavers: reflections on broad-tipped large cutting tools in the British Earlier Paleolithic. In *Axe Age: Acheulian Tool-making from Quarry to Discard*, eds. N. Goren-Inbar and G. Sharon, 365–386. London: Equinox.

White, M. and N. Ashton. 2003. Lower Palaeolithic core technology and the origin of the Levallois method in northwestern Europe. *Current Anthropology* 44(4): 598–609.

White, M.J. 1998a. On the significance of Acheulean biface variability in southern Britain. *Proceedings of the Prehistoric Society* 64: 15-44.

White, M.J. 1998b. Twisted ovate bifaces in the British Lower Palaeolithic: some observations and implications. In *Stone Age Archaeology: Essays in Honour of John Wymer*, eds. N. Ashton, F. Healy and P. Pettitt, 98-104. Oxford: Oxbow Books.

Whittaker, B.N., R.N. Singh and G. Sun. 1992. *Rock fracture mechanics: principles, design and application*. Developments in Geotechnical Engineering 71, Elsevier.

Wymer, J.J. 1968. *Lower Palaeolithic archaeology in Britain*. London: John Baker Publishers.

Wynn, T. 2002. Archaeology and cognitive evolution. *Behavioral and Brain Sciences*, *25*(03): 389-402.

Wynn, T. and F. Tierson. 1990. Regional comparison of the shapes of Later Acheulean handaxes. *American Anthropologist* 92: 73-84.

Yadav, G.S., A.S. Dasgupta, R. Sinha, T. Lal, K.M. Srivastava and S.K. Singh. 2010. Shallow sub-surface stratigraphy of interfluves inferred from vertical electric soundings in western Ganga Plains, India. *Quaternary International* 227: 104-115.

Zhu, R., R. Potts, F. Xie, K. A. Hoffman, C. L. Deng, C. D. Shi, Y.X. Pan, H.Q. Wang, R.P. Shi, Y.C. Wang, G.H. Shi and N.Q. Wu. 2004. New evidence on the earliest human presence at high northern latitudes in Northeast Asia. *Nature* 431: 559–562.