Summery and Conclusion

Present work is an attempt to find answers for three major questions of archaeological research of India as well as that of the world. First is question is related to the variability of the fracture pattern of different lithic raw materials used by the prehistoric people and impact of these raw materials on lithic anlysis. The second problem is related to the judgment or validation of the reconstruction of lithic reduction sequence of a particular type of lower paleolithic artifact of eastern India. Finally the third problem is related to the representation of the results of actualistic or experimantal studies in archaeology in an 'emic' way.

Blueprint of present work is formulated in such a way that solutions may be derived for all the above mentioned problems. The major objectives of this work are as follows:

1. The first and foremost objective is to get an idea about the reduction sequence of the entire manufacturing process of different types of lower Paleolithic handaxes found in eastern India and subsequently to reconstruct related behavior patterns of the knapper connected with this manufacturing process.
2. Second one is to study the debitage produced during the experimental manufacture of the bifaces. The debitage thus produced may give an idea about the effect of raw material variability. It will also throw light on knapping techniques and stages of reduction, which can be done on analysis and identification of flaking debris or debitage.
3. The third objective is to study the thoughts and the condition of the knapper's mind at the time of manufacturing a stone tool. The third goal is very much related to the first one and in some cases both these goals overlap with each other. For this reason the study methods and results of first and third objectives are represented in a combined way.

It is expected that fulfillment of the above mentioned objectives will help to understand classification of the different stages of tool manufacture, planning, formulating knapping strategies and the ultimate design and shaping of the finished product. Study of the manufacturing process of experimentally made tools, study and analysis of finished products and resulting debitage will also help to reconstruct some behaviors of prehistoric people, who lived in different parts of the plateau region of Eastern India. Finally, it can be said that this study will also help to reconstruct part of the *chaine operatoire* of lithic assemblages of the selected sites. In this context it is mentionable that this work is probably the first attempt of this kind in eastern India.

A total of 29 pieces of raw material, collected from three different lower paleolithic sites of eastern India, are knapped in this experimentation. The selected sites are Pallahara of Orissa, Dahigora of Jharkhand and Belpahari of West Bengal. The author has covered three main States of the eastern plataeau region of eastern India. These are areas which had yielded lower Palaeolithic sites in this part of India. Out of the 29 pieces of raw materials, only 15 raw materials, 10 of quartzite, 4 of quartz and 1 of metadolerite were successfully knapped into Hand axes. Among them one raw material (DGR-13-08) was broken into two pieces after a few blows. However, those two broken pieces were successfully knapped into two hand axes. A total 16 implements were made out of 15 pieces of raw materials, which were successfully knapped. The two broken pieces of DGR-13-08 were named as DGR-13-08a and DGR-13-08b.

One thing must be mentioned regarding knapping experience that quartzite is easier to knap than quartz and metadolerite. It is observed that out of the 16 quartz raw materials, knapped in the laboratory, only four were successfully tailored into hand axes. On the other hand out of the 12 quartzite raw materials 10 were successfully knapped into handaxes. Single metadolerite gravel was knapped and it turned into what may be called a proto hand axe.

The main problem, faced at the time of knapping of quartz is that it is an extremely fragile raw material and its fracture pattern is not ideal for making stone tools. However after detaching a flake from quartz pebble it showed all the features of Hertzian cone fracture but they were not very prominent like that of quartzite. The brittleness of the raw material makes it vulnerable to breakage, especially when heavy blows were given to detach large flakes. In addition to this some quartz raw materials, especially which were collected from Belpahari, were with highly weathered surfaces and high percentage of phenocrysts or mineral line cavities. Presence of these mineral line cavities gives undesired fractures and even sudden shattering of raw material at the time of knapping. However, six quartz raw materials collected from Dahigora were less weathered and out of these three were successfully knapped into hand axes. On the other hand, among 10 quartz nodules collected from Belpahari only one was successfully turned into biface.

The problem faced at the time of knapping metadolerite was due to its hardness. The raw material was extremely resistant to the blows from both hard hammer and soft hammer and great force was required to detach a flake from it. Quartzite was easier to knap than quartz and metadolerite. This raw material usually gives good and desirable Hertzian cone fracture, which is preferable for making good quality stone tool.

Experiences with quartzite knapping indicate that its hardness ranges in between quartz and metadolerite. Some quartzites present weathered surfaces and line of mineral deposition within it, which sometimes made it unsuitable for knapping.

As a result of this work five reduction sequences are identified. These are based mainly on the shape and cross section of the raw materials that were used for knapping. Most important was the planning of the knapper for proper reduction of the diversely shaped raw materials into hand axes. Each of these reduction sequences has three different stages. These are identified on the basis of diagnostic attributes of the resulting product of knapping that is, debitage, finished tools and preforms and on the type of percussor and technique used in these stages and also on purpose of knapping. Reduction stages that are identified in this research work are named as First Stage of Reduction (FSR), Second stage of Reduction (SSR) and Third Stage of Reduction (TSR). During FSR preliminary edging of the implement was done by hard hammer percussion technique. SSR is characterized by the use of soft hammer technique and in this stage thinning of biface was done. TSR is identified as the last stage during which final shaping of biface was done usually with the use of soft hammer technique.

Raw materials with oval cross section were knapped firstly by giving a few heavy blows from the right and left borders. These blows were given in such a way that flakes were removed from two opposite surfaces of two borders e.g. in case of right border of the raw material blows were given from dorsal surface and as a result flakes were detached from ventral surface. Reverse type of flaking was done in case of left border. Gradually in this way flaking on the top and bottom borders of the raw material were flaked until preliminary edging of the raw material became complete. The stage, where preliminary edging of raw material was done is identified as the first stage of reduction (FSR) in a reduction sequence.

After the completion of FSR flakes were detached in an alternate way from different borders of the raw material. This was done for thinning of the biface. As a result of this type flaking the raw material gradually attained a rhomboid or roughly bi-convex cross section. Due to the detachment of such biface reduction flakes the raw material gradually became thinner in profile and also got a nearly straight working edge. This particular stage of reduction was identified as the second stage of reduction (SSR) of the raw material.

After that, final finishing of the raw materials was done by detaching either biface reduction flakes or by detaching simple flakes. In this stage usually the implement got their final shape and a number of very small flakes were detached from its borders to make them straight, sharp and durable; this stage is known as third stage of reduction (TSR).

Knapping strategy of the raw materials with rhomboid cross section is quite similar to those of the raw materials with oval cross section. In the F.S.R of the rhomboid cross sectioned raw materials the bevelled sides of the dorsal and ventral surfaces of the raw material were selected as the striking platforms for initial knapping. After this a set of flakes were removed either from the dorsal or from the ventral surface of the raw material, from both its right and left borders. Usually, aim of the flaking in this way was to remove flakes as large as possible. Sometimes the flakes, removed in this way were so large that their scars covered entire surface area of the raw material, at times both the dorsal and ventral surfaces of the raw material. At this point of time if it was apparent that the detached flakes were large enough and they had removed most of the cortical surface and that thickness of the raw material and the initial edging of the raw material were achieved, then F.S.R usually ended there. In case the previously mentioned result was not achieved in the first stage of knapping, then another set of flakes were removed, but this time from a completely opposite direction and from the completely opposite region of the first flaking. At the time of S.S.R the main aim was to reduce the thickness of the preform as much as possible and to straighten its working edge without changing the shape of the cross section. Throughout the entire S.S.R a number of biface reduction flakes were detached bifacially from the raw material. Together with this small flakes intended for platform preparation were also detached. This depended on the necessity of preparing striking platforms. Aim of the T.S.R of the present reduction strategy was same, that is, to give the implement its final shape. During T.S.R only the modifications in the shape of the bifaces were done. To achieve this, combination of hard hammer technique and soft hammer techniques were applied according to requirement.

In case of the raw materials with rectangular cross section, first few blows of FSR were given at the borders of the raw material in such a way that, after FSR cross section of the raw material took the shape of a rhombus. After that, reduction strategy similar to that of the rhomboid cross sectioned raw material was followed.

Raw materials with triangular cross section were flaked from the ventral surface during FSR. Usually large flakes were removed only along all borders on the ventral surfaces. As a result of this, the raw material usually took either a diamond like pentagonal cross section or an elongated rectangular cross section after FSR. During the first part of SSR, flakes were removed gradually and carefully from the dorsal surface, so gradually that the diamond like cross section became flatter in outline. In the later part of SSR a number of biface reduction flakes were removed along one border only, that is, either on right or left margin on the ventral surface of the material. As a result the raw material took a roughly rhomboid cross section after SSR. During TSR small biface reduction flakes were removed from both the surfaces and as a result the final shape of the finished tool gradually attained its specific morphology from the raw material.

Reduction strategy of the raw materials with isoceles triangular cross section is little bit complex than the reduction strategies, described above. During FSR flakes were removed from the dorsal surface and after removal of a few larger flakes it seemed to the present author that initial edging of the raw material was complete. In this stage the raw material had an almost rhomboid cross section. During SSR flakes were removed from the ventral surface in the same way and this resulted reduction of the thickness of the preform. After completion of SSR, the preform looked almost like an oval hand axe in shape.

The debitage were compared with respect to the raw material types. This had given some significant results. First important observation was made on the debitage conditions.

Observation was made to see whether debitage produced were broken or not and whether breaking of debitage depended on the brittleness of the raw materials. Statistical tests were made for patterns of significance. Results of χ^2 had shown that the debitage condition is significantly different for quartz, quartzite and metadolerite. Another individual flaking attribute tested by χ^2 statistics was debitage termination. Study of debitage termination of each flake showed that there were four different types of terminations present within the entire collection. These were named as, feather, step, hinge and unidentified according to the nature of breakage of flakes. Results of χ^2 had shown that the proportion of these four types of debitage terminations differed significantly for quartz, quartzite and metadolerite.

Mean value of a number of other individual flaking attributes, such as, flake length, flake width, flake thickness, striking platform width, thickness and angle of striking platform were compared with the use of one way ANOVA. This was done for finding out how far raw materials influenced the type of the flakes/ debitages produced As a result of this test the differences observed in the mean flake thickness, mean flake length turned out to be significant and difference in mean striking platform thickness was highly significant. Flake/debitage attributes like flake thickness, flake length and striking platform thickness differed significantly for three types of raw materials, quartz, quartzite and metadolerite. Post hoc multiple comparisons by Scheffe test have shown that these differences were more significant when quartz and metadolerite were compared.

Reduction stages were compared with the help of various attributes of debitages also. In this regard it must be mentioned that three different reduction stages i.e.first stage of reduction or FSR, second stage of reduction or SSR and third stage of reduction or TSR were identified in the entire reduction sequence and all these reduction stages varied according to their purpose and also according to the type factor of the finished products. Mean of six different individual flaking attributes like length, breadth, thickness of flakes and angle, width, thickness of striking platform were compared by one way ANOVA to find out whether any significant difference lies among debitage of different reduction stages. Results of one way ANOVA showed that highly significant difference was present in mean value of all attributes i.e. flake length, flake thickness, flake width, striking platform angle, striking platform thickness and striking platform width. Results of post hoc test (multiple comparisons by Scheffe test) show that differences in all these attributes were greater when FSR was compared with SSR and with TSR but differences between SSR and TSR were not very significant.

In the entire reduction sequences of present experimentation only two different techniques were used for detaching flakes, they were hard hammer percussion technique or HHT and soft hammer percussion technique or SHT. Both of these techniques were also compared with each other on the basis of various features of flake debitages they produced. Both these techniques were compared with the use individual flaking attributes of resultant debitages, such as, mean values of flake length, flake width, flake thickness, striking platform angle, width and thickness. T- Test was used for comparing these individual flaking attributes and its result showed mean value of all the attributes like striking platform angle, striking platform thickness, striking platform width, flake length, flake width and flake thickness were significant.

Results of present work indicate that experimental flintknapping may have major application areas in Indian archaeology. In present context it has been successfully used to understand hand axe technology of eastern India as well as to understand diversity of lithic assemblage according to raw material, technology of knapping and according to different phases of entire reduction sequence. Results of present work may also be used in field archaeology, especially in eastern India to compare and understand different phases of tool manufacture. Another major application of its result may be the development of a new method of stone tool analysis; in which errors occurred by the diversity of raw material may be calibrated.

Present work may be extended in future for further experimentation to reconstruct reduction sequence of various lower paleolithic tools of this subcontinent. Further extension of this work may lead to the analysis of the lithic assamblage of a particular site and replicate entire lithic assemblage of a particular site to understand procurement, economization of lithic raw material, curation of damaged lithic artifacts and the entire lithic reduction strategy of the prehistoric people, who inhabited that site. This work may also be extended to understand fracture property of various lithic raw materials, used by the prehistoric people of this subcontinent and also technology and typology of lithic artifacts used by the prehistoric people. To some extent glimpses of the mental template of knapper could also be reconstructed. Finally, it can be said that present study with all its limitations may be a model for further work on experimental flint knapping as well as analysis of lithic artifacts of Indian subcontinent.