

Palaeolithic Hafting in Himachal Sub-Himalaya

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Abstract

Hafting has brought a landmark change in technology and behavior of the Palaeolithic man heralding evolution of anatomical modernity and behavior. The author recently discovered large assemblages of Late Acheulian to Middle Palaeolithic industries from the Quaternary fans of the Sub-Himalayan piedmont area of Ghumarwin Sir Khad valley of Himachal Pradesh. He identified 20 typological categories in a collection of 450 stone implements, which include several new tool types, so far unknown in other Indian sites. There is a remarkable occurrence of 111 hafted implements; almost one in four is the hafted tools (24.67%). They include large-sized axes/adzes, spears, sickles, shovels, picks, chopping tools, etc. among the frequent types, noticed for the first time in north-western Sub-Himalaya of India. The diversified hafting in the region suggests diverse activities of the prehistoric man, like intense wood cutting/wood work, large game hunting, butchering, and some warfare as well. In addition, soil processing for primeval farming is also indicated.

Keywords

Palaeolithic, Middle Palaeolithic, Hafting, Shouldering, Tanging

1. Introduction

The Sub-Himalayan region of Ghumarwin Siwalik terrain is best known world-wide for the fossil remains of the Late Miocene primates, like lorises, tree shrews and *Krishnapithecus*, and large hominids, like *Sivapithecus* and *Gigantopithecus*. Attention towards the occurrences of Soan Palaeolithic pebble implements in the Siwalik confinements of this area was first drawn by the author (Sankhyan, 1979, 1983). But, he encountered the large flake Acheulian for the first time in the year 2010 at Kallar - Balghad tri-junction of the Sir Khad and the Saryali Khad with the major river Satluj (Figure 1). These explorations were resumed for the Acheulian in the year 2014, but more vigorously and systemati-

cally during 2017 and 2018 with a brief reporting (Sankhyan, 2017c, 2018). These led to a large collection of over 500 implements displayed in the Palaeo Museum galleries set up at Ghumarwin in the years 2017 and 2018 and opened for public. A detailed analysis of 450 select stone tools catalogued and studied for various tool-types presented in **Table 1**. They also include some Soanian pebble choppers found mixed up at Drugh, Tanda, Nalti and Ghumarwin sites in the mainstream Sir Khad dominated by the Late Acheulian and Middle Palaeolithic industries. This co-occurrence of the two distinct industries might indicate some sort of occasional confrontations between the two prehistoric people.

Extensive mining for sand, gravel, cobbles and medium-sized boulders in the Sir Khad and its tributaries has resulted in heavy loss of tools for the archaeologists/palaeoanthropologists, and the sites would soon be lost forever. At Triveni in Jahu, where two tributaries meet the Sir Khad, huge boulders are conspicuously overlooking the landscape due to intensive mining of the pebbles.

Table 1. Typological and size distribution of 450 Palaeolithic implements and their hafted content from Ghumarwin area (H.P.), north India.

<i>Sr. No.</i>	<i>Tool Type</i>	<i>Total</i>	<i>%</i>	<i>Hafted</i>	<i>%</i>
1	Handaxes*	155	34.44	-	-
2	Cleavers/Tanged Spuds (ta)	86	19.11	10	1.78
3	Scrapers	46	10.22	-	-
4	Choppers/Chopping tools (sh)	34	7.56	2	0.44
5	Axes/adzes (sh)	22	4.89	22	4.89
6	Spears (sh + ta)	17	3.78	17	3.78
7	Backed Knives	14	3.11	14	3.11
8	Tortoise Cores	14	3.11	-	-
9	End Scrapers (ba)	10	2.22	10	2.22
10	Arrows (ret)	9	2	9	2
11	Sickles (ba + sh)	8	1.78	8	1.78
12	Picks & Drills	6	1.33	1	0.22
13	Notches	7	1.56	1	0.22
14	Shovels /Hoes (ta)	7	1.56	7	1.56
15	Hammers	6	1.33	2	0.44
16	Splitters (ta)	3	0.67	3	0.67
17	Foliate/Laurel Leaf (ret)	3	0.67	3	0.67
18	Awl (ta)	1	0.22	-	-
19	Saw cutter (ba)	1	0.22	1	0.22
20	Hide Planner (ta)	1	0.22	1	0.22
	TOTAL	450	100	111	24.22

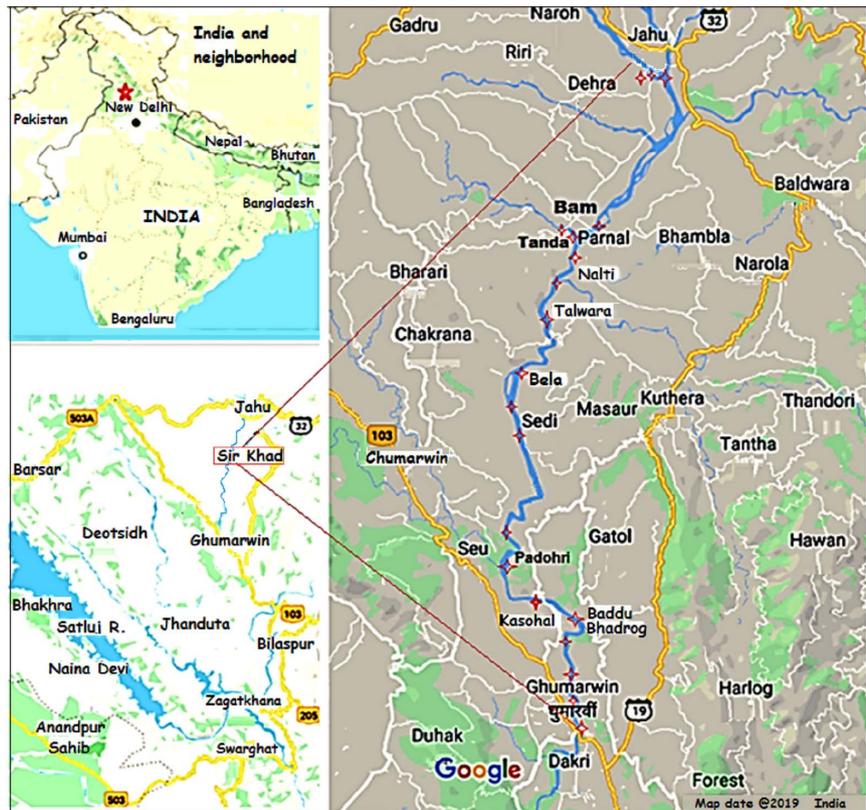


Figure 1. Google Map of Ghumarwin- Jahu area, Himachal Pradesh showing the Pa-laeolithic sites on the alluvial fans along Sir Khad river.

2. Geomorphology & Chronology

The Sub-Himalayan terrain in Ghumarwin region is the uplifted Siwalik piedmont zone between the Lesser Himalayan hill (*dhar*) in the east and the Upper Siwalik Boulder Conglomerate Formation, including outcrops of the Middle Siwalik in the west. The Boulder Conglomerate was deposited during 1.8 - 1.1 million years ago (Valdiya, 1993; Kumar et al., 2007; Tandon et al., 1984). With the greatest upheavals in the Himalaya during Middle Pleistocene around half a million years ago, the Siwalik sedimentary uplifted and tilted. With this began the post-Siwalik Quaternary sedimentations of the alluvial fans comprised of gravels and boulders eroded from the Boulder Conglomerate Formation, including the Middle Siwalik sandstone clasts. The boulders served the source of raw material for prehistoric stone tool making. Therefore, the stone tools made on or just after erosion of the Boulder Conglomerate are of the earliest antiquity here. The post-Siwalik Quaternary sedimentations lead to aggradations of two conspicuous Quaternary fans, termed *Qf-1* (the older) and *Qf-2* (the younger) fan deposits that occurred in the *intra*-montane hog-back basin surfaces (Kumar et al., 2007). Therefore, the stone tools in these aggradational fans (Figure 2, Figure 3) bear their dates. The piedmont zone was formed between the time of aggradations of *Qf1* and the recession of the Boulder Conglomerate Formation around 0.6 ma or even earlier.

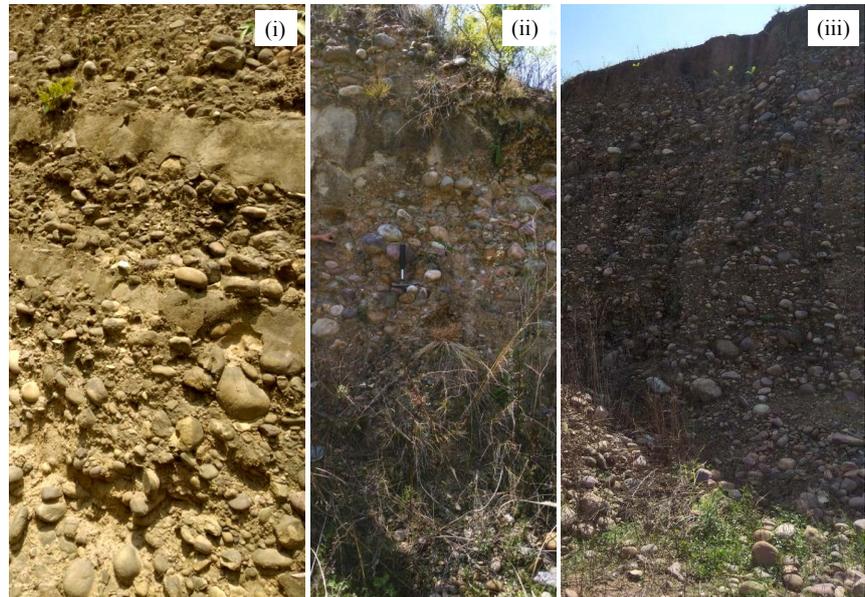


Figure 2. Stratigraphic sections in study area: (i) Boulder Conglomerate at Bam; (ii) (iii) Qf-1 at Jahu.

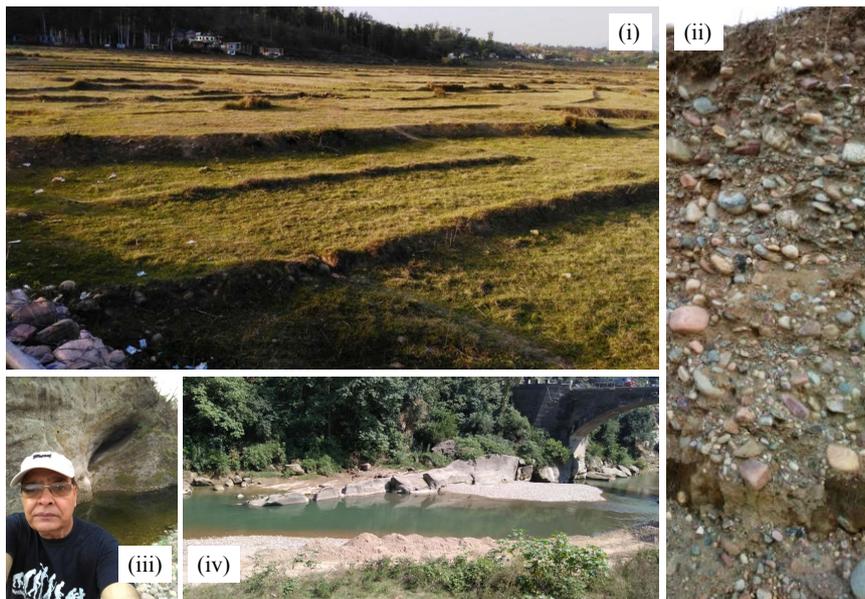


Figure 3. (i) Qf-2 profile view at Bam; (ii) Qf-2 section at Drugh; (iii) Nain Gufa (cave) in the Upper Siwalik rock wall at Talwara; (iv) Ghumarwin Sir Khad Bridge Site.

The piedmont streams are the sole feeders to the alluvial fans, and the largest stream formed in the study area is the Sir Khad, also spelled as *Seer Khad*. It emerges near Sarkaghat and runs a 35 km long course through Ja-hu-Bam-Ghumarwin area and joins the Satluj at Serimatla near Bilaspur. The Sir Khad is fed by a large numbers of smaller streams emerging from the Sub-Himalayan hills in the east and the choes emerging from the Siwaliks in the west. As per the OSL dates, the *Qf1* is the highest aggradational piedmont fan whose sedimentation started over 100 ka and stopped ~84 ka (Kumar et al.,

2007). It is time transgressive laterally from east to west with the central part remaining as the uplifted inter-fan domain, linked to the intra-foreland thrusting. In Ghumarwin-Bam-Jahu study area its thickness was measured to about 6 - 7 meters. The *Qf1* piedmont zone was inhabited by the Acheulian man, evident from the heavy duty handaxes, cleavers, choppers and other large tools derived from its section, but without any hafted tools. Therefore, the maximum dates of the Acheulian tools in *Qf-1* could be linked with recession of the Boulder Conglomerate Formation.

The *Qf-1* was gradually entrenched and eroded resulting in formation of *Qf-2* alluvial fan beginning over 73 ka and went on for long until - 24.5 ka (Kumar et al., 2007). In Ghumarwin-Bam-Jahu-Mundkhar area the *Qf-2* section is about 4 - 5 meters in thickness comprised of graded layers of boulders, cobbles (including some *Qf-1* stone tools), gravel, sand lenses and silt (Figure 3). The *Qf2* alluvial fan deposit looks like hog-back aggradational piedmonts occurring at lower basin-ward elevations. The Ghumarwin Sir Khad valley expands gradually northwards forming extensive Bam-Jahu dun. But, south of Bam-Tanda it forms relatively narrow terraces at Nalti, Talwara, Bela, Padohdi, Kasohal, Bad-du-Bhadrog and Ghumarwin Sir Khad Bridge and Stadium area. Further downwards, the Sir Khad traverses a narrow gorge course until Sunhani.

The intra-montane entrenchment of *Qf-2* by the Sir Khad exposed its contents along and on the river bed. Most of the hafted implements belong to the *Qf-2*, sometimes found mixed up with some heavy duty tools eroded from the *Qf-1*. Deep natural erosional trenches in Bam valley provide glimpses of in situ Middle Palaeolithic tools in the *Qf2* context, which included hafted tools. The *Qf2* eroded by the Sir Khad bed exposes incredible concentration of this mixed up industry spread all over where hafted tools are found in greater number.

At Bam, a major tributary of Sir Khad is Drugh, which emerges from a deep gorge formed within the Upper Siwalik Boulder Conglomerate Formation. Its collapsed *Qf2* near Bam-Tanda-Talwara has yielded a remarkable number of almost fresh stone tools from the cutting of the *Qf-1* and *Qf-2*.

Extensive mining in the Sir Khad and its tributaries has resulted in heavy loss of tools and the sites would soon be lost forever. At Jahu Triveni trijunction, where two tributaries meet the Sir Khad, extensive mining for sand, gravel, cobbles and medium-sized boulders, the left out huge boulders and erratics are conspicuously overlooking the landscape.

3. Material and Methods

The Ghumarwin stone tool assemblage is so varied and unique in typology with hitherto unknown types anywhere in north India. Till date, the only one large known Acheulian site in north India is Atabarpur in Punjab Siwalik Frontal Range that has yielded considerable Acheulian artifacts (Mohapatra, 1981; Kumar & Rishi, 1986). These, a sample of 50 tools that included handaxes, cleavers, scrapers and choppers, were analyzed in depth by Gaillard et al. (2008). However, in comparison the Ghumarwin assemblage is very huge with great richness,

intensity, variety and uniqueness of tools. The Bam site near the village of Bam, alone provided a large sample of 350 with large number of unique hafted tools. It is, therefore, christened as Bamulian (Sankhyan, 2018).

Techniques Used

The Ghumarwin implements are made on medium to coarse-grained quartzite cobbles and boulders of various hues from light gray, ash gray, ash-brown chocolate, ash black and black, besides many on milky quartz. The quartzite is generally fine-grained and highly metamorphosed. The toolmaker has intelligently chosen the large flakes, cores and blanks and worked one surface only leaving the other natural convex smooth surface intact in production of unifacial handaxes, which presents biconvex look. In fact, due to abundance of raw material on the site, the toolmaker spent minimum energy on refinement of the tools such that most of the handaxes are unifacial. In true core bifaces the proximal part of the tool cortex is trimmed retaining the hind thick cortical butt. The tool-maker preferred to make long and ovate or round handaxes, trimmed at the circumference with minimum effort. The Kombewa core reduction technique is frequently employed for handaxes and cleavers to shed out the core burden. Among the Middle Palaeolithic tools, the Levalloisian broad and elongated tongue-like ventral face of the large and small flakes is a common feature, where the striking platform is short or broad and internally angles at about 30°. In most of cases the bulb of percussion is defused. Large and small tortoise cores are in good number. The long flakes are trimmed to produce chopping tools with a long handle-like shoulder. Both shouldered and tanged spears are produced. Large to small axes/adzes are produced with beveled large horizontal or slightly convex cutting edge and shouldered neck for a haft. Some cleaver type tools were made with a large tang, likely used as spuds (*khurpi*). Large to medium-sized sickles are retouched at their inner concave side retaining the thick convex side with a small shoulder or tang at butt end for hafting. Meticulously obtained large, oval and very thin flakes are retouched to produce foliates or “Laurel Leaf” like swords. Some wood Splitters (*addu*) were also found with mid tangs and wide striking platform made for hammering. There are also a good number of large to small retouched arrow points.

4. Results

4.1. Total Ghumarwin Assemblage

A total sample of 450 stone tools was catalogued, analyzed of which the Bam site alone has yielded about 350 tools, excluding the untouched flakes and unfinished artifacts which were not sampled leaving lots of artifacts in the site. Massive handaxes also form part of the industry as are the large-sized cleavers as well as the choppers, only a few of them were sampled. 20 typological categories were distinguished listed in Table along with the numbers of implements in each category, their per cent occurrence in the total sample. Among the same types, the number and percentage of hafted implements are listed in the table. It may be

noted from **Table 1** that the tool assemblage from Ghumarwin area is characterized by a preponderance of 155 handaxes (34.44%), 84 cleavers (18.67%), followed by 46 scrapers (10.22%) and 34 choppers (7.56%), 25 hafted axes/adzes (5.56%) and 17 hafted spears (3.78%). The other types are lesser in number.

Special mention was paid to 155 handaxes to classify and measuring. Their main shapes were: *ovate* = 54 (34.84%), *pear* = 34 (21.94%), *almond* = 26 (16.77%) and *chordate* = 14 (9.03%). There were several other categories, lumped as miscellaneous types totaling to 27 (17.42%). The handaxes were further classified as unifacial (UF), which are 59 in number (38.06%), the bifacial (BF) numbering 52 (33.55%). Considerable number 40 (25.81%) of handaxes look biconvex or intermediate unifacial/bifacial (UF/BF). Four handaxes (2.6%) were unclassified. The sites had many heavy and gigantic handaxes, including gigantic cleavers and choppers, but only a few of them were sampled.

4.2. Ghumarwin Hafted Implements

The Acheulian tools were used for long by holding them in hands from the rounded smooth butt and used for short distance hunting and butchering. Gradually, to avoid direct encounter with dangerous animals, Palaeolithic man learned the art of throwing them from a distance. Thus, he got the idea of sharpening the implements and of a handle-like shoulder or a tang (neck) to tie them with a wooden post. Thus, he invented a hammer, an axe/adz, a spade or hoe and a spud which provided more effective leverage. Similarly, he invented a spear and arrow point to hit the target from a distance. Hafting, thus tremendously improved implement's effectiveness and range to hit the target and brought about radical change in technology development.

The scrutiny of the Ghumarwin sample for hafting evidence brings out at least 111 (24.67%) shouldered and tanged or side-backed haftable stone tools in the sample of 450 tools. Some types of hafting categories include: 1) *shouldering* in most of the hafted tools, chopping tools, hammers, axes, spears and arrow points, 2) *tanging* in axes, shovels/hoes, spears, arrow points, Splitters and Spuds, and bone spatulas, 3) *backing* in sickles, knives, end scrapers, in bone dagger, 4) *re-touching* in foliates, arrow points, etc.

It is observed that the shouldered *axes or adzes* totaling to 25 (5.56%) are the most frequent among the haftable tools, which vary in size from large (8) to medium (7) and small (10) ones (**Figures 4-6**). This is an impressive evidence to reveal intensive wood cutting/wood work activities, further supported by 3-tanged Splitters (locally called *addu*) and one large saw cutter- part of a carpenter's tool kit (**Figures 7**). The second largest haftable tool category is of 17 spears, which vary in size from large to small (large = 5, small = 12) and suggest large-scale hunting, and even a warfare between different prehistoric groups. The third frequent category is of the backed knife which are indented and total to 14 (3.11%) and indicate fine slicing of small wild edible plants, vegetables and fruits. Next sizeable category is of 10 end-scrapers (2.22%) used for skillful scarping of flesh or skinning of the hunt. The shouldered or tanged arrow-head

points come next in plentiful number, though here only 9 (2%) better refined ones are included in **Table 1**; they indicate frequent shooting at the pray or enemy from a distance.

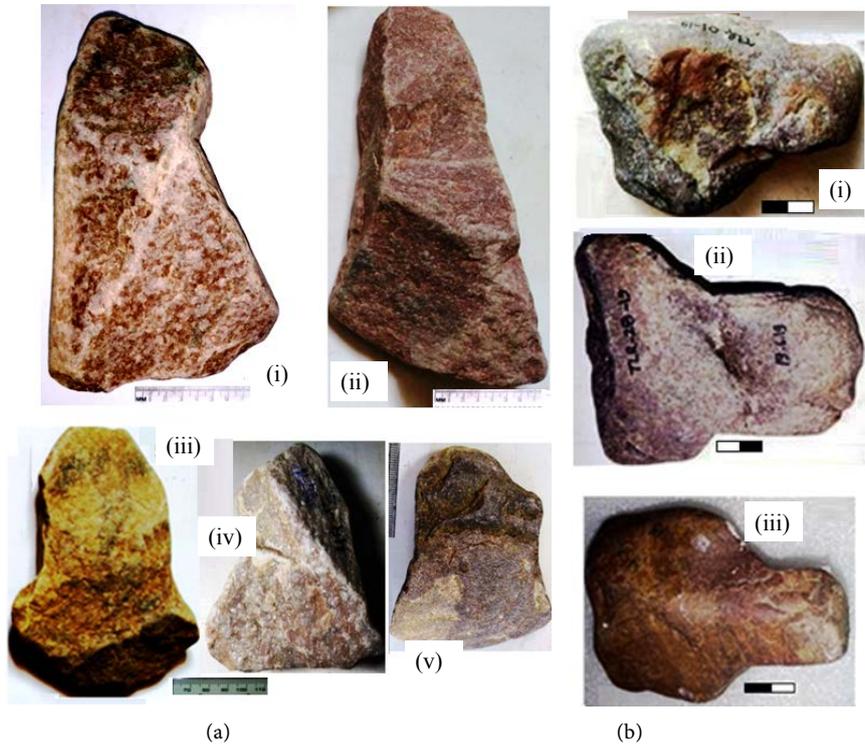


Figure 4. (a): (i)-(v) Large to medium-sized hafted axes/adzes. (b): (i)-(iii) Hafted Spuds (*Khuipi*).

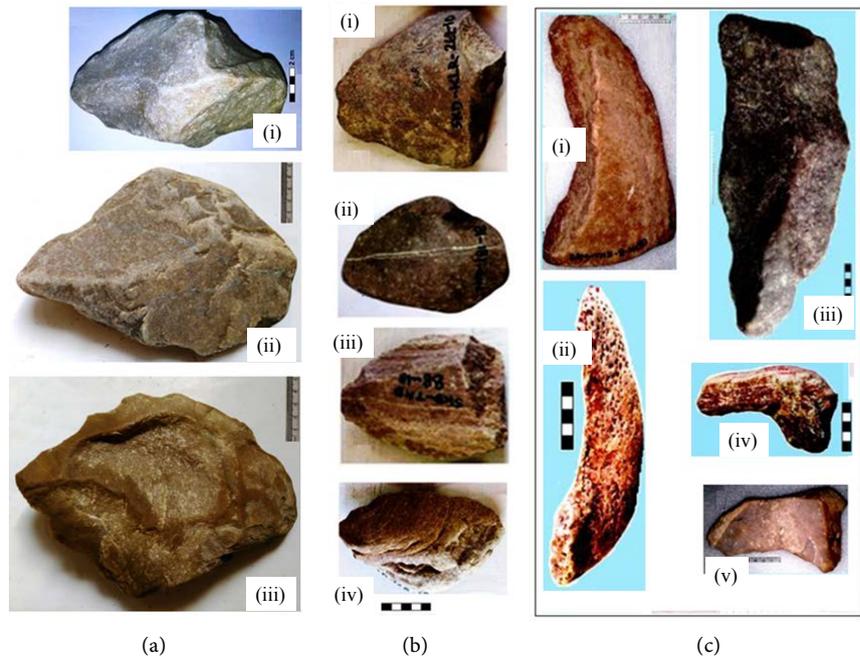


Figure 5. (a): (i)-(iii) Tanged Spears; (b): (i)-(iv) Arrow-heads; (c): (i)-(iii) Large Sickles, (iv)-(v) small sickles.

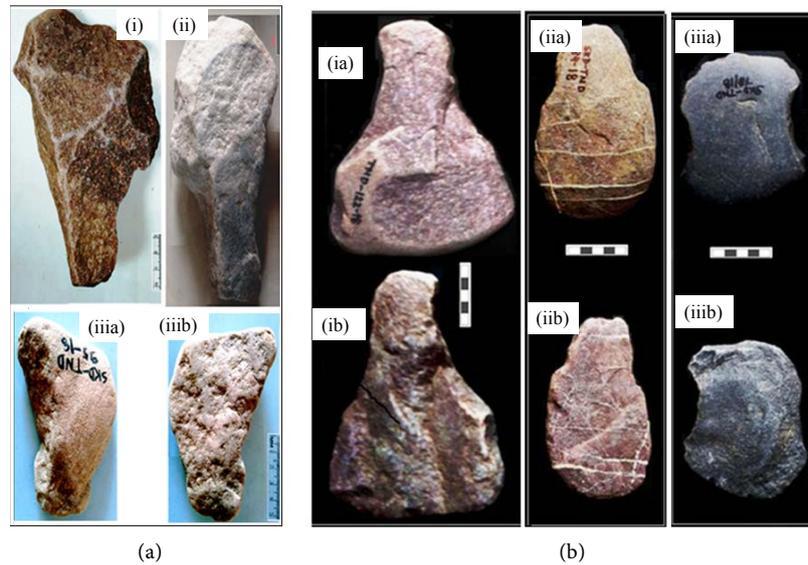


Figure 6. (a) (i)-(ii) Large chopping tools; (iiiia) (iiib): Precision hammers; (b) (i)-(ii): Hoes, (iii)-(iv). Shovel in dorsal and ventral views.

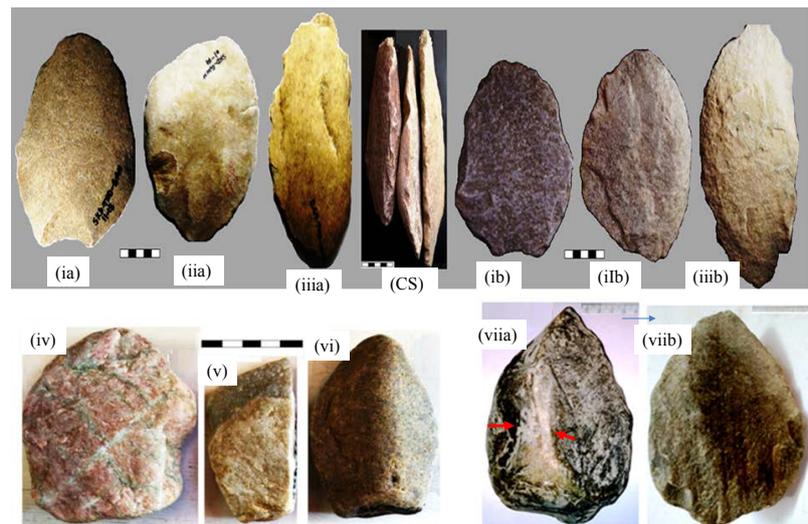


Figure 7. Upper row: 3-Foliates in dorsal, cross section and ventral views; (iv)-(vi) Tanged Splitters (*addu*); (viiia), (viiib) Hide Planner in dorsal and ventral views. Two arrows indicate the dorsal side haft.

Other hafted categories include 8-tanged spuds (*Khurpi*) (1.78%) (**Figure 4(b)**) and 8-sickles (1.78%) of which five are large-sized and three small ones (**Figure 5**). They reveal cutting of bushes and cutting of small branches of trees or even wild-grown crops. There are 7-tanged shovels/hoes (1.56%) which could be used some sort of earthwork-clearing of the soil from the settlement area or even for some gardening. In addition, there are 3-tanged large, thin, retouched foliates or “Laurel leaves” which could be used as swords to kill the game or even the enemy. 2-shouldered/handled large chopping tools are efficient meat-chopping devices of the Palaeolithic hunter. One extremely rare hide Planner (presser) with triangular flat smooth ventral surface and small dorsal tang to hold, appears

to be special tool for pressing the hides for tent or clothing.

All above 109 late Acheulian to Middle Palaeolithic hafted diverse implements endorse engagements of the prehistoric man in different activities right from hunting, meat chopping, plant cutting and wood work and soil processing, including cloth-making. They speak a proxy for a developed mental capacity and arrival of modern man in the Sub-Himalayan region of Ghumarwin area, as early as 70 ka.

5. Hafting in Rest of India & South Asia

The only other reported nearby Acheulian site is Atabarpur in Panjab Frontal Range, where there is no evidence of hafting, and only common artifact types are represented in their sample of 50 tools, such as handaxes, cleavers, choppers, scrapers and discoids. Here the cleavers are double than the handaxes unlike Ghumarwin, where it is just reverse.

The hafting in the form of Shouldered pieces appeared in western India about 96 ka, whereas the tanged pieces and points appeared there in different sites between 96 - 58 ka (Blinkhorn 2014, 2018, 2019). The tanged tools appear there less frequently in Late Palaeolithic and continued use unto the terminal Pleistocene (Sali, 1989).

In South India the tanged-point hafting is dated with YTA signatures in the Middle Palaeolithic Jwalapuram 22 site at ~77 ka (Haslam et al., 2012), and at the Late Palaeolithic Jwalapuram 9 for the backed points at ~35 ka, which is regarded as the most secure evidence of hafting across South Asia (Clarkson et al., 2009). Another famous site in South India is Attirampakam (Tamil Nadu), wherefrom two tanged pieces recovered and dated between about 385 ka and 175 ka (Akhilesh et al., 2018). Blinkhorn (2019) considers 385 ka Attirampakam date as enigmatic solitary isolated local innovation in view of “Out of Africa” origins of hafting in Africa and subsequent spread to western Eurasia between 300 - 200 ka claiming that hafting was discovered by the common ancestors of *Homo sapiens* and Neanderthals.

Hafting in the form of *retouched backing* for production of arrow-head points, backed knives, etc. was very frequent during Upper Palaeolithic times and wide spread in South Asia around 45 - 12 ka Many Indian sites of this age bracket include Mehtakheri (Mishra et al., 2013), Mahadebbera (Basak et al., 2014), Jwalapuram 9 (Clarkson et al., 2009) and Patne (Sali, 1989). They have extended to extreme south in Sri Lanka (Perera et al., 2011) at Batadomba Lena and in Fa Hien. In the latter, four *bone points* were like spear projectiles (Wedage et al., 2019). Non-hafted Middle to Late Palaeolithic industries had already reached there between 130 - 67 ka (Demeter et al., 2012; Grun et al., 2005; Liu et al., 2015) unto Sahul around 80 - 65 ka (Clarkson et al., 2017).

In his latest review Blinkhorn (2019) made no mention of hafting in the N-E, Central, North and East India. However, a solitary tanged spear of basalt collected by the author from north Bengal indicates eastward expansion of hafting technology during Holocene. Hafting in the form of shouldered or tanged small

axes, later to 3 ka, therefore, expanded to N-E India quite late (Sankhyan, 2020a). The first report of hafting in Central India is from the Narmada valley mentioned below.

6. Inventors of Hafting

Hitherto hafted tools were not previously reported from the Hathnora hominin site in the Central Narmada valley that yielded a partial hominin skullcap (calvarium) (Sonakia, 1984). It is debated an “evolved” *Homo erectus* or “archaic” *Homo sapiens* or *Homo heidelbergensis* (Sankhyan, 2006, 2010) and tentatively dated to ~236 ka (Patnaik et al. 2009). Its higher cranial capacity (1200 - 1400 mm) led to speculation of capability for hafting (Athreya, 2015). However, for the first time the author and associates excavated direct evidence of hafting (Figure 9) from the hominin fossil beds both at Hathnora and Netankheri (Sankhyan et al., 2012a, 2012b). A large flake Acheulian shouldered chopping tool was found at the Hathnora calvarium bed below U1 cemented gravel. A tanged spear was found at Sardarnagar U2 bed along with a very thin ovate sharp razor knife. Hafted bone tools, and chert arrow-head points at Netankheri U3/U2 interface in association with a human fossil humerus and two sacra datable to ~70 ka (Figure 9). Earlier, the yellow sand Hathnora U1/U2 interface, datable to ~150 ka, had also yielded two tiny hominin clavicles and a 9th rib (Sankhyan, 1997a, 1997b; Sankhyan, 2005), belonging to a “short and stocky” hominin resembling the Andaman pygmy in body dimensions (Sankhyan & Rao, 2007; Sankhyan, 2020b). The Hathnora and Netankheri hominin postcranial fossils establish continuity of the “short and stocky” lineage unto ancient Indian heartland, like Pauri Bhuiya, which share mtDNA signatures with the Andaman pygmy until they branched off ~25 ka.

So far the author and associates have collected 14 hominin postcranial fossils from different localities in the Central Narmada valley in stratified contexts (Sankhyan, 2017a, 2017b, 2020b) that suggest it a long solitary “paradise” of Middle to Late Pleistocene hominins in South Asia. None among many Narmada explorers could lay hand on such rare human fossils, perhaps therefore, a few scholars in their superficial overviews create confusion on their stratigraphic contexts. It may be clarified here that we followed the stratigraphic classification competently worked out by Tiwari and Bhai (1997).

Close to Narmada valley Pal (2013) recovered two tanged tools from the northern fringe of the Kaimur Range in the Vindhya overlooking the Belan valley in the north. The author also collected portable art objects from Narmada valley (Figure 9). In the year 2016, the author collected two tanged spears and a round knife of granite reported here from the eastern flank of the rocky Aravalli hill, called northern Delhi Ridge. It is, therefore, quite likely that hafting arrived in the Ghumarwin Sub-Himalaya ~100 ka via the Aravalli/Vindhya/Narmada valley. This Sub-Himalayan region is turning an interesting hot spot of intense and diverse prehistoric hafting activities during Late Acheulian to Middle Palaeolithic time, further attested by the recent report of portable archaeological art (Figure 8,

Figure 9 by the author (Sankhyan, 2017d). It is further strengthened by the recent notices of cupules on the Siwalik sand-rocks (Sankhyan, unp.).

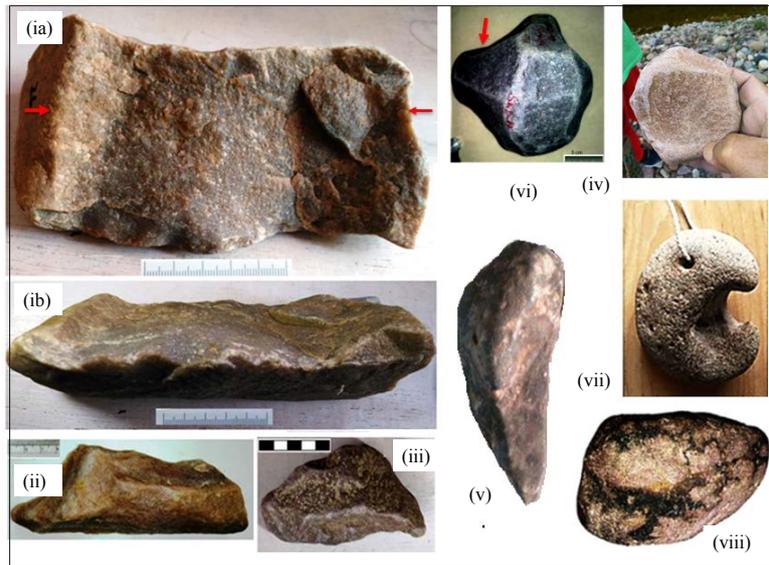


Figure 8. (ia) lateral view, (ib) view of the cutting edge, (ii) End scraper, (iii) Awl, (iv) Hammer with round tang haft; (v) Neolithic digging pick, (vi) Grinding pestle, (vii) Basalt pendant, (viii) Painted pebble chopper.

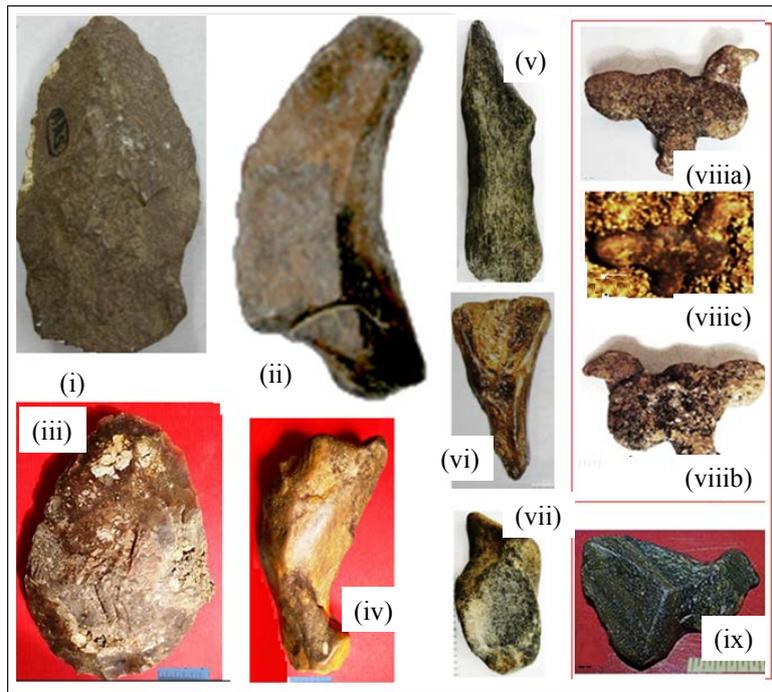


Figure 9. Some Narmada valley artifacts: (i) Tanged spear from Sardarnagar U2, (ii) Large chopping tool from Hathnora U1, (iii) Ovate sharp knife from Sardarnagar U2, (iv) Precision hammer from Pilikarar surface with grip haft, (v) Bone tool (dagger), (vi) Bone tool (spatula) (vii) Bone tool (drill); (viii a) Bid figurine on chert flake from Hathnora U3, (viii b) Basalt bird figurine a & b two side faces, c in situ buried state in Baneta Fm at Hathnora.; (ix) Bird figurine on chert flke.

7. Conclusion

1) Present study is a first report of Palaeolithic hafting from Ghumarwin Sub-Himalayan region of North India presenting richest signatures compared to the rest of India.

2) The Sub-Himalayan hafted tools are highly diversified and indicate diverse human activities at the Middle Palaeolithic to Upper Palaeolithic level. These include extensive wood cutting probably for hut-making, efficient hunting, earth-work or soil processing. These hafted tools were precursors for the subsequent modern hafted metal tools and weapons.

3) Present study also adds data on hafting from other parts of India, e.g., the central Narmada valley associated with human fossil record of the inventors of hafting in South Asia.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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