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The Palaeolithic of the Middle Son valley, north-central India: Changes in hominin lithic technology and behaviour during the Upper Pleistocene

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ABSTRACT

The Middle Son valley in north-central India preserves extensive Quaternary alluvial deposits. A long history of archaeological and geological research in the valley has resulted in the discovery of lithic assemblages ranging from Lower Palaeolithic to microlithic, a rich corpus of fossilised faunal remains, and ash deposits from the ~74,000 year-old Toba supereruption. This paper reviews the chronology and stratigraphy of the valley's Quaternary sediments, and presents a model that hypothesizes the temporal sequence of important lithic assemblages from excavated and surface contexts. Artefacts in these assemblages are analysed and changes in lithic technology through time are described; this evidence is used to propose shifts in hominin behaviour and demographic structure in this region during the Upper Pleistocene. Recognising gaps in our understanding of the Middle Son record, future avenues of research are recommended that will build upon previous research and address questions of palaeoanthropological significance. The Middle Son valley preserves a long and rich record of hominin occupation from all periods of the Palaeolithic that is rarely paralleled by other sites in India.

Introduction

The Middle Son river valley in north-eastern Madhya Pradesh preserves extensive alluvial deposits that accumulated during the Upper Pleistocene and probably Middle Pleistocene periods. From within these deposits, Lower, Middle and Upper Palaeolithic artefacts have been recovered, as well as microlithic and Neolithic artefacts. Thousands of faunal fossils, representing a diverse range of species, have been discovered in Pleistocene alluvial contexts at numerous localities in the valley (Dassarma and Biswas, 1977; Blumenschine and Chattopadhyaya, 1983; Badam et al., 1989). Further, exposures of volcanic ash have been documented within alluvial sediments in four areas of the valley (Williams and Royce, 1982; Basu et al., 1987; Acharyya and Basu, 1993), the ash belonging to the ~74,000 year-old supervolcanic eruption of Toba in northern Sumatra (Rose and Chesner, 1987). This evidence results from a long history of geological and archaeological research in the valley that has involved extensive surveys, several excavations, and analyses of lithic collections (Sharma, 1980; Sharma and Clark, 1983; Clark and Williams, 1987, 1990; Williams and Royce, 1982; Williams and Clarke, 1984, 1995; Jones and Pal, 2005; Pal et al., 2005; Williams et al., 2006). The Quaternary sediments of the Son have been assigned to four different geological formations, where the geomorphological processes and palaeoenvironmental conditions underlying their accumulation have been hypothesized (Williams and Royce, 1982, 1983). In addition, several absolute dates, confined to the Upper Pleistocene and Holocene periods and determined using a range of chronometric techniques, have provided ages for various sedimentary contexts within these formations (Mandal, 1983; Williams and Clarke, 1984, 1995; Pal et al., 2005; Williams et al., 2006).

The information gathered during previous research in the Middle Son valley has revealed its rich Palaeolithic cultural record and long sedimentary sequences. Through an analysis of lithic artefacts from various contexts and sites in the Middle Son, this paper examines changes in technology, typology and hominin behaviour through time. Several issues are raised regarding changes in hominin adaptations and demography in the valley during the Upper Pleistocene. The high amplitude palaeoclimatic fluctuations that occurred with significant frequency during the Upper Pleistocene period (e.g. Dansgaard et al., 1993; Lowe and Walker, 1997) would have directly impacted Indian palaeoenvironments, altering ecosystems and plant, animal and hominin habitats. Notable environmental changes in the Middle Son valley would have been caused by shifts in the monsoonal system. During glacial periods, such as Oxygen Isotope Stage 4 (OIS 4), there is evidence of a depressed southwest summer monsoon but enhanced northeast winter

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monsoon (e.g. Pandarinath et al., 1999; Prabhu et al., 2004; Juyal et al., 2004). This resulted in increased aridity in areas of northern India in particular (e.g. Kudrass et al., 2001; von Rad et al., 2002). These Upper Pleistocene shifts in monsoonal regime would have had a direct impact on habitats in the Middle Son valley (e.g. Williams et al., 2006). Type and distribution of plant cover and availability of and accessibility to water sources would have governed the distribution and density of faunal species as well as hominin populations. It is assumed that shifts in the optimality of habitats throughout the Pleistocene, which affected the density and distribution of food and water resources, was one of several factors affecting hominin behaviour and demography. Additional factors may have been changes in access to raw material sources, social practices and networks, and group structure and dynamics. The interplay between these factors during the Pleistocene would have had an impact on hominin behaviour and population dynamics; this likely affected aspects of hominin lithic technology. Lithic artefacts from multiple contexts in the Middle Son valley currently represent the only evidence of past hominin behaviour in the region; by examining this evidence, changes in behaviour and demography through time can be hypothesized.

Quaternary stratigraphy and chronology

The middle reaches of the river Son are bordered by the Kaimur Range to the north and the hills of the Baghelkhand plateau to the south. Quaternary sedimentary sequences are exposed throughout the valley and incision of these deposits by the Son river has resulted in the exposure of extensive cliff sections, some ~38 m-high (Thapar, 1979). Seasonal streams feed the Son from the northern and southern banks, creating numerous meandering incisions in the Quaternary deposits and exposing additional cliff sections further away from the main river. Intensive archaeological surveys in the area began in the 1960s, reaching their peak in the early 1980s when several sites were excavated by an international team of scholars from the University of Allahabad and American and Australian universities (Sharma, 1980; Sharma and Clark, 1983). These early investigations revealed the existence of numerous archaeological and palaeontological sites throughout the valley. For example, more than 6000 animal fossils have been recovered (Dassarma and Biswas, 1977; Thapar, 1979; Blumenschine and Chattopadhyaya, 1983; Mitra, 1984; Badam et al., 1989) and at least 47 Lower Palaeolithic, 86 Middle Palaeolithic and 120 Upper Palaeolithic sites have been recorded (Sharma, 1980: p. 93). Fig. 1 illustrates the locations of Palaeolithic and Mesolithic artefacts encountered during these surveys, as well as additional sites discussed in the text.

Geological investigations in the early 1980s led to the construction of geomorphological models that hypothesized the sequence of deposition of alluvial sediments during the Pleistocene and Holocene periods. Four geological formations were defined; in chronological order, these are the Sihawal, Patpara, Baghor and Khetaunhi formations, the latter being the most recent (Williams and Royce, 1982, 1983; Williams and Clarke, 1984, 1995). The Baghor formation is sub-divided into a lower coarse member and an upper fine member (Williams and Royce, 1982). Approximately 1–2 km away from the present-day river channel, the coarse member lenses out as it approaches the foothills. Here, the Baghor sediments adjacent to the Kaimur Hills are entirely composed of fine sandy clay that has been interpreted as reworked loess (Williams and Clarke, 1984). More recently, the Khunteli formation (named after the nearby village of Khuteli) has been added to this stratigraphic sequence; this is argued to post-date the Sihawal formation and pre-date the Patpara formation (Pal et al., 2005; Williams et al., 2006).

Stone artefacts are found throughout the valley's Quaternary deposits. Lower Palaeolithic assemblages, described as well-developed, advanced, or Upper Acheulean, have been recovered from the

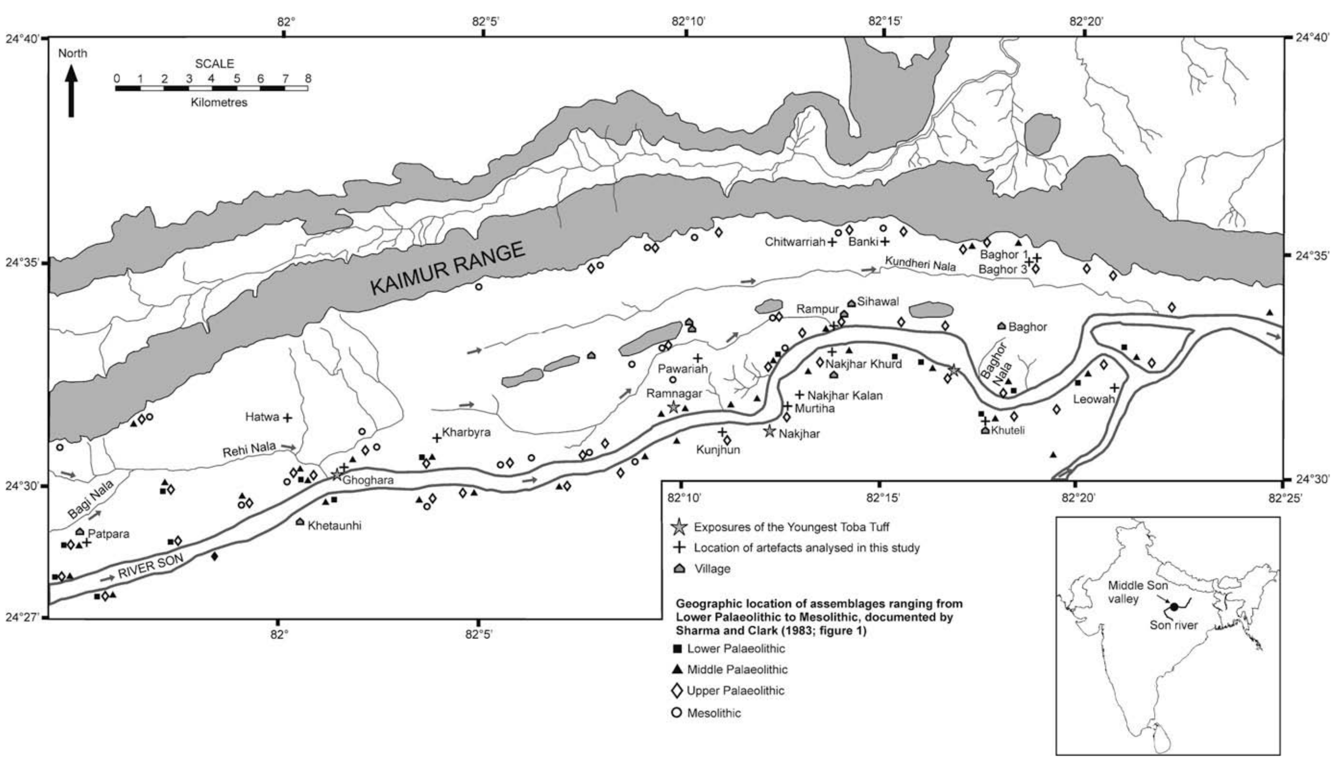

Fig. 1. Map of the Middle Son valley and its location in India (inset). Following (Sharma and Clark (1983); Fig. 1), the location of Lower Palaeolithic, Middle Palaeolithic, Upper Palaeolithic and Mesolithic artefacts, documented during surveys in the valley during the 1970s and 1980s, are indicated. The geographic location of assemblages analysed in this study and exposures of YTT are also depicted.

Sihawal formation. No sediments containing earlier assemblages have been documented (Sharma and Clark, 1982; Clark and Sharma, 1983). The Patpara formation is associated with Middle Palaeolithic artefacts, yet it appears that two typologically distinct phases of the Middle Palaeolithic are represented within it. The "early" phase is defined by the presence of diminutive bifaces and cleavers together with typically Middle Palaeolithic technologies, excavated at the sites of Patpara 1 and 2. This phase has been described as "final Acheulean" or "transitional" between the Lower and Middle Palaeolithic (Sharma and Clark, 1982). The "late" phase of the Son Middle Palaeolithic is "inadequately known" (Clark and Williams, 1987: p. 29), it is minimally described as based on disc core, flake and flake-blade technologies (Clark and Sharma, 1983: p. 262), and includes occasional Levallois cores (Clark and Dreiman, 1983; Clark and Williams, 1987). However, this phase is known only from a handful of surface artefacts and the direct stratigraphic and hence temporal relationship between these artefacts and those of the so-called "early" phase remains unknown. Abraded and unabraded Middle Palaeolithic flakes (Williams and Royce, 1982; Williams and Clarke, 1995: p. 306) as well as blades have been recovered from the Baghor coarse member (Williams and Royce, 1982), the latter representing the first appearance of a true blade technology (Clark and Sharma, 1983: p. 262). Upper Palaeolithic and microlithic assemblages are present in the Baghor fine member. Microliths as well as Neolithic pottery are preserved in the Khetaunhi formation, a Holocene terrace deposit (Clark and Williams, 1987: p. 25, 28).

In 1980, the first deposits of ~74,000 year-old Toba volcanic ash (the Youngest Toba Tuff (YTT)) were discovered in India, found at the confluence of the Rehi and Son rivers (Williams and Royce, 1982), and later geochemically identified as YTT (Rose and Chesner, 1987). Typical exposures have been described in the vicinity of the villages of Ghoghara (at the Rehi-Son confluence), Ramnagar, Nakjhar and Khuteli, extending over ~30 km and occurring as discontinuous lenses within the alluvial deposits (Basu et al., 1987; Acharyya and Basu, 1993) (Fig. 1). To date, ash deposits have only been found within the cliff sections that border the main river Son and not further to the north or south.

There are conflicting reports regarding the stratigraphic position of YTT in relation to the Quaternary formations of the Son. YTT at the Rehi-Son confluence was first illustrated as a channel-fill deposit located in the middle of ~11 m of Baghor coarse member deposits (Williams and Royce, 1982: Fig. 5g). YTT has also been described as located beneath the Baghor coarse member (Williams and Clarke, 1995), within the Baghor formation (Basu et al., 1987), or in the lower levels of the Baghor coarse member (Acharyya and Basu, 1993). In contrast to all previous reports, Williams et al. (2006) present an alternative stratigraphy where YTT is preserved within the new Khunteli formation. This formation is argued to have aggraded after the Sihawal formation and before the Patpara formation. The introduction of the Khunteli formation and its temporal relationship with the other formations of the Son, defined in the 1980s (Williams and Royce, 1982), is problematic.

The Khunteli formation is described at only two sections in the valley, both of which preserve YTT; these are at Khunteli, the type site, and at the confluence of the Rehi and Son rivers (RS1) (Williams et al., 2006). Such limited exposure is currently of insufficient evidence to warrant the introduction of a new geological formation, and there are no sections where a stratigraphic correlation between the Khunteli formation and either the Sihawal or Patpara formations has been demonstrated. A further issue concerns archaeological associations. The Sihawal formation is associated with Lower Palaeolithic artefacts (Kenoyer and Pal, 1983; Misra et al., 1983a) and the Patpara formation with late Lower Palaeolithic and Middle Palaeolithic artefacts (Blumenschine et al., 1983). To accept a post-YTT age for the Patpara formation would also mean acceptance of a date of less than ~74,000 years for late Lower Palaeolithic artefacts. This is inconsistent with what is currently known about the Indian Palaeolithic record for this period (Misra, 1989, 1995, 2001; James and Petraglia, 2005). The argument that the Khunteli formation pre-dates the Patpara formation appears to rest solely on one IRSL date of 58,000 ± 6000 years for feldspar grains in a sediment sample argued to be from the Patpara formation at the excavated site of Sihawal (Pal et al., 2005; Williams et al., 2006). By accepting this date as accurate, the YTT-bearing Khunteli formation must therefore be older than the Patpara formation. However, IRSL dates of feldspar grains are particularly liable to fading (Spooner, 1994; Wintle, 1994; Prescott and Robertson, 1997; Aitken, 1998; Auclair et al., 2003), this can result in unrealistically young ages, and is a problem recognised by Williams et al. (2006). Further, the exact context of the dated sample is not specified and there is inadequate geological and archaeological evidence to support the argument that the sample is derived from the Patpara formation in the first instance (as it is defined at the type site of the formation ~30 km away) (Table 1). In sum, a number of problems associated with the introduction of the Khunteli formation into the Quaternary geological sequence of the Son have been described and because of these, further research is necessary in order to clarify its chronological and geological contexts.

On the basis of field observations (Jones and Pal, 2005; Jones, 2007b), the deposits overlying the Toba ash at Khuteli more closely resemble Baghor coarse member sediments at the type site, Baghor Nala, located ~1.13 km to the east. However, the identity of the geological formation that underlies the ash is less clear because of talus obstruction. The yellow-brown pre-ash sediments are not comparable to the distinctive reddish-brown sediments that form the lower parts of the Patpara formation. Instead, the deposits underlying the ash at both sites may constitute a lateral variant of the Patpara formation or the lower levels of the Baghor coarse member. At Ghoghara, artefacts discovered in 2005 within a gravel layer that crops out ~3 m beneath the YTT are broadly comparable to the late Lower Palaeolithic and Middle Palaeolithic artefacts found during excavations of the Patpara formation at Patpara 1 and 2 in the 1980s. Two arguments are made regarding the stratigraphic relationship between YTT and the Son formations. The accumulation of the Baghor coarse member was already underway at the time of the Toba ash-fall, however, it was only in its early stages with YTT being buried within its lower levels. More plausibly, YTT was deposited on top of the younger, less oxidised (and rubified) levels of the Patpara formation, with aggradation of the Baghor coarse member commencing at some point after the Toba ash-fall.

Sedimentary contexts in the Middle Son have been dated by radiocarbon (Mandal, 1983; Williams and Clarke, 1984), thermoluminescence (two dates) (Clark and Williams, 1987; Williams and Clarke, 1995; Pal et al., 2005) and infra-red stimulated luminescence (five dates) (Pal et al., 2005; Williams et al., 2006). Five radiocarbon dates of shell (Williams and Clarke, 1984, 1995; Clark and Williams, 1987, 1990), three of charcoal (Mandal, 1983; Williams and Clarke, 1984) and four of carbonate (Sharma and Clark, 1982; Mandal, 1983; Williams and Royce, 1982) are available; some of these dates have been calibrated (Williams et al., 2006). Only two dates are directly associated with lithic assemblages. These are 8330 ± 220 ^{14}C years BP and 6660 ± 180 ^{14}C years BP for microlithic assemblages at the excavated sites of Baghor 2 and 3, respectively; however, the latter is a *terminus ante quem* for the artefacts (Mandal, 1983: p. 286). The remaining dates are not directly associated with lithic assemblages and assumptions made regarding the stratigraphic relationships between dated samples and nearby artefact assemblages need to be confirmed via a thorough dating program. This should be taken into account when viewing existing composite stratigraphies for the Middle Son valley that incorporate both dates

Table 1
A list of all chronometric dates for Middle Son deposits, including an assessment of the validity of each date.

Date (kyr BP) (^{14}C kyr CalBP[a])	Lab no.	Method	Site and context	Formation	Reference	Valid?	Associated archaeology
3.215 ± 0.07 (3.26–3.63)	Beta 4879	^{14}C (shell)	Not specified	Khetaunhi	Williams and Clarke (1984)	Yes	Neolithic
4.13 ± 0.11 (4.25–5)	Beta 6414	^{14}C (charcoal)	Not specified	Khetaunhi	Williams and Clarke (1984)	Yes	Neolithic
4.74 ± 0.08 (5.31–5.61)	Beta 6415	^{14}C (shell)	Not specified	Khetaunhi	Williams and Clarke (1984)	Yes	Neolithic
5.305 ± 0.09 (5.91–6.28)	SUA 1422	^{14}C ($CaCO_3$)	Brown clay loam, immediately above the Baghor coarse member	Baghor fine member	Mandal (1983), Williams and Royce (1982)	No (post-depositional carbonate)	None specified
6.66 ± 0.18	PRL 714	^{14}C (charcoal)	Baghor 3 – just below artefact layer (~83 cm below datum)	Baghor fine member (or yellow-brown loam/loess)	Mandal (1983)	No (intrusive charcoal in older sediments)	Microliths
8.33 ± 0.22	PRL 715	^{14}C (charcoal)	Baghor 2 – ~20 cm below artefact layer	Baghor fine member	Mandal (1983)	Yes	Microliths
11.87 ± 0.12 (13.4–14)	Beta 4792[b]	^{14}C (shell)	Rampur	Baghor fine member or coarse member?	Williams and Clarke (1984), Clark and Williams (1987)	Yes (but context is unclear)	Upper Palaeolithic (blades and bladelets)?
12.81 + 0.22/ −0.21	PRL 711	^{14}C ($CaCO_3$)	Top of the Baghor coarse member	Baghor coarse member	Mandal (1983)	No[c] (post-depositional carbonate)	None specified
13.145 ± 0.14 (15.1–16.1)	SUA 1420	^{14}C ($CaCO_3$)	Top of the Baghor coarse member – from a massive carbonate-cemented bench	Baghor coarse member	Mandal (1983), Williams and Royce (1982)	No (post-depositional carbonate)	None specified
19 ± 2	BN-1	IRSL	Baghor Nala	Baghor fine member	Pal et al. (2005), Williams et al. (2006)	Minimum date[d]	None specified
20.135 ± 0.22 (23.45–24.75)	Beta 4791	^{14}C (shell)	Khunderi Nala – yellow-brown loess	Baghor fine member (?)	Williams and Clarke (1984, 1995: p. 303)	Yes (but the loess is several metres thick at this section and the context of the dated sample is unspecified)	None specified
24 ± 3 (or 22 ka in Pal et al. (2005))	BN-2	IRSL	Baghor Nala	Baghor coarse member (middle part)	Pal et al. (2005), Williams et al. (2006).	Minimum date[d]	None specified
26.1 ± 5.4	Alpha 898	TL	Nakjhar Khurd (section G8). Sample from dark brown sandy clay at −5 m depth	Baghor formation	Pal et al. (2005)	Probably (context is unclear)	None specified
26.25 ± 0.42 (29-~31)	Beta 4793	^{14}C (shell)	Rampur – black clay	Baghor coarse member?	Williams and Clarke (1984, 1995), Clark and Williams (1987, 1990)	Yes (but context is unclear)	Upper Palaeolithic?
26.85 + 0.82/ −0.75	PRL 710	^{14}C ($CaCO_3$)	Gerwa well. Sample from a red-brown sandy clay loam, "believed to represent the upper part of the Patpara Formation" (Mandal (1983: p. 285))	Patpara	Mandal (1983), Sharma and Clark (1982).	No (post-depositional carbonate)	None specified
39 ± 9	BN-3	IRSL	Baghor Nala	Baghor coarse member (lower part)	Pal et al. (2005), Williams et al. (2006).	Minimum date[d]	None specified
58 ± 6	S-1	IRSL	"Sihawal main section" (Pal et al. (2005)), "Sihawal" (Williams et al. (2006)). Context of date is unclear	Assignation to Patpara formation is questionable[e]	Pal et al. (2005), Williams et al. (2006)	No (minimum date[d])	None specified
~100	N-1	IRSL	Nakjhar Khurd – 50 cm-thick mottled brown clay loam	Sihawal (upper clay member)	Pal et al. (2005)	Minimum date[d]	None specified
103.8 ± 19.8	Alpha 899	TL	Nakjhar Khurd – step trench 20 m east of 1980 excavated trench	Sihawal (upper clay member)	Clark and Williams (1987), Williams and Clarke (1995)	Probably	None specified

[a] Calibrated radiocarbon dates are taken from Williams et al. (2006), expressed in the 2σ range.

[b] In Clark and Williams (1987), the sample name for this date is Beta 4752 and in Williams and Clarke (1995), it is Beta 4793.

[c] At Didwana in the Thar Desert, radiocarbon dating of soil carbonate associated with the Acheulean gave a date of ~25 ka (Mitra, 1983). Such a young age for the Acheulean demonstrates that dating carbonate present in archaeological contexts is extremely unreliable. In fact, the Didwana Acheulean has since been dated by Th^{230}/U^{234} and TL to 390–150 ka (Misra, 2001).

[d] The IRSL dates should be considered to be minimum dates as no tests of long-term fading were carried out on the samples. If fading took place, these IRSL ages may be underestimates of the true age of the sediments (Williams et al., 2006). The dated grains of feldspar are particularly liable to both anomalous and normal fading, which can result in unrealistically young ages (Spooner, 1994; Wintle, 1994; Prescott and Robertson, 1997; Aitken, 1998; Auclair et al., 2003).

[e] Sample S1 is minimally described as derived from the Patpara formation at the excavated site of Sihawal (Pal et al., 2005; Williams et al., 2006). Here, the Patpara formation is said to consist of ~50–70 cm of red-brown coarse sands; late Upper Palaeolithic artefacts have been found in the upper 30 cm (Kenoyer and Pal, 1983). Given that the Patpara formation at the type site (Patpara 2) preserves late Lower Palaeolithic and Middle Palaeolithic artefacts, the presence of late Upper Palaeolithic artefacts in the so-called Patpara formation at Sihawal is unexpected; such artefacts would be more typical of the Baghor formation. It has been suggested that these artefacts are in secondary contexts, having been translocated from the surface into the upper levels of the sands via root action (Kenoyer and Pal, 1983). Assuming that this was the context of the dated sample, this process could have similarly resulted in the introduction of grains with younger IRSL dates into older deposits. However, these sands at Sihawal may not be representative of the Patpara formation in the first instance. It appears that affiliation of the dated sample to the Patpara formation is based on sediment colour alone. Type site deposits of the Patpara formation at Patpara are also red-brown in colour. However, sediment colour should not be used to correlate strata at two sites that are ~30 km apart and in different contexts with respect to local geology, topography and proximity to the main river.

and archaeology; these are both highly interpretative and ignore the considerable lateral variation in depositional regime that existed throughout the valley. The latter is illustrated in Fig. 2, which demonstrates considerable spatial variability in the processes of sediment accumulation in the valley during the Quaternary, revealing noticeable differences in depositional sequences between localities, even between those in close proximity.

Details of all chronometric dates obtained for Middle Son contexts as well as an assessment of the validity of each date are provided in Table 1. For example, problems with certain dates include radiocarbon dates of post-depositional carbonate and IRSL dates of feldspar, both of which can provide ages that are too young (Table 1). Two dates have been obtained for samples from the upper levels of the Sihawal formation; a TL date of 103,800 ± 19,800 years (Clark and Williams, 1987; Williams and Clarke, 1995) and an IRSL date of ∼100,000 years (Pal et al., 2005). Both date sediments at Nakjhar Khurd, where the first sample was taken from a step trench located ∼20 m to the east of excavations by Misra et al. (1983a). The exact geographic location of the second dated sample is not specified. These dates provide an upper age limit for Acheulean

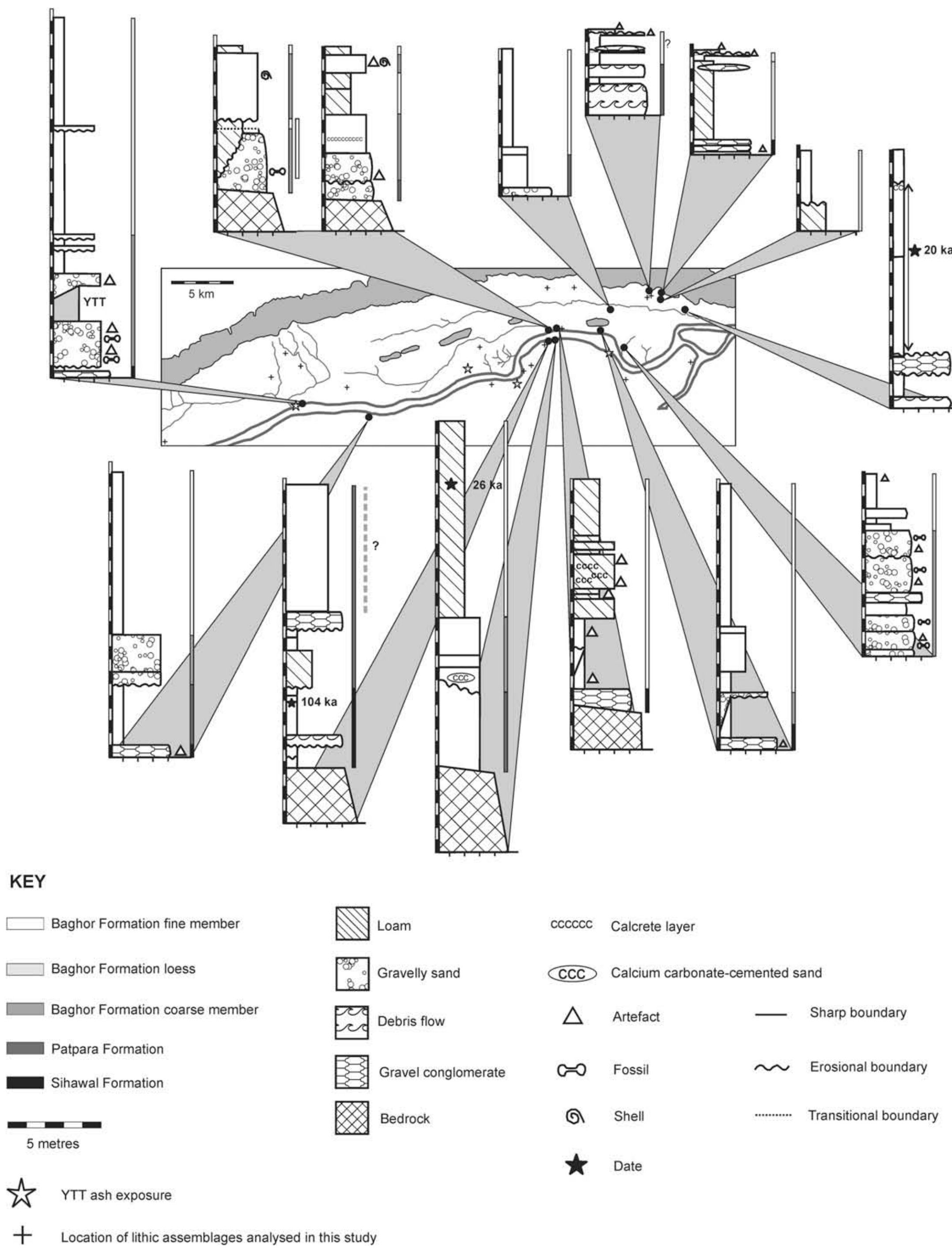

Fig. 2. Alluvial sequences in different regions of the Middle Son valley, illustrating the high degree of spatial variability in the sequence of deposition. This figure results from a compilation of all known section drawings for the Middle Son; section drawings are adapted from figures published in several sources (Williams and Royce, 1982; Williams and Clarke, 1995; Williams et al., 2006).

artefacts recovered from the Sihawal lower member at Nakjhar Khurd (Misra et al., 1983a) and possibly at Sihawal 2 (Kenoyer and Pal, 1983). The Patpara formation is the most poorly dated of all the Son formations. One IRSL date of 58,000 ± 6000 years was obtained for sediments from the Sihawal main section, said to belong to the Patpara formation (Pal et al., 2005; Williams et al., 2006) (see above). The context of this date is poorly described, it is a minimum date at best, and it can be argued that its affiliation with the Patpara formation is erroneous (Table 1). At present, the Middle Palaeolithic of the Middle Son remains undated. Two IRSL dates provide minimum ages for the Baghor coarse member at the type site of the formation at Baghor Nala; 39,000 ± 9000 years for its lower levels and 24,000 ± 3000 years for its middle levels (Pal et al., 2005; Williams et al., 2006). No artefacts are directly associated with these dates but Middle to Upper Palaeolithic artefacts are known to occur in the Baghor coarse member. The reworked loess deposits of the Baghor formation, located close to the foothills region, have been dated at one locality to 20,135 ± 220 ^{14}C years BP (Williams and Clarke, 1984, 1995: p. 303), however, the total length of time taken for this later Pleistocene loess to accumulate remains unknown. The Baghor fine member has been dated by IRSL to 19,000 ± 2000 years at Baghor Nala (Pal et al., 2005; Williams et al., 2006). Other deposits, probably equivalent to the Baghor fine member, have been dated by TL to 26,100 ± 5400 years at Nakjhar Khurd (Williams and Clarke, 1995; Pal et al., 2005) and 8330 ± 220 ^{14}C years BP at Baghor 2 (Mandal, 1983). The latter currently provides the only chronometric date for microlithic assemblages from the Middle Son. Two dates of 11,870 ± 120 ^{14}C years BP and 26,250 ± 420 ^{14}C years BP have been reported for sediments in the vicinity of the important archaeological site of Rampur (Williams and Clarke, 1984, 1995; Clark and Williams, 1987, 1990). However, a reliable stratigraphic correlation between these dates and the technologically and typologically critical surface lithic collection at Rampur remains to be demonstrated.

Analysis of lithic assemblages and a relative chronological model of their stratigraphic placement in the Middle Son valley Quaternary sequence

In the early 1980s, several localities in the Middle Son valley were surveyed and excavated, producing a vast collection of lithic artefacts from sites spanning all phases of the Palaeolithic (Sharma and Clark, 1983). Patpara formation deposits were excavated at Patpara 1 and 2 (Blumenschine et al., 1983). At Nakjhar Khurd, the Patpara and Sihawal formations and a small exposure of the Baghor coarse member were all excavated (Misra et al., 1983a). Trenches at Baghor 1 (Kenoyer et al., 1983a) and Baghor 3 (Clark and Dreiman, 1983) concentrated solely on the Baghor fine member and upper Baghor loess deposits (Williams and Clarke, 1995: p. 300). Collections from the Patpara "lower" and "middle" gravels produced a large number of lithic artefacts, yet the Rampur Upper Palaeolithic assemblage represents the most extensive of the surface collections. A small number of Palaeolithic artefacts were discovered at Nakjhar Kalan (Clark and Sharma, 1983: p. 262), Kunjhun (Clark and Williams, 1987: p. 29), Baliar, Murtiha, Pawariah, Baghor 5, and in the Patpara "upper gravels". A collection of artefacts from Baghor coarse member deposits at a variety of localities is catalogued in the G.R. Sharma Memorial Museum ("Upper Palaeolithic showcase"). As part of the present study, further small collections of surface artefacts were made in 2005 during surveys of pre-YTT sediments along the main river at Ghoghara, and of the Baghor coarse member at Baghor Nala.

Lithic collections from the aforementioned sites were analysed in 2005 at the G.R. Sharma Memorial Museum in the Department of Ancient History, Culture and Archaeology at the University of Allahabad. Artefacts were assigned to different type classes, such as flake, retouched flake, core, flaked piece, biface or cleaver. A number of attributes (metric and non-metric measurements) were recorded on each artefact. For flakes, retouched flakes, cores and flaked pieces, all attributes were measured according to methods in Clarkson (2007) and Jones (2007b). Equipment used included digital callipers with a resolution of 0.01 cm, a goniometer, a pocket scale with a resolution of 0.1 g for weighing artefacts up to 200 g, and a mechanical scale for artefacts over 200 g. Up to 17, 24 and 31 metric traits and 19, 33 and 20 non-metric traits were measured respectively on flakes, retouched flakes and cores. Raw material type, artefact typology, and degree of artefact patination and edge-rounding were recorded on all artefacts. Weight and length, width and thickness dimensions were measured on flakes and cores, as were cortex coverage, type and location, and platform dimensions, surface morphology and preparation technique. Termination type and the number and pattern of dorsal scar removals were recorded on flakes. As additional measures of core reduction stage and technique, the dimensions and termination morphologies of the last four flake scars were recorded together with the number of core rotations and platform quadrants (a measure of the extent of flaking around the perimeter of the last core platform). Retouched flake attributes included retouch dimensions, location and technique, and the dimensions and features of notches and burins where present. In addition, attributes required for the calculation of Kuhn's geometric index of unifacial reduction (Kuhn, 1990) and Clarkson's index of invasiveness (Clarkson, 2002), both measures of retouch intensity, were recorded. Using the continuous data of certain attributes, various indices were calculated in order to quantify aspects of flake and core size and shape. Simple parametric and non-parametric statistical tests were applied to quantitative and qualitative data in order to determine if significant differences exist between assemblages through time.

The main objective behind the analysis of these excavated, surface and section artefacts was to determine changes in lithic technology and hominin behaviour in the Middle Son valley during the Upper Pleistocene (see Fig. 1 for locations of assemblages). Table 2 provides details of these assemblages as well as an assessment of the stratigraphic integrity of each collection. Using this evidence, we have created a model (Fig. 3) that hypothesizes the stratigraphical, and hence temporal, relationships between assemblages. The most plausible stratigraphic position of the Toba ash-fall in relation to the valley's stratigraphy is also included in the model. Analysed surface collections are tentatively placed within the model's temporal sequence and although their small sample size is problematic, they currently represent the only archaeological evidence to fill the temporal gap in between the excavated assemblages at Patpara and Baghor 1 and 3. This model presents a chronology of lithic assemblages that is largely relative, representing a hypothesis that could be tested through future studies in the valley that employ both excavation and dating of sediments in direct association with artefacts in primary contexts.

Results

Analysis of attributes on flakes, retouched flakes and cores indicate temporal changes in several aspects of lithic technology (Figs. 4–12). Statistical methods could not be applied in an analysis of some attributes and temporal groups because of small sample size. Tables 3 and 4 provide technological and typological breakdowns of the types of artefacts in each collection.

Lithic materials

There is a significant difference ($p < 0.001$) between temporal groups in the frequency of different materials used in artefact manufacture. More artefacts were made from quartzite in the Early

Table 2
Analysed artefacts collections from the Middle Son valley.

Site	Number of artefacts analysed	Son formation	Site type	Stratigraphic integrity	Comments	Reference
Patpara 1	73	Patpara formation	Excavated	Good	All artefacts are from light red-brown clay. Excavated artefacts are in a secondary context (channel fill) but transportation from primary to secondary context was probably limited (Sharma and Clark (1982))	Blumenschine et al. (1983)
Patpara 2	131	Patpara formation (type section)	Excavated	Good	Vast majority of artefacts were from red-brown clay (as at Patpara 1). Upper and lower members of Sihawal formation underlie Patpara formation. Sihawal formation excavated but no artefacts recovered. Excavated artefacts are found in a channel fill but minor abrasion of the artefacts suggests that little transportation from primary to secondary context occurred (Blumenschine et al. (1983))	Blumenschine et al. (1983)
Nakjhar Khurd	3	Baghor coarse member	Excavated	Moderate	Artefacts in the upper 20–30 cm of the trench are argued to be from the Baghor coarse member (Misra et al. 101–102) but this deposit may contain reworked Patpara formation sands and associated artefacts	Misra et al. (1983a,b)
Nakjhar Khurd	32	Patpara formation	Excavated	Good	Artefacts found in a ferruginous gravel layer. Sihawal formation is present beneath the Patpara formation (artefacts not analysed). Although the analysed artefacts are in secondary contexts (in the gravel layer), it is argued that little transportation occurred because of low levels of artefact abrasion (Misra et al. (1983a))	Misra et al. (1983a,b)
Baghor 1	33	Lateral equivalent of Baghor fine member/ upper Baghor loess	Excavated	Very good	Distinct ∼5 cm primary artefact horizon occurs within a grey, yellow-grey or brown clay with Mn and Fe nodules. Site of so-called Upper Palaeolithic “shrine”. Only a very small selection of artefacts in the entire assemblage was analysed, representing a biased sample of artefacts on display in the G.R. Sharma Memorial Museum	Kenoyer et al. (1983a,b)
Baghor 3	1123 (detailed attribute analysis of 271)	Upper levels of Baghor loess	Excavated	Very good	∼8 cm-thick primary artefact horizon occurs at the contact between grey-yellow clay loam and black Mn/Fe stained clay. Artefacts stratigraphically pre-date Baghor 1 artefacts. Microwear analysis conducted on some artefacts. Very few retouched artefacts. Haematite pieces recovered	Clark and Dreiman (1983), Mitra (1984: p. 43–44), Sinha (1989), Williams and Clarke (1995)
Patpara middle gravels	245	Patpara formation (middle levels)	Surface and section	Moderate	The artefacts are argued to be “more or less contemporaneous” with artefacts from Patpara 1 and 2. Artefacts are referred to as a “selected assemblage” because they have been highly selected in terms of artefact type (Blumenschine et al. (1983: p. 45)), a degree of sampling bias exists	Blumenschine et al. (1983)
Patpara upper gravels	30	Patpara formation (upper levels?)	Surface and section?	Poor	Poor stratigraphic integrity because this is a collection of surface and possibly section artefacts housed in G.R. Sharma Memorial Museum; no details published	None
Rampur	377 (detailed analysis of 217)	Baghor coarse member?	Surface	Poor	Context and date of this extensive assemblage is uncertain. The high density of artefacts on the surface may indicate either intensive artefact manufacture in the area or that the artefacts form a lag deposit. *In situ* artefacts exist at the site but their context has yet to be dated	Misra et al. (1983b), Mitra (1984)
Nakjhar Kalan	8	Patpara formation (uppermost levels)	Surface or section?	Poor	Artefacts from an iron-cemented gravel; this probably represents the junction between Patpara formation and Baghor coarse member	Clark and Williams (1987)
Kunjhun	1	Patpara formation (uppermost levels)	Surface or section?	Poor	Artefact recovered from an iron-cemented gravel, possibly the same as that at nearby Nakjhar Kalan. This gravel is overlain by a yellow-brown loess	
Baliar	20	Baghor CM	Surface or section?	Poor	All artefacts are probably from the Baghor coarse member; few details regarding context are available. Site location is unclear	Mitra (1984: p. 47), Singh (1996: p. 57)
Murtiha	11	Baghor CM	Surface or section?	Very poor	Exact provenance not recorded	None
Baghor 5	4	Baghor CM	Surface or section?	Very poor	Exact provenance not recorded	None
Pawariah	4	Baghor CM	Surface or section?	Very poor	Exact provenance not recorded	None
Various sites[a]	23	Baghor CM	Surface or section?	Very poor	Highly selected sample of artefacts displayed in the “Upper Palaeolithic showcase”, G.R. Sharma Memorial Museum. Artefacts are from the Baghor coarse member but exact provenance is uncertain	None

(*continued on next page*)

Table 2 (*continued*)

Site	Number of artefacts analysed	Son formation	Site type	Stratigraphic integrity	Comments	Reference
Ghoghara	10	Patpara (middle?) gravels	Section	Moderate to poor	These artefacts were found in 2005 eroding out of fluvial gravels located ~3–4 metres below the Toba ash. They show variable degrees of abrasion; significant transportation of some artefacts is likely	None
Baghor Nala	20	Baghor CM	Section and surface	Poor	These artefacts were collected from the sands of the Baghor coarse member in 2005. They show varied degrees of abrasion; it is doubted that any artefacts are in their primary contexts, some may have undergone significant transportation	None

[a] Ramnagar, Khuteli, Kharabara, Ghogara (Rehi Locality 51), Amaradan, Leowah, Chitawariah, Nakjhar Khurd, Rampur and Sihawal.

and Middle Patpara assemblages, and proportionally more limestone was used in the latter, when compared to all later groups. In contrast, more artefacts from Baghor CM were made from chert, although the sample size of this collection is small. Chalcedony was used rarely, and only in Baghor CM (9%; $n = 7$), Rampur (2%; $n = 8$), Baghor 1 (15%; $n = 5$) and Baghor 3 (4%; $n = 48$). The use of porcellanite, a white fine-grained cherty material that occurs interbedded within sandstones in the Kaimur Hills (Spate and Learmonth, 1967: p. 630), was restricted to Baghor 3 (15%; $n = 165$ artefacts). Fifteen pieces of red ochre were recovered during excavations at Baghor 3, of which one piece shows evidence of use. Ochre is absent from all other assemblages, however, this does not preclude its use by earlier hominins.

Flake morphology

Flakes decrease in size from Early Patpara to Middle Patpara, and from Middle Patpara to Rampur, and to Baghor 3. The latter assemblage preserves the smallest flakes, where 90% ($n = 147$) have lengths $\leqslant$ 20 mm, in contrast to only 5% ($n = 14$) of flakes from Middle Patpara, 1% ($n = 2$) from Rampur, and 0% from Baghor CM and Early Patpara. The Baghor 3 assemblage represents the earliest known evidence of intentional microlith production in the Middle Son.

There is a significant difference between Middle Patpara, Baghor CM and Rampur in the proportion of flakes with an elongation index (flake length: flake medial width) >2 and flake length >20 mm ($p < 0.001$), more Baghor CM (67%; $n = 10$) and Rampur flakes (47%; $n = 59$) exhibit these properties when compared to Middle Patpara flakes (6%; $n = 11$). However, if Late Patpara flakes are included, four out of the six flakes (67%) possess these attributes (Fig. 8). Therefore, Middle Patpara flakes are less elongated than Baghor CM, Rampur, Baghor 3 and Baghor 1 ($p < 0.001$). Blades are rare in Patpara contexts (with the exception of Late Patpara) and become more abundant in later contexts (Fig. 11d). Crested blades, or core rejuvenation blades (Misra et al., 1983b: p. 145), are only present in Baghor CM and are relatively common at Rampur.

There were several changes through time in flake platform attributes. Middle Patpara platforms are proportionally larger than Baghor CM, Rampur, Baghor 3 and Baghor 1 platforms ($p < 0.001$) when compared to the size of the remainder of the flake. Baghor 1 platforms are proportionally smaller than Baghor CM, Rampur and Baghor 3 platforms ($p < 0.001$). The frequency of different platform preparation types is significantly different between assemblages ($p < 0.001$). Middle Patpara has more faceted platforms as well as those that show both faceting and overhang removal (Fig. 5b). All assemblages from Baghor deposits have more platforms with overhang removal and fewer with faceting.

Flakes also show significant differences through time in methods of core reduction as indicated by differences in the direction of scar removals visible on the dorsal surface. More flakes from Patpara assemblages express different forms of radial flaking (arrised radial, strongly radial and, in particular, weakly radial) (Figs. 4b, 5a, 7a). Fewer flakes from later Baghor formation contexts exhibit these patterns ($p < 0.001$), in these, bidirectional, crested and from proximal patterns are more common (Fig. 11). More Middle Patpara flakes possess radial arrises and few exhibit unidirectional or bidirectional arrises. Conversely, more Baghor CM and Rampur flakes exhibit unidirectional and bidirectional arrises, and Baghor 3 flakes have notably more unidirectional arrises.

Core technology

There are temporal differences in the size of cores when all raw materials are considered. Middle Patpara cores are significantly heavier than Baghor CM cores ($p = 0.026$), however, the sample is

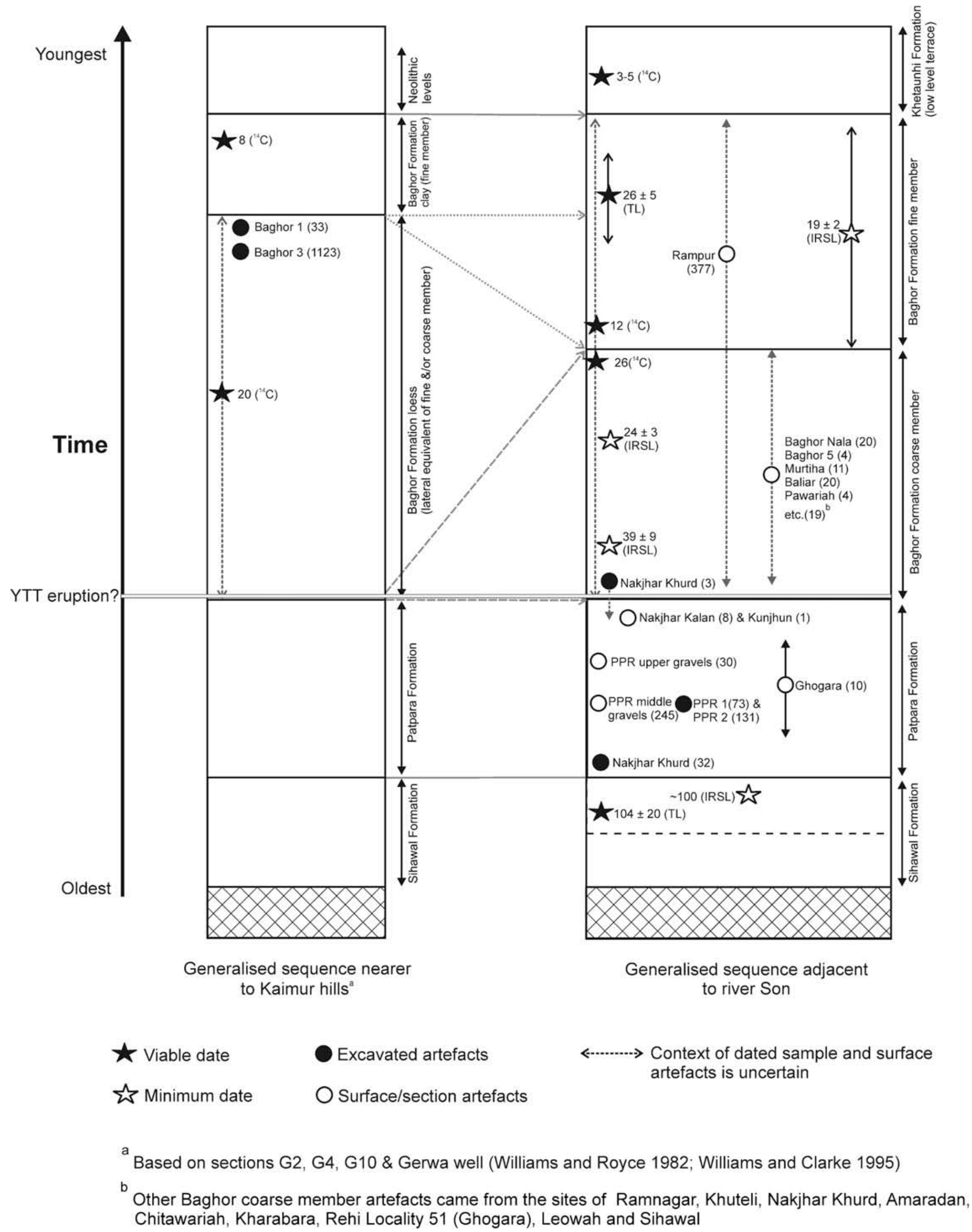

Fig. 3. A chronological model of the temporal placement of lithic assemblages analysed in this study and the YTT ash-fall within the geological sequence of Quaternary deposits that are proximal and distal to the main river in the middle reaches of the Son.

biased by several large quartzite cores (Fig. 4c). When only chert cores are compared there is no significant difference between assemblages in the weight of Middle Patpara and Baghor CM cores. The area of the last flaked face is significantly larger in Middle and Late Patpara cores when compared to Baghor CM cores ($p = 0.004$). Bidirectional and unidirectional flake removals and cores with elongate parallel scars are all more common in Baghor contexts (Fig. 12). In addition, cores from these contexts show more intensive flaking around the circumference of the last-used platform and possess a high number of non-feather terminations. However, cores from Patpara contexts underwent a higher number of rotations during reduction than Baghor context cores. Faceting and a combination of both overhang removal and faceting are more common in cores from Patpara contexts, whereas overhang removal is more common in later contexts; this confirms frequencies of different platform preparation techniques seen on flakes from these temporal groups. Further, core platform preparation techniques are more common in Baghor contexts.

Multiplatform cores are the most common type of core and are present from Early Patpara onwards (Table 3) (Figs. 4c, 6c, 7b). Single platform cores are rare in both Patpara and Baghor contexts. Levallois cores are also rare and are first encountered in the Late

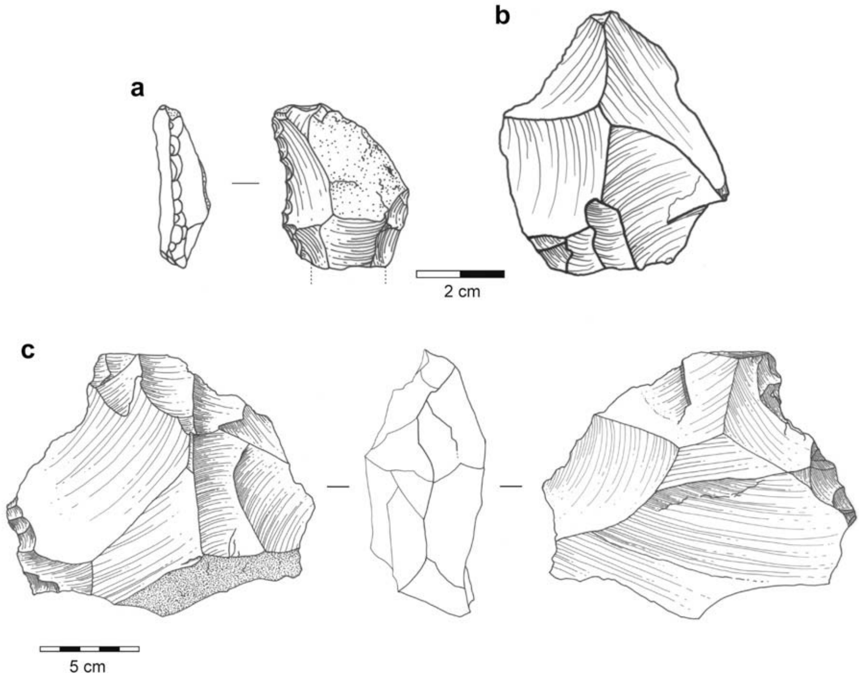

Fig. 4. (a) Double side retouched flake (chert, broken) from Ghoghara; (b) limestone flake from Ghoghara, and (c) quartzite multiplatform core from excavations at Patpara 2.

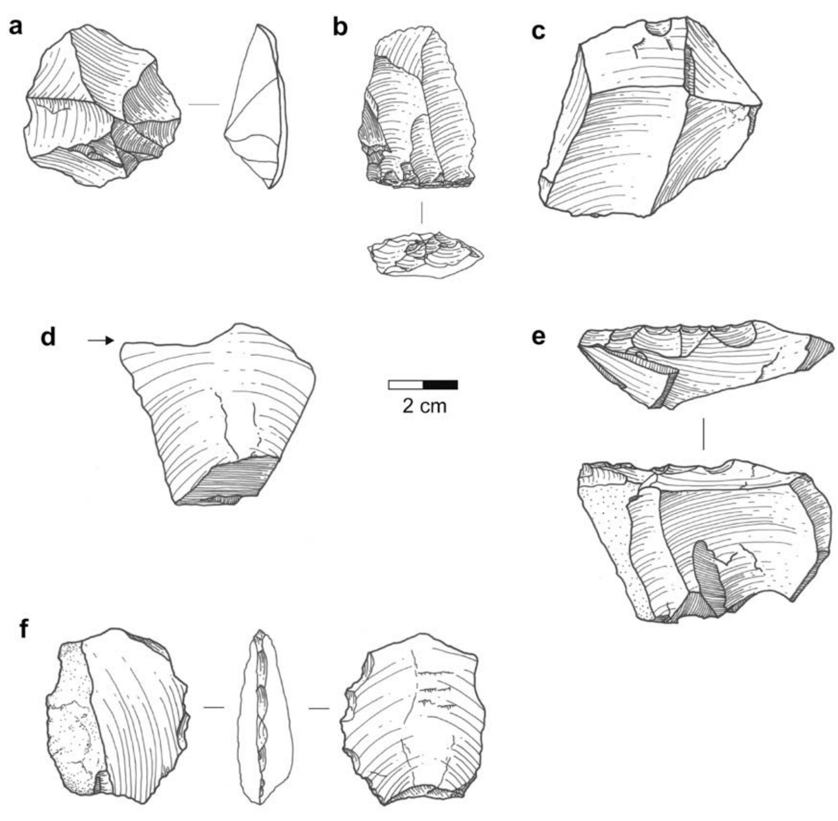

Fig. 5. Flakes from Middle Patpara; (a) Patpara 1, quartzite flake; (b) Patpara 1, chert flake; (c) Patpara Middle Gravels, quartzite flake; (d) Patpara 2, quartzite burin; (e) Patpara 1, quartzite notched and end retouched flake, and (f) Patpara Middle Gravels, quartzite side retouched flake.

Patpara assemblage ($n = 1$) (Fig. 8e), with one Levallois core in Baghor CM (Fig. 10d). However, atypical Levallois cores have been documented in the Patpara Middle Gravels (Blumenschine et al., 1983). Disc cores are slightly more common, appearing first in Patpara MG ($n = 3$), then in Late Patpara ($n = 2$) (Fig. 8d) and Baghor CM ($n = 1$) (Fig. 9g). In contrast, a number of core types are only present in Baghor formation contexts. These include bidirectional cores and all types of blade core (bidirectional, unidirectional and

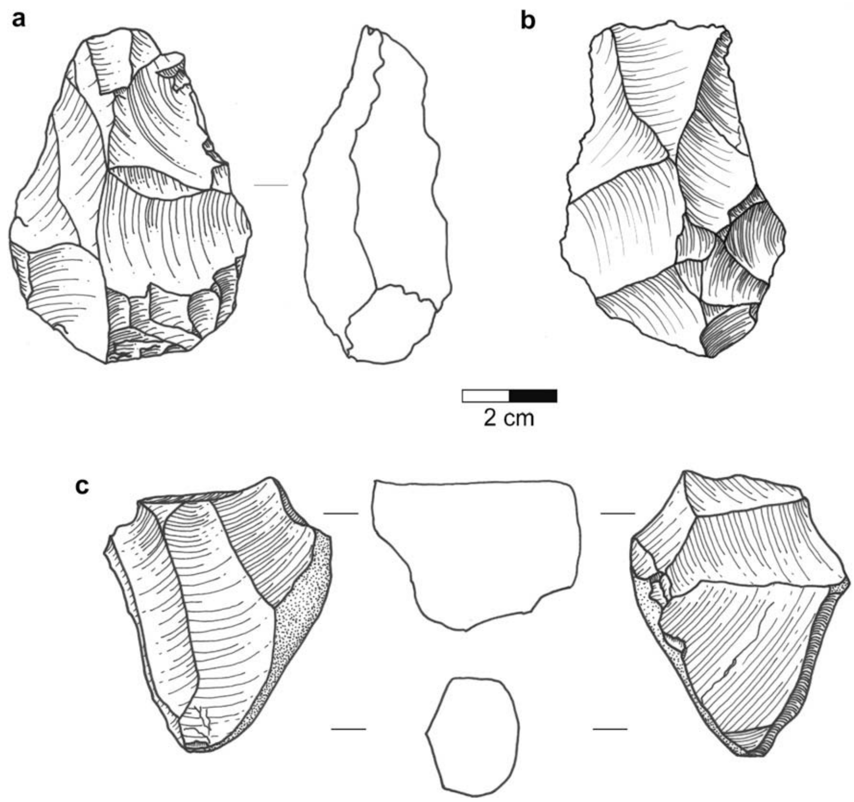

Fig. 6. Middle Patpara artefacts; (a) Patpara Middle Gravels, quartzite biface; (b) Patpara Middle Gravels, chert cleaver, and (c) Patpara 2, chert multiplatform core.

Levallois blade cores) as well as microblade cores, all of which are only present in Baghor CM sediments (Fig. 12). Bifaces are present in Early Patpara, Middle Patpara and Ghoghara assemblages (Fig. 6a). At Ghoghara, they were recovered from gravels a few

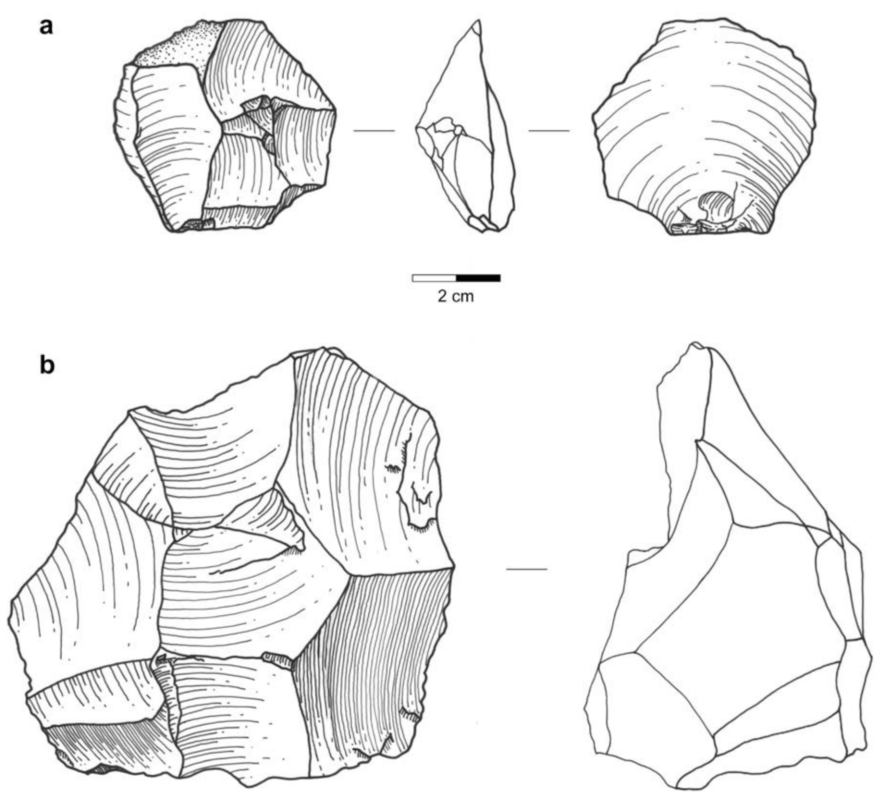

Fig. 7. Artefacts from Patpara Upper Gravels; (a) chert flake and (b) quartzite multiplatform core.

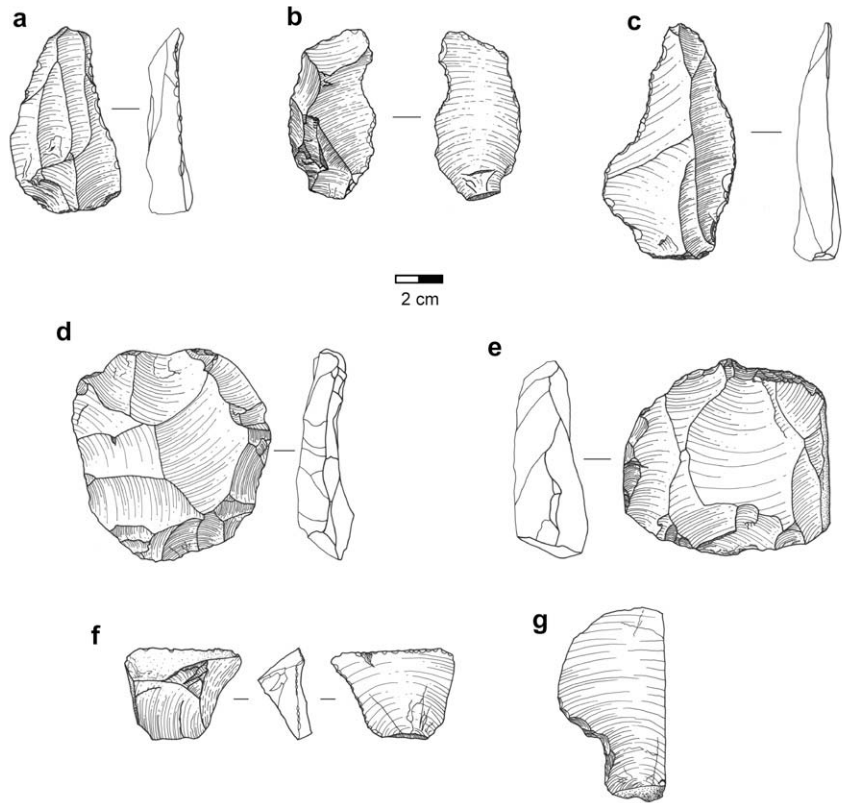

Fig. 8. Late Patpara artefacts; (a) Nakjhar Kalan, chert double side retouched flake; (b) Nakjhar Kalan, chert notched and double side and end retouched flake; (c) Nakjhar Kalan, chert double side and end retouched flake (faceted platform), (d) Kunjhun, chert disc core; (e) Nakjhar Kalan, chert Levallois core; and, Early Baghor coarse member artefacts from the Nakjhar Khurd excavations; (f) chert side and end retouched flake, and (g) chert notched and side retouched flake.

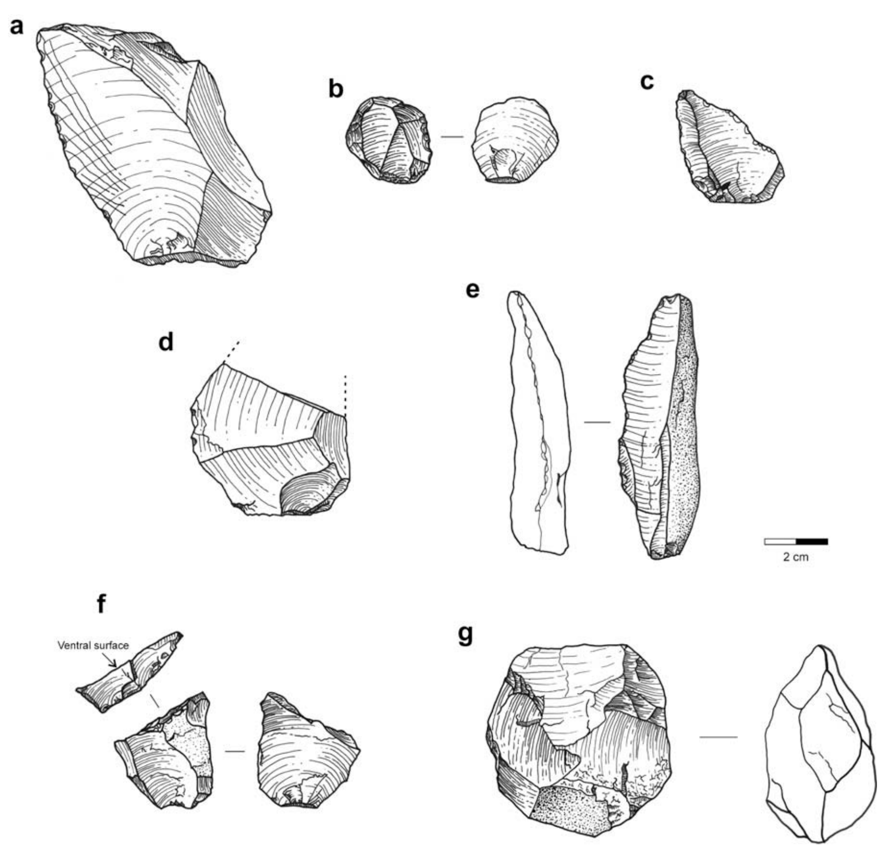

Fig. 9. Artefacts from Baghor Nala; (a) chert side retouched flake; (b) chert side retouched flake; (c) chert double side retouched flake; (d) broken limestone flake; (e) chert blade; (f) chert redirecting flake, and (g) chert disc core.

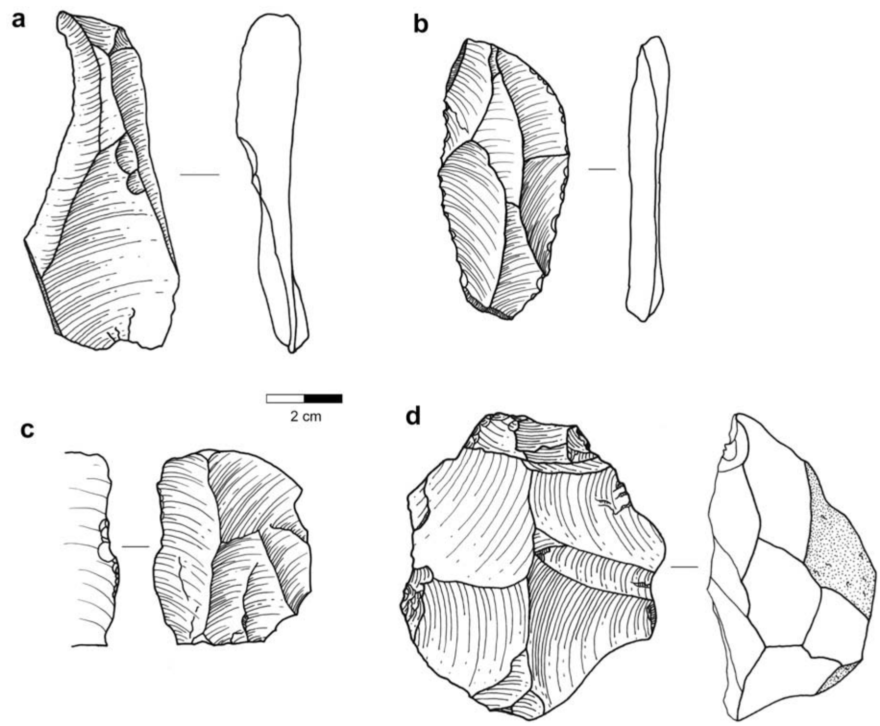

Fig. 10. Baghor coarse member artefacts from Pawariah; (a) chert blade; (b) chert double side retouched blade; (c) chert side retouched flake, and (d) chert Levallois core.

metres beneath YTT deposits. Cleavers are present in Early Patpara and Patpara MG (Fig. 6b). No bifaces or cleavers have been recovered from the Patpara Upper Gravels, Late Patpara or any of the Baghor formation assemblages.

Retouched flake technology

In the Patpara Middle Gravels, more quartzite and chert and fewer limestone flakes were retouched ($p = 0.01$). Conflating all Patpara formation flakes, more chert flakes in particular were

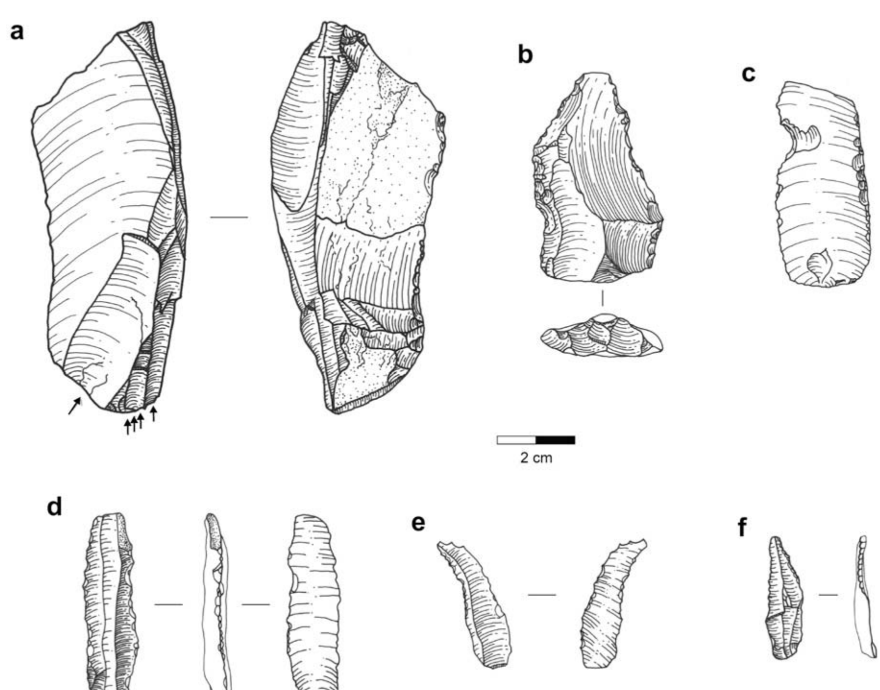

Fig. 11. Baghor coarse member artefacts from Baliar; (a) chert burinated side retouched flake, the ventral view is tilted slightly to the left in order to show the burin blows; (b) chert double side and end retouched flake, note the faceted platform; (c) Notched and double side retouched blade; (d) chert double backed blade; (e) chalcedony blade double backed to a point, and (f) chalcedony blade backed to a point.

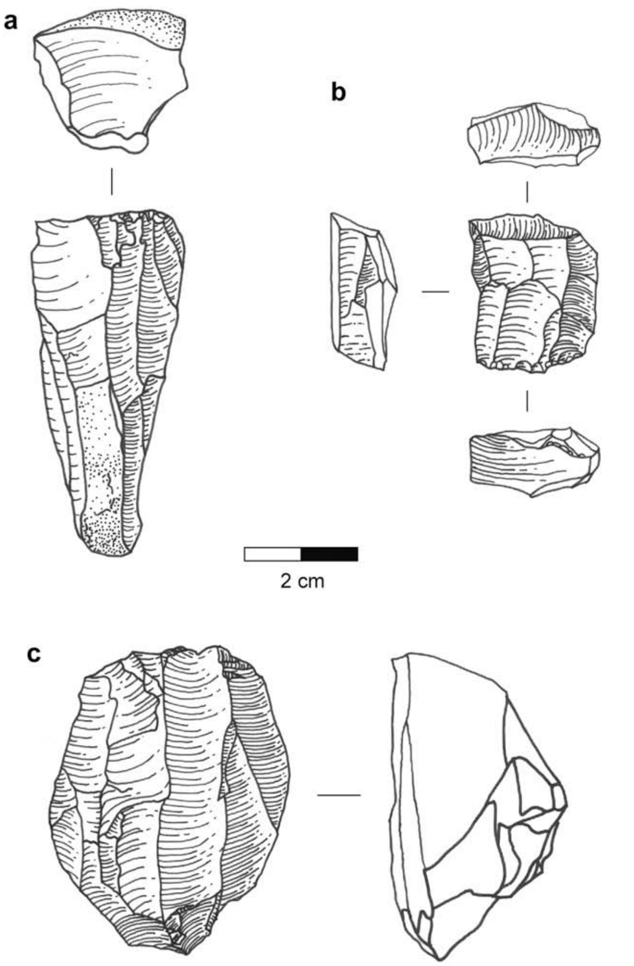

Fig. 12. Baghor coarse member artefacts from Baliar; (a) chert unidirectional blade core; (b) chert microblade core, and (c) chert Levallois blade core.

retouched ($p = 0.005$). Certain raw materials were not selected for retouch in the later Baghor contexts. In addition, larger flakes were retouched in Middle Patpara ($p = 0.013$), however, certain flake sizes were not selected for retouch in Baghor CM or Rampur. Retouch on Middle Patpara flakes is more convex than that on Baghor CM flakes ($p < 0.001$). The location of retouch on flakes is significantly different between Patpara and Baghor formation contexts ($p = 0.005$), more Patpara formation flakes have retouch on the ventral surface only and more Baghor formation flakes have alternating retouch and dorsal only retouch. Notching is more common in the Patpara Upper Gravels (15% of flakes are notched; $n = 4$) and less common in Baghor CM and Rampur, where 6% ($n = 4$) and 7% ($n = 14$) of flakes are notched respectively (not statistically tested) (Fig. 8b and g). Backed artefacts occur in several Baghor formation assemblages, particularly in the Baghor CM (Fig. 11). Backing is very rare in Patpara formation contexts; the two backed artefacts that do exist in the Patpara MG may be out of context. Blades that have been backed to form a point at one end of a blade are only encountered in Baghor CM and Baghor 1. Burins are very rare and there are no differences through time in the frequency of burination.

Statistical tests indicate that certain methods of retouch did not change through time. Certain flake shapes were not selected for retouch in both Patpara and Baghor formation assemblages. Aspects of retouch intensity did not change; there is no difference between Patpara and Baghor assemblages in the extent to which flake margins were retouched, and there is no difference between flakes in these temporal groups in the Geometric Index of Unifacial Reduction (Kuhn, 1990), nor in the Index of Invasiveness (Clarkson, 2002). Baghor CM flakes have more invasive retouch than those from Rampur, however, there is no difference between Patpara formation and Baghor CM flakes.

Discussion of results

Changes in raw material acquisition, lithic technology and hominin behaviour in the Middle Son valley during the Upper Pleistocene

Following a synthesis of all currently available geological and archaeological evidence, we argue that the lithic collections analysed here are derived from contexts that span most, if not all, of the Upper Pleistocene period. We hypothesize that those stratigraphic contexts that have been assigned to the Patpara formation accumulated from the beginning of the last interglacial, OIS 5e, until the end of OIS 5. Aggradation of the Baghor loess and coarse member deposits is argued to have commenced respectively during arid OIS 4 and more humid OIS 3, continuing until the end of the Pleistocene. Analysis of the lithic assemblages from these Upper Pleistocene contexts, assigned to the relative chronology outlined in Fig. 3 (and temporal groups in Tables 3 and 4), has revealed the occurrence of several notable shifts in lithic technology during this period.

The types of stone selected for artefact manufacture changed substantially through time; higher quality materials, particularly chert, became used in far greater abundance in all Baghor formation contexts as well as in the Late Patpara collection. This marks a dramatic move away from the procurement of quartzite in particular, and to a lesser extent limestone. Quartzite was barely used in Baghor contexts and this stark change may reflect a demographic shift rather than a solely adaptive strategy by pre-existing populations. Shifts in material preference may be one of the factors that contributed to an overall decline in flake size through time, the size of flakes being constrained by the size of the procured nodules. For example, chert and chalcedony nodules would have, as a whole, been smaller than quartzite clasts in particular. As chert became used far more frequently, chalcedony was also used for the first time in the Baghor CM. Porcellanite was used frequently and exclusively at Baghor 3. Porcellanite artefacts have not been encountered at other sites in the valley, even at the nearby site of Baghor 1. The exploitation of this material at Baghor 3, the microlithic nature of the assemblage and evidence for the use of red ochre may all be representative of a different population in this region of the valley during this period.

Bifaces and cleavers are only encountered in Early and Middle Patpara assemblages and have not been recovered from later contexts. The disappearance of these classes of artefact could have important hominin demographic implications, perhaps marking the replacement of pre-existing populations by new populations. Alternatively, behavioural adaptations through time may have resulted in the gradual loss of these cultural elements, perhaps in response to a shift in population dynamics, or a change in environmental or social conditions. Disc cores, and occasional Levallois cores, are found in Middle Patpara, Late Patpara and Baghor CM contexts. However, bidirectional cores, microblade cores and all types of blade core (bidirectional, unidirectional and Levallois blade cores) are first encountered in Baghor CM contexts. This marks a shift away from a predominance of radial patterns of flake removals in Patpara formation contexts towards unidirectional and particularly bidirectional flaking in Baghor formation contexts. This is supported by an increase in the occurrence of blades in the latter, including a notable increase in backed blades. A tendency towards the production of more elongated flakes possibly

Table 3
Summary table of all measured artefacts from Middle Son sites according to technological type. Numbers in parentheses represent artefacts that were not subjected to attribute analysis (these include some broken flakes, broken blades and flaked pieces), instead, minimal information was recorded for each piece, such as raw material type and presence of retouch.

Temporal group	Site	*N*	Flake				Core		Biface		Cleaver	Flaked piece		Chips [d]	Ochre
			Unretouched		Retouched							Unretouched	Retouched		
			Complete	Broken	Complete	Broken	Complete	Broken	Complete	Broken					
Early Patpara	Nakjhar Khurd	32	8	4	1	2	4		7	1	2	2	1		
Middle Patpara	Ghoghara	10	2	1	1	1	3		2						
	Patpara 1	73	32	15	10	1	5		1		1	8			
	Patpara 2	131	41[a]	38	8	3	7	1				33			
	Patpara MG	245	114	20	32	2	37	1	8	1	1	23	6		
	Patpara UG	30	16	2	8		3					1			
Late Patpara	Nakjhar Kalan	8	1		5		2								
	Kunjhun	1					1								
Baghor CM	Nakjhar Khurd	3			2							1			
	Baghor 5	4	1		2		1								
	Murtiha	11	2	4	1	2	2								
	Baghor Nala	20	4	5	5		2	1				3			
	Baliar	20	4	1	7	2	5					1			
	Pawariah	4	1		2		1								
	Baghor CM sites	23	3		15	2	2						1		
Rampur	Rampur	217 (160)	128[b]	40 (127)	30	11 (11)	3					4 (20)	1 (2)		
Baghor 3	Baghor 3	271 (852)	161[c]	39 (275)		1						49 (165)		6 (412)	15
Baghor 1	Baghor 1	33	10	3	5	9	6								

[a] Includes 1 bipolar flake.
[b] Includes 2 bipolar flakes.
[c] Includes 2 eraillure flakes.
[d] "Chips" can be defined as any flaked piece with a maximum dimension of <7 mm.

begins towards the end of the accumulation of the Patpara formation, evident in the Late Patpara collection. However, given the paucity of artefacts in this assemblage as a whole, this hypothesis needs to be tested with a larger dataset from these sediments.

This change through time in core reduction strategies is supported by differences between assemblages in various core attributes. Core platform preparation techniques such as faceting occurs more commonly on cores from Patpara contexts and cores were rotated more frequently during the reduction process than those from Baghor contexts. Cores from Baghor contexts show a higher incidence of platform preparation as a whole, principally overhang removal, with more frequent non-feather terminations and more extensive flaking of the circumference of the last platform used. Therefore, with the aggradation of the Baghor coarse member, there was a notable shift in core reduction strategies and hence, core typologies.

Although there are no changes through time in retouch intensity, retouched flakes from Patpara formation contexts do show greater edge curvature (more convex retouch) and a higher frequency of ventral only retouch when compared to those from Baghor contexts. In addition, there were changes in the type of blanks selected for retouch; certain materials (quartzite and particularly chert) and sizes of flake (larger flakes) were preferentially retouched in Patpara contexts but not in those from the Baghor formation. These differences between Patpara and Baghor artefacts in retouch strategies may have been influenced to some degree by lithic material type but could also signal a change in subsistence activities or perhaps a demographic discontinuity.

These changes in lithic technology clearly document differences in aspects of hominin behaviour through time. In the absence of other forms of evidence, these Middle Son Palaeolithic assemblages currently offer the only evidence of past behaviours of hominin groups. For example, changes in the frequency with which different materials were exploited may coincide with changes in group mobility and/or functional requirements. Similarly, a decrease through time in flake size may correspond to increased mobility, conservation of relatively high quality lithic materials, developments in hafted technologies, changes in resource availability and/or new subsistence strategies. Given the absence of hominin fossil evidence from the Middle Son valley, as well as from Upper Pleistocene contexts in adjacent regions, it is not possible to establish if these changes in technology and behaviour correspond to the occupation of the valley by different hominin populations or species, or if the changes document behavioural adaptations by pre-existing populations to changed conditions. For example, the latter may have been driven by the frequent palaeoclimatic fluctuations that were so characteristic of the Upper Pleistocene period. Hypotheses of demographic change can be postulated; for example, the cessation of biface and cleaver manufacture in the early Middle Palaeolithic assemblages may plausibly mark the disappearance from the valley of the hominin populations or perhaps species that made them. Or, as another example, the porcellanite microliths at Baghor 3 may signal the appearance of a new hominin population in the valley. However, these remain hypotheses until relevant palaeontological evidence is available that allows us to distinguish behavioural adaptation from hominin population or species replacements.

The long stratigraphical sequences of the valley, the diversity of associated Palaeolithic artefacts and the long history of past archaeological and geological research in the valley all emphasize

Table 4
Typological classification of artefacts in the analysed Middle Son lithic assemblages.

	Early Patpara *n* = 32	Ghoghara *n* = 10	Patpara Middle Gravels *n* = 449	Patpara Upper Gravels *n* = 30	Late Patpara *n* = 9	Early Baghor CM *n* = 3	Baghor CM *n* = 82	Rampur *n* = 368	Baghor 3 *n* = 705	Baghor 1 *n* = 33
Biface	8	2	10							
Cleaver	2		3							
Core fragment			2				1			
Multiplatform core	4	3	43	3			4	3		3
Single platform core			1							1
Bidirectional core							1			2
Disc core			3		2		1			
Levallois core					1		1			
Levallois blade core							1			
Bidirectional blade core							2			
Unidirectional blade core							1			
Blade			2		1		10	86	4	4
Crested blade							2	18		
Backed blade			2				2	2		7
Double backed blade							3			
Backed blade (point)							2			2
Double backed blade (point)							1			
Retouched blade (unspecified type)								1		
Side retouch (blade)								1		
Double side retouch (blade)					1		8			
Side and end retouch (blade)								1		
Double side and end retouch (blade)				1			1			
Double side and double end retouch (blade)							1			
Notched blade							1	3		
Notched and double side retouch (blade)							1	1		
Notched and backed blade (point)										1
Burinated scraper (blade)								1		
Microblade core							2			
Microblade			1						15	
Microlith									8	
Backed microblade									1	
Backed microblade (point)										1
Flake	12	3	259	18			12	186	441	8
Point (flake)				1				1		
Side retouch (flake)	1		15				7	8		
End retouch (flake)	1		11	1			1	6		
Side and end retouch (flake)	1		7			1		3		
Double side retouch (flake)		1	6		1		4	2		
Double end retouch (flake)			1							
Double side and end retouch (flake)		1	5	1	2		2	1		
Double side and double end retouch (flake)			1		1			2		
Notched flake			3	4			2	4		1
Notched and side retouch (flake)			1			1		2		1
Notched and end retouch (flake)			1					1		
Notched and double side and end retouch (flake)			1					2		
Notched and side and end retouch (flake)								1		1
Burin			1				1			
Burinated scraper							1			
Notched and burinated flake			1							
Bipolar flake			1							
Bipolar blade								2		
Redirecting flake			1				1	3		1
Eraillure flake									7	
Flaked piece	2		61	1		1	4	24	214	
Retouched flaked piece	1		6					3		
Retouched tabular piece							1			
Red ochre (pigment)									15	

the significance of the Middle Son in terms of its palaeoanthropological record for this region of India during the Upper Pleistocene. However, this analysis of changes in Middle Son lithic technology through time, as well as a synthesis and critical review of the geology and chronology of the Son's Quaternary deposits, has highlighted several key issues that warrant further investigation (discussed below). The importance of driving forward research in the valley in order to obtain accurate chronologies for archaeological assemblages and a clear understanding of the sequence of Quaternary sedimentary deposition cannot be underestimated. Future investigations should aim to collect high resolution data via valley-wide surveys, excavation of primary context sites, and palaeontological, sedimentological and geochronological studies. These will result in lithic datasets with good stratigraphic integrity and chronological control, providing information on change and stasis in aspects of Palaeolithic technology through time, perhaps lending information about past hominin population or species dynamics in this region. Specialist studies of sediments and palaeontological remains promise to reveal important information about changes in palaeoenvironment and palaeoclimate during the Quaternary; this evidence can then be factored into models of Pleistocene hominin demographic change in this region.

Searching for palaeontological evidence of hominins

No hominin fossils have been recovered from the Pleistocene sediments of the Middle Son; this is surprising given the vast number of both faunal fossils and stone artefacts discovered in the valley. Because of this, there is no hominin fossil evidence to indicate which species manufactured the different industries of the Son Palaeolithic. In fact, no hominin fossils have been discovered in India that date to between ~150–250 ka (*Homo heidelbergensis* from the Narmada valley in central India; Kennedy, 2001; p. 167; Cameron et al., 2004) and ~31 ka (*Homo sapiens* in Sri Lanka; Deraniyagala, 1992). Given this paucity of hominin fossils, it is currently not possible to establish the temporal and spatial pattern of hominin occupation in South Asia during the Upper Pleistocene. However, fossils are well-preserved in the Middle Son valley, and therefore, surveys targeted at recovering hominin fossil remains from this region should be a priority of future studies.

Investigating initial hominin occupation of the valley

The Acheulean artefacts from the Sihawal formation signal the first evidence of hominin habitation of the Middle Son valley. Primary context stratified Acheulean sites have yet to be discovered, however, buried Acheulean artefacts in fluvial contexts do exist. Dates for the upper member of the Sihawal formation currently provide an upper age limit of ~100,000 years for these artefacts, however, the Acheulean of the valley could be considerably older than this. Primary context Lower Palaeolithic sites should be sought via survey, followed by excavation and chronometric dating of archaeological contexts. This data will produce important information that is currently missing regarding the age of initial hominin occupation of the valley.

Diversity within the Middle Palaeolithic

As seen above, there is evidence of techno-typological diversity within the Middle Palaeolithic of the Middle Son with some notable changes in technology occurring though time. Middle Palaeolithic technologies that included elements from the Acheulean (namely handaxes and cleavers) appear to have been replaced by an increase in Levallois, disc core and blade technologies; however, the nature and timing of this change within the Middle Palaeolithic is unknown (e.g. if it was gradual or sudden). The later phase of the Middle Palaeolithic, preserved in the upper levels of the Patpara formation and the lower part of the Baghor coarse member, is far less well known than the valley's Lower Palaeolithic, earlier Middle Palaeolithic or Upper Palaeolithic/microlithic. This important stratigraphic junction has never been excavated and is only known from a small number of artefacts from surface and section contexts. Through excavation and dating of primary context sites, the true chronological relationship between these different phases can be tested.

The appearance of Upper Palaeolithic and microlithic industries

The earliest blade technologies that occur without artefacts typical of the Middle Palaeolithic are known from the Baghor coarse member but artefacts from this context are relatively few in number, undated and in secondary contexts. Sites such as Rampur and Baghor 1, where artefacts from the latter are in a primary context, have produced assemblages that are characterised by both macroblade and microblade technologies. In contrast, the Baghor 3 assemblage is solely microlithic but possibly older than Baghor 1. Unfortunately, Rampur and Baghor 3 are inadequately dated and Baghor 1 remains undated. Technological studies of these assemblages can establish how these artefacts, defined as "Upper Palaeolithic", relate to Upper Palaeolithic assemblages from elsewhere in India as well as regions outside (e.g. the >45,000 year-old Upper Palaeolithic artefacts from Site 55 in Pakistan (Dennell et al., 1992)). Further, it is interesting that microblade and macroblade production were not chronologically separate as has been assumed in past models of technological development in which microlithic assemblages are often assumed to be younger that macroblade assemblages and Holocene (or Mesolithic) in age. This assumption is now known to be erroneous due to the presence of microlithic assemblages dating to ~28,000 years ago at several sites in India (Sali, 1989) and Sri Lanka (Deraniyagala, 1992) (see James and Petraglia, 2005). Therefore, a mosaic-like pattern of different lithic industries appears to have existed in the Middle Son, where there was overlap between microblade and macroblade technologies, and between the latter and Middle Palaeolithic technologies. It is necessary to determine the interrelationships between these technologies as well as their chronology, and to explore what this technological diversity might mean in terms of hominin population dynamics in this region of India.

Investigating the impact of the Toba eruption on hominin populations in the valley

The ~74,000 year-old Toba eruption is argued to have caused rapid climatic deterioration, destruction of habitats and extinction of modern human populations (Rampino and Self, 1992, 1993a,b), resulting in a population bottleneck that left only a few thousand surviving *H. sapiens* in tropical refugia in Africa (Ambrose, 1998; Rampino and Ambrose, 2000). However, others have contested the severity of the eruption's impact on both global climate (Oppenheimer, 2002) and on faunal species in Southeast Asia (Gathorne-Hardy and Harcourt-Smith, 2003; Louys, 2007). YTT deposits have been recovered from river valley contexts throughout India (Acharyya and Basu, 1993; Shane et al., 1995; Westgate et al., 1998), in some locations, Palaeolithic artefacts are associated with YTT (Jones, 2007a). Recently, dated lithic assemblages, in direct association with YTT deposits, have been documented in the Jurreru valley in southern India. An examination of the technological attributes of these artefacts, from dated contexts that predate and post-date the eruption, indicated that the eruption had no substantial human impacts and did not result in a population extinction in the region (Petraglia et al., 2007). All four known occurrences of Toba ash in the Middle Son are in fluvial contexts, and therefore, all artefacts in association with YTT are in secondary contexts. Although it is possible to assign either a pre- or post-Toba age to these artefacts, little can be said about the direct impacts of the eruption on hominins in the valley using data that possesses such a low temporal resolution. Future research in the Middle Son valley should aim to resolve some of these problems. Primary context sites where ash and archaeology are in direct association are essential if the impacts of the eruption on hominin technologies, behaviour and demography are to be addressed.

Conclusions

This paper has highlighted the diversity of the Middle Son archaeological and geological records during the Upper Pleistocene period. While concerns have been raised about several chronometric dates and aspects of geomorphological models for the Middle Son deposits, the evidence obtained thus far relating to the Palaeolithic and Quaternary geology of the Middle Son region is relatively rich when compared to other regions of India. Because of this, there exists an excellent source of information for future studies to build upon. A detailed analysis of lithic assemblages from the Middle Son reveals several stark changes in lithic technology through time, largely marked by gross typological shifts. However, a number of small-scale changes in technology also occurred, as revealed by an in-depth analysis of multiple lithic attributes. These technological changes correspond to shifts in hominin behaviour that were probably driven by changes in habitat, social conditions and/or demographic structure. Upper Pleistocene palaeoclimatic fluctuations and subsequent local environmental changes may have been a driving force behind these behavioural adaptations. The Toba eruption may have further contributed to behavioural changes after 74,000 years ago. During this period, it is proposed that certain key demographic shifts occurred, most certainly at the population level, but possibly at the species level; for example, a species change may have accompanied the transition from the Lower to Middle Palaeolithic in the valley. However, an absence of hominin remains from the Son and surrounding regions precludes any solid conclusions regarding the taxonomy of the hominin species that manufactured the Middle Son artefacts. Until future palaeontological evidence is discovered, statements regarding hominin demographic change, and the contributions that population shifts may have made to changes in lithic technology and hominin behaviour in the valley, must remain hypotheses. Given the excellent preservation of fossil faunal remains in Middle Son Quaternary deposits, exploration of this valuable region for hominin remains would be an excellent place to start.

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