The oldest and longest enduring microlithic sequence in India: 35 000 years of modern human occupation and change at the Jwalapuram Locality 9 rockshelter

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The Jwalapuram Locality 9 rockshelter in southern India dates back to 35 000 years ago and it is emerging as one of the key sites for documenting human activity and behaviour in South Asia. The excavated assemblage includes a proliferation of lithic artefacts, beads, worked bone and fragments of a human cranium. The industry is microlithic in character, establishing Jwalapuram 9 as one of the oldest and most important sites of its kind in South Asia.

Keywords: India, Microlithic, Microblade, Middle Palaeolithic, Terminal Pleistocene, LGM

Introduction

Microlithic technologies play a central role in debates over modern human origins and dispersals, responses to risk and climate change, and the emergence of modern human capacities for complex behaviour and symbolic thought (Clark 1968; Neeley & Barton 1994; Bar-Yosef & Kuhn 1999; Kuhn & Stiner 1999; Klein 2000; Hiscock 2002; Foley & Lahr 2004; James & Petraglia 2005; Mellars 2006; Anikovitch *et al.* 2007; Brantingham *et al.* 2001; Seong 2008). The repeated invention of microlithic industries, here defined as systematic microblade and/or backed artefact production, has been documented for both modern and archaic humans at different times and in widely separated parts of the world. This mosaic-like appearance of the microlithic over the course of later human evolution

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Received: 2 January 2008; Revised: 25 November 2008; Accepted: 14 December 2008

ANTIQUITY 83 (2009): 326–348

suggests that organisational and functional advantages resulted in strong convergence on these diminutive technologies at various times and places in the past. Typical benefits of microlithic technologies include increased standardisation of implements facilitating easier repair and maintenance, multifunctionality via different hafting arrangements, and the potential for increasing the effectiveness and reliability of weapons and tools through the use of multiple serial inserts (Bleed 1986; Myers 1989; Hiscock 2002; Lombard 2008; Robertson & Attenbrow 2008).

To date, South Asia has played a minor role in most discussions of early microlithic innovation, other than as a passive recipient of technologies developed elsewhere (Mellars 2006). Here we redress the balance by demonstrating that the origins and regional chronological variability of the Indian microlithic reflect dynamic human responses to local and regional environmental and demographic pressures in South Asia during the late Pleistocene and Holocene.

The Jwalapuram Locality 9 rockshelter site, located in southern India's Kurnool District, (Figures 1–3), preserves the oldest microlithic sequence yet obtained in India, and one of the longest known continuous records of microlithic technology in the world. Detailed lithic attribute analysis has revealed a number of technological, cultural and ecological changes at the site over the last 34 000 years and more. Faunal remains, shell and stone ornaments, and worked bone from the same time-range provide contextual evidence of demographic and climatic shifts in the local area. Described here for the first time, the technological sequence recovered at Locality 9 therefore makes a significant contribution to South Asian and global prehistory, and re-confirms the importance of the Kurnool District as a source of valuable information concerning long-term technological and cultural continuity and change (Newbold 1844; Foote 1884a & b, 1885; Lydekker 1886; Allchin 1962; Sarma 1968; Murty 1974, 1979, 1985; Thimma Reddy 1980; Nambi & Murty 1983; Prasad 1996; Petraglia *et al.* 2007, 2008).

Jwalapuram Locality 9

The Locality 9 rockshelter is located on the northern margin of the Jurreru River Valley in Andhra Pradesh, India. The shelter is formed by a large quartzite boulder lying at the base of a talus slope beneath a visually impressive quartzite escarpment (Figures 1–3). The boulder's southerly face provides shelter from sun and rain for an area of around $60m^2$ (Figure 3). Partially buried slabs of rock at the front of the shelter indicate that a much larger overhang once existed prior to collapse. The southern shelter wall preserves figurative and non-figurative red and white ochre paintings directly above the occupational deposit.

Stratigraphy and dates

Between 2003 and 2009, a 4 × 4m excavation positioned against the southern rockshelter wall revealed five stratigraphic units (Strata A to E) with associated cultural material to a depth of 3.3m, and a culturally sterile hard calcium carbonate encrusted layer beneath (Stratum F) (Figure 4). The topmost Stratum A comprises loose brown surface sediments with abundant organic remains. Stratum B is subdivided into an intrusive pit feature at the front of the shelter (B1), and a second pit at the rear of the shelter (B2). A partly collapsed

Figure 1. The JWP9 rockshelter and excavation area seen from the south.

stone cairn structure was found in close association with large pieces of burnt human bone and ceramic sherds in Stratum B2. Strata B1 and B2 are both intrusive into C. Stratum C is comprised of compact calcium carbonate encrusted sediments and contains an abundance of flat limestone slabs and quartzite roof spalls suggestive of the construction of a platform at this level. Very large numbers of stone artefacts and freshwater mussel shells are found in or slightly above this stone feature. Bone is also found throughout Stratum C, including pieces of cut and worked bone and antler. Strata D through G become increasingly lighter in colour and more compact, with tightly packed calcium carbonate nodules becoming more common with depth. Stone artefacts, bone and shell decrease in number with increasing depth below Stratum C, and no artefacts were found in Stratum F. Excavation ceased when a very hard, culturally sterile, calcium carbonate rich layer (Stratum G) was encountered that was virtually impenetrable with hand tools.

The two pits at the top of the sequence (Strata B1 and B2) contain pottery of Late Neolithic to early Iron Age/Megalithic date (i.e. within the last 3000 years). Ceramics found in Stratum A consist of black polished, red slipped and polished, black and red polished, and wheel-made jars with elaborated rims, with a few classic Megalithic types. Most ceramics are thin-walled, hand-made sherds that suggest continuities with Neolithic potting traditions. Strata B1 and B2 therefore likely date to the late Holocene. AMS radiocarbon dating of landsnail and bivalve shelves (*Unio* sp.) returned calibrated ages of 20–12kya (thousand years ago) for Stratum C, and around 34kya for Stratum D. Note that although we recognise

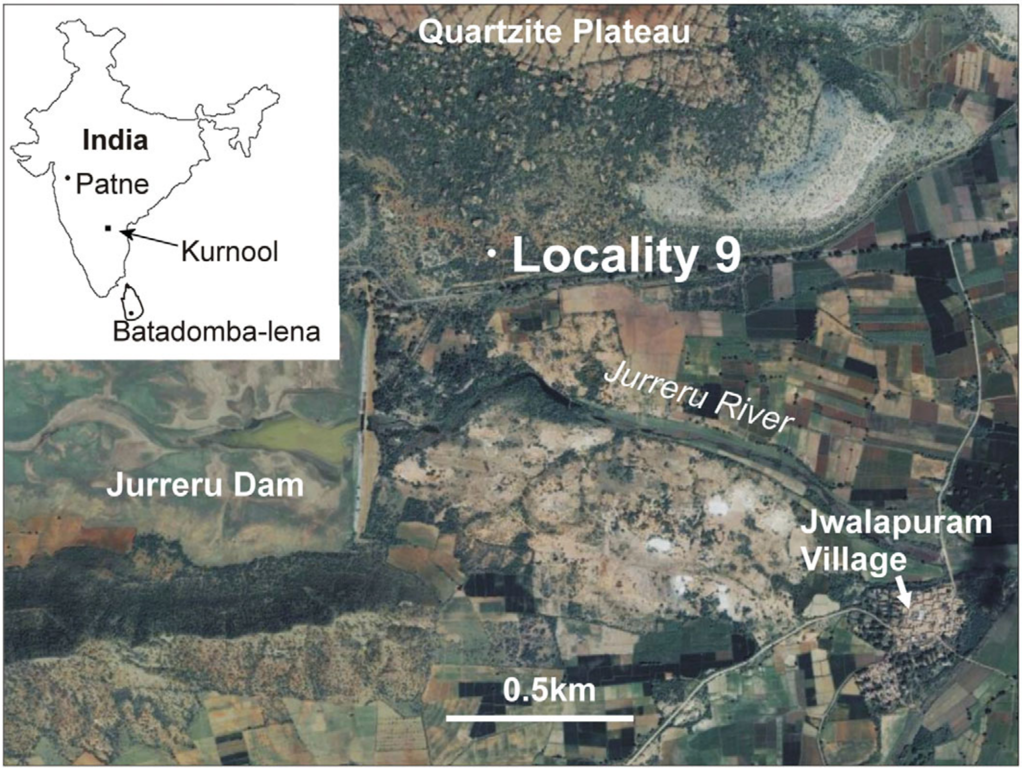

Figure 2. The Jurreru Valley showing the location of the Locality 9 rockshelter.

the limitations of current calibration curves, to ensure comparability with environmental datasets all radiocarbon determinations presented in this paper are calibrated (see Table 1 and Figure 4 for details and context of uncalibrated ages). Stratum E is assigned an age of >34kya, as material for radiocarbon dating was not available.

Human remains, ornaments and fauna

Jwalapuram Locality 9 preserves the earliest securely-dated remains of *Homo sapiens* in India (Figure 5a). Together with the Narmada cranial vault (likely *Homo heidelbergensis*) (Athreya 2007) and human remains from Bhimbetka (Kennedy 2000), these are the only hominin remains of Pleistocene date yet found in India. The skeletal elements include four cranial vault fragments and an isolated tooth, bracketed by ages of 20 and 12ky cal BP. Significantly, other than the tooth, all of these fragments have been burned (calcined), probably indicating cremation practices.

A total of 25 limestone and bone beads was also recovered in Stratum C (Figure 6, Table 2), making this one of the largest collections of late Pleistocene symbolic items in South Asia. There is a predominance of stone beads found towards the base of Stratum C and bone beads higher up. The central bore hole for these beads is between 1.5 and 3mm in diameter with an external diameter for the beads of between 4 and 8mm. The thickness of the stone pieces averages 2.1±0.2mm, and that of the bone beads 1.6±0.5mm. Several

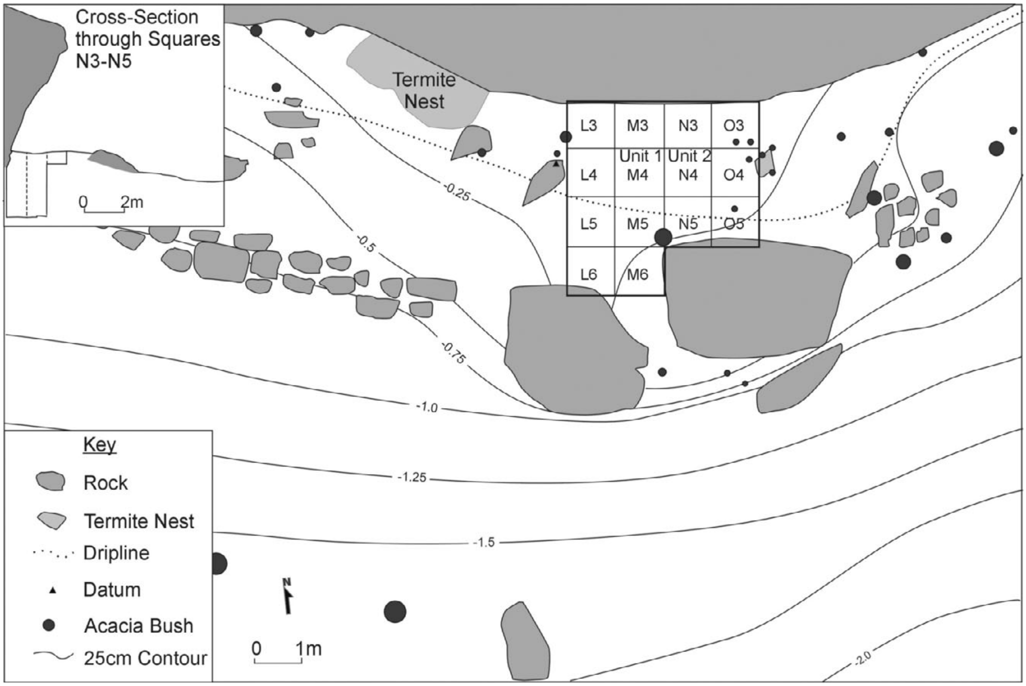

Figure 3. Plan and cross-section of the Locality 9 rockshelter showing excavated squares.

round, flat bone and stone discs lack bore holes and have diameters of up to 14mm. We hypothesise that these are bead blanks, suggesting that bead manufacture took place on site. Elongate stone artefacts backed on both lateral margins and with a stout tip are found in the deposit at the equivalent depth to the beads. Use-wear observations made by one of the authors (MH) indicate use with a rotational crushing motion, supporting the hypothesis that these artefacts served as drills for bead production at the shelter.

The flat round bone and stone beads present through Stratum C are not present in Stratum B. Personal ornaments of a different kind appear in Strata A and B, including a pierced bivalve shell found in Stratum B (0.999m depth), a grooved reptile tooth (0.64m depth) found slightly above this, and a terracotta bead in Stratum A.

A broken bone point dating to 34–20 kya is considered to be an awl based on use-traces found on the tip, and a uniserial harpoon fragment (likely antler, but heavily coated with a calcium carbonate rind) was found at around the same depth as the initial proliferation of backed artefacts, likely dating to *c*. 34kya (Figure 5b, Table 2).

In addition to beads and cremated human remains, a striated red ochre crayon is present at the interface between Stratum C and D, dated 20–12kya, while many ochre fragments are present throughout Stratum C, indicating that artistic activities were an important component of site use over time. Faded red rock art on the shelter wall depicting anthropomorphs and large animals (including an elephant) could conceivably date to the late Pleistocene, as thick mineral deposits cover the panels in some places. Several quartzite

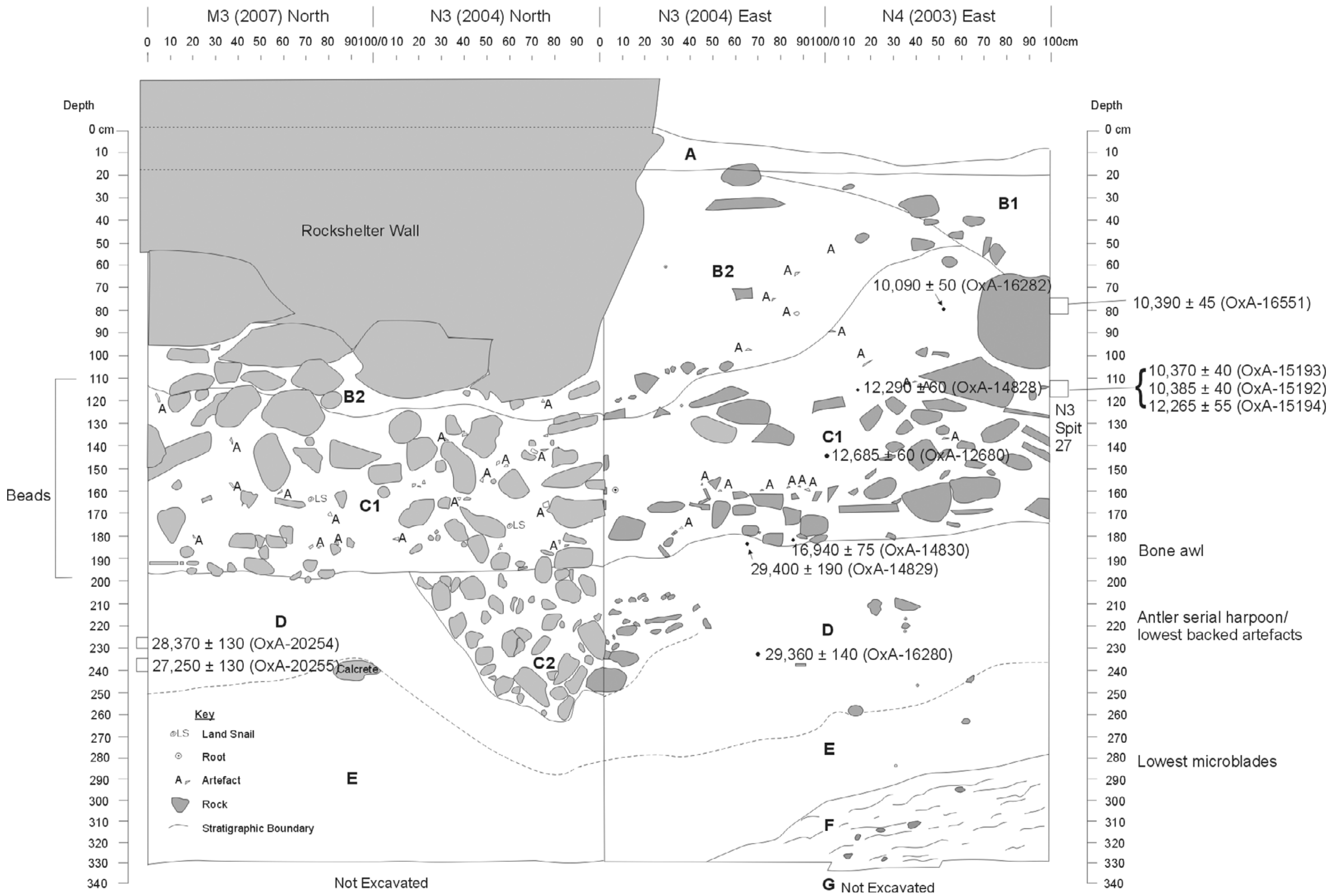

Figure 4. Section drawing of the north and east walls of the Locality 9 rockshelter excavations.

Table 1. Radiocarbon dates for Locality 9.

Sample	Material	Provenance	Type	Radiocarbon age	Age (cal BP) at 2 sigma
OxA-16282	Shell, aragonite, snail	Stratum C, 0.80m	AMS	10090 ± 50	11 398–11 834
OxA-16551	Charcoal	Unit 1, Stratum C, 0.737–0.813m	AMS	10390 ± 45	12 400–12 074
OxA-15192	Shell aragonite, snail	N3, Stratum C, Level 27, 1.15–1.21m	AMS	10385 ± 40	12 397–12 075
OxA-15193	Shell, aragonite, snail	N3, Stratum C, Level 27, 1.15–1.21m	AMS	10370 ± 40	12 395–12 053
OxA-15194	Shell aragonite, bivalve	N3, Stratum C, Level 27, 1.15–1.21m	AMS	12265 ± 55	14 455–13 959
OxA-14828	Shell aragonite, snail	N3, Stratum C, Level 27, 1.10–1.20m	AMS	12290 ± 60	14 592–13 991
OxA-16281	Shell aragonite, snail	Stratum C, 1.45m	AMS	12685 ± 60	14 691–15 215
OxA-14830	Shell aragonite, snail	N3, Stratum D, Level 35, 1.80–1.90m	AMS	16940 ± 75	20 274–19 897
OxA-14829	Shell aragonite, bivalve	N3, Stratum D, Level 35, 1.80–1.90m	AMS	29400 ± 190	34 305–33 351
OxA-20254	Shell aragonite, bivalve	M3, Stratum D, Level 48, 2.24–2.3m	AMS	28370 ± 130	32 916–30 520
OxA-16280	Shell aragonite, snail	Stratum D, 2.30m	AMS	29360 ± 170	33 350–34 284
OxA-20255	Shell aragonite, bivalve	M3, Stratum D, Level 50, 2.34–2.4m	AMS	27250 ± 130	30 985–29 966

spalls showing traces of red ochre were found in Stratum C, confirming the likely Pleistocene antiquity of rock art at the site.

A faunal assemblage of 2732 non-human vertebrate remains and 1644 mollusc shells was recovered from Squares N3 to M4, representing one of the largest and most securely dated faunal collections of South Asia (Table 3). The faunal assemblage is dominated by the remains of wild animals (including *Gazella gazella*, *Antilope cervicapra*, *Boselaphus tragocamelus*, *Sus* sp., *Tetracerus quadricornis* and *Muntiacus mutjak*). The remains of small- and medium-sized ungulates dominate the mammalian assemblage. Only a few bones derive from carnivores and non-human primates, and microvertebrates are rare. All of the identified taxa are known from the wider region, although most of the wild ungulates have been locally exterminated. The Locality 9 assemblage shows that impoverishment of the wild mammal fauna occurred within the last 3000 years.

The macrovertebrate assemblage shows a shift in habitat preference from grassland to woodland from Strata D to C, suggesting broad environmental changes in the local region

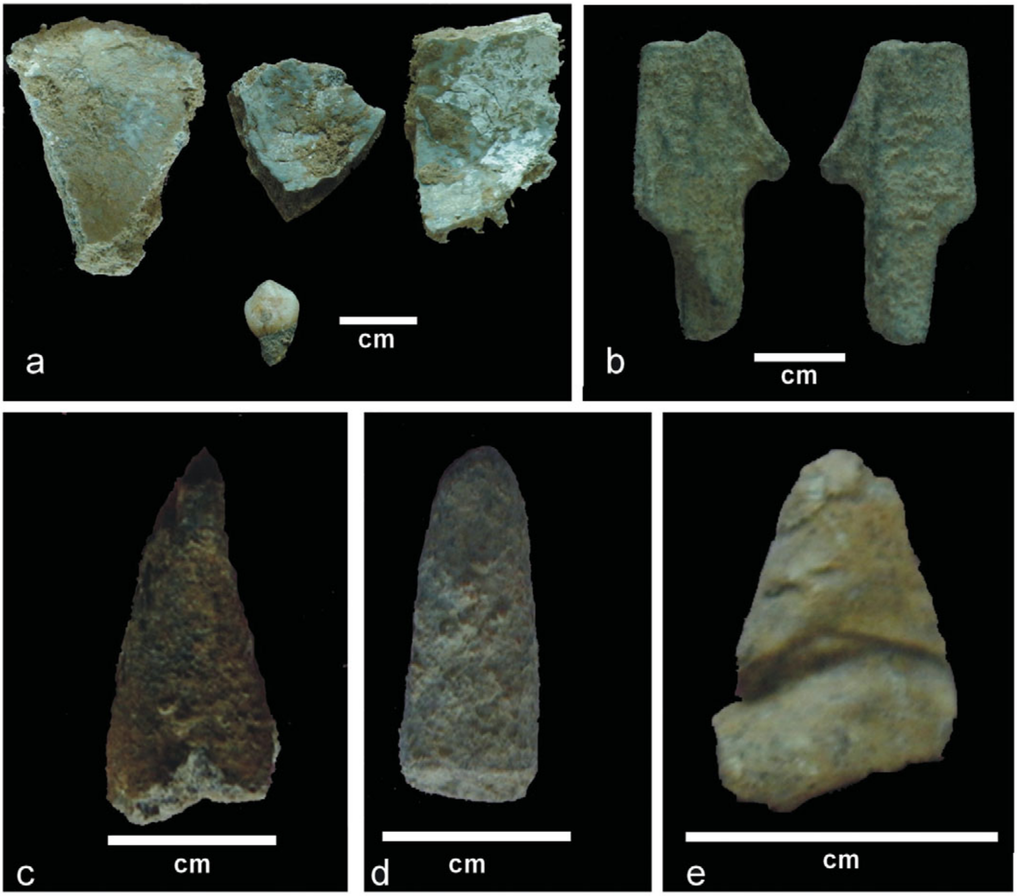

Figure 5. Skeletal fragments and worked bone artefacts from Locality 9: a) human cranial fragments and tooth; b) uniserial antler harpoon; c) bone awl; d) snapped antler tine; e) grooved tooth.

over the duration of occupation (Figure 7). Stable carbon isotopic data from Locality 9 soil carbonates support this finding, indicating a trend from mixed C4 grass and C3 woodlands prior to and around the time of initial systematic microblade production, towards more closed and wooded C3-dominated environments between 20 and 12 000 years ago.

The mollusc assemblage reveals important information about foraging and intensity of site use (Table 4). First, it shows that mollusc gathering, particularly of freshwater bivalves, was a systematically used strategy during all phases of site use. There is a significant decrease in bivalve size over time (between Strata C and B2); one potential cause is sustained predation pressure but data from other local sites is required to test this hypothesis. Large landsnails (*Cryptozona*) appear to have been collected and perhaps consumed during the earlier phases (D, C, and perhaps B2), but they drop out of the record during the later phases of occupation (Figure 8). The smaller landsnails (*Cyclotopois* and *Zooiticus* sp.) and freshwater snails probably accumulated at the site during periods of less intensive human occupation as their frequency varies inversely with the frequency of macrovertebrate remains.

Table 2. Significant artefacts from Jwalapuram Locality 9.

Type	Provenance	Notes
Iron	L5, Level 2, Stratum A, 80mm	Long, thin piece of iron with a hook-shaped tip (35 × 3.0 × 3.3mm). Squared and hand-cut. Weight: 1.6g.
Bead	N5, Level 4, Stratum A, 160mm	Likely terracotta, bright brown in colour. Sub-round, ball shape (15.5 × 14.8 × 13.8mm). Bore hole width is 4.0mm. Weight: 2.3g.
Worked stone fragment	M5, Level 5, Stratum A/B, 200mm	A piece of worked stone (14.5 × 15.7 × 7.2mm) with ground surface, probably limestone. On one face a series of six shallowly engraved grooves (max length 14.5mm, depth 1mm) along entire face, with plain opposite face. Weight: 2.3g.
Bone awl fragment	M5, Level 9, Stratum B, 0.32m	Elongated fragment (15.3mm length) and semi-flat shape (5.2 × 2.7mm); series of long, linear striation marks present, polished surface. Tapers slightly towards a tip. Weight: 0.3g.
Grooved tooth	N3, Level 9, Stratum B, 0.6412m	Fragment of a reptile (?) tooth that shows deep grooves cut near its base.
Pierced shell	N3, Level 18, Stratum B, 0.999m	A pierced fresh water bivalve shell (27.9 × 16.4 × 5.9mm). Hole is near apex. Hole shows a sheered, flat upper surface. Bore hole width is 4.1mm. Weight: 1.1g.
Grooved and snapped antler tine	M3, Level 18, Stratum C, 1.03m	An antler tine that shows evidence of having been grooved and snapped. There is not any evidence of working on the antler tip. This piece thus represents manufacturing waste. The piece is 18.6mm long. The cross-sectional dimensions of the snapped end are 7.3 × 6.2mm.
6 Beads	N3, Level 28–33, Stratum C, 1.25–1.65m	1 shell, 3 bone and 2 limestone beads, 4 with central bore hole, and one blank with an incomplete hole. Weight ranges from <0.1–2g. Maximum dimensions is from 4.5–12mm, and thickness ranges from 1–3mm.
19 Beads	M3, Spits 36–43, Stratum C, 1.73–2.04m	5 bone beads and 14 stone (limestone and quartzite) beads. 11 beads have well-formed central bore hole, the remaining beads are blanks with either no hole or a partly formed hole. Beads range in weight from <0.1–0.4g, 4.3–10mm in width (mean = 7.74mm), and 1–3mm in thickness.
Ochre crayon	N3, Level 34, Stratum C/D interface, 1.65–1.81m	Striated red ochre crayon with several grinding facets.
Broken awl (?)	N3, Level 34, Stratum C/D interface, 1.8182m	A distal metapodial shaft with unfused epiphysis showing slight polish and rounding to the broken shaft. Its width at the base (unfused end) is 10.8mm and its thickness at the base is 5.8mm.
Uniserial harpoon fragment	N3, Level 38, Stratum D, 2.1582m	A probable antler harpoon fragment covered with a calcium carbonate rind. The piece is 34.4mm long with a width of 12.6mm below the barb and 17.5mm across the barb. It is 7.9mm thick at the barb and the cross-section is oval.

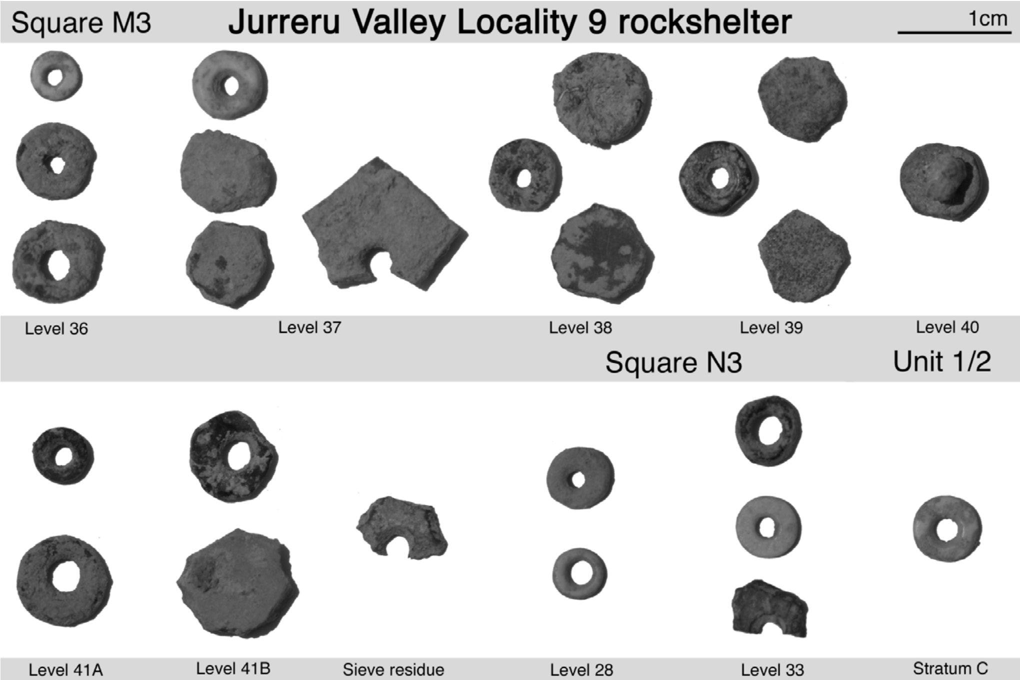

Figure 6. Bead assemblage from Stratum C (1.10–2.00m below surface).

The Locality 9 lithic sequence

A large lithic assemblage has been recovered from excavations at the site, consisting of 53 162 artefacts from the deepest 1 × 3 × 3.3m excavation area. Artefact deposition is near-unimodal over the depth of the site (Figure 9), with a pronounced peak in deposition between 1.90 and 1.30m depth, bracketed by radiocarbon ages of 20 and 12kya. This peak in artefact deposition takes place directly above the apparent platform structure built across the base of Stratum C using flat slabs of exotic limestone. This suggests that occupation was intensive enough at this time to warrant significant alteration of the site to create a more habitable surface. As there are few detailed studies of microlithic technology in India, a summary of the technology through time is warranted.

Microblades are a dominant feature of the lithic assemblage from first occupation at the base of Stratum E (2.90m) to the top of the deposit (Figure 9), and therefore form a continuous microlithic record from sometime prior to 34 000 years ago up until the late Holocene. While 'microblade' is a poorly-defined term that is used differently in various parts of the world, we employ a cutoff of 40mm for maximum microblade percussion axis length and an elongation of >2:1 length:width (Figure 10). This cutoff equates to a sharp drop in the frequency distribution of blade lengths from the site, as well as being two standard deviations above mean microblade length. Ninety-seven per cent of microblades under 40mm in length also have a width less than 15mm, conforming with a common criterion used elsewhere (Tixier 1963; Owen 1988; Bar-Yosef & Kuhn 1999). Our definition also stipulates a near-absence of cortex on the dorsal face (<20 per cent coverage), at least one

Table 3. Macrovertebrates identified from Jwalapuram 9 by stratum.

	Stratum				
Species	**A**	**B1**	**B2**	**C**	**D**
Capra			1		
Capra/Ovis/Gazella	1	3			
Capra/Gazella			1		
Gazella		2	2	6	5
Gazella/Antilope				1	
Gazella/Tetracerus		2	1	3	1
Antilope			1	2	2
Antilope/Axis		2			
Tetracerus		1	3	1	
Tetracerus/Muntiacus					1
Muntiacus				2	
Muntiacus/Axis				1	
Axis	1	3	3	3	
Cervus/Axis			2		
Cervus			1	2	
Cervus/Boselaphus		1			
Bos/Bubalus/Boselaphus	2	3	2	3	2
Boselaphus		1	1	6	2
Bubalus			1		
Bos/Bubalus		1			
Sus		2	3	2	
Equus sp.			1		
Manis				1	1
Lepus		2	2	2	4
Herpestes		3	7	2	2
Erinaceus			1		
Hystrix		3	2		
Presbytis			1		
small-medium sized carnivore			4		
large-sized carnivore				1	
Canis sp.			1		
Felis chaus					2
hare sized		7	12	4	4
small-ungulate sized		9	14	10	13
medium-ungulate sized	1	4	4	7	1
large-ungulate sized		1			
indeterminate			1	3	
Total	5	50	72	62	40

longitudinal dorsal ridge, and parallel to sub-parallel lateral margins. Blades >40mm in length are present at the site but never prominent (<4 per cent of elongate flakes), with one larger blade to every 22 microblades. Microblades are most common in Stratum E and the lower part of Stratum C, with a pronounced decline in abundance in Strata D, B and A.

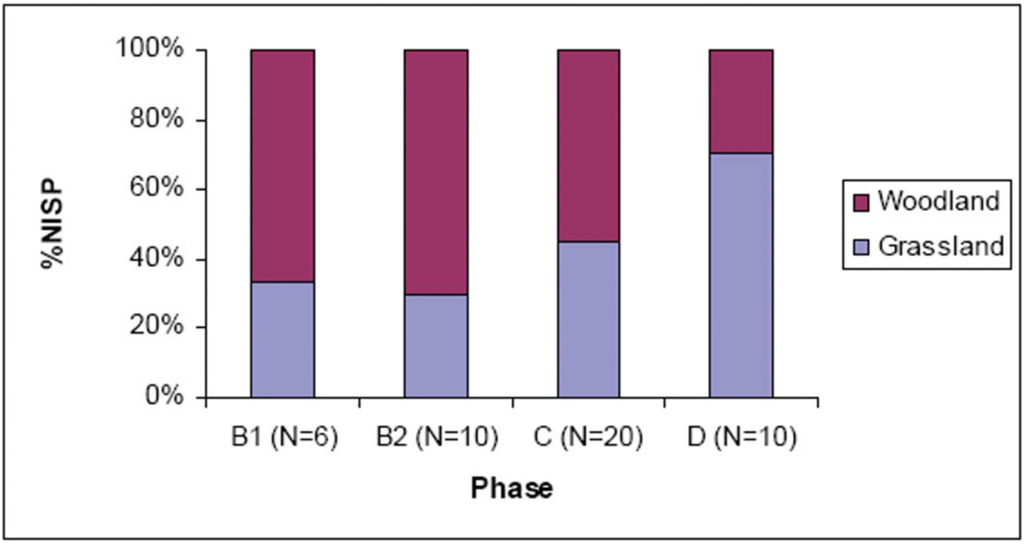

Figure 7. Frequency of woodland and grassland taxa by phase at Jwalapuram 9.

Table 4. Mollusc assemblages from Jwalapuram 9 by stratum.

	Stratum				
Species	**A**	**B1**	**B2**	**C**	**D**
	Large landsnails				
Cryptozona	43	136	371	363	64
	Small landsnails				
Cyclotopois	5	6	20	16	7
Pterocyclus		2	5	1	1
Zooiticus	32	70	58	6	
Freshwater Bivalves	50	260	1188	501	129
	Bivalves (MNE)				
Parreysia	4	44	204	99	13
Lamellidens		4	37	10	7
Unidentified	1	5	1	1	1
	Freshwater snails				
Thiara		1			
Brotia		3	2	1	
Total	135	531	1886	998	222

Backed artefacts and burins make their first appearance at a depth of 2.20m, about 100mm above the date of 34kya, and remain at high frequency until just before the peak in total artefact discard rates approximately 20 000 years ago (Figure 9). Their absence below 2.20m may simply reflect small sample size. Backed artefacts are almost always made on the thin, elongated flakes that comprise the unretouched microblade assemblage, and both types possess almost identical size ranges. Much of the microblade production at the site therefore

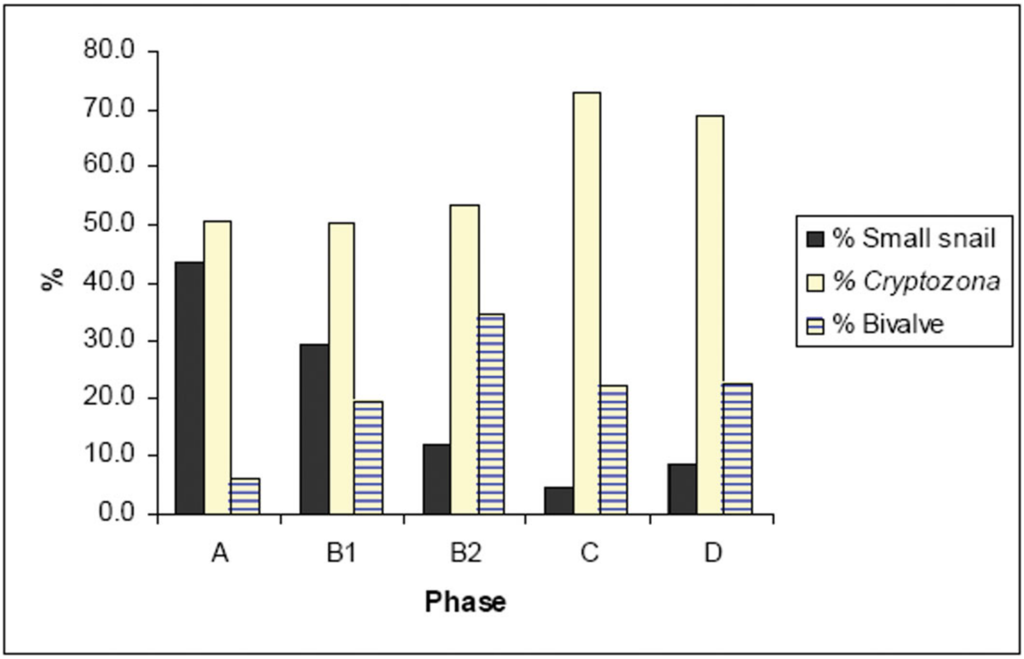

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Figure 8. Frequency of small landsnails (Cyclotopois, Pterocyclus, Zooiticus)*, large landsnails* (Cryptozona) *and bivalves within the mollusc assemblages at Jwalapuram 9.*

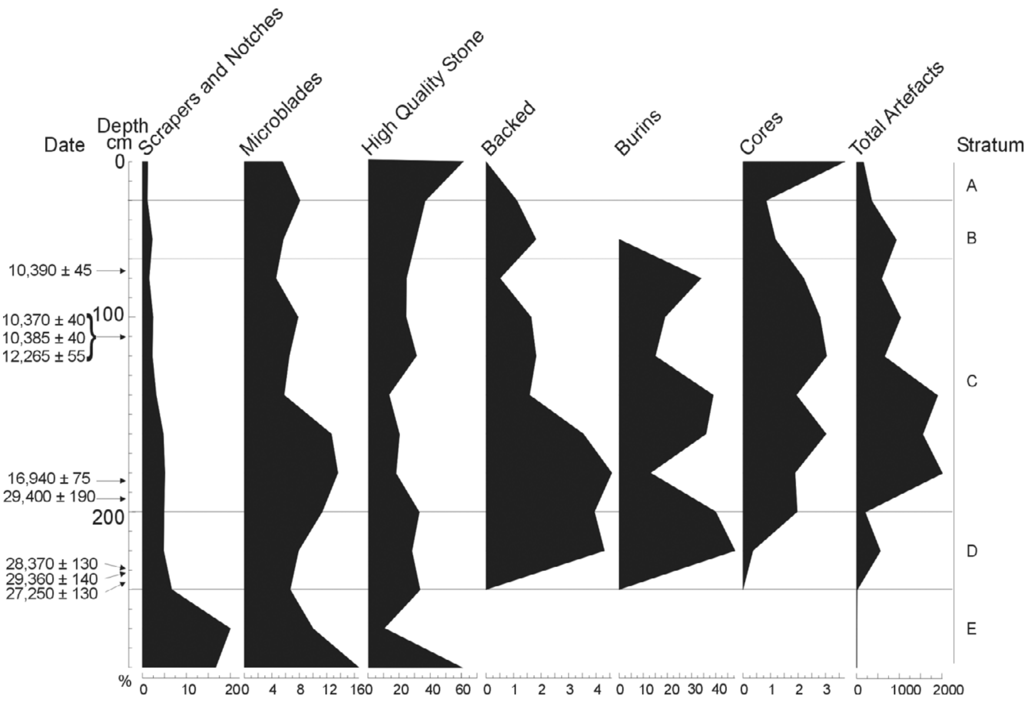

Figure 9. Technological sequence for Locality 9 showing major technological and typological classes.

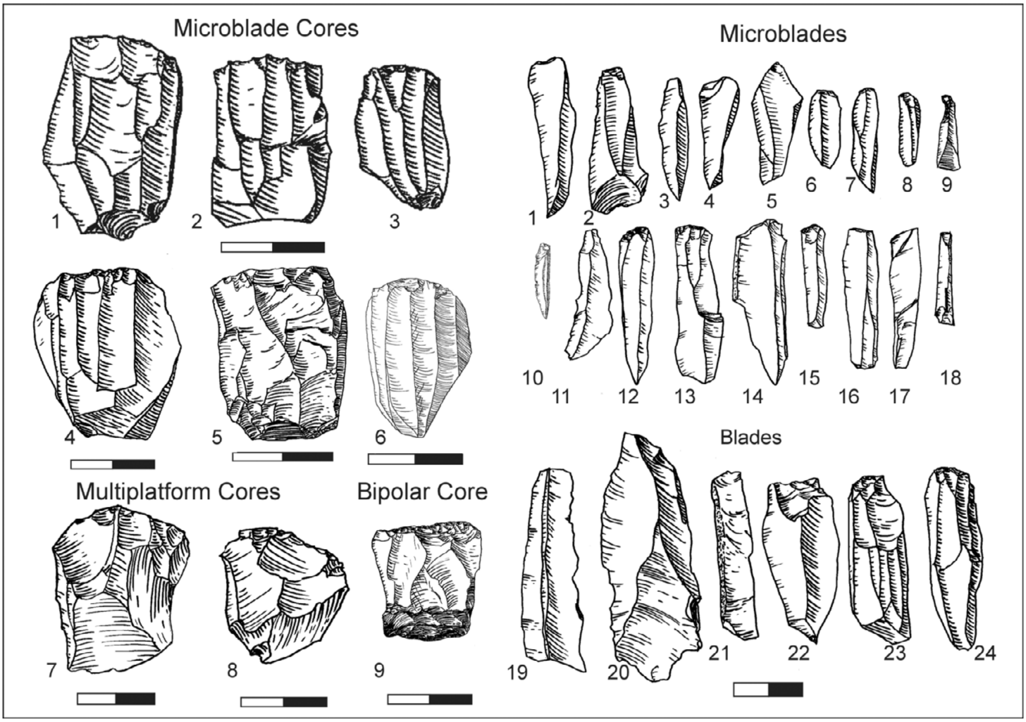

Figure 10. Blades, microblades and cores from Spits 33 and 34 of Square N3, Locality 9, during the peak of the microlithic phase.

seems to have been geared toward the production of backed artefacts. This is evident from the dorsal scar morphology of backed artefacts, which almost always exhibits parallel ridges on the dorsal surface, a near-absence of cortex, and parallel to sub-parallel margins (Figure 11). Backed artefacts are also slightly shorter (mean for microblades = 23.6mm, mean for backed = 19.5mm) and narrower (mean for microblades = 8.05mm, mean for backed = 6.07mm) than microblades, as would be expected for microblades that have been steeply retouched along one margin and at the tip. Microscopic use-wear and residue analysis have shown that hafting backed artefacts using a resinous mastic was practiced in the late Pleistocene at Locality 9, however, determining the frequency and range of hafting conformations requires analysis of greater sample sizes.

Cores take the form of single platform (often faceted) and bidirectional microblade cores, as well as small heavily rotated cores and bipolar cores (Figure 10). The absence of cores below 2.40m depth may also be explained by small sample size. Around 30 per cent of microblade cores show heavy platform faceting and occasional cresting on the back of the core. Crested ridge straightening and ridge creation flakes are also present in the assemblage. Some heavily rotated cores appear to have been microblade cores at previous stages of reduction, judging from the presence of truncated parallel flake scars. Retouched scrapers and notches are most common in Stratum E and decrease in frequency with time (Figure 9). Scrapers take a range of forms, including side and end scrapers as well as end scrapers on blades and carinated end scrapers (Figure 11).

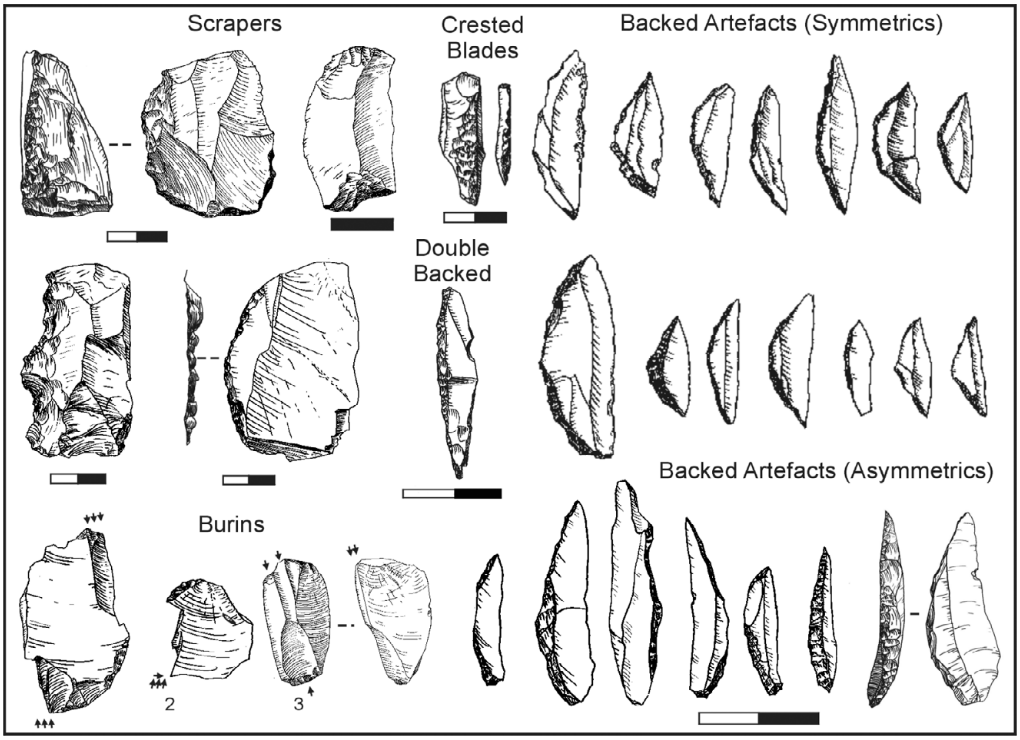

Figure 11. Retouched artefacts from Spits 33 and 34 of Square N3, Locality 9, during the peak of the microlithic phase.

Technological change during the microlithic

Evidence for pronounced technological changes within the Locality 9 sequence challenges the common conception of the microlithic as a largely unchanging industry. For example, there are clear changes in the kinds of backed artefacts made through time. Asymmetric backed artefacts (i.e. trapezes and triangles) are most common between 2.20–1.80m depth, while symmetric backed artefacts (i.e. lunates) increase in frequency between 1.80–1.50m. Artefacts backed along both margins to form a point are only present in Stratum C between 1.82–1.10m depth. Given that one hypothesised use for these artefacts is as drills, it is significant that they closely mirror the depth-range for beads at the site (2.04–1.25m).

Chronological changes in microblade production are also evident at the site, indicating that the Indian microlithic is not a homogeneous unit. The number of ridges on microblades increases through time, from an average of 1 ridge in Stratum E to around 1.5 in Stratum B. Since microblades also become narrower over time (median width of microblades reduces from 8.6 to 7mm over the sequence), increasing numbers of dorsal ridges suggest blade removals became more closely spaced over time. This is supported by a rise in the proportion of elongate parallel flake scars on microblade cores from around 40 per cent to over 60 per cent of scars through time. In the Neolithic and late prehistoric periods, as represented by Strata A and B, the production of extremely narrow and elongate blades using soft hammer and/or pressure techniques appears for the first time (e.g. Figure 10, no. 6), and this may

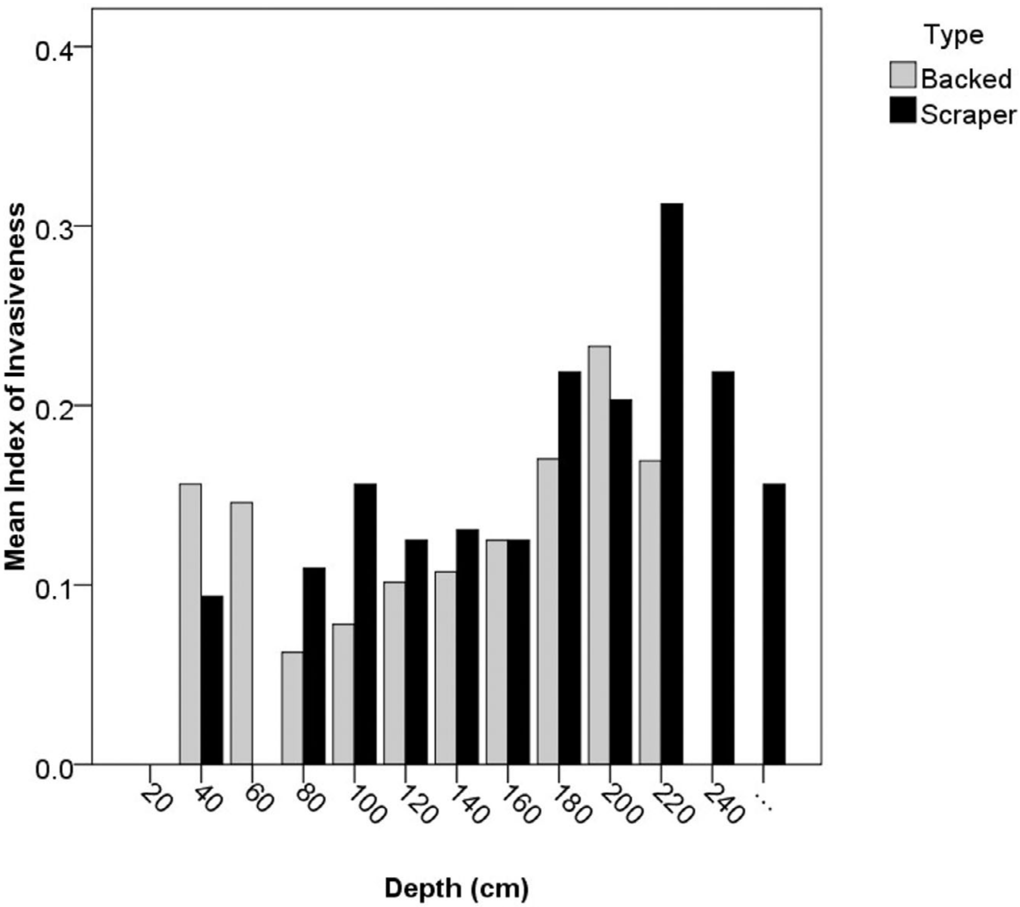

Figure 12. Change in reduction intensity over the depth of the site, measured using the Index of Invasiveness (Clarkson 2002).

explain the reduction in blade width as well the closely spaced dorsal ridges. Dorsal scar orientations also change from proximal-to-distal prior to 34kya to increasingly bidirectional, crested and lateral orientations in later units.

The extent of flake retouch also changes dramatically through time. Retouch intensity, measured using Clarkson's (2002) index of retouch scar coverage, peaks early in the sequence (Figure 12), with the highest degree of retouch found at the base of Stratum E (2.85m, >34kya) through to the top of Stratum D (2.00m, ~20kya). This reflects the degree to which flakes were resharpened and reshaped to extend the supply of raw material or to transform flakes in ways that suited different tasks. Core reduction intensity drops in Stratum C, but rises again steeply in Stratum B, suggesting reduced pressure on raw material supply and use in Stratum C (Figure 13).

The use of high quality raw material such as chert, chalcedony and crystal quartz is greatest (40–60 per cent) throughout the lower two artefact-bearing strata, coinciding with the period of highest reduction intensity (Figure 9). High quality raw material use then falls

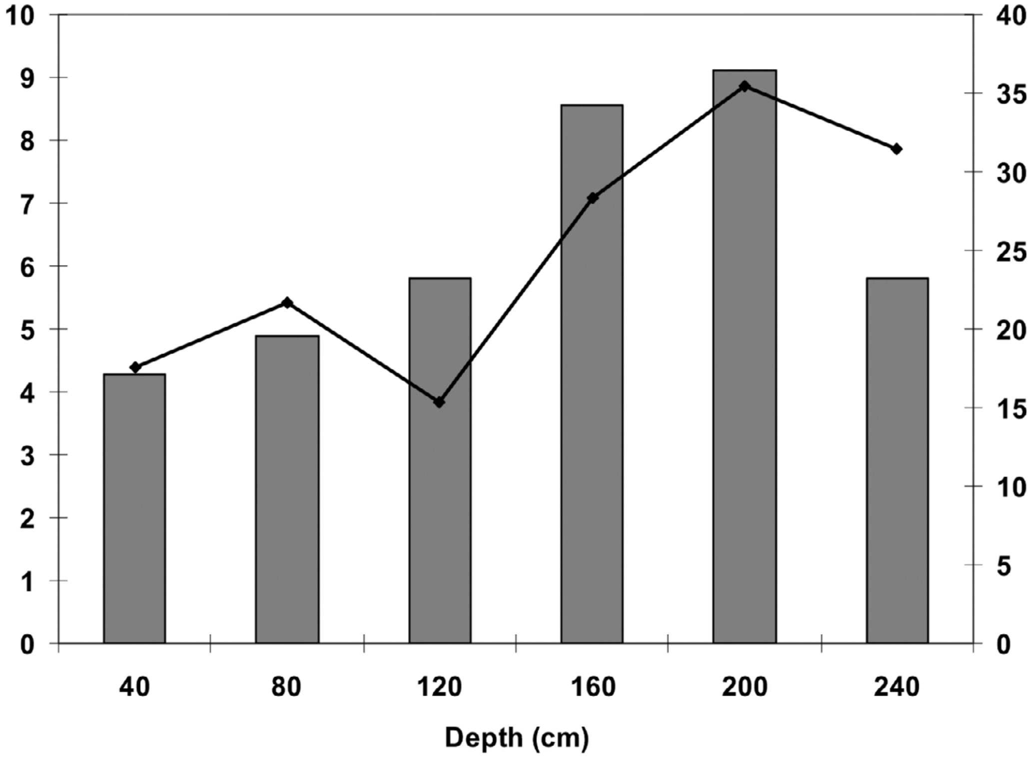

Figure 13. Change in core reduction intensity over the depth of the site. Left Y-axis represents mean number of flake scar on cores (bars). Right Y-axis represents mean % of non-feather terminations on cores (line).

to lower levels in Stratum C (15–30 per cent) with greater use of local silicified limestone, but the proportion of high quality stone climbs again in Stratum B (30–35 per cent), and becomes very important again in Stratum A (58 per cent), perhaps reflecting the tighter raw material constraints associated with soft hammer and pressure blade techniques. At present, the sources of these materials are not well known, but small quantities and nodule sizes of chert, chalcedony and crystal quartz are found in the gravels of the Jurreru River, and chert and limestone are both available on the slope behind the site. Note that the shift to limestone use in Stratum C coincides with the early use of the same material for bead production at the site.

Overall, the lithic sequence documents a number of important alterations to the organisation of technology over the occupational history of Locality 9. These indicate that the period from initial occupation until shortly after the last glacial maximum (LGM) saw high frequency production of standardised microblades and heavily retouched flakes of high quality raw material. Backed artefact production became noticeable and indeed prolific from before until shortly after the LGM, and then declined significantly by 12kya. Transformation and recycling of flakes through burination is also common at the same time as backed artefact production peaks, and cores indicate higher levels of reduction. Intensity of occupation appears to peak during and shortly after the LGM, but declined thereafter.

Discussion

The length and variability of the Jwalapuram Locality 9 microlithic record raises a series of questions with implications for the introduction, continuance and in some cases disappearance of microlithic phases elsewhere in the world. For example, what drove the initial appearance of the Indian microlithic? Why did it persist for such a long time at Locality 9, through a number of changes in raw material acquisition, reduction intensity and implement manufacture? And what factors contributed to intensified activity at the site during the LGM, a period of intense aridity and likely resource depression?

We have argued elsewhere (Petraglia *et al.* 2009) based on archaeological, genetic and environmental data that the appearance of microlithic technology in South Asia around 35–30 000 years ago represents a local solution to increasing aridity and population pressure in the lead up to the LGM. Specifically, this solution involves switching to the use of more reliable and maintainable toolkits given higher mobility and reduced predictability in resource location and capture. The initiation of the few well-dated South Asian microlithic industries at sites such as Patne in India (Sali 1989) and a number of Sri Lankan caves (Deraniyagala 1992) coincides temporally with the Locality 9 sequence. Lithic evidence from elsewhere in the Jurreru Valley demonstrates the continuance of Middle Palaeolithic assemblages until 38kya, ruling out the possibility that the Indian Pleistocene microlithic was the result of the initial out of Africa spread of *Homo sapiens* (Roberts & Jones 1994; O'Connell & Allen 2004; Hudjashov *et al.* 2007; contra Mellars 2006). We therefore think it likely that modern humans brought lithic technologies characteristic of the Middle Palaeolithic/Middle Stone Age to India, rather than microlithic technology. This conclusively demonstrates that short-lived microlithic technologies such as the Howiesons Poort in South Africa (Jacobs *et al.* 2008) are convergent and unrelated to the South Asian assemblages. Furthermore, subsequent changes to the organisation of microlithic technology, such as raw material use, reduction intensity and artefact recycling evident at the site of Locality 9 support the idea that technology was highly responsive to climatic changes leading up to and during the LGM. This contrasts markedly with common depictions of the Indian microlithic as confined to the Holocene and unchanging following initial introduction, except through external contact with agricultural groups (Misra 2002).

Fitzhugh (2001) posits technological experimentation as an appropriate response to increasing risk, and suggests that risk sensitive populations should switch from a risk-averse to a risk prone attitude to technological innovation when mean yields fall below minimum requirements. Foragers should first invest in improving technologies that aid the capture of high ranked prey (such as larger mobile mammals) and only switch to improving processing technologies for handling low ranked prey once resource depression sets in. Switching to the manufacture of multi-component spears with microlithic barbs or long cutting edges to enhance blood loss, for instance, would fit this prediction well. Torrence (1989) also argues that risk-prone populations should invest heavily in toolkit design and manufacture if this helps dampen the effects of variability and time-stress. Tool specialisation and complexity are the two most obvious signatures of increased investment, and the Locality 9 sequence provides a test case for relating microlithic specialisation to long-term stresses. A third likely response is the selection of high quality raw materials that facilitate the production of implements to tighter design standards while also being more amenable to longer use-lives through resharpening or recycling (Goodyear 1989). The move toward microblades and then backed artefacts at Locality 9 very likely represents such a technological response to increasing aridity, by switching to the production of standardised blanks and implements made from high quality raw materials for use as serial components in composite technologies.

While technological experimentation in response to increased risk might explain the origins of the microlithic around 34 000 years ago, technological change did not end with the introduction of the microlithic. Throughout the earliest phases of occupation at Locality 9 and leading up to the LGM, reduction intensity increased, and high quality raw materials were preferentially selected. As conditions worsened, people adopted the manufacture of backed artefacts (whether through experimentation or diffusion from nearby regions), perhaps to further standardise serial inserts, or even to improve the adhesion of segments to the haft and reduce the loss of serial components. Along with results from microscopic residue analysis, the small size of many pieces – too small to be effective when held in the hand – and the presence of bone and antler points from the initial period of occupation, all indicate that composite technologies were likely to have been in use during the LGM.

Why backed artefacts remained in use throughout the terminal Pleistocene and Holocene is less clear, but as Bar-Yosef and Kuhn (1999) note, while the emergence of these strategies was historically contingent, once present they remained highly successful in a range of contexts. Indian microlithic sites are abundant, however, almost all dated microlithic contexts fall within the Holocene, suggesting an increase in site foundation rates over that recorded for prior Late Palaeolithic technologies (James & Petraglia 2005). Combined with genetic evidence for early Holocene population increase (Petraglia *et al.* 2009), it is likely therefore that resource pressures remained significant following the LGM, with population pressures replacing environmental stress as the key driver of continued microlithic production. The local extirpation of the larger mammal fauna from the Jurreru River area within the last 3000 years may explain reduced investment in the manufacture of complex, composite hunting technologies and the decline in backed artefacts in Strata A and B, and greater emphasis on lower ranked prey and processing technologies. The decline in backed artefact production also coincides with increasing emphasis on cereal cultivation in the area.

It is clear that while microlithic technology remained common, it also underwent significant transformations. By 12 000 years ago, for instance, reduction intensity, the use of high quality raw materials and the reliance on microblade and backed technologies had all relaxed considerably. The relaxation of pressures on technological performance likely resulted from climatic amelioration after the LGM, as also indicated by the shift in macrovertebrate remains from species favouring grassland to woodland at this time. This may have allowed more variable systems of flake production to emerge, as seen in the declining use of standardised backed artefacts. The Locality 9 sequence therefore provides a model of internal technological dynamics to be compared to circumstances where microlithic and backed technologies diminished after only a few thousand years (for example in eastern Australia) (Hiscock 2008), contributing to a global understanding of the limits and drivers of modern human technological change.

Interestingly, the site appears to have witnessed intensified human activity, or even intensified occupation, around the time of the LGM. There are a number of possible reasons why Locality 9 might have been an attractive location at which to camp and manufacture tools at this time. The site sits high enough above the valley floor to afford a good view over the river flats below. At times of much reduced tree cover this view would have been virtually unimpeded. The site is also close to a major river that was fed by limestone springs located in tributary valleys, including those close to Locality 9 itself. A large semi-permanent freshwater body such as the Jurreru River must have been exploited by the occupants of Locality 9 to account for the abundant freshwater bivalve shells found at the site. At times of greatly increased aridity, such as during the LGM, there may have been less certainty over the location and abundance of mobile game, and the use of elevated hunting stands beside major rivers, as Locality 9 was well placed to have been, would have increased the chances of observing such game without being observed in turn. This interpretation is consistent with the faunal assemblage, which is dominated by small- and medium-sized ungulates that would have grazed the valley floor. The slopes behind Locality 9 are a source of limestone and chert, and the site was therefore likely also an ideal place to gear up for hunting trips.

While this hypothetical reconstruction of Locality 9 as a temporary hunting camp is consistent with the technological and faunal evidence, the presence of bead manufacture, human cremation and artistic activities indicates a more complex site history. The presence of beads at 20kya is accompanied by other sites in South Asia with beads such as Patne and Batadomba-lena which date to around 30 000 years ago (Sali 1989; Deraniyagala 1992). Manufacture of personal ornamentation may indicate that occupation at the site was of long enough duration for a wide range of domestic, artistic and ritualistic activities to be performed there. Given the association between the beads found higher in the profile and cremated human remains, it is also possible that beads were deposited as grave goods at the site. There is evidence for both changing media (from stone to bone) and styles of personal decoration through time. The ochre fragments and detached ochre-coated quartzite spalls from the 20–12kya layer attest not only to personal symbolic display but also on the rockshelter itself during the terminal Pleistocene.

Conclusion

Jwalapuram Locality 9 preserves the best-dated and most comprehensively analysed microlithic sequence in India. Its geographic and temporal position within the poorly-understood South Asian Pleistocene provides a new benchmark for comparison with assessments of human behaviour and dispersals to the west and east. Furthermore, the length of the sequence, encompassing the millennia before and after the last glacial maximum as well as most of the Holocene, will allow us to test existing hypotheses on the role of microlithic technology against a number of demographic and environmental shifts at the one site. Locality 9 was clearly an important location for the manufacture and maintenance of composite tools throughout its long occupational history, perhaps because it was well-located for lithic procurement, and for monitoring the activities of people and animals in the river valley below. The site was also the location of a complex range of Pleistocene human behaviours (including the manufacture of personal ornaments, production of rock art and cremation/burial) for which little evidence exists elsewhere in the South Asian record. Detailed analysis of the large stone artefact assemblage has provided one of the first glimpses of microlithic sequence changes on a timescale of tens of millennia, interpreted here as a series of continuous modifications to the organisation of technology and toolkit design.

This conclusion is aligned with an increasingly commonly expressed view that microlithic technology likely emerged multiple times in multiple places and represents strong convergence on highly successful technological strategies for dealing with difficult climatic, social and or demographic conditions, and did not arise and spread as a single package. By adopting the view that the microlithic was a solution to a problem that may not have been similar in all times and places, as we have done here, we are able to interpret variation within and between microlithic assemblages as a valuable record of human responsiveness and cultural evolution (O'Brien 1996; Barton & Clark 1997; Shennan 2002; Richerson & Boyd 2005), rather than as a static tradition of common origin.

Acknowledgements

This project was funded by the British Academy, The Leverhulme Trust, The Leakey Foundation, McDonald Institute for Archaeological Research, Natural Environmental Research Council (NERC) Environmental Factors in the Chronology of Human Evolution and Dispersal Programme, NERC Arts and Humanities Research Council Oxford Radiocarbon Accelerator Dating Service, Australian Research Council, and Queens' College (Cambridge). We thank the Archaeological Survey of India for permission to conduct the fieldwork and the Smithsonian Institution and the American Institute of American Studies for assistance. We thank other participants in the project for their contributions to the excavations and artefact cataloguing.

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