New fossils of Early Stone Age man from Central Narmada Valley

The 1980s witnessed the first human fossil discovery in South Asia in Central Narmada Valley. First, a right part of the skullcap (calvarium)[1] and then a complete right collarbone (clavicle)[2,3] were discovered from the basal cemented gravels of Hathnora, probably around half a million years old. Two more human fossils are reported here – a partial left clavicle and a left ninth rib from the same site, which shed new light on the body dimensions, bio-ecological adaptations and affinities of Narmada Man with bearing on the origins of early *Homo* in South Asia.

The Lower and Upper Group Quaternary alluvium accumulated in a trough basin of Central Narmada Valley has been well known since over a century and a half for the Middle to Late Pleistocene mammalian fauna[4,5], associated with rich assemblages of the Lower Palaeolithic implements. These deposits were recently reclassified into different formations[6], and palaeomagnetically dated, ca. 0.73 million years ago[7,8] at the base, ca. 75,000 years BP at the upper middle level based on the Youngest Toba Ash Datum[9,10], besides the Holocene top.

The first human fossil – a right portion of the skullcap[1], discovered from Hathnora, represents the earliest unequivocal *Homo* in South Asia after the late survivor[11] of *Ramapithecus* (= *Sivapithecus sivalensis*) the popular Siwalik 'ape-man'. The second human fossil was a right clavicle reported[2,3] from the same site in 1997. In the exposed site, two hominin fossils along with an upper tooth (P^2) of *Equus namadicus* from the hominin site were recovered. Being fragmentary, however, these were mind-boggling and a challenge to unequivocally establish their hominin identity and to interpret their morphological peculiarities without a detailed comparative study incorporating fossil and modern reference material. The study revealed the new findings as hominin left clavicle and a left rib (Figure 1, A2 and B2; A3 and B3).

The clavicle specimen preserves the medial 2/3 portion without the lateral 1/3 – the acromial epiphysis that is broken-off beyond the conoid tubercle. The broken end has turned blunt, suggesting a pre-fossilization trauma, apparently due to *ante mortem* injury, attested by the presence of a chemical deposition through fossilization at the end. The typical sternal articular capsule along with its facet, the posterior curve, the lack of the medullary canal, the conspicuous conoid tubercle, etc. are the clear morphologies diagnostic of a hominin clavicle present in the specimen. It is also completely mineralized like the right clavicle (Figure 1, A1 and B1) bearing similar ash-gray hue also shared by the rib fossil. The rib specimen preserves the diagnostic posterior portion and is broken at the two natural weak points of the rib, viz. anteriorly at the angle and posteriorly at the neck/tubercle junction.

The left clavicle, compared to the right clavicle, has its diaphysis slightly more rounded, gracile and less curved, with the costoclavicular attachment facet (rhomboid fossa) and the subclavican groove less distinct. Similarly, the muscular rugosities of the *M. sternocleidomastoideus*, *M. subclavius* and *M. pectoralis major* are also slightly less developed in the left clavicle compared to the right. A comparative study of 30 modern clavicles was made to understand/interpret the left/right varia-

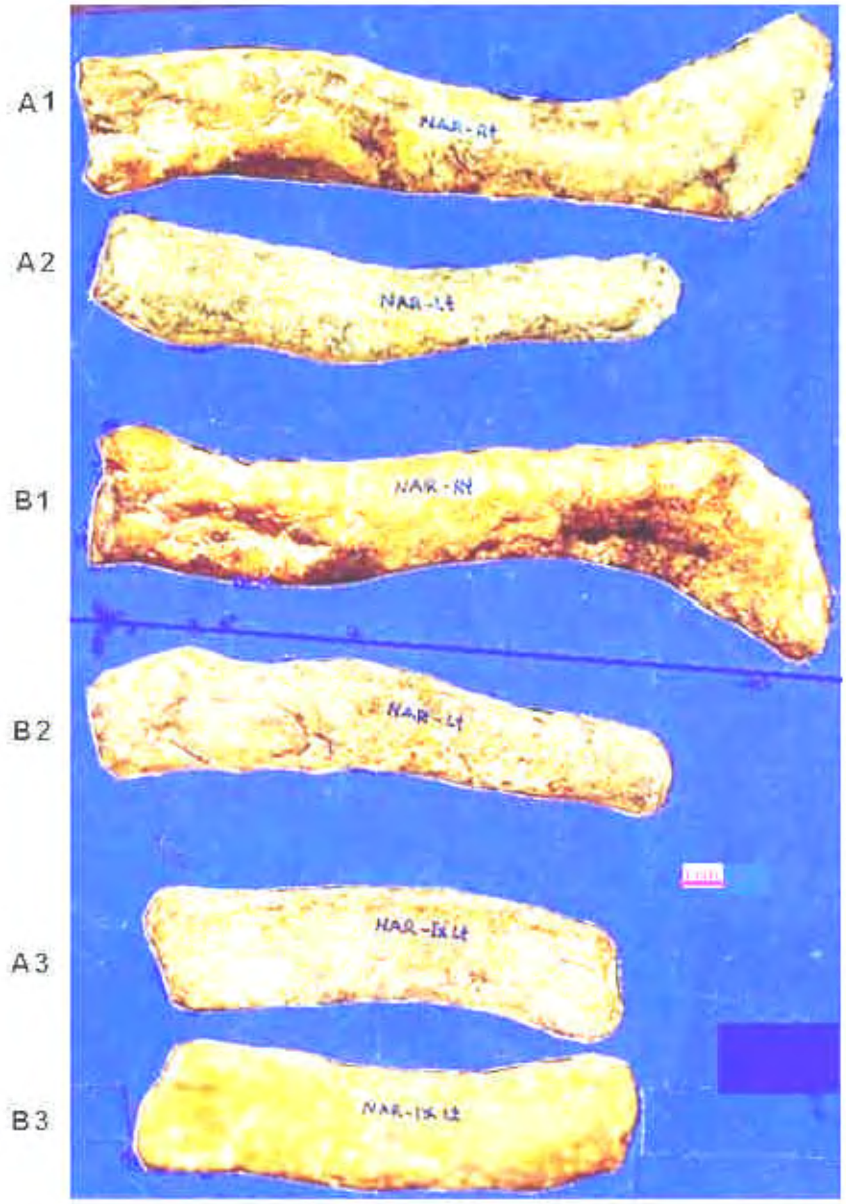

Figure 1. Narmada hominin postcranials. A1, Dorsal and B1, Ventral view of right clavicle. A2, Dorsal and B2 ventral view of left clavicle. A3, Postero-lateral, B3 Interior view of ninth left rib.

tion, and it is observed that a considerable metric and non-metric bilateral variation occurs in modern clavicles (Tables 1 and 2). The variation is noteworthy in the development of the rhomboid fossa, the deltoid and conoid tubercles, and the deltoid ridge, which is accountable to a differential use of the two shoulders/arms employed habitually in various occupations or life styles[12]. Studies show that a distinctly deep and prominent rhomboid fossa is a clear sign of handedness[13–15]. Therefore, the exaggerated rhomboid fossa on the Narmada right clavicle, besides other bilateral differences in the two clavicles, speak for an overuse of the right shoulder/arm, expectedly as a consequence of an apparent injured left shoulder.

Both Narmada clavicles appear to be adult in age as revealed by the muscular rugosities and the apparent fusion of the sternal epiphyseo-diaphysis that occurs among *Homo sapiens* between 25 and 35 years of age[16–19]. The early Pleistocene African *Homo erectus* (=*H. ergaster*) shows modern upper chest morphology[20], such that modern sexing non-metric criteria hold equally good for the Narmada *Homo* clavicles, indicating a female sex because of: (i) a narrow sternal end (low inner-end index)[21]; (ii) the conspicuous conoid tubercle; (iii) the smaller acromial facet, which is quite prominent even on the otherwise robust or male-looking right clavicle; (iv) the less curved diaphyses of both the clavicles; and (v) the unusually short clavicle length[22–25], unlike most extinct and extant humans, such that the metrical criteria to differentiate the two sexes as laid down for various north Indian populations[26–28] are inapplicable to the Narmada clavicles. Interestingly, the Narmada clavicles are comparable to those of the female Pygmy – the Onges and the Andamanese in length (Table 1).

The Narmada rib (Figure 1, A3 and B3) could be differentiated from the similar-sized ribs of mammals compared, e.g. pig, bear, sheep and tiger, and the primates, e.g., the baboon, gibbon, chimpanzee, orangutan and the gorilla, both in the size and shape of their tubercles, thickness of the shaft, and in the depth and location of the costal grooves. The ribs of the quadrupeds, for instance, have prominent and over-rising/over-looking and highly exaggerated articular facets of the tubercles, thick shafts with bilateral (in the anterior/upper thoracic ribs) and deeper costal grooves. The Narmada rib, on the other hand, shows a typical human/hominin character in the possession of: (i) the less prominent or depressed type of tubercle; (ii) the thinner and more twisted shaft; (iii) the shallower and single costal groove, (iv) the marked angle (a character of the lower thoracic human ribs), and (v) the marked impression of the *M. scalenus posterior*.

The diagnostic non-metric traits in the 'neck/tubercle – angle' portion preserved in the Narmada specimen and for the modern human ribs (Table 3) suggest that the Narmada rib is a left lower thorax (eighth to tenth) rib because of: (i) the similar width and thickness of the preserved shaft; (ii) the angle–tubercle distance; (iii) the shaft width, (iv) the depressed type of the tubercle; (v) the lesser twist of the shaft, and (vi) in the greater development of the *M. scalenus posterior* impression behind the angle. In addition, it possesses the peculiarities of the 9th rib, viz. (i) the comparable thickness and breadth at the angle and the tubercle region; (ii) the large tubercle projecting below the inferior border; (iii) the shallower and broader costal groove, obliterated or narrow below the tubercle; (iv) the non-articular part of the tubercle elongated or rectangular; (v) the outer lip of the superior border descending from the angle broadens while running to the upper margin of the tubercle, etc. In its expanse, the fossil rib is similar to a pygmy 9th or modern human 4th/5th rib, again pointing towards a thorax scaled to a Pygmy-size. Interestingly, the features of the rib corroborate with those of the clavicles in being relatively more robust or thicker and broader, with *M. scalenus posterior* muscular impression more marked.

The postcranial bones are important to reflect on the body dimensions. A further study conducted on these aspects reveal that the Narmada *Homo* was lesser 135 cm (4′ 4″) in stature and had about 30 cm broad shoulder, and a moderate chest

Table 1. Morphometrics of selected traits in Narmada and modern human clavicles

Measurement	Narmada (N = 2)		Pygmy (N = 16)			Modern Indians (N = 14)			Bilateral difference ($R – L$) in mean	
	Right	Left	Min	Mean	Max	Min	Mean	Max	Narmada (N = 2)	Modern (N = 30)
Preserved clavicle length	88.0	69.4	96.0	106.9	114.9	119.3	130.2	150.8	–	–
Max. clavicle length (CL)	90.0	88.0	96.0	107.0	115.0	119.0	130.6	150.8	2.0	–0.3
Prox. Curv. Chord = Conoid Length (COL)	73.5	68.0	77.5	85.9	92.0	101.1	107.3	124.6	5.0	1.0
Midshaft diaphyseal AP diameter (MDAP)	13.5	13.4	8.0	8.8	10.0	9.9	11.0	14.2	0.1	0.3
Midshaft diaphyseal SI diameter (MDSI)	11.0	11.2	6.6	8.0	9.0	8.0	10.4	13.0	–0.2	0.6
Midshaft diaphyseal circumference (MDCF)	41.0	38.0	23.5	27.6	30.0	30.0	34.4	43.0	5.0	1.3
Sternal epiphyseal AP diameter (STAP)	17.1	15.3	15.1	19.1	21.6	17.0	21.0	25.1	1.8	2.0
Sternal epiphyseal SI diameter (STSI)	11.0	13.0	13.1	18.1	20.6	14.3	18.2	22.7	–2.0	–0.5
Caliber index (CALI = MD CF./CL. × 100)	45.6	43.0	22.6	26.1	30.2	23.2	26.4	30.1	2.6	1.2
Inner-end index (INEI = STAP + MDSI)	28.0	28.3	31.0	37.4	41.6	33.4	39.1	47.0	–0.2	2.2
Conoid index (CONI = COL./CL × 100)	81.7	78.4	76.7	80.5	83.8	78.3	82.1	86.4	3.3	0.9
Midshaft index (MIDI = MDSI/MDAP × 100)	81.5	83.6	109.8	80.0	91.3	80.0	94.7	110.1	–2.1	3.1
Robusticity index (ROBI = MDAP + MDSI/CL × 100)	27.2	28.0	17.7	13.7	15.7	14.0	16.4	20.9	–0.8	0.9

AP, Antero-posterior; SI, Supero-inferior; ROBI, Robusticity index.

Table 2. Degree of development of selected non-metric traits in Narmada and 11 pairs of modern clavicles

			Modern human clavicles (11 pairs)																					
	Narmada		4		5		6		7		8		9		10		11		12		13		4a	
Trait	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
COT	2	2	2	0	1	1	4	4	2r	2r	2r	2r	4r	4r	3r	1	2	3	2r	2	3r	1r	3	3r
DET	0	2	2	3	1	1	3	4	4	1	3	0	1	0	1	3	3	3	0	0	1	0	1	1
DER	1	0	0	0	1	1	1	1	0	0	1	1	0	1	1	1	1	1	1	0	1	0	1	1
RHF	4	1	1	2	3	4	4	3	3	3	4	1	3	2	2	1	3	4	4	4	3	1	4	4
ROB	4	3	2	2	2	1	3	2	1	1	3	1	2	2	1	1	1	2	2	2	2	1	1	1

COT, Conoid tubercle; DET, Deltoid tubercle; DER, Deltoid ridge; RHF, Rhomboid fossa; ROB, Robusticity, r, Ridged; 0, Blunt/absent; 1, Sharp/little; 2, Moderate, 3, Large; 4, Very large.

Table 3. Degree of development of non-metric traits in Narmada (NAR) and 12 modern human ribs

Trait	NAR	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
ROB	4/b	1/fb	2	2	3	3	3	3	3	3/b	3/b	1	1
CRV	2	4	4	3/o	3/o	3/o	3/o	3/o	3/o	2	2	1	0
AGL	4	0	1	2	2	2	2/w	2	3	4	4	0	0
APT	4d/si	1/sl	2/osl	3/osl	3/os	3d/s	3/sm	3/om	3/m	4d/si	3/m	0	0
NAT	4	0	0	1	1	1	2	2	3	4	4	0	0
CGV	1/n	0	1/n	1/c	2/c	2/c	3/c	3/c	3/w	1/n	1/w	0/1/n	0
MSP	4/P/o	2/A/ob	3/A/ob	1/A/ob	1P/e	2/P/e	4/P/ob	4/P/ob	4/P/ob	4/P/o	3/P/o	0	0

ROB, Robusticity; CRV, Curvature; AGL, Angle; CGV, Costal groove; APT, Articular part of tubercle; NAT, Non-articular part of tubercle; MSP, *M. scalenus posterior*; A, Anterior to angle; P, Posterior to angle; 1–4, Degrees of development/size/depth; 0, Absence; o, Oblique; ob, Oblong; e, Elongated; f, Flat; b, Broad; w, Wide; n, Narrow/obliterated below tubercle; c, Continuous below tubercle; s, Superior; i, Inferior; m, Mid; d, Depressed; l, Lateral.

depth. All of these dimensions correspond to a modern pygmy body frame, but with the difference of a very robust body build. The postcranial evidence thus documents a robust, short and stocky archaic *Homo* in the Narmada Valley as the maker of the Acheulian tools, found in association with the hominid fossils. The findings enhance our understanding of the early human lifestyle, ecological adaptation, the affinities of the Narmada *Homo*. If the cranium and the postcranials come from the same skeleton in consideration of their same site and stratigraphic position, besides the inferred same female sex and similar age, the dispute on the taxonomic status of the skullcap may probably be diluted, whether of a *Homo erectus*[30] or *Homo sapiens*[29,31–33] or a different species, *Homo heidelbergensis*[34,35].

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A. R. SANKHYAN

Anthropological Survey of India,
27, Jawaharlal Nehru Road,
Kolkata 700 016, India
e-mail: sankhyan51@rediffmail.com

Reducing arsenic concentration in groundwater

Arsenic is found in various rock types[1–5]. It is dissociated in the groundwater by water–rock interaction in particular, by hydrogeological processes such as weathering return and biological acting. Anthropogenic activities may also cause enrichment of arsenic in groundwater[6–8]. Arsenic-enriched groundwater has been found in various parts of India, including West Bengal, Orissa and Andhra Pradesh. Studies were carried out regarding the occurrence, source, speciation[9–16] and also the effect of arsenic if consumed in drinking water[17].

Not much attention was given to the removal/reduction of arsenic from groundwater. However, studies showed that attempts were made for reducing arsenic concentration, without much success[18–20]. In this study, an attempt has been made to reduce arsenic concentration in the groundwater using economical, easily available, natural inorganic compounds. For this, Column Chromatographic Separation Technique (CCST) has been experimented and tested with a large number of inorganic chemical absorbents along with various complex derivatives. The water (10 μS/cm) with variable solute constituents and their concentration was run with specific time conditions. A large number of chromatographic separated fractions were collected. These fractions were quantitatively analysed for arsenic concentration, and also for pH and EC. Data showed that arsenic concentration could be reduced by the application of various type of adsorbents and coagulants. Activated alumina (Al_2O_3) was used in this study as an absorbent. It is an inorganic porous compound, prepared by dehydration of $Al(OH)_3$ in the temperature range 300–600°C. The effective size of Al_2O_3 is 0.4 to 0.6 mm. Another absorbent used was a coagulant-type of inorganic compound, namely calcium carbonate ($CaCO_3$). Fine clay (calcium/sodium montmorillonites) and calcium oxy-chloride were also used. Laboratory investigation was carried out in three different stages and in each stage the type of absorbent, absorbent quantity and concentration of aqueous medium were altered. The Column Chromatographic fractions were collected and analysed quantitatively for arsenic, EC and pH. Arsenic was analysed using selective ion electrodes, namely E-As-201, E-As-040 (Wissenschaftlich–Technische–Werkstatten GMBH (WTW), 2000).

The purpose of this work was to develop an approachable and economical technique for reducing the concentration of arsenic in groundwater.

CCST is used for reducing arsenic concentration in groundwater. For adsorption,

Table 1. Chemical components and aqueous ionic species used in the experimental study

	Montmorillonite	Al_2O_3	$CaCO_3$	$CaOCl_2$	pH	EC	Arsenic
Stage 1	500	50	25	25	7.3	1050	200
Stage 2	500	50	25	25	7.8	1500	400
Stage 3	500	50	25	25	8.2	1800	800

Weight in g; pH: –log H^+ at 25°C, EC, Electrical conductance in μS/cm at 25°C; Arsenic in μg/cm.

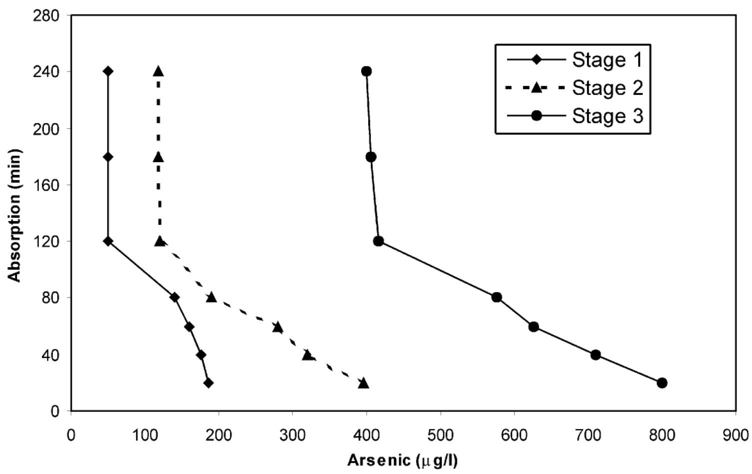

Figure 1. Rate of reducing arsenic concentration.