Occupational Histories, Settlements, and Subsistence in Western India: What Bones and Genes can tell us about the Origins and Spread of Pastoralism

Ajita K. PATEL
Peabody Museum, Harvard University
11 Divinity Avenue, Cambridge, MA 02138 (U.S.A.)
akpatel@fas.harvard.edu

Patel A.K. 2009. – Occupational Histories, Settlements, and Subsistence in Western India: What Bones and Genes can tell us about the Origins and Spread of Pastoralism. *Anthropozoologica* 44(1): 173-188.

ABSTRACT
By at least 7000 calBC, hunter-gatherers were encamped upon stabilized sand dunes in steppic and semi-arid areas of northwestern South Asia. Within 4500 years, pastoral camps, agricultural settlements, and even the occasional urban complex could be found over parts of this same landscape. Investigation of animal bone remains from a few of these sites, together with consideration of recent studies of animal genetics, provide a basis for understanding some of the processes involved in this prehistoric transformation. Discussion in this paper focuses on the dune-top site of Loteshwar in North Gujarat, for which a strategic dating program has generated a series of AMS C14 determinations spanning five millennia of first hunter-gatherer and then pastoral occupations. Archaeofaunal remains demonstrate a change in animal use from an exclusive focus on wild animals to the exploitation of domestic cattle. The evidence for both wild and domestic cattle at Loteshwar indicates that North Gujarat is an important area to investigate as one of the multiple centers for zebu (*Bos indicus*) domestication that are suggested by genetic research on modern forms. In contrast, because of the absence of any evidence for their wild relatives having been in the region, it is clear that domestic sheep and goat were brought into the North Gujarat region, probably from areas to the Northwest.

KEY WORDS
South Asia,
North Gujarat,
Loteshwar,
site formation processes,
Bos indicus,
cattle domestication,
pastoralism,
Microlithic, Chalcolithic,
animal genetics.

RÉSUMÉ
Occupations, peuplements et subsistance en Inde occidentale : apports de l'ostéologie et de la génétique à la recherche sur les origines et la diffusion du pastoralisme
Dès 7000 av. J.-C. au moins, des chasseurs-cueilleurs campaient sur des dunes de sable stabilisées, dans les régions steppiques et semi-arides du nord-ouest de l'Asie du Sud. En 4500 ans, se succèdent, sur certaines parties de ces mêmes paysages, des campements de pasteurs, des occupations agricoles

et même occasionnellement un complexe urbain. L'examen de vestiges osseux animaux provenant de quelques-uns de ces sites, associé à la prise en compte de récentes études sur la génétique animale, fournissent une base pour la compréhension de quelques-uns des processus impliqués dans cette transformation préhistorique. Cet article est centré sur le site de Loteshwar, qui se trouve au sommet d'une dune, dans le nord du Gujarat et pour lequel un programme stratégique de datation a fourni une série de déterminations en AMS 14C, s'étendant sur cinq millénaires, d'occupations d'abord de chasseurs-cueilleurs puis de pasteurs. Les vestiges de faune démontrent un changement dans l'utilisation des animaux, qui passe d'un intérêt exclusif pour la faune sauvage à l'exploitation de bétail domestique. La présence de bovins sauvages aussi bien que domestiques à Loteshwar indique que le nord du Gujarat est une zone importante à explorer, en tant que l'un des multiples centres pour la domestication du zébu (*Bos indicus*), ce que suggèrent les recherches génétiques sur les formes modernes. En revanche, en raison de l'absence de formes sauvages de moutons et chèvres dans la région, il est clair que les formes domestiques ont été importées dans le nord du Gujarat, probablement des zones du nord-ouest.

MOTS CLÉS
Asie du Sud,
nord du Gujarat,
Loteshwar,
processus de formation des sites,
Bos indicus,
domestication du bétail,
pastoralisme,
Microlithique,
Chalcolithique,
génétique animale.

INTRODUCTION

Throughout most regions of the Old World animal exploitation has changed from the more immediate returns of hunting and scavenging to the more delayed returns of animal husbandry and pastoralism. How did this change take place? What happened to the hunter-gatherers? Did pastoralism spread through interaction between peoples, or through population replacement resulting from immigration, or through societal transformation? Or was the situation more complex, involving various mixes of the three during the development of herding and farming and the coming of urbanism? This paper represents *part* of the process of addressing these issues for northwestern South Asia where, in landscapes that are less disturbed by modern activities, archaeological investigations have revealed the remains of hunter-gatherer and pastoral activities, sometimes both on the same site (Sankalia 1946, 1965, 1974; Allchin & Allchin 1982, Possehl & Rissman 1992, Ajithprasad & Sonawane 1993).

"Pastoralism" as used in this paper refers to the breeding, raising, and managing of domesticated ungulates by members of a human society (*e.g.*, Meadow 1992, Patel 1997, Meadow & Patel 2003). In the South Asian context, any person who keeps domestic cattle (bulls, cows, bullocks), goats, sheep, water buffalo, camels, and/or equids is considered a pastoralist, whatever the number of animals husbanded and wherever on the continuum of sedentary to mobile the lifestyle falls. Pastoral practices can be combined with one or more of hunting, gathering, cultivation, and plant agriculture, the degree to which each of these activities contributes to the livelihood of a population being subject to investigation.

Some 9000 calendar years ago, populations of hunter-gatherers occupied the tops of stabilized sand dunes in steppic and semi-arid areas of northwestern South Asia. Within 4500 years, agricultural settlements and pastoral camps were spread over this same landscape, and scattered urban complexes covered areas of up to a square kilometer each. Zooarchaeological investigations of a few sites in North Gujarat and Kutch (Fig. 1), combined with consideration of the implications of genetic studies of animals, provide a framework for understanding some of the processes involved in this major change of human-animal relationships in the past. This paper particularly focuses on the dune-top site of Loteshwar in North Gujarat where a strategic, site-formation-specific dating program generated a series of AMS C14 dates. While these dates show a long occupational history for the site spanning

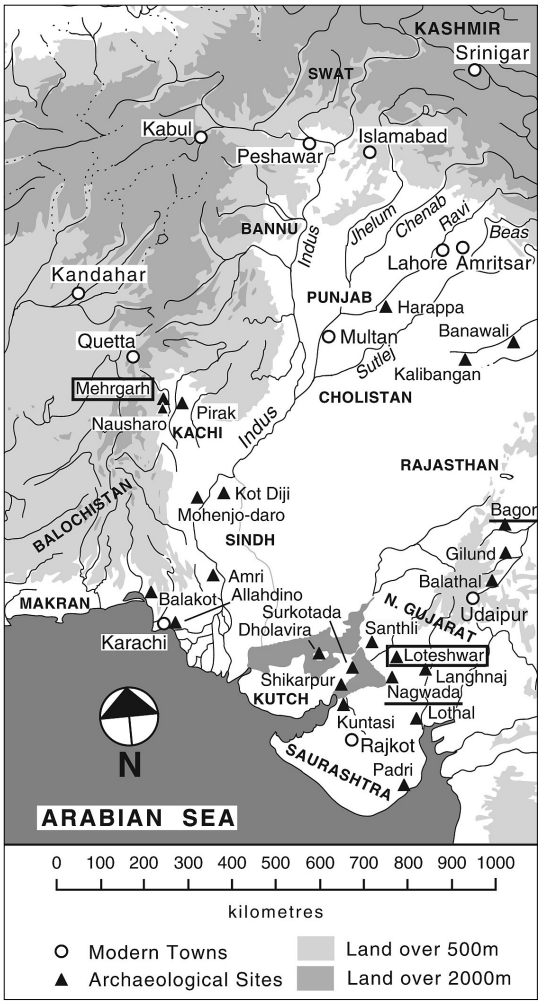

FIG. 1. — Map showing locations of archaeological sites in northwestern South Asia.

five millennia, they also help us to understand the unique nature of the hunter-gatherer and pastoral settlements in the region. In addition, they serve to highlight notable changes in animal use from an exclusive focus on wild fauna to the incorporation of domestic animals particularly cattle. The evidence for both wild and domestic cattle at Loteshwar suggests that North Gujarat is an important area to investigate as a possible local center of zebu (*Bos indicus*) domestication, a possibility that has recently been supported by genetic research (Magee, Mannen & Bradley 2007). In contrast, because of the absence of any evidence for wild relatives in the region, it is evident that domestic sheep and goat were brought into North Gujarat region, probably from areas to the Northwest (Meadow & Patel 2003; Patel 2008).

ARCHAEOLOGICAL BACKGROUND AND TERMINOLOGY

The archaeological landscape of northwestern South Asia is represented by a cultural mosaic, which includes sites characterized by Microlithic, Chalcolithic, and/or Harappan components. Microlithic settlements are those often called "Mesolithic" in the literature and can date anywhere from the early Holocene to the historic period (*e.g.*, Sankalia 1946, 1965, 1987; Misra 1985, 1996). Deposits at some of these sites have only microlithic tools and bones, while deposits at other sites have yielded ceramics and even metals together with the microlithics. At sites with evidence for multiple occupations, a so-called "Mesolithic" may be defined below a Chalcolithic, in turn below an Iron Age, and so on. Considering the long time span and varied nature of such deposits, I prefer to use the term "Microlithic" only as a neutral descriptor referring to the stone tool industry in order to avoid any chronological, cultural, and economic overtones (Patel 2008: footnote 4).

Chalcolithic settlements are dominated by ceramics together with some metal and stone objects. These have varying degrees of Harappan affiliation that is judged on the basis of the quantity and quality of classic Harappan paraphernalia, including ceramics, which have become the hallmarks of the Indus civilization (ca. 2600–1800 calBC). These sites also vary in size, nature of the remains, and site function. Sites located on the fossil sand dunes of North Gujarat that were surveyed and excavated in the 1980s and 1990s belong to this category (Hegde & Sonawane 1986; Hegde *et al.* 1988, *Indian Archaeology* – A Review (hereafter "*IAR*") 1982 to 1995) (Fig. 1).

The development and expression of the Harappan phenomenon and of the Chalcolithic in the different parts of northwestern South Asia are variable. This variability is clearly reflected in the different ceramic traditions found throughout the region.

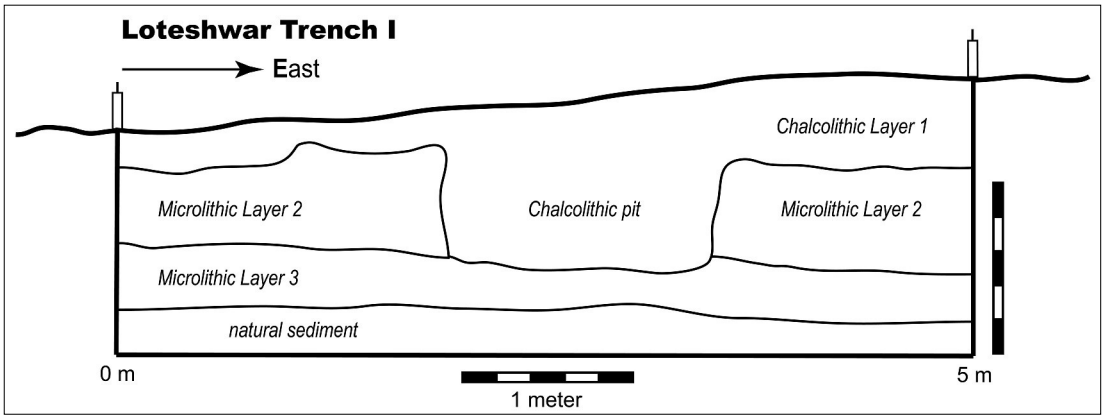

FIG. 2. — Drawing of stratigraphic section at Loteshwar: North section of Trench I.

The ceramics from the Chalcolithic deposits at many sites in North Gujarat have been defined as belonging to a distinct regional pottery tradition, called "Anarta" (Ajithprasad & Sonawane 1993). The beginning of this tradition is dated as early as the fourth millennium BC, which is a millennium before the development of the Harappan phenomenon in the region. Anarta ceramics continue through the third and into the second millennium BC at many sites with some associated changes including the incorporation of Harappan vessel shapes (Sonawane & Ajithprasad 1994).

LOTESHWAR

Loteshwar, located on the margin of a salty waste depression east of the Little Rann of Kutch, is one of a number of sites in North Gujarat with Microlithic and Chalcolithic deposits. The Microlithic component, called Period I, is stratified below Chalcolithic Period II with no sterile layer between the two. Neither of the components has yielded any evidence of significant architecture (*IAR* 1990-91: 12-16). The Microlithic deposits are 50 to 100 cm in thickness and are represented by an earlier Layer 3 and a later Layer 2 (Fig. 2). They are rich in both geometric and non-geometric microliths, lithic debitage, "pallette stones", and faunal remains. These deposits are devoid of any ceramics and are referred to as "Aceramic Microlithic". There is one conventional radiocarbon date run on charred bone from Period I at Loteshwar (PRL-1567). This calibrates to a median probability of 4703 BC and is discussed in more detail below. (Note that median probability calibrated BC dates are cited in the text; uncalibrated determinations, both 1- and 2-sigma calibrated ranges BC, and the median probability calBC are presented in Table 1 and displayed in Fig. 3).

The Chalcolithic deposits are between 10 and 80 cm thick located immediately below the surface. In addition there are also many Chalcolithic pits that penetrate the Aceramic Microlithic deposits sometimes to natural sediment. These pits vary in dimensions, ranging between 50 to 200 cm in diameter and 50 to 200 cm in depth (Fig. 2). They contain Anarta ceramics, animal bones, steatite micro-beads, shell bangles and beads, stone beads, terra-cotta objects, and burnt clay lumps with reed impressions. Microlithic tools are also found in these pits. Given that the Chalcolithic pits were dug into and sometimes through the Aceramic Microlithic deposits, many of these tools and animal bones from the pits could have come from the earlier Aceramic Microlithic component. This aspect of site formation processes at Loteshwar is significant for interpreting all of the archaeological remains from the site. Two carbon samples from two different pits have yielded conventional radiocarbon dates with median probabilities of 3706 and 2993 calBC (PRL-1565 and PRL-1564, respectively: Table 1 and Fig. 3).

TABLE 1. — Radiocarbon determinations from Loteshwar in approximate stratigraphic order (latest on top). Calibrations calculated using CALIB 5.0.2.
See Stuiver and Reimer (1993) for the computer program and Reimer et al. (2004) for the calibration datasets. Median prob. = Median probability. Conventional determinations: for PRL-1564, PRL-1565, PRL-1567, see IAR (1993-94: 140). AMS determinations: CAMS samples were pretreated by Stafford Research Laboratories, Inc. and were dated by the Lawrence Livermore National Laboratory's Center for Accelerator Mass Spectrometry (CAMS); for sample preparation protocol, see Patel (2008).

Lab no.	Site	Period and Context	Material	Determ.: 5568 half life	calBC +2 sigma	calBC +1 sigma	calBC Median prob.	calBC –1 sigma	calBC –2 sigma
CAMS-55905	Loteshwar	Chalcolithic Trench I, Pit 3 Bone# LTS IP3AC29#145	charred bone	3800±50	2458	2333	2243	2141	2049
CAMS-55904	Loteshwar	Chalcolithic Trench I, Pit 2 Bone# LTS IP2AC25#14	charred bone	4850±50	3760	3698	3645	3537	3521
CAMS-55903	Loteshwar	Chalcolithic Trench I, Pit 1 Bone# LTS IP1AC22#5	charred bone	4890±50	3787	3709	3681	3639	3536
PRL-1564	Loteshwar	Chalcolithic Trench I, Pit 2	charcoal	4334±110	3349	3316	2993	2779	2639
PRL-1565	Loteshwar	Chalcolithic Trench I, Pit 4	charcoal	4907±110	3957	3909	3706	3534	3382
CAMS-55898	Loteshwar	Microlithic Trench I, Layer 2 (top) 20-60 cm Bone# LTS IA'AC10#171	charred bone	7210±40	6210	6098	6067	6014	6005
CAMS-35362	Loteshwar	Microlithic Trench I, Layer 2 60-70 cm Bone# LTS IA'AC18#8	charred bone	6630±60	5642	5620	5567	5527	5479
CAMS-55902	Loteshwar	Microlithic Trench I, Layer 3 (lower) 96-100 cm Bone# LTS IA'AC2#102	charred bone	8170±50	7319	7287	7168	7073	7061
PRL-1567	Loteshwar	Microlithic Trench I, Layer 3 (base) 143-155 cm	charred bone	5840±115	4990	4830	4703	4549	4453

LOTESHWAR FAUNAL REMAINS

The analysis of faunal remains from Loteshwar focused on material excavated from Trench I located on the western side of the highest portion of the mound. Trench I was selected for the analysis because of its deep stratification and well recorded contextual information. In addition, the samples that produced the three conventional dates mentioned above come from this excavation unit. Bones were hand picked

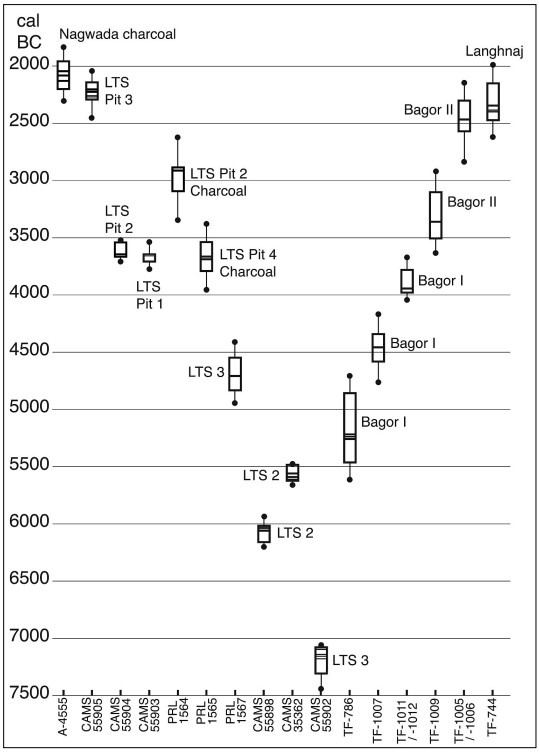

FIG. 3. — Radiocarbon dates from Microlithic sites in northwestern South Asia: Loteshwar, Nagwada, and Langhnaj (North Gujarat) and Bagor (southern Rajasthan). Laboratory sample identifiers and numbers are presented on the x-axis: A = University of Arizona; CAMS = Lawrence Livermore National Laboratory's Center for Accelerator Mass Spectrometry, PRL = Physical Research Laboratory, Ahmedabad, Gujarat, India; TF = Tata Institute of Fundamental Research, Bombay, India. All determinations except CAMS are conventional radiocarbon dates. Bar-and-whisker plots show 1-sigma and 2-sigma ranges and intercepts of calibrated BC dates. See Table 1 for details of Loteshwar dates and Patel (2008) for details of the dates from Nagwada, Langhnaj, and Bagor.

from each excavated lot as well as recovered through dry sieving using a ca. 2mm mesh, which ensured the recovery of smaller skeletal elements such as small animal carpals and tarsals. The recovered material was generally in a good state of preservation, although most specimens, especially from the earlier layers, were encrusted with calcium carbonate, which precluded detailed study of bone surfaces for cut marks and for agency of breakage. However, this condition did help to preserve a number of articulated joints, particularly of the carpals, tarsals, and lower limbs, thus providing information on carcass-processing practices.

Faunal material from the Aceramic Microlithic deposits comes from Layers 2 and 3 and that of the Chalcolithic deposits from Layer 1 and from Pits 1, 2, 3, and 4. Material from each of these seven contextual units was analyzed separately. As there were no obvious differences in faunal profiles within the Chalcolithic deposits, however, the analytical results for that component were combined to produce an assemblage closer in size (2,201 specimens) to those from Aceramic Microlithic Layers 2 (15,412 specimen) and 3 (7,150 specimens).

The results of the faunal analysis show that remains from only wild animals are found in the two Aceramic Microlithic layers. The faunal profiles for both Layers 2 and 3 are similar, with bones from blackbuck (*Antilope cervicapra*) dominating the assemblages (Fig. 4). Much less well-represented animals include gazelle, boar, wild cattle, wild water buffalo, nilgai, hemione, and at least two forms of deer (see Table 2) (Patel & Meadow 1998a; Patel 2008). The Chalcolithic deposits are also dominated by the remains of blackbuck, but with the significant addition of the bones of domestic cattle (see below). Excluding cattle from the faunal profile for the Chalcolithic produces a result similar to that from the Aceramic Microlithic, raising the possibility that most, if not all, of the smaller wild bovid bones found in the Chalcolithic deposits actually derived from the earlier Microlithic component. That this possibility is well worth considering is strengthened by evaluation of kill-off patterns and bone condition.

Looking at kill-off patterns based on epiphyseal union for the small wild bovids (blackbuck and gazelle) (Fig. 5), those from all three analytical units are similar, with the exception of the values for the latest fusing (low bone density) long-bone articular ends, which are also the least well represented, probably for taphonomic reasons. As for bone condition, most of the small wild bovid bones from the Chalcolithic were found covered with calcium carbonate encrustations in a manner similar to those from the Aceramic Microlithic layers, in contrast to the situation with the bones of small (domestic) cattle, which were not so covered. If one does not take into account the differences in bone condition, then one can interpret the faunal profiles (Fig. 4) and small wild bovid kill-off patterns (Fig. 5) for the

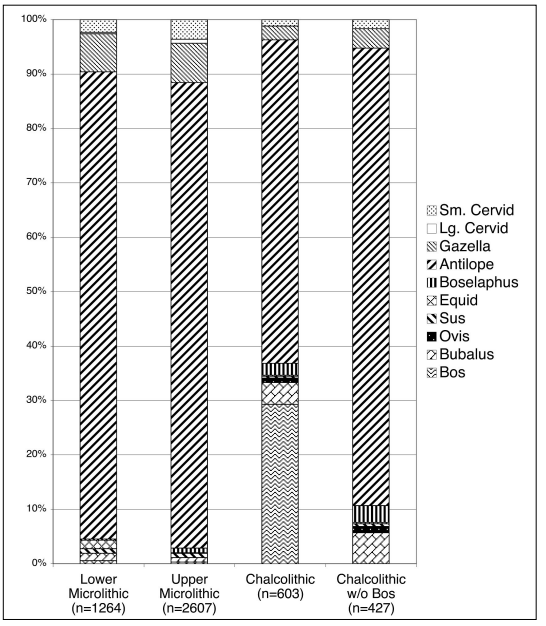

FIG. 4. — Relative frequencies of occurrence of different mammalian taxa from the Microlithic and Chalcolithic components at Loteshwar. Percentages are based on numbers of identified specimens. "Chalcolithic w/o Bos" is calculated from the same assemblage as "Chalcolithic" but does not include "Bos" specimens. "Lower Microlithic" is material from Microlithic Layer 3; "Upper Microlithic" is material from Microlithic Layer 2. "Chalcolithic" includes material from both Chalcolithic Layer 1 and the Chalcolithic pits (see Fig. 2).

Chalcolithic at Loteshwar to suggest the adoption of cattle pastoralism by hunter-gatherers. However, the similarity between the Aceramic Microlithic and Chalcolithic components as far as small wild bovid data are concerned, as well as consideration of bone condition and of the presence of Chalcolithic pits dug into the Microlithic deposits, mean that one must consider the likelihood that there was mixing of earlier Aceramic Microlithic remains with later Chalcolithic ones. Under such circumstances, only types of remains not found in earlier deposits can be securely attributed to the later deposits.

TABLE 2. — Mammalian taxa identified from Loteshwar.

Wild forms:			
Equidae			
		Equus hemionus	khur
Cervidae			
	Small cervid		
		Axis axis	chital deer
		Axis porcinus	hog deer
	Large cervid		
Bovidae			
	Small bovid		
		Antilope cervicapra	blackbuck
		Gazella bennetti	chinkhara, gazelle
	Large bovid		
		Boselaphus tragocamelus	nilgai, blue bull
		Bos primigenius	wild cattle
		Bubalus arnee	wild water buffalo
Leporidae			
		Lepus sp.	hare
Felidae			
	Small felid		
	Medium felid		
Domestic forms:			
Bovidae			
	Small bovid		
		Ovis aries	domestic sheep
	Large bovid		
		Bos indicus	zebu

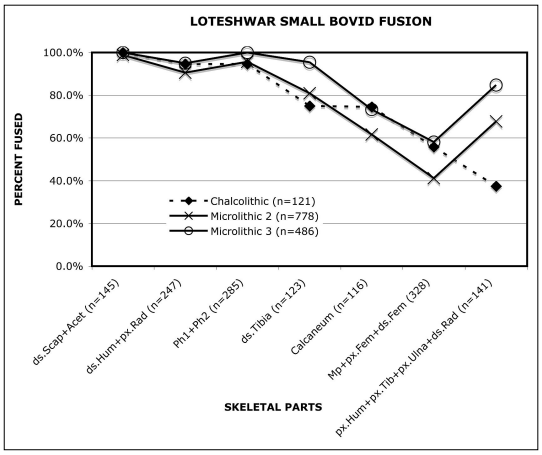

FIG. 5. — Small bovid (blackbuck and gazelle) kill-off patterns from Loteshwar based on state of epiphyseal fusion of appendicular skeletal parts arrayed along the x-axis from youngest (left) to oldest (right). In the absence of published data for blackbuck (Antilope cervicapra), the fusion sequence is based on that published for West Asiatic Gazella (Davis 1980), supplemented by observation of modern blackbuck specimens in zoological collections.

LOTESHWAR AMS RADIOCARBON DATES

In order to evaluate these interpretations, as well as to determine the chronology of the site and how early it was that domestic cattle were being exploited, a program of direct AMS dating of animal bones was developed, building on the previously available conventional charcoal and bone dates from the site (for details, see Patel 2008: 128-129). As noted above, these conventional dates include one on charred bone from the Aceramic Microlithic and two on charcoal from the Chalcolithic. As noted previously, the Aceramic Microlithic date has a median probability of ca. 4703 calBC, and the Chalcolithic dates have median probabilities of 3706 and 2993 calBC (Table 1 and Fig. 3).

A problem with the Aceramic Microlithic determination is that the date is from an unidentified specimen, the pretreatment of which is not specified. A problem with the Chalcolithic determinations is that the charcoal pieces could have come originally from the Aceramic Microlithic component. In such a situation what needs to be dated is material that has a high probability of belonging to a particular component. By dating bones of wild animals from the Aceramic Microlithic levels and those of domestic animals from the Chalcolithic pits, we are directly dating materials of cultural significance and not depending on associated dates provided by charcoal pieces.

Six charred bone fragments were selected for dating, three from each component. Those from the Aceramic Microlithic levels are from wild animals. They include one humerus fragment from blackbuck and two long bone shaft fragments also probably from blackbuck. Those from the Chalcolithic are all from domestic cattle. They include a femur, a humerus, and a first phalanx. Burned bones were selected because previous collagen extraction attempts on uncharred bones from Loteshwar showed that there is no bone protein surviving. In contrast, charred bone protein is more resistant to leaching and thus stands a better chance of providing sufficient original carbon for a date. The bones were submitted to Stafford Research Laboratories for pretreatment and dating. The resulting determinations are a total-organic-carbon bone date and as such provide minimum ages for the specimens dated (Patel 2008: 128-129).

The three Aceramic Microlithic AMS dates (Table 1 and Fig. 3) calibrate to the end of the eighth millennium (CAMS-55902: median 7168 calBC), to the end of the seventh millennium (CAMS-55898: median 6067 calBC), and to the middle of the sixth millennium (CAMS-35362: median 5567 calBC). They are all earlier than the conventional bone date that comes from the base of the Aceramic Microlithic deposits (median 4703 calBC). As stated above we have no information on how the conventionally dated specimen was pretreated and thus cannot evaluate its reliability.

As for the Chalcolithic determinations from bovine bones (Table 1 and Fig. 3), two of the three dates calibrate to the first half of the fourth millennium (CAMS-55903: median 3681 calBC and CAMS-55904: median 3645 calBC) and the third to the second half of the third millennium (CAMS-55905: median 2243 calBC). The two early AMS dates fall in the same range as the earlier of the conventional charcoal dates (PRL-1565: median 3706 calBC), suggesting that the latter is reliable. All five of the Chalcolithic dates taken together confirm an early

fourth millennium beginning for that component at Loteshwar and indicate a later Chalcolithic presence or continuation through the third millennium calBC.

IMPLICATIONS: CHRONOLOGICAL AND SETTLEMENT TYPE

There are a number of implications of these dates from Loteshwar. First, they situate the Aceramic Microlithic habitation early in the Holocene, making it among the earliest dated sites for the microlithic in northwestern South Asia (Misra 1996; Lechevallier 2003). Second, there is a gap of nearly 1500 years between the Microlithic and the Chalcolithic components. Third, each of the two components covers a significant period of time — more than a thousand years. This suggests that there are actually the remains of multiple occupations within each of the components. Given the apparent absence of structural activity at Loteshwar, these occupations are likely to have been short-lived. They may represent episodic year-round or, more likely (because of the seasonality of moisture availability in the region), single-season settlements or camps. Like many sites in North Gujarat, Loteshwar is located on top of a stabilized sand dune. Depressions between the dunes collect water during the monsoons and continue to be reservoirs of moisture and of vegetation during the dry season. They thus serve as prime feeding and watering zones for animals and an attraction to hunters and pastoralists especially when other areas have dried up.

IMPLICATIONS: DOMESTICATION AND PASTORALISM

A fourth implication of the dates relates to animal exploitation. There is no zooarchaeological evidence for any kind of pastoralism during the Aceramic Microlithic at Loteshwar. This contrasts with what has been claimed for other Microlithic sites in southern Rajasthan and Gujarat (see below). In the Chalcolithic deposits, however, there is a relatively high proportion of cattle bones. These are all smaller in size than the cattle bones from the Aceramic Microlithic and comparable in size to cattle bones from the late Neolithic and Chalcolithic at Mehrgarh (see below) and from the third millennium urban site of Dholavira in Kutch (Patel 1997). On that basis it is very likely that the Chalcolithic cattle bones from Loteshwar come from domestic animals. Fifth, as the dates clearly show, domestic cattle were part of the economy of North Gujarat as early as the beginning of the fourth millennium calBC. This determination itself raises an important question. Were these animals brought from another area of South Asia or were they domesticated locally?

Cattle domestication by the sixth millennium calBC has been established for the site of Mehrgarh in eastern Pakistani Balochistan, far to the northwest of Loteshwar (Meadow 1981, 1993, 1996). During the earliest period at Mehrgarh, that of the Aceramic Neolithic, there were significant changes in the exploitation of cattle. These are indicated by a marked increase in their representation in the faunal assemblage through time and an overall decrease in the size of the animals represented. This combination of quantitative and morphometric evidence led to a suggestion of local cattle domestication that subsequently has been supported by genetic evidence (see below).

However, the broad distribution of wild cattle through much of northwestern South Asia leaves open the possibility that there may have been multiple local centers of domestication of these animals. As noted, there are the remains of large wild cattle in the Aceramic Microlithic deposits at Loteshwar, indicating that such animals were available locally. This, together with the presence of morphometrically small-sized cattle at Loteshwar by the first half of the fourth millennium calBC, suggest that North Gujarat is an important area to investigate for the possibility of local domestication (Meadow & Patel 2003; Patel 2008). In addition, to date there is no evidence of direct cultural interaction between the Mehrgarh region and North Gujarat, although the intervening area is archaeologically poorly known for this period.

GENES: CATTLE

That multiple domestications of cattle took place in South Asia is supported by genetic studies. Over the course of the 1990s, the work of geneticists from Trinity College, Dublin, established that the

major genetic divide in cattle is between humped zebu forms (*Bos indicus*) and European non-humped forms (*Bos taurus*), both of which were most likely to have been domesticated separately (Loftus *et al*. 1994; Bradley *et al*. 1996). Work since that time has primarily focused on documenting genetic diversity within *Bos taurus* (*e.g.*, Troy *et al*. 2001; Bruford *et al*. 2003 for mtDNA). Some studies for *Bos indicus* have taken place, however, and these suggest the existence of two major mitochondrial DNA haplogroups (or haplotype clusters), namely, Z1 and Z2 (Baig *et al*. 2005; Magee, Mannen & Bradley 2007). Based on the distribution of the modern sampled populations, the Z1 type sequence appears more frequently in the western portion of the subcontinent and Z2 more to the east. The existence of these two phylogeographically differentiated haplogroups suggests that there were two or more separate loci of domestication for *Bos indicus* in South Asia. Indeed, the mitochondrial data would seem to support multiple maternal contributions to the genetic make-up of modern domestic zebu, given the amount of phylogenetic distinctiveness evident in the *Bos indicus* portion of the mitochondrial DNA tree.

In sum, the genetic evidence supports the likelihood that the modern distribution of zebu cattle resulted both from multiple domestication events in different parts of South Asia and from the spread of the resulting domestic animals to new areas within and outside of subcontinent. In contrast, the situation with sheep and goat is different both genetically and archaeologically.

GENES: GOAT AND SHEEP

Taking the phylogeographic situation for goats first, at present six distinctive mitochondrial DNA (mtDNA) haplogroups have been defined in modern domestic animals (Naderi *et al*. 2007, following previous studies by Luikart *et al*. 2001 and by Joshi *et al*. 2004, among others). Each represents a contribution to the goat gene pool from a different ancestral population probably from within the species *Capra aegagrus* (but see Pidancier *et al*. 2006 for the possibility of both paternal and maternal genetic contributions from at least one other species). Mitochondrial DNA group A is by far the most commonly represented among the modern animals tested from almost all areas of Eurasia. Of the other five groups, B, C, and D are found in higher frequencies in different parts of Asia outside of West Asia. These may represent recruitment of does (female goats) into an original domestic stock from other wild populations of *Capra aegagrus*. In addition or alternatively, they may reflect separate domestication events based on local wild forms in far-flung areas of the original zone of distribution of *Capra aegagrus* in West Asia (including the Iranian Plateau and Balochistan highlands west of the Indus Valley: Uerpmann 1987). Analysis of mtDNA sampled from modern populations of *Capra aegagrus* across the Middle East, however, has led Naderi *et al*. (2008) to suggest that there were only two significant centers of goat domestication – one in southeastern Anatolia/northwestern Zagros (haplogroup A) and the second in southeastern Iran (haplogroup C). They state that "our results confirm that goats were not domesticated in the area of the Indus Valley and suggest that the early Neolithic domestic goats in this area came from (greater than) 1,000 km to the west: that is, much further than previously suspected" (Naderi *et al*. 2008: 17663). As for domestic sheep, up to five mtDNA haplogroups have been identified (Meadows *et al*. 2007, following previous work published by Hiendleder *et al*. 2002 and by Pedrosa *et al*. 2005, among others). Of these, the most frequently represented in modern populations tested so far are haplogroups A and B, the latter dominated by domestic individuals from Europe, the former including animals from across Eurasia. Group C comprises mostly domestic sheep from the Middle East and Asia, while D and E have recently been identified on the basis of study of a very few individuals from the northern Caucasus (group D: Tapio *et al*. 2006) and from Israel and Turkey (group E: Meadows *et al*. 2007). However, no mtDNA from any studied extant wild sheep seems to cluster closely with the mtDNA from any of the five domestic haplogroups. This leaves open the possibility that now-extinct populations of wild sheep, possibly most closely related to modern *Ovis orientalis* (mouflon), provided the domestic founder stock. As with goats, however, there seems to have been more than one sheep domestication event (or possibly recruitments) within the area of distribu-

tion of the wild forms between the Mediterranean and the Indus Valley.

Based on the origin and distribution of domestic individuals tested at that time, Hiendleder *et al*. (2002) suggested that sheep haplogroup B reflects an ancestral *Ovis orientalis* population in West Asia, and group A derives from a founding mouflon population farther East. Such a scenario is supported by the work of Cai *et al*. (2007), who analyzed ancient mtDNA from eight specimens from the site of Erlitou (Henan Province, China, ca. 2100-1800 calBC). The results from all specimens were found to cluster with group A, which would seem to support a more eastern origin in prehistory for this group. As has also been shown by genetic analyses of ancient cattle (*Bos* sp.) and pig (*Sus* sp.) specimens, this approach to the study of the origins and spread of domestic animals can provide particularly valuable insights into changing patterns of animal distribution through time (*e.g.*, Edwards *et al*. 2007, Larson *et al*. 2007a, 2007b).

BONES AND ARCHAEOLOGY

As early as 1981, Meadow (1981, 1984, 1993, 1996) proposed that the faunal remains from Mehrgarh provided evidence for the local domestication of at least cattle and sheep in eastern Balochistan (Pakistan), with wild goats being exploited together with some already domestic ones. These arguments were based, in part, on the overall reduction in the size of the bones from each of these taxa through time as represented in the archaeological record between ca. 7000 and 4500 calBC. Such size reduction could not be explained merely by a demographic shift to a decreased number of adult males relative to adult females. This is because the smallest animals represented by their bones in each cultural period from the Aceramic Neolithic into the Chalcolithic also became smaller through time, and evidence for large animals disappeared almost entirely. Concomitant with size diminution was increasing representation particularly of cattle and sheep in the archaeological record relative to such wild taxa as gazelle, blackbuck, nilgai, water buffalo, and deer, as well as relative to goat. Of the domestic forms, only goat provided evidence of at least some animals having been domesticated from the beginning of occupation at the site. Not only were small adult individuals represented early, but human burials were sometimes accompanied by up to five young goats all under three months of age, suggesting ready access to herded populations (Lechevallier, Meadow & Quivron 1982).

Mehgarh lies on the eastern margin of the Middle East, which is also today the eastern margin of the distribution of West Asian wild sheep (*Ovis orientalis*) and wild goats (*Capra aegagrus*) as well as home to local forms of wild sheep (*Ovis vignei*) and wild goat (*Capra falconeri*) (Uerpmann 1987, Roberts 1997). Thus these animals could have been domesticated locally in South Asia, albeit in an area restricted to the northwestern margin of the subcontinent. Well before 3000 calBC, however, domestic sheep and goat had spread into the Indus Valley, to judge from their remains identified from Period 1a deposits at Harappa (Punjab, Pakistan, 3700-3000 calBC: R.H. Meadow, personal communication). By the middle of the third millennium, these animals were widespread throughout northwestern South Asia, within the sphere of the Indus Civilization and beyond. The processes and mechanisms of this spread remain poorly known, because there is little information available about the archaeology of areas east and southeast of Balochistan for the fourth and early third millennia calBC. This makes the findings from Loteshwar, that cover this time period, that much more significant.

At Loteshwar, there have been only three elements of sheep recorded. These have been securely identified and come from a context that could be late Chalcolithic or could incorporate Medieval material from a squatter settlement on top of the dune. Unfortunately, it has not been possible to date the specimens directly, and there are no sheep or goat bones from the Aceramic Microlithic. This stands in contrast to the situation at the dune top site of Bagor in nearby southern Rajasthan (Misra 1973), where the presence of sheep and goat has been published for the microlithic levels at the site (Fig. 3). These identifications, however, have been questioned (Meadow & Patel 2002, 2003).

For all three phases of the so-called "Mesolithic" of Bagor, domestic sheep, goat, and cattle have been identified by two of the three analysts who

have reviewed the faunal remains, namely, K.R. Alur (1971) and P.K. Thomas (1975, 1977). As a result, these analysts and other archaeologists have perpetuated the idea that Bagor represents a case of the adoption of pastoral practices by microlithic-using populations of the late sixth and fifth millennia calBC (*e.g.*, Possehl 1999; Shinde *et al.* 2004). In contrast, D.R. Shah (1971), the first to analyze material from Bagor, identified only the remains of wild animals. Review of the available published material suggests that the bones identified as goat and sheep from at least Bagor Phase I are actually from blackbuck and gazelle (Meadow & Patel 2002, 2003).

Distinguishing sheep and goat bones from those of blackbuck, gazelle, and even small deer is difficult in the absence of an adequate comparative collection of modern animals and of detailed comparative osteological studies of these morphologically similar forms. And since archaeological specimens are rarely complete, it is essential that zooarchaeologists use features that work consistently on fragmentary material. Additional variables that have to be considered are sex, age, size, and breeding population. Furthermore, given the nature and early dating of a site like Bagor (Fig. 3) and the kinds of locally available wild animals, identification of non-local forms such as sheep and goat warrant greater than normal caution on the part of analysts and skepticism on the part of subsequent users of the data.

Returning to North Gujarat, there is securely documented faunal evidence for the exploitation of domestic sheep and goat as well as cattle at the Harappan-affiliated third millennium village site of Nagwada located on the very eastern margin of the Little Rann of Kutch, south of Loteshwar (Fig. 1; Patel 1989). Unlike many other North Gujarat sites of this period, Nagwada has substantial architecture made of mud-bricks and stone rubble. It is also characterized by significant quantities of ceramics and other paraphernalia that are known hallmarks of the Indus Civilization, and there is evidence for craft activities including stone-bead and shell object manufacturing (Hegde *et al.* 1988).

While the occupations of Nagwada and Loteshwar were contemporary during the course of the mid to late third millennium calBC (Fig. 3), the first use of Loteshwar by cattle pastoralists is much earlier than the initial settlement of Nagwada or of other villages in the area as known to date. The chronological priority of the Loteshwar Chalcolithic, together with its focus on domestic cattle to the exclusion of goat and sheep, raises the issue of what role such cattle pastoralists may have played in communication and trade throughout the region as well as in opening up the area for more permanent settlement. The long span of the Chalcolithic at Loteshwar, as attested by the radiocarbon dates, combined with the apparently ephemeral nature of the settlements, can be interpreted as representing periodic visits by mobile pastoralists who traveled to the area seasonally and who may have covered large territories on their yearly rounds.

BONES, GENES, AND ARCHAEOLOGY

In the introduction, a number of questions were posited about the development of animal husbandry with particular reference to northwestern South Asia. To date, it has been possible at only one site in the region, namely, Mehrgarh in eastern Pakistani Baluchistan, to document something of how husbandry developed between the seventh and sixth millennia calBC and how hunter-gatherer economies became transformed into agro-pastoral ones. Elsewhere in South Asia the nature of this transformation remains unclear, because there has been little problem-oriented archaeological investigation of this phenomenon. Sheep could have been domesticated from local wild stock in the highlands on northwestern margin of South Asia – a proposal of the 1980s based on zooarchaeological evidence that has been provided support by genetic research more than 20 years later. Morphologically wild goats too, were exploited in that region, although the degree of their possible contribution to what now seems to have been an imported domestic gene pool remains unknown. The spread of both of these small domestic bovids across the subcontinent outside of the area of distribution of their wild relatives had to have taken place through the movement of people with their animals or through the trade of animals between human groups or both. The situation is different for cattle. The zebu (*Bos indicus*) could have been domesticated anywhere within the range of its wild

ancestor, which included much of at least northern South Asia, and genetic evidence suggests that this likely occurred more than once.

As suggested above, one locality where local wild cattle stocks could have been domesticated is North Gujarat, a proposal made in the late 1990s that has since received support from the results of genetic research. As noted, bones of wild cattle have been identified on the basis of their large size from Aceramic Microlithic Loteshwar in deposits that that are securely dated from the late eighth up to the sixth millennium calBC. In the subsequent Chalcolithic period at the site, bones from domestic cattle have been directly dated to the period between the early fourth and late third millennium calBC. The people of Loteshwar, in contrast to those from Mehrgarh, however, did not herd goat or sheep. Combined with the nature of the occupation of the site, this focus on cattle points to a form of dedicated, possibly mobile pastoralism that could have been based on local domestication of cattle in the fifth millennium calBC or earlier. The temporal gap between the Aceramic Microlithic and Chalcolithic components at Loteshwar, however, does not permit direct documentation of such a possibility at that site.

Work at Loteshwar has raised significant issues about chronology, site formation, seasonalilty, pastoralism, domestication, and the interpretation of archaeological evidence. Dune-top settlements in North Gujarat and southern Rajasthan have complicated depositional histories that can be disentangled only through the use of a combination of techniques that include well-designed dating protocols together with micro-depositional studies with a focus on individual activity areas and episodes of occupation. As noted, the dates from Loteshwar have shown that there is a considerable temporal gap between the Aceramic Microlithic and the Chalcolithic, at least at that site. Additional research is underway to explore the possibilities of continuing occupations at single or multiple nearby sites vis-à-vis the appearance of specific cultural practices and changing subsistence economies.

An important aspect of research on tracing ancient pastoralism during the last decade is that genetic research has provided another kind of evidence that can be employed to evaluate hypotheses and raise new issues about the domestication of animals. In particular, it is now possible to reject the single center of domestication scenario for a number species, including especially cattle, but also sheep and goat among others. Investigating multiple localities of animal domestication and/or recruitment from the wild is now becoming an important and accepted archaeological and zooarchaeological endeavor. Northwestern South Asia is one such area where the study of genetics especially of cattle but also of water buffalo (not discussed here, but see Patel & Meadow 1998b; Kumar *et al*. 2007; Yang *et al*. 2008), in conjunction with new excavations employing a wide range of archaeological techniques, would likely provide important insights into development and spread of a mosaic of pastoral practices. The study of ancient DNA has provided some insights into changing patterns of animal distribution through time (*e.g.*, Larson *et al*. 2007a, 2007b; Edwards *et al*. 2007). While such analyses have the potential to make valuable contributions in the South Asian context, given the hot humid climatic conditions and poor organic preservation, there is also considerable question about the feasibility of obtaining useable results from such analyses in the sub-tropical and tropical parts of the region. Perhaps new and improved scientific techniques and applications could help overcome some of these disadvantages in the future. Notwithstanding this drawback, it is clear that genetic research is an extremely valuable investigative approach in the study of the origins of domestic animals and their past spread across and between regions. It is important, however, that investigators — geneticists and archaeologists alike — evaluate and understand the significance of modern and ancient DNA results within the contexts of the archaeological, zooarchaeological, and genetic records.

Acknowledgements

I would like to dedicate this paper to the memory of Stine Rossel, who has left a void both as a friend and in her potential contributions to the field of Zooarchaeology.

In its initial form as "Occupational Histories, Settlement, and Subsistence Systems in Western India: What the Bones Can Tell Us," this paper was presented in a session at the 2006 Society for

American Archaeology annual meeting held in San Juan, Puerto Rico. I especially would like to thank Benjamin S. Arbuckle for taking the initiative to successfully organize the session and to invite me to participate in it. Ben's perseverance, patience, and support throughout the publication process have been essential to the completion of this paper. I would like to acknowledge the American School of Prehistoric Research and the Zooarchaeology Laboratory, Peabody Museum, Harvard University, for funding to carry out the research upon which this paper is based. Anonymous reviewer(s) provided useful comments and suggestions. Jade D'alpoim Guedes and Marielle Santoni assisted with translation into French of the title, abstract, and key words. Finally, I am grateful to Richard H. Meadow for his unfailing support through the course of this research. His insightful comments and valuable help in all aspects of this paper have been vital to its final form.

REFERENCES

Allchin, B. & Allchin R. 1982. — *The Rise of Civilization in India and Pakistan*. Cambridge University Press, Cambridge, UK.

Ajithprasad P. & Sonawane V.H. 1993. — *The Harappa Culture in North Gujarat: a regional paradigm. Symposium on Harappa Culture in Gujarat: Problems and Prospects, Pune*. Department of Archaeology and Ancient History; Maharaja Sayajirao, University of Baroda.

Alur K.R. 1971. — *Animal Remains from Bagor*. Deccan College, Pune.

Baig M., Beja-Pereia A., Mohammad R., Kukkarni K., Farah S. & Luikart G. 2005. — Phylogeography and origin of Indian domestic cattle. *Current Science* 89: 38-40.

Bradley D.G., Machugh D.E., Cunningham P. & Loftus R.T. 1996. — Mitochondrial diversity and the origins of African and European cattle. *Proceedings of the National Academy of Science of USA* (*PNAS*) 93: 5131-5135.

Bruford M.W., Bradely D.G. & Luikart G. 2003. — DNA markers reveal the complexity of livestock domestication. *Nature Reviews Genetics* 4: 900-910.

Cai D.-W., Han L., Zhang X-L., Zhou H. & Zhu H. 2007. – DNA analysis of archaeological sheep remains from China. *Journal of Archaeological Science* 34: 1347-1355.

Davis S.J.M. 1980. — A note on the dental and skeletal ontogeny of *Gazella*, Israel. *Journal of Zoology* 29: 129-134.

Edwards C.J., Bollongino R., Scheu A., Chamberlain A., Tresset A., Vigne J-D., Baird J.F., Larson G., Ho S.Y.W., Heupink T.H., Shapiro B., Freeman A.R., Thomas M.G., Arbogast R.M., Arndt B., Bartosiewicz L., Benecke N., Budja M., Chaix L., Choyke A.M., Coqueugniot E., Döhle H.J., Göldner H., Hartz S., Helmer D., Herzig B., Hongo H., Mashkour M., Ozdogan M., Pucher E., Roth G., Schade-Lindig S., Schmölcke U., Schulting R.J., Sephan E., Uerpmann H-P., Vörös I., Voytek B., Bradley D.G. & Burger J. 2007. – Mitochondrial DNA analysis shows a Near Eastern Neolithic origin for domestic cattle and no indication of domestication of European aurochs. *Proceedings of the Royal Society* B 274: 1616-1377.

Hegde K.T.M. & Sonawane V.H. 1986 — Landscape and settlement pattern of Harappa culture villages in Rupan Estuary. Man and Environment. *Journal of the Indian Society for Prehistoric and Quaternary Studies* 10: 23-31.

Hegde K.T.M., Sonawane V.H., Shah D.R., Bhan K.K., Ajithprasad P., Krishnan P. & Chandran S.P. 1988. — Excavation at Nagwada, 1986 and 1987: a preliminary report. Man and Environment. *Journal of the Indian Society for Prehistoric and Quaternary Studies* 12: 55-65.

Hiendleder S., Kaupe B., Wassmuth R. & Janke A. 2002. — Molecular analysis of wild and domestic sheep questions current nomenclature and provides evidence for domestication from two different subspecies. *Proceedings of the Royal Society* B 269: 893-904.

Indian Archaeology: a Review (*IAR*). — Archaeological Survey of India: New Delhi. 1982-83: 28; 1985-86: 20-22, 24; 1986-87: 30-31; 1987-88: 19-20; 1988-89: 12-17; 1989-90: 25-26; 1990-91: 12-18; 1991-92: 19-20; 1992-93: 19, 22-26; 1993-94: 31-33 & 140; 1994-95: 11-18.

Joshi M.B., Rout P.K., Mandal A.K., Tyler-Smith C., Singh L. & Thangaraj K. 2004. — Phylogeography and origin of Indian domestic goats. *Molecular Biology and Evolution* 12(3): 454-462.

Kumar S., Nagarajan M., Sandhu J.S., Kumar N. & Behl V. — 2007. Phylogeography and domestication of Indian river buffalo. *Evolutionary Biology* 7(186): 1-8.

Larson G., Albarella U., Dobney K., Rowley-Conwy P., Schibler J., Tresset A., Vigne J.-D., Edwards C.J., Sclumbaum A., Dinu A., Bălăçsescu A., Dolman G., Tagliacozzo A., Manaseryan N., Miracle P., Van Wijngaarden-Bakker L., Masseti M., Bradely D.G. & Cooper A. 2007a — Ancient DNA, pig domestication, and the spread of the Neolithic into Europe. *PNAS* 104(39): 15276-15281.

Larson G., Cucchi T., Masakatsu F., Matisoo-Smith E., Robins J., Anderson A., Rolett B., Spriggs M., Dolman G., Kim T-H., Thuy N.T.D., Randi E., Doherty M., Due R.A.W., Bolt B.,

Djubiantono T., Griffin B., Intoh M., Keane E., Kirch P., Li K-T., Morwood M., Pedrina L.M., Piper P.J., Rabett R.J., Shooter P., Van Den Bergh G., West E., Wickler S., Yuan J., Cooper A. & Dobney K. 2007b — Phylogeny and ancient DNA of *Sus* provides insights into Neolithic expansion in Island Southeast Asia and Oceania. *PNAS* 104(12): 4834-4839.

Lechevallier M. 2003. — *L'Industrie lithique de Mehrgarh : Fouilles 1974-1985*. Éditions Recherche sur les Civilisations, Paris.

Lechevallier M., Meadow R.H. & Quivron G. 1982. — Dépôts d'animaux dans les sépultures néolithiques de Mehrgarh, Pakistan. *Paléorient* 8(1) : 99-106.

Loftus R.T., Machugh D.E., Bradley D.G., Sharp P.M. & Cunningham P. 1994. — Evidence for two independent domestications of cattle. *PNAS* 91: 2757-2761.

Luikart G., Gielly L., Excoffier L., Vigne, J.-D., Bouvet J. & Taberlet P. 2001. — Multiple maternal origins and weak phylogeographic structure in domestic goats. *PNAS* 98: 5927-5932.

Magee D.A., Mannen H. & Bradely D.E. 2007. — Duality in *Bos indicus* mtDNA diversity: Support for geographic complexity in zebu domestication, in Petraglia M.D. & Allchin B. (eds), *The Evolution and History of Human Populations: Inter-disciplinary Studies in Archaeology, Biological Anthropology, Linguistics and Genetics*. Springer, Dordrecht: 385-391.

Meadow R.H. 1981. — Early animal domestication in South Asia: a first report of the faunal remains from Mehrgarh, Pakistan, in Härtel H. (ed.), *South Asian Archaeology 1979*. Dietrich Reimer Verlag, Berlin: 143-179.

Meadow R.H. 1984. — Animal domestication in the Middle East: a view from the eastern margin, in Clutton-Brock J. & Grigson C. (eds), *Animals and Archaeology 3. Early Herders and their Flocks*. BAR International Series 202. Archaeopress, Oxford: 309-337.

Meadow R.H. 1992. — In-conclusive remarks on pastoralism, nomadism, and other animal related matters, in Bar-Yosef O. & Khazanov A. (eds), *Pastoralism in the Levant: Archaeological Materials in Anthropological Perspectives Madison*. Prehistory Press, Madison (WI): 261-269.

Meadow R.H. 1993. — Animal domestication in the Middle East: a revised view from the eastern margin, in Possehl G.L. (ed.), *Harappan Civilization*. Second revised edition. Oxford & IBH, New Delhi: 295-320.

Meadow R.H. 1996. — The origins and spread of agriculture and pastoralism in northwestern South Asia, in Harris D.R. (ed.), *The origins and spread of agriculture and pastoralism in Eurasia*. UCL Press, London: 390-412.

Meadow R. H. & Patel A.K. 2002. – From Mehrgarh to Harappa and Dholavira: prehistoric pastoralism in North-Western South Asia through the Harappan Period, in Settar S. & Korisettar Ravi (eds), *Indian Archaeology in Retrospect*. Volume II. *Protohistory: Archaeology of the Harappan Civilization*. Indian Council of Historic Research, Manohar, New Delhi: 391-408.

Meadow R.H. & Patel A.K. 2003. — Prehistoric pastoralism in Northwestern South Asia from the Neolithic through the Harappan Period, in Weber S. & Belcher W. (eds), *Indus Ethnobiology: New Perspectives from the Field*. Lexington Books, Lanham, MD: 65-93.

Meadows J.R.S., Cemal I., Karaca O., Gootwine E. & Kijas J.W. – 2007. Five Ovine mitochrondrial lineages identified from sheep breed of the Near East. *Genetics* 175: 1371-1379.

Misra V.N. 1973. — Bagor - a Late Mesolithic settlement in North-West India. *World Archaeology* 5: 92-110.

Misra V.N. 1985. — Microlithic industries in India, in Misra V.N. & Bellwood P. (eds), *Recent advances in Indo-Pacific prehistory*. Oxford & IBH, New Delhi: 111-122.

Misra V.N. 1996. — Mesolithic India: history and current status of research, in Afanas'ev G.E., Cleuziou S., Lukacs J.R. & Tosi M. (eds), *The prehistory of Asia and Oceania*. Colloquium XXXII. Series Colloquia, The Colloquia of the XIII International Union of Prehistoric and Protohistoric Sciences 16. ABACO, Forli: 245-250.

Naderi S., Rezai H-Z., Taberlet P., Zundel S., Rafat S-A., Nagash H-R., El-Barody M.A.A., Ertugrul O. & Pompanon F. 2007. — Large-scale mitochondrial DNA analysis of domestic goats reveals six haplogroups with high diversity. *PLoS ONE* 10 (e1012): 1-12.

Naderi, S., Rezai H-Z., Pompanon F., Blum M.G.B., Negrinie R., Nagash H-R., Balkiz Ö., Mashkour M., Gaggiottia O.E., Ajmone-Marsan P., Kencef A., Vigne J.-D. & Taberlet P. 2008. — The goat domestication process inferred from large-scale mitochondrial DNA analysis of wild and domestic individuals. *PNAS* 105(46): 17659-17664.

Patel A.K. 1989. — *Vertebrate Archaeofauna from Nagwada: a Preliminary Study*. M.A. Dissertation. Department of Archaeology and Ancient History, Faculty of Arts, M.S. University of Baroda, Baroda.

Patel A.K. 1997. — The pastoral economy of Dholavira: a first look at animals and urban life in third millennium Kutch, in Allchin R. & Allchin B. (eds), *South Asian Archaeology 1995*. Oxford & IBH, New Delhi: 101-113.

Patel A.K. 2008. — New radiocarbon determinations from Loteshwar and their implications for understanding Holocene settlement and subsistence in North Gujarat and adjoining areas, in Raven E.M.

(ed.), *South Asian Archaeology 1999*. Egbert Forsten, Leiden: 123-134.

Patel A.K. & Meadow R.H. 1998a. — *The problem of blackbuck (Antilope cervicapra) and gazelle (Gazella bennetti) in the identification of faunal remains from northwestern South Asia*. Paper presented at the Fourth International Conference on the Archaeozoology of Southwest Asia (and Adjacent Areas). Muséum national d'Histoire naturelle, Paris, 29 June 1998. S.e. S.v.

Patel A.K. & Meadow R.H. 1998b. — The exploitation of wild and domestic water buffalo in prehistoric northwestern South Asia, in Buitenhuis H., Bartosiewicz L. & Choyke A.M. (eds), *Archaeozoology of the Near East III*. Centre for Archaeological Research and Consultancy, Rijksuniversiteit, Groningen: 180-199.

Pedrosa S., Uzun M., Arranz J.-J., Guitiérrez-Gil B., Primitivo F.S. & Bayón Y. 2005 — Evidence of three maternal lineages in near eastern sheep supporting multiple domestication events. *PNAS* B 272: 2211-2217.

Pidancier N., Jordan S., Luikart G. & Taberlet P. 2006. — Evolutionary history of the genus *capra* (Mammalia, Artiodactyla): Discordance between mitochondrial DNA and Y-chromosome. *Molecular Phylogenetics and Evolution* 40: 739-749.

Possehl G.L. 1999. — *Indus Age: The Beginnings*. University of Pennsylvania Press, Philadelphia.

Possehl G.H., & Rissman P.C. — 1992. The chronology of Prehistoric India: from earliest times to Iron Age, in Ehrich R.W. (ed.), *Chronologies in Old World Archaeology*. 3rd edition. University of Chicago Press, Chicago: vol. 1: 465-490; vol. 2: 447-474.

Reimer P.J., Baillie M.G.L., Bard E., Bayliss A., Beck J.W., Bertrand C., Blackwell J.H., Paul G., Buck C.E., Burr G.S., Cutler K.B., Damon P.E., Edwards R.L., Fairbanks R.G., Friedrich M., Guilderson T.P., Hogg A.G, Hughen K.A., Kromer B., McCormac G., Manning S., Bronk R.C., Reimer R.W., Remmele S., Southon J.R., Stuiver M., Talamo S., Taylor F.W., Van Der Plicht J. & Weyhenmeyer C.E. (2004). – IntCal04 terrestrial radiocarbon age calibration, 0-26 cal kyr BP. *Radiocarbon* 46(3): 1029-1058.

Roberts T.J. 1997. — *The Mammals of Pakistan*. Oxford University Press, Oxford; New York; Karachi; Delhi.

Sankalia H.D. 1946. — *Investigations into prehistoric archaeology of Gujarat. (Sri Pratapsimha Maharaja Rajyabhisheka Grantha-mala)*. Memoire 4. Baroda State Press, Baroda.

Sankalia H.D. 1965. — *Excavations at Langhnaj: 1944-63*. Part I: *Archaeology*. Deccan College Postgraduate and Research Institute, Poona.

Sankalia H.D. 1974. — *The Prehistory and Protohistory of India and Pakistan*. Deccan College Postgraduate and Research Institute, Poona.

Sankalia H.D. 1987. — *Prehistoric and historic archaeology of Gujarat*. Munshiram Manoharlal, New Delhi.

Shah D.R. 1971. — A note on unmodified animal remains from Bagor. *Eastern Anthropologist* 24(3): 319-320.

Shinde V., Deshpande S.S. & Yasuda Y. 2004. — Human response to Holocene climatic change: A case study of western India between 5th and 3rd millennia BC, in Yasuda Y. & Shinde V. (eds), *Monsoon and Civilization*. International Research Center for Japanese Studies. Lustre Press; Roli Books, New Delhi : 383-406.

Sonawane V.H. & Ajithprasad P. 1994. — Harrappa Culture and Gujarat. Man and Environment. *Journal of the Indian Society of Prehistoric and Quaternary Studies* 19(1-2): 129-139.

Stuiver M. & Reimer P.J. 1993. — Extended (super 14) C data base and revised CALIB 3.0 (super 14) C age calibration program. *Radiocarbon* 35(1): 215-230.

Tapio M., Marzanov N., Ozerov M., Ćinkulov M., Gonzarenko G., Kiselyova T., Murawski M., Viinalass H. & Kantanen J. 2006. — Sheep mitochondrial DNA variation in European, Caucasian, and Central Asian areas. *Molecular Biology and Evolution* 23(9): 1776-1783.

Thomas P.K. 1975. — Role of animals in the food economy of the Mesolithic culture of western and central India, in Clason A.T. (ed.), *Archaeozoological Studies*. North Holland Publishing, Amsterdam: 322-328.

Thomas P.K. 1977. — *Archaeozoological Aspects of the Prehistoric Cultures of Western India*. Ph.D. Dissertation. University of Poona, Pune.

Troy C.S., Machugh D.E., Bailey J.F., Magee D.A., Loftus R.T., Cunnigham P., Chamberlain A.T., Sykes B.C. & Bradely B.C. 2001 — Genetic evidence for Near-Eastern origins of European cattle. *Nature* 410: 1088-1091.

Uerpmann H.-P. 1987. — *The Ancient Distribution of Ungulate Mammals in the Middle East and Northeast Africa*. Ludwig Reichert Verlag, Wiesbaden.

Yang D.Y., Liu L., Chen X. & Speller C.F. 2008. — Wild or domesticated: DNA analysis of ancient water buffalo remains from North China. *Journal of Archaeological Science* 35(10): 2778-2785.

Submitted on 1st May 2008;
accepted on 24 April2009.