The Process of Ungulate Domestication at Çayönü, Southeastern Turkey: A Multidisciplinary Approach focusing on *Bos* sp. and *Cervus elaphus*

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Hongo H., Pearson J., Öksüz B. & İgezdi G. 2009. — The Process of Ungulate Domestication at Çayönü, Southeastern Turkey: A Multidisciplinary Approach focusing on *Bos* sp. and *Cervus elaphus*. *Anthropozoologica* 44(1): 63-78.

ABSTRACT
Bos and *Cervus* remains from Prepottery and Pottery Neolithic levels at Çayönü Tepesi are examined employing a multidisciplinary approach, combining the analysis of morphology, age profiles, and stable isotopes in bone collagen. The results show that the process of cattle domestication started at about the same time as three other ungulate taxa (sheep, goats and pigs), by the Channelled Building Subphase (end of Early PPNB/ beginning of Middle PPNB). Two stages are evident in the process of domestication: the initial appearance of domestic animals could be detected in the faunal

KEY WORDS
Çayönü Tepesi,
Southeastern Turkey,
Prepottery Neolithic,
Domestication,
Pigs, Sheep,
Goats, Cattle,
Red deer,
Kill-off patterns,
Size index analysis,
stable isotope analysis

remains by the appearance of some small-sized individuals and subtle changes in the kill-off patterns, as well as in the changes in stable isotope ratios of carbon and nitrogen. While hunting of wild progenitors continued, there was an overall decrease in the proportion of miscellaneous wild taxa in the assemblage. The second stage of the domestication process begins in the late-final PPNB, suggested by marked size reduction and demographic change, namely the increase of females in the assemblage, as well as dramatic increase in sheep and goats.

RÉSUMÉ

Le processus de domestication des Ongulés à Çayönü, Turquie du Sud-Est : approche multidisciplinaire à propos de Bos *sp. et de* Cervus elaphus

Les restes de *Bos* et de *Cervus* provenant des niveaux néolithiques précéramiques et à poterie à Çayönü Tepesi ont été étudiés en suivant une approche multidisciplinaire, combinant l'analyse morphologique, les profils d'âge et les isotopes stables dans le collagène des os. Les résultats montrent que le processus de domestication du bétail a commencé en même temps que trois autres Ongulés (moutons, chèvres et cochons) par la phase *Channelled Building* (fin du PPNB ancien/ début du PPNB moyen). Deux étapes sont mises en évidence dans le processus de domestication : les premières traces d'animaux domestiques peuvent être détectées dans les restes de faune par l'apparition de quelques individus de petite taille et de subtils changements dans les modèles d'abattage, évolution attestée par l'observation de changements dans les ratios des isotopes stables du carbone et de l'azote. Bien que des animaux sauvages aient continué à être chassé, on note une diminution globale des individus sauvages dans les assemblages. La deuxième étape du processus du domestication commence dans le PPNB tardif, comme le suggèrent une nette réduction de la taille, un changement démographique, à savoir l'augmentation des femelles, et aussi l'augmentation considérable des moutons et des chèvres.

MOTS CLÉS
Çayönü Tepesi,
Turquie du Sud-Est,
Néolithique précéramique,
domestication,
cochons, moutons,
bétail,
chèvres,
Cerf élaphe,
profils d'abattage,
indices de taille,
analyses isotopiques stables

INTRODUCTION

Domestication of four important livestock species (sheep, goats, cattle and pigs) progressed in the northern and eastern part of the "Fertile Crescent" during the Early and Middle PPNB. Evidence from faunal remains from archaeological sites in the area suggests that the management of goats began in the northern part of the Zagros Mountains by about 10 000 years ago (Hesse 1978, Zeder 1999, 2005, 2006; Zeder & Hesse 2000). The process of sheep domestication also began at about the same time, probably in the area including the foothills of Taurus Mountains in southeastern Anatolia. Recent research at Early and Middle PPNB sites in southeastern Anatolia and northern Syria, such as Cafer Höyük, Nevalı Çori, Tell Halula, as well as Çayönü suggests that the domestication process of pigs and cattle might also have begun at about the same time (Helmer 1988, Hongo & Meadow 1998, 2000; Rosenberg & Redding 1998, Peters *et al.* 1999, 2005; Ervynk *et al.* 2001, Hongo *et al.* 2002, 2004; Helmer *et al.* 2005).

Morphological changes, including reduction of body size, and kill-off patterns are important and commonly used markers in zooarchaeological research to monitor initial domestication. Changes observed in each of these markers, however, are in many cases subtle and often allow multiple interpretations. Therefore, it is useful to examine the faunal assemblage employing more than one analytical method, in order to see whether the changes observed in different kinds of analysis coincide in timing, and whether there is a trend that might suggest a kind of human intervention on the animal population that might lead to domestication of the species.

In this paper, we examine *Bos* remains from Çayönü in southeastern Turkey using multiple analytical approaches in order to document the timing and process of the domestication of cattle. The trend observed in *Bos* remains through time is compared with that in *Cervus*, another large ungulate exploited at the site, as well as in caprines and pigs.

THE SITE

Çayönü Tepesi is located on one of the small tributaries of the Tigris, about five kilometers from the foot of the Taurus Mountains in southeastern Turkey (Özdoğan & Özdoğan 1990). Like other PPN sites in the region, the site is situated at the foot of the mountains along an important route connecting the mountain area and the plains and steppes to the south. The occupation of the site spans about 3000 years, from Late PPNA into the early Pottery Neolithic. Thus, the faunal assemblage from Çayönü provides us with the opportunity to examine changes in the animal exploitation patterns through time at a single site over the critical period when the process of animal domestication progressed in the region.

The Prepottery Neolithic period at Çayönü is divided into six subphases, with each period named for characteristic architectural types (Özdoğan & Özdoğan 1990, 1998; Özdoğan A. 1995, 1999; Bıçakçı 1998, Erim-Özdoğan 2007). The Round Building subphase (ca. 10200-8500 cal. BC, with possible hiatus between 9300-8700 BC) corresponds to the Prepottery Neolithic A (PPNA) period of the Levant. The early part of the Grill Building subphase is also considered to be contemporary with the Prepottery Neolithic A (PPNA) period (Özdoğan A. 1995, 1999). The remainder of the Grill Subphase corresponds to the Early PPNB (ca. 8500–8300 cal. BC). The following Channelled Building Subphase goes into the beginning of the Middle PPNB (ca. 8300-8200 cal. BC), which continues with the Cobble-paved (ca. 8200-7800/7500 cal. BC) into the Cell Building Subphases. The Late PPNB includes most of the Cell and Large Room Building (ca. 7800/7500-6800 cal. BC) Subphases, but with at least part of the latter continuing into the Final PPNB (or "PPNC": ca. 6800-6300 cal. BC) (calibrated dates based on the CANeW Upper Mesopotamia 14C chart, updated Feb. 2006, www.canew.org). This Prepottery sequence is immediately followed by early Pottery Neolithic (Özdoğan 1995, 1999; Hongo & Meadow 2000, Ervynck *et al.* 2001), which is also contemporary with the Final PPNB in the Levant. Although it is problematic to apply the terms used in Prepottery Neolithic chronology in the Levant to Anatolia, in this paper the terms are used strictly as the periodization without reference to material culture.

TRENDS OBSERVED IN THE RELATIVE PROPORTION OF ANIMAL TAXA THROUGH TIME

Pigs are the most abundantly represented taxon during the Prepottery Neolithic at Çayönü, and always represent close to 40 percent of the identified specimens, especially in the earlier three subphases (Table 1) (Hongo & Meadow 1998, 2000; Hongo *et al.* 2002, 2005). Four species of domestic livestock (pigs, cattle, sheep, and goats) and their wild progenitors are grouped together in Table 1. Sheep and goats were insignificant in the early phase at the site, but their proportion, especially of sheep, increases steadily. A wide range of wild taxa were exploited in early subphases, including red deer, gazelle, roe deer, Asiatic wild ass, brown bear, leopard, red fox, hare, and a few other small mammal species. Some birds and tortoise were also exploited, and fish remains exist, though rare. The proportion of these miscellaneous wild taxa, however, decreases significantly after the Channelled Building Subphase. On the other hand, the proportion of the four 'pro-domestic' taxa, by which we mean pig, sheep, goat, and cattle, steadily increases through

TABLE 1.— Relative proportion of pigs, sheep and goats, cattle, and miscellaneous wild taxa in each subphase at Çayönü (percentage based on NISP).

Building subphase	Pigs	Sheep and Goats	Cattle	Total of the four "pro-domestic" taxa	Other wild taxa
Round	35,9	6,9	17,9	60,7	35.9
Grill	44,6	10,8	9,4	64,8	31.9
Channelled	37,9	14,7	5,9	58,5	37.9
Cobble-paved	31,3	22,9	13,9	68,2	26.4
Cell	31,9	24,2	17,9	74,1	19.2
Large Room	21,9	53,6	13,1	88,7	9.4
Early PN	35,4	46,6	11,3	93,3	6.2

Notes: "Other wild taxa" include gazelle, cervids, equids, bear, fox, hare, and miscellaneous small mammals, birds, and amphibia.
Wild and domestic forms of pigs, sheep, goats, and cattle are not differentiated.
Animal taxa not reflected in this table are domestic dogs and unidentified medium and large bovids or cervids.

time. Sheep and goats, especially, increase in the later subphases and their proportion reached over 50 percent of the total NISP by the end of PPNB. Thus, two important trends through time can be observed at Çayönü: the first is the decrease in the proportion of miscellaneous wild taxa around 8300 calibrated BC. The second is the increase of sheep and goats, which in the beginning was gradual, becoming dramatic in the Late PPNB.

These two trends are universal in southeastern Anatolia. The initial sign of change in the continuum of the domestication process is manifested as a shift from a broad-spectrum animal exploitation strategy combined with the intensive exploitation of a dominant taxon to a strategy concentrating on sheep and goats around 7500-7000 calibrated BC. During the PPNA and Early PPNB, settlements in southeastern Anatolia specialized in the exploitation of one particular animal species that was the most accessible taxon at the site (Table 2). Wild pigs were heavily exploited at Çayönu and wild sheep at Hallan Çemi. Located closer to the higher elevation of Taurus mountains, wild goats were abundant at Cafer Höyük, while gazelles were the main game at sites located close to the Harran Plains. Proportions of sheep and goat bones at most sites are only about 10 percent until the end of the Early/ beginning of the Middle PPNB. The exceptions are Hallan Çemi (Rosenberg *et al*. 1995; 1998) and Cafer Höyük (Helmer 1998), where the remains of wild sheep and wild goats dominate faunal assemblages, respectively. While intensively exploiting the most accessible taxon, which generally comprised more than one third and up to as much as 60 percent of the faunal remains at a site, a wide variety of wild animals were also hunted. The shift in subsistence from such broad-spectrum strategy to increasing dependence on four "pro-domestic" taxa occurred by Middle PPNB (Hongo *et al.* 2002, 2005). Sheep and goats, which were insignificant in the early subphases at the site, became dominant by Late PPNB. This phenomenon was probably related to the initial keeping of domestic animals.

The second shift in animal exploitation patterns at archaeological sites in the region is a dramatic increase in sheep and goats in the Late to Final PPNB. At sites like Hayaz Höyük (Buitenhuis 1985), Gürcütepe II (Driesch & Peters 1999), Çayönü (Large Room and early Pottery Neolithic levels), and Gritille (Stein 1986), the proportion of sheep and goats, the majority of which are considered domestic based on both bone size and kill off patterns, jumps to 50-70 percent of the faunal remains (Table 2).

COMPARISON OF CATTLE (*BOS* SP.) AND RED DEER (*CERVUS ELAPHUS*)

Comparison of changes observed in various morphological and non-morphological markers in *Bos* and deer through time provide us with a useful

TABLE 2. – Dominant species at Neolithic sites in southeastern Anatolia.

Site	Dominant Species	%
Hallan Çemi	wild sheep	43.0
Çayönü r	pig	36.5
Göbekli Tepe	gazelle	43.0
Nevali Çori I/II	gazelle	63.0
Çayönü g	pig	44.7
Çayönü ch	pig	37.9
Nevali Çori III	gazelle	59.0
Cafer Höyük	wild goat	42.9
Çayönü cp	pig	31.3
Nevali Çori IV	gazelle	42.0
Çayönü c	pig	31.9
Gritille	sheep and goat	71.0
Hayaz Höyük	sheep and goat	64.0
Gürcütepe II	sheep (and goat)	65.0
Çayönü lr	sheep and goat	53.6
Çayönü PN	sheep and goat	46.6

insight in the process of domestication. Both aurochs and red deer are large ungulates adapted to forest environments and were actively hunted at Çayönü during the Prepottery Neolithic period. Only *Bos*, however, was domesticated at some point during the PPNB. Therefore, comparison of these two species would help us distinguishing human induced factors from the environmental factors that might have affected the morphology, demography, and behavior of these two species.

PROPORTION OF *BOS* AND *CERVUS*

Figure 1A and B show the proportion of *Bos* and *Cervus* in each level at Çayönü. The proportion of *Bos* is close to 20% of the total NISP in the PPNA Round Building Subphase, but decreases during the Early PPNB and early part of Middle PPNB (Grill and Channelled Building Subphases), then turn to a sudden increase. The proportion of *Cervus* increases dramatically in the Channelled Subphase, as if compensating for the decrease in *Bos* by intensive red deer hunting. This might have resulted in the near extermination of red deer in the vicinity of the site. The proportion of *Cervus* began to decrease in the following Cobble-Paved Subphase. The decrease in wild taxa in general is observed starting after the Channelled Building Subphase, and the aurochs, the largest mammal species in the region, might have been the first wild mammal that was affected by hunting and the modification of the environment in the vicinity of the site, namely, the decrease of forests because of continuous occupation of the site and other human activities. This process is suggested by the

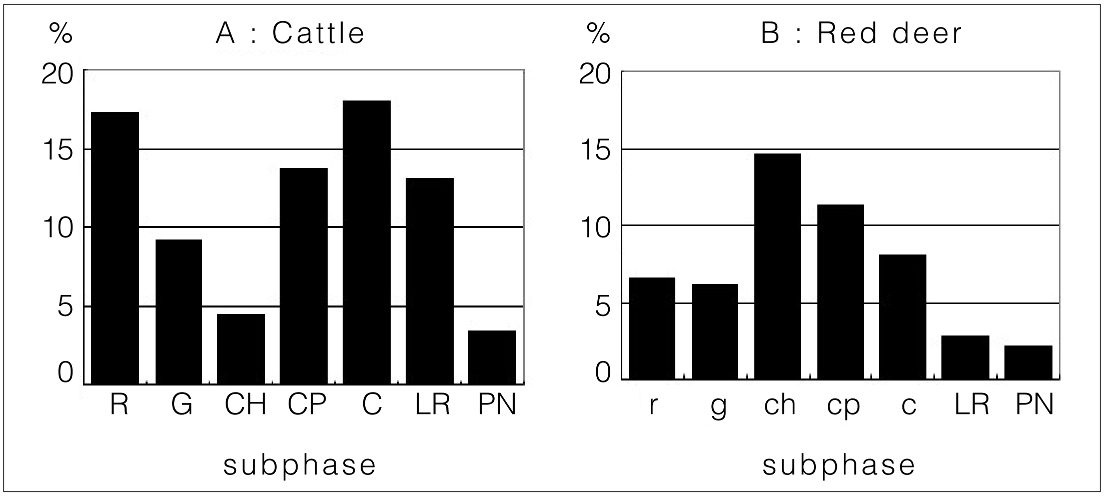

Fig. 1. — Proportion of cattle and red deer in each subphase at Çayönü.
R: round; G: grill; CH: channelled; CP: cobble paved; C: cell; LR: large room; PN: Pottery Neolithic.

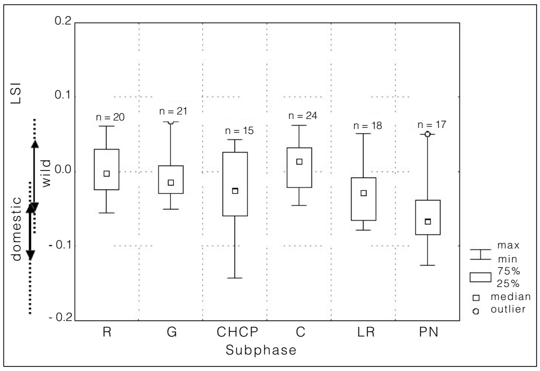

FIG. 2. – Size of cattle at Çayönü.
R: round; G: grill; CHCP: channelled and cobble paved; C: cell; LR: large room; PN: Pottery Neolithic.

sharp decrease in the number of *Bos* remains in the assemblage during the Early and early Middle PPNB. Finally the sudden increase in *Bos* in the Cobble-paved Subphase may indicate the shift to keeping domestic cattle at the site.

BODY SIZE OF *BOS* AND *CERVUS*

In order to assess whether or not a shift from aurochs hunting to cattle keeping occurred by the Middle PPNB, the body size of *Bos* and *Cervus* from Çayönü were examined. The sizes of *Bos* long bones in each subphase at Çayönü were compared against the measurements of a standard animal, which is a Danish female aurochs (Fig. 2, Degerbøl 1970, but following the corrected measurements by Grigson 1989), using the "Difference of Logs" technique (Uerpmann 1979; Meadow 1981, 1983, 1999). Although overlap in the size of female Aurochs and male domestic cattle often makes the clear distinction between domestic and wild populations, estimated ranges of the size of wild and domestic *Bos* are indicated by arrows on the left side of the chart. These estimated size ranges are based on the Bronze Age aurochs and domestic cattle remains from Didi Gora in Georgia (H.-P. Uerpmann, personal communication 2007). The proposed size range for aurochs is narrower than that indicated by Grigson (1989). Even though chronologically apart, because of geographical closeness, the aurochs population in Georgia might be comparable in its size range to the Neolithic aurochs in eastern Anatolia. The size of *Bos* in the PPNA Round Building Subphase at Çayönü, as well as that at Çatalhöyük, which are considered to be wild (Russell & Martin 2005; Russell *et al.* 2005) fit in the hypothesized size range in the aurochs (Fig. 2). The size distribution of *Bos* at PPNA level of Körtik Tepe, also located on the upper Tigris (Arbuckle & Özkaya 2006), also shows a similar range, though slightly larger. When the Log Size Indices (LSI) of *Bos* are plotted in the form of histogram, the size of *Bos* in the Round Building Subphase shows a bimodal distribution (Fig. 3A), which probably reflects the sexual dimorphism of aurochs in the region. The female aurochs in Anatolia tend to be smaller than the Danish female used as the standard animal.

The overall range of size distributions did not change in the following Grill-Building Subphase, where the *Bos* samples came mostly from Early PPNB levels. There seem to be more females among the samples in this subphase (Figs 2 & 3B), but small sample size makes this observation tentative. The specimens from the Channelled (n = 8) and Cobble-paved (n = 7) Building Subphases were combined because of small sample size and because the size ranges of *Bos* in these two subphases are similar. There is a slight decrease in the size of *Bos* in these early Middle PPNB subphases (Figs 2 & 3C). At the same time, the size range became much broader, with a few specimens falling below the size range of aurochs. The smallest specimen in Figure 3C, with LSI value -0.14, and another small one with LSI value -0.077 belong to the Channelled Building subphase. The smallest specimen from the Cobble-paved Building Subphase has the LSI value -0.086. There is a rebound in size in the following Cell Building Subphase, with all the specimens from this subphase falling in the size range of wild *Bos* (Fig. 3D).This rebound might partly be caused by greater number of older individuals in the assemblage whose breadth dimensions can be larger than younger individuals (see the section on age profiles below). Given the small number of samples, it is also possible that just by chance all the measured specimens from this subphase came from wild individuals. A clear shift to smaller size is observed in the Late-Final PPNB Large-room Subphase, which is at least in part due to the increase of females in the assemblage (Fig. 3E), Further size diminution occurred in the following Pottery Neolithic, manifested in the overall shift

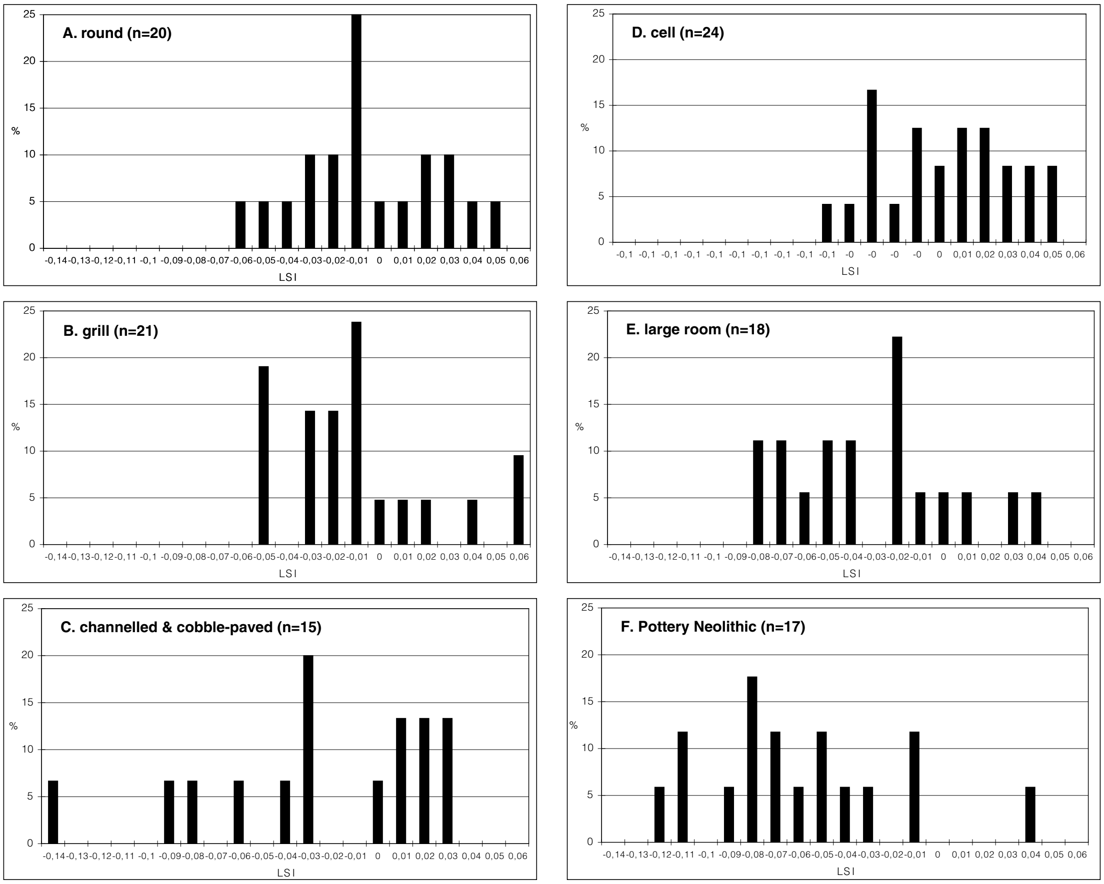

Fig. 3. – Size of *Bos* at Çayönü.
A. round; B. grill; C. channelled and cobble paved; D. cell; E. large room; F. Pottery Neolithic. LSI: Log Size Index.

in the range of the size distribution and increase in females (Fig. 3F). The majority of the specimens in Late-Final PPNB and Pottery Neolithic levels are well within the size range of domestic cattle.

Sex-specific changes in slaughter pattern could not be examined with the data at hand mainly due to small sample size. Although we did measure both fused and unfused specimens, the number of measurable unfused specimens was very small, and their size all fell in the smallest end of the size distribution: unfused specimens with LSI values far below the range of LSI distribution of other specimens from the same level were not included in the charts. An unfused distal humerus from the Large-room Subphase had an LSI value -0.079, which was included in the chart.

The size range of *Bos* from PPNA and PPNB levels at Çayönü corresponds very well with that at contemporary sites in southeastern Anatolia, such as from Göbekli Tepe, Nevali Cori, and Gürcütepe (Peters *et al.* 2005: fig. 11).

For the size comparison of *Cervus*, measurements of a modern female collected in Turkey were used as the standard (İlgezdi 2002). In contrast to *Bos*, the size of *Cervus* was remarkably stable throughout the Prepottery Neolithic and Pottery Neolithic (Fig. 4). If the size diminution observed in *Bos* were caused by environmental changes, such as unfavorable climate or deterioration in vegetation, *Cervus* should also have been affected. The fact that the shift in size is observed only in *Bos* suggests that there were

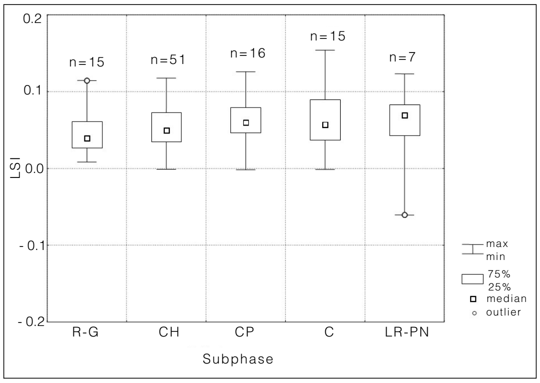

Fig. 4. – Size of red deer at Çayönü.
R-G: round and grill; CH: channelled; CP: cobble-paved; C: cell; LR-PN: large room and Pottery Neolithic.

other factors involved in the reduction of size in *Bos*, probably human induced ones.

Kill-off patterns for *Bos* and *Cervus*

Figure 5A shows the kill-off patterns of *Bos* in each subphase at Çayönü. *Bos* in the PPNA Round Building Subphase show high survival rates at both juvenile and subadult age stages. In the following Grill Building Subphase, the kill-off schedule became earlier, with only about 60 % of the animals surviving the subadult age stage. This continues in the following subphases, with *Bos* being slaughtered mainly between late juvenile and subadult age stage, except in the Cell Building Subphase where the survival rate is rather high in all age stages. In the cases of some subphases, a "rebound" at the juvenile age stage occurs, which is caused primarily by large numbers of fused distal tibiae and metapodials, the elements that tend to be preserved better than other skeletal parts. Slaughter at even younger ages is observed in the Late-Final PPNB and Pottery Neolithic. The survival rate at the infantile age stage in these late subphases is lower compared to that in the earlier phases, and only 30 to 45 % of *Bos* survived into full adult. Again, in contrast to *Bos*, there was little change in the kill-off patterns of *Cervus* through time (Fig. 5B). The majority of deer remains in the assemblage belong to adult individuals throughout the occupation of the site.

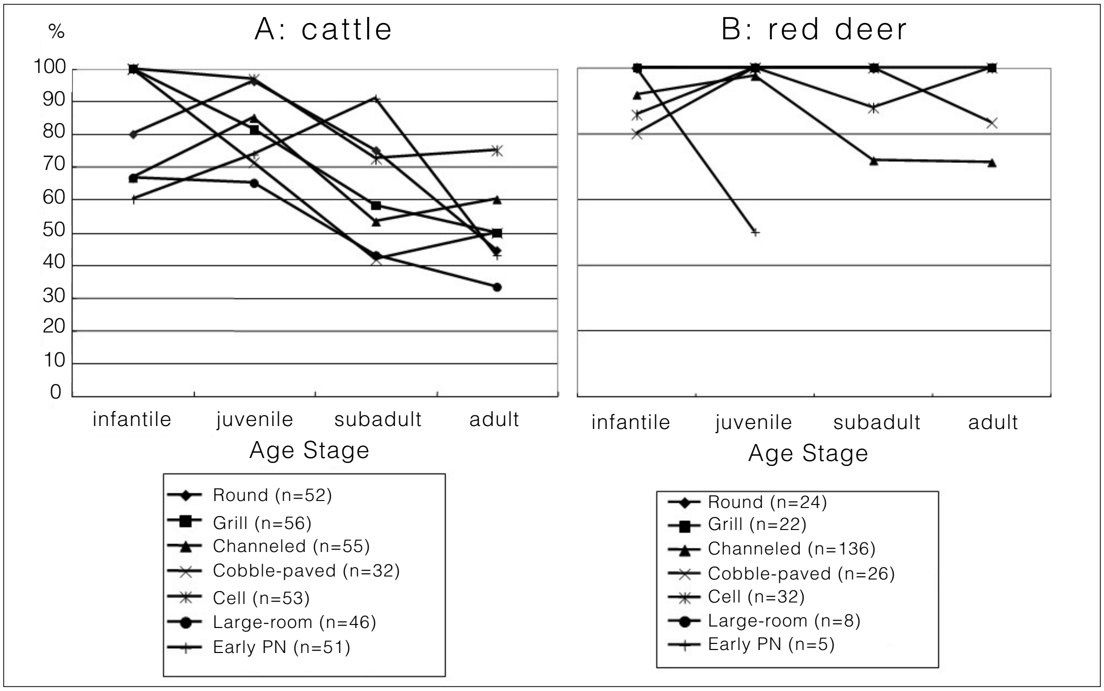

Fig. 5. — Age profile of cattle and red deer at Çayönü.

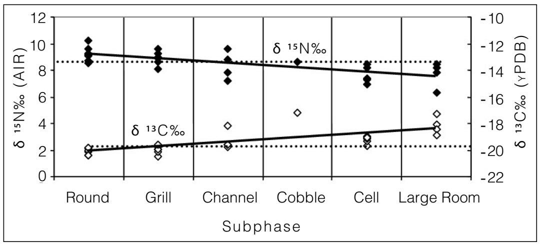

FIG. 6. — Carbon and nitrogen isotope ratio of cattle from Çayönü.

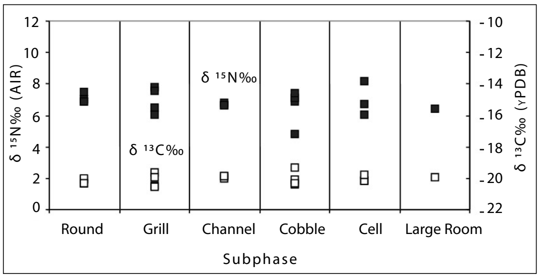

Fig. 7. — Carbon and nitrogen isotope ratio of red deer from Çayönü.

Slightly younger kill-off pattern during the Channelled Building Subphase was observed, coinciding with when the proportion of *Cervus* in the assemblage suddenly increases, suggesting higher hunting pressure on *Cervus* during this period.

ANALYSIS OF CARBON AND NITROGEN ISOTOPE RATIOS

Carbon and Nitrogen isotope ratios in human and animal bone remains from Çayönü were analyzed by one of the authors (J. Pearson). Evaluation of the physiology of plants identified from the site showed that all plants preserved as charred material are C3 plants (Table 3, see Appendix).

The *Bos* spp. results vary in δ^{13}C from -20.48 to -17.2‰ (3.28‰) and in δ^{15}N from 6.31 to 10.20‰ (3.89‰ variation) with both isotopes revealing a trend towards lighter δ^{15}N and heavier δ^{13}C (Fig. 6) over time. A number of individuals probably had access to C4 plants starting in the Channel Building Subphase although which plants may have been consumed is unknown since no C4 plants have been identified in the archaeobotanical assemblage (Van Zeist & de Roller 1992). A gradual trend in isotope values, as shown here, might be indicative of climatic change. However, this seems unlikely for two reasons. Firstly, if the climate was changing due to variations in precipitation and/or temperature this would have knock-on effects on animal physiology across all genera as well as on plant communities (in terms of both physiology and the appearance and disappearance of particular genera of plants). An examination of the *Cervus* isotope values, which vary in δ^{13}C from -20.56 to -19.29‰ (1.27‰ variation) and in δ^{15}N from 4.80 to 8.17‰ (3.37‰ variation), does not show any trends in lighter or heavier isotope values over time (Fig. 7) further suggesting the trend seen in the *Bos* is not a climate-driven phenomenon. Secondly, the trends in isotope values contradict each other if interpreted in terms of climate change. Specifically, higher δ^{15}N values have been identified as a response to increasing aridity in both plants (Schwarcz *et al.* 1999) and animals (Schoeninger and DeNiro 1984; Gröcke *et al.* 1997). Therefore, the trend in *Bos* might suggest *decreasing* aridity over time. However, the δ^{13}C values become heavier over time, which is normally indicative of *increasing* aridity over time (Tieszen 1991). As a result, a simple model of climatic change cannot explain the observed trend, and we therefore postulate that these trends are human-induced changes in diet.

Since the last aurochs became extinct in Europe in the 17th century, we have very little knowledge about the habitat, behavior, or diet of this animal, which hinders our interpretation. We assume that aurochs were adapted to forest environments, but there might have been several subspecies of aurochs within Southwest Asia, wich where adapted to different environments (Uerpmann 1987). Generally speaking, more positive δ^{13}C values may indicate more open vegetation and drier environments (Tieszen 1991). Thus, one explanation for the more positive δ^{13}C values in some of the *Bos* bones in the Channelled Building Subphase and later is that it indicates the deterioration of the aurochs habitat, perhaps because of the impact of long-term human occupation and deforestation. It is possible that, prior to domestication, some aurochs became adapted to more open areas (with differing $\delta^{15}N$ values underpinned by a separate plant biomass) near the edge of the forest and to the secondary vegetation created by human activities, which laid foundation for domestication. Red deer may not have been as adaptive as aurochs and retreated with the forest, resulting in the unchanged $\delta^{13}C$ values in their bones. The fact that the proportion of *Cervus* in the assemblage decreased after the Channelled Building Subphase may also suggest that it became increasingly difficult to hunt deer in the vicinity of the site.

Further evidence for differences between *Bos* across the subphases of occupation at the site is provided through evaluation of the nitrogen isotope values. Drucker *et al.* (2003) has discussed how more negative $\delta^{13}C$ and more positive $\delta^{15}N$ values can be the result of carbon and nitrogen recirculation in organisms living on the floor of dense canopied woodland. In the earliest subphase of occupation at Çayönü (Round Building Subphase) the *Bos* specimens have the most negative $\delta^{13}C$ and most positive $\delta^{15}N$ values. Over time $\delta^{13}C$ becomes more positive and $\delta^{15}N$ values are lower. Thus, we interpret the Çayönü *Bos* isotope data as indicating the gradual movement of these animals out of canopied woodland and into a more open environment. The second interpretation is that we might be seeing an influx of another *Bos* population from a different ecological niche underpinned by plants with slightly different $\delta^{13}C$ and $\delta^{15}N$ values. At Çayönü, specimens with $\delta^{13}C$ values over -20 and $\delta^{15}N$ values below 8 appear starting in the Channelled Building Subphase. Since we have already identified size diminution morphologically it is tempting to suggest that the dietary variations support the idea of changes in the relationship specifically between humans and *Bos* during the Channelled Building Subphase of occupation at Çayönü Tepesi, which may indicate the appearance of domesticated *Bos*. Noe-Nygaard *et al.* (2005) made an observation on aurochs in Denmark that aurochs generally shows more negative $\delta^{13}C$ values and more positive $\delta^{15}N$ values than domestic cattle. If we assume these observations also apply for Aurochs populations in Anatolia, the appearance of *Bos* with more negative $\delta^{13}C$ values and more positive $\delta^{15}N$ values at Çayönü would also support the hypothesis that domestic cattle appeared during the Channelled Building Subphase. As for southeastern Anatolia, Lösch *et al.* (2006) analyzed faunal remains from Nevali Çori and point out that smaller-sized specimens of sheep, goats and pigs have lower $\delta^{15}N$ values in the bone collagen than large-sized specimens. As a possible explanation for the difference in $\delta^{15}N$ values, they suggest that smaller-sized animals (presumably representing individuals under cultural control) might have been given legumes as fodder which could cause lower $\delta^{15}N$ values. This assumption might also explain the lower $\delta^{15}N$ values in some cattle specimens from the Channelled Building and later subphases at Çayönü.

Timing of domestication of four livestock animals at Çayönü

Changes in overall proportion, kill-off schedule, and isotope ratios in the bones of *Bos* occurred in the Channelled Building Subphase, which were not observed in *Cervus*. As only *Bos* was domesticated at some point during the PPNB, it is likely that these changes are at least partly due to human intervention on aurochs populations that eventually led to full domestication. Based mainly on body size, Peters *et al.* (2005) suggested that in the upper Euphrates region *Bos* were domesticated by the Middle PPNB. Helmer *et al.* (2005) proposed *Bos* domestication at even earlier date, in the Early PPNB (8800-8300 cal. BC), based on the size and degree of sexual dimorphism of cattle at D'jade in northern Syria. At Çayönü, a shift toward earlier slaughter schedule and possible increase of female *Bos* in the samples are indicated in the late Early PPNB (Grill Building Subphase), although these observations are hindered by small sample size. More clear changes in other markers, body size and isotope ratio of bones, took place in the following Channelled Building Subphase. Thus, the results of analysis at Çayönü corroborate the evidence from other sites in the region. By combining multiple lines of evidence, we can conclude that domestic cattle were present also in the upper Tigris region probably by the end of Early PPNB, and certainly by the beginning of Middle PPNB. This observation leads to the conclusion that the domestication process of all four important livestock animals began at Çayönü at about the same time, and progressed in parallel (Hongo *et al.* 2004, 2005). With the data at hand, however, we cannot exclude the possibility that domestic cattle were introduced into the upper

Tigris region from elsewhere. Whether or not the upper Tigris region was one of the primary centers where the domestication process for *Bos* progressed locally should be investigated further. If successful, genetic analysis might help clarify this issue.

We have already reported in detail about the size and kill-off patterns of pigs from Çayönü (Hongo & Meadow 1998, 2000; Ervynck *et al.* 2001; Hongo *et al.* 2002;). Both the body size and the length of mandibular third molar of pigs from Çayönü show a gradual diminution over time, with some smaller individuals starting to appear as early as in the Grill Building Subphase. Hunting of wild pigs also continued throughout the Prepottery Neolithic, resulting in increasing variability in the size of pigs through time. Most of the pig M3s from Prepottery Neolithic levels are comparable in size to that of modern wild pigs, but some teeth that fall in the range of size overlap for wild and domestic pigs appear from the late Middle PPNB. A clear shift in the size range of post-cranial bones of pigs did not take place until Cell Building Subphase, and clear reduction of the length of M3 is observed only in the samples from Pottery Neolithic (Hongo & Meadow 1998, 2000; Hongo *et al.* 2004). Another line of evidence, kill-off patterns, show progressively earlier slaughter schedule in later subphases. The trends observed in the size and kill-off patterns of pigs are gradual, but one directional, and we have concluded that at least small number of domestic pigs existed at the site as early as the Early PPNB.

The sizes of both sheep and goats in the PPNA and Early PPNB levels at Çayönü were relatively large, suggesting the hunting of a wild population. More small animals appear by the end of Early PPNB or the beginning of Middle PPNB. A clear shift in the size distribution toward smaller size is observed in the Late-Final PPNB Large Room Subphase, which was at least partly due to an increase in the number of females in the measured assemblage (Hongo *et al.* 2005: figs 3 & 4). For the case of sheep and goats, small sample sizes of the late-fusing skeletal parts, which cause "rebounds" in the survivorship curves at subadult and adult age stages makes the analysis of kill-off patterns difficult. We have, however, compared the survivorship rates at the juvenile age stage in each subphase and reported that, in contrast to pigs and cattle in which slaughter schedule became earlier through time, both sheep and goats showed higher survival rate in later subphases, especially in the Late and Final PPNB (Hongo *et al.* 2005: figs 5 & 6).

SUMMARY AND CONCLUSION

The domestication process of ungulates at Çayönü consisted of two stages. The initial signs included the appearance of a small number of smaller-sized pigs and a subtle change in the slaughter schedule of sheep, goats, cattle, and pigs (but not of red deer) by the end of Early PPNB or beginning of the Middle PPNB. This coincides with the shift in the subsistence patterns, namely the decrease in the variety of hunted taxa and gradual increase in caprines, beginning in the Middle PPNB (around 8200 calibrated BC). A growing social complexity at the site is also suggested in the end of Early PPNB and early Middle PPNB, by the appearance of specialized workshop areas and the importance given to communal space within the site. However, the subsistence patterns based on a long tradition of sedentary hunter-gatherers in the region still persisted. While there was a gradual but steady increase in sheep and goats through time at the site, it seems that animal keeping (and farming) was initially only an additional option in a broad-spectrum subsistence strategy. A continuous and increasingly intensive exploitation of wild resources by the sedentary villagers, however, gradually exhausted the resources around the site over the next several hundred years. This process of environmental deterioration is evident in the steady decrease of the relative proportion of miscellaneous wild animals in the faunal assemblage.

As the second stage, a drastic shift in the faunal record is observed during the Late to Final PPNB, characterized by a sharp increase in sheep and goats and by heavy reliance on domestic animals. The traditional subsistence pattern collapsed and the socio-economic basis of the site was drastically transformed. A clear shift toward smaller-sized animals is observed in all four taxa, including sheep, goats, pigs and cattle. An increase in females in the measured assemblage is also suggested by the size distribution. Clay figurines depicting sheep or goats are found only from the Late PPNB subphases, which also suggests a change in the relationship between these animals and humans. As discussed elsewhere (Hongo *et al.* 2004, 2005), this major shift in subsistence took place together with a fundamental change in the social system. In other words, the shift from the tradition of sedentary hunter-gathers to the socio-economic (and perhaps also psychological) system of agro-pastoralists, which laid the foundation for the Pottery Neolithic tradition, occurred in parallel with the major shift in subsistence.

As for cattle the domestication process for *Bos* began by the end of Early the PPNB at about the same time as for the other important livestock species and progressed in a parallel manner. Although initial signs of domestication in different aspects of the faunal record are usually subtle, they can be detected by combining more than one marker to examine the timing and trend of changes over time. Comparing prodomestic species and other wild taxa has also proved to be a useful tool in detecting human-induced shifts in exploitation patterns that lead to domestication.

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Submitted on 8 February 2008;
accepted on 24 October 2008.

APPENDIX

Table 1. – Archaeobotanical list identified at Çayönü Tepesi (after van Zeist & de Roller1992).

Key to photosynthetic pathway reference column
1: Watson and Dallwitz 1992 onwards
2: Sage and Monson 1999
3: pers. comm.

Family	Genera/Species	Common	Photosynthesis	REF
Ranunculaceae	*Adonis* sp.	pheasant's eye	C3 (all species)	1
Poaceae	*Agrostis* type	bentgrass	C3 (all species)	1
Rosaceae	*Amygdalus* sp.	wild plum/almond	C3 (all species)	1
Primulaceae	*Anagallis* sp.	scarlet pimpernel	C3 (all species)	1
Boraginaceae	Anchusa sp.	bugloss	C3 (all species)	2
Leguminosae/Fabaceae	*Astralagus* sp.	milk vetch	C3 (all species)	1
Poaceae	*Bromus* sp.	brome grass	C3 (all species)	1
Ulmaceae	*Celtis* sp.	Hackberry	C3 (all species)	1
Euphorbiaceae	*Chrozophora* sp.	Dyer's croton?	unknown	x
Fabaceae	*Cicer* sp.	chick pea	C3 (all species)	1
Poaceae/Graminae	*Cynodon* sp.	bermuda grass	unknown	x
Lilicaeae	*Echinaria* sp.	?	unknown	x
Moraceae	*Ficus* sp.	fig	C3 (all species)	1
Fumariaceae	*Fumaria* sp.	fumitory	No C4 recorded for family	2
Rubiaceae	*Galium* sp.	bedstraw/cleavers	C3/CAM, *Galium*=C3	1
Cistaceae	*Helianthemum* sp.	Frost weed/Rock rose	C3 (all species)	1
Poaceae	Hordeum spontaneum	2 row hulled	C3 (all *Hordeum* sp.)	1
Leguminosae/Fabaceae	Lathyrus cicera/sativus	vetchling	C3 (all species)	1
Fabaceae	*Lens* sp.	Lentil	C3 (all *Lens* sp.)	1
Linaceae	*Linum* sp.	flax	C3 (all species)	1
Boraginaceae	Lithospermum tenuiflorum	gromwell?	C3 (all *Lithospermum* sp.)	1
Poaceae	Lolium rigidum/perenne	rye grass	C3 (all species)	1
Solanaceae	*Lycium* type	honey thorn?	unknown	x
Malvaceae	*Malva* sp.	mallow	C3 (all species	1
Fabaceae	*Medicago* sp.	medick	C3 (all species)	1
Fabaceae	*Melilotus* sp.	clover	unknown	x
Poaceae	*Phalaris* sp.	canary grass	C3 (all species)	1
Anacardinaceae	*Pistacia* sp.	Pistachio	C3 (all species)	1
Fabaceae	Pisum	pea	C3 (all species)	1
Plantaginaceae	*Plantago lagopus* type	Plantain/Ribwort	C3 (all species)	1
Polygonaceae	*Polygonum* sp.	knotweed	C3 (all species)	1
Fagaceae	*Quercus* sp.	oak	C3 (all species)	1
Ranunculaceae	*Ranunculus* spp.	Buttercup genus	C3 (all species)	1
Cyperaceae	Scirpus maritimus	sea club-rush	C3 (all species)	3
Caryophyllaceae	Silene	campion	unknown	x
Poaceae/Graminae	*Stipa* spp.	Needle grass	C3	1
Thymelaeaceae	*Thymelaea* sp.	thymelaea	C3 (all species)	1

Family	Genera/Species	Common	Photosynthesis	REF
Fabaceae	*Trigonella* sp.	trigonel	C3 (all species)	1
Poaceae	Triticum aestivum/ durum	bread/durum wheat	C3 (all species)	1
Poaceae	Triticum boeoticum	wild einkorn	C3 (all species)	1
Poaceae	Triticum dicoccum	emmer	C3 (all species)	1
Poaceae	Triticum dicoccoides	wild emmer	C3 (all species)	1
Poaceae	Triticum monoccum	einkorn	C3 (all species)	1
Poaceae	Triticum spp.	wheat species	C3 (all species)	1
Caryophyllaceae	Vacarria	Cow basil/cowherb	C3 (all species)	2
Scrophulariaceae	Verbascum	Mullein?	C3 (all species)	2
Verbenaceae	*Verbena* spp.	vervain	C3	1
Fabaceae	*Vicia* cf. *ervilla*	bitter vetch	C3 (all species)	1
Vitidaceae	*Vitis* spp.	grape	C3 (all species)	1
Lamiaceae/Labiatae	Ziziphora	Mint family	Non C4 anatomy	1