

Identifying the Beginnings of Sheep Husbandry in Western China

Part i

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Abstract

Situated at the two sides of Eurasia, Western Asia and China are both important centres for the origins of agriculture and civilization. Key suites of domestic crops, animals, and technologies were independently developed at these two centres. Scholars have been interested in seeing whether there was communication between these ‘nuclear centres’ in prehistory, and how they were influenced by each other. The domestication of sheep and goat, which first occurred about 10,000 years before present (BP) in the region of modern-day Syria, Turkey, and Iran, has long been assumed as introduced from the West to China, behind which there were population movements and cultural exchanges.

However, this hypothesis has not yet been systematically examined. This is because in Western China there is such a complex distribution of wild Caprinae and *Gazella* species, which all have similar skeletal morphology to domestic sheep (*Ovis aries*) and goats (*Capra hircus*), and are difficult to separate from each other based on fragmentary and eroded archaeological remains. This project carries out a systematic osteoscopic and osteometric study of the Caprinae and *Gazella* in Western China and different *Ovis* species in Eurasia by examining a large quantity of the modern specimens. Systematic differences in correlating elements between these species were found to be related to the ecology of the animals. These criteria were applied to the archaeological specimens from five sites in Western China from Epipaleolithic era (c. 10,000 BP) to the Bronze Age (c. 3500 BP). Together with other methods, a process of transition from the local wild Caprinae hunting to the adoption of sheep husbandry was discovered. There might be complex interactions between the different animals and humans in the unique ecological and social contexts.

Declaration of Original Research and Intent

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except where specifically indicated in the text.

No part of this thesis has been submitted for any other qualification.

Statement of Length

The length of this dissertation does not exceed the 80,000-word limit set by the Degree Committee for the Department of Archaeology and Anthropology

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1. Introduction

This chapter introduces the research questions and objectives. An outline of the whole dissertation is given at the end.

1.1 Research Questions and Aims

For about 99% of the human history, we were hunter-gatherers. Our lives were mobile, and survival was based on the collecting of wild plants and animal protein for energy. Only since the beginning of the Holocene at around 12,000 years ago, people began to live a sedentary lifestyle and agriculture started, which is one of the most profound developments in human history. In the words of Gordon Childe, it is like a revolution for human beings (Childe 1928). It radically modified both the natural environment and human society, allowed people to settle down, increased the amount and reliability of the food supply and opened up new pathways to economic and social complexity (Barker 2006). Nowadays, a relatively restricted range of crops and livestock support the population in most parts of the world, and enormous areas of previous forests, steppes, and other uncultivated lands have been occupied by the domestic crops and animals. The study of the origins and spread of agriculture has long been a major topic in prehistoric archaeology, as a focus of both field and laboratory research in archaeology.

A number of explanatory models have been built to interpret this process (Bar-Yosef and Belfer-Cohen 1992; Bender 1978; Binford 1968; Cohen 1977; Hodder 1990), and different methodologies were applied to detect the nature of this transition. The research in this dissertation attempts to explore one episode of the story in the origins of agriculture from the perspective of zooarchaeology.

1.1.1 Spread of Agriculture and Prehistoric Cultural Exchange in Eurasia

Long-standing questions in archaeology and anthropology have been whether the origins of agriculture were single or multi-centred phenomena and whether the subsistence

practices based on domestic taxa over vast areas reflect several independent domestication practices, indigenous adoptions, colonisations, or a combination of these (Meadow 1996). The concept of the 'centre' of the origin of domestication started with Vavilov, who argued that the centres of modern varietal diversity were also likely to be the home of primaeval agriculture (Vavilov 1926). It is now generally accepted that agriculture originated independently in several 'nuclear' centres and then spread to other parts of the world (Bellwood 2005).

Both primary centres of origins of agriculture and ancient civilizations, Southwest Asia and China are located in different parts of Eurasia and developed different suites of domestic plants and animals in the early stage of agriculture, depending on the species locally available and probably also influenced by the local cultures. In Southwest Asia, people domesticated barley, wheat, dogs, pigs, cattle, goats, and sheep; in China, millet, dogs and pigs were domesticated in the North, while rice and pigs were domesticated in the South (Conolly et al. 2011; Davis 1987; Yan 1989; Zeist and Bottema 1991; Zohary et al. 2012). It is clear that some domestication began independently at the different places, but all started soon after the Holocene. The agriculture developed in one region then spread to the adjacent neighbouring areas, such as from Southwest Asia to Europe (Zohary et al. 2012).

Scholars' interests have, thus, arisen in investigating whether there were early communications between the different early centres of agriculture and influence on one from another (Boivin et al. 2012; Jones et al. 2011). It seems that early communications are likely to have existed, but the nature and the exact times of the process are complex, as shown by the study of millet (Hunt et al. 2008; Hunt et al. 2011; Motuzaitė-Matuzevičiūtė et al. 2013) and bread wheat (Flad et al. 2010).

1.1.2 Sheep, Goats, and Human Beings

Except for dogs, sheep and goats are the earliest mammals that were domesticated by humans in the world, approximately dated from the middle of the eleventh millennium

BP1 firstly in Southeastern Anatolia, Turkey (Peters et al. 2005; Peters et al. 2014; Vigne 2008, 2011). They are still important animals in modern human societies globally. Like many other domestic animals, they are utilised by people for meat, wool, and milk. In some places, there is a value in their skins and manure as well (Ponting 1980). At the same time, people have modified their own behaviours and ways of life to get along with the breeds. The association between humans and sheep/goats has become one of the closest among existing species.

1.1.3 Origins of Domestic Sheep and Goats and Their Spread in Eurasia

The current archaeological evidence points to Southwest Asia as the primary centre of origin of domestic sheep and goats (Chessa et al. 2009). Early domestication was likely to be a local phenomenon on the high slopes of the Taurus Mountains in the Northern Fertile Crescent, which coincides with the beginning of the cultivation of domestic cereals and legumes (Peters et al. 2005). The domestic sheep and goats were imported to the south to the Damascus region and Cyprus shortly after their origin (Tresset and Vigne 2011; Vigne 2008; Vigne et al. 2011). The local distribution and comparative rarity of pre-Neolithic caprine bones contrast with their great abundance and wide dispersal during the later Aceramic Neolithic, and their adoption and dispersal were very rapid once their domestication was achieved (Legge 1996).

There is evidence that the domestic sheep and goats were diffused across Europe along with other domestic animals like pigs and cattle following the Mediterranean and Danubian routes during the ninth to sixth millennia BP (Vigne et al. 2011), and were spread to North Africa by the eighth millennium BP (Wendorf and Schild 1998). Since there have been no distributions of the wild relatives of sheep and goats in the south and west of the Middle East, the sheep and goats in these regions chronologically later than in the Middle East should have been domesticated and spread there (Peters et al. 2014).

¹The majority of the dates are presented using the BP convention, meaning 'Before Present' (year 1950), which are calibrated radiocarbon dates unless otherwise noted.

There is less zooarchaeological research on the diffusion of domestic sheep and goats in East Asia compared with the west (Flad et al. 2007). Research based on mtDNA found that sheep from the Middle Eastern domestication centre might have migrated across the Caucasus and Central Asia, and arrived in China (Lv et al. 2015). Nevertheless, events of introgression of wild lineages should not be neglected, as indicated by analysing the whole mitochondrial genomes of goats (Colli et al. 2015). In Northeast Iran, wild as well as domestic sheep and goats (*Ovis aries*, *Ovis orientalis*, *Capra hircus*, *Capra aegagrus*) were identified from the Neolithic to the Iron Age periods (Francfort et al. 2014; Mashkour 2001, Mashkour et al. 1999; Monchot et al. 2005). Domestic sheep and goats were also identified at the Neolithic site Jari B at Southwest Iran (Mashkour et al. 2007), dated from the first half of the 8th millennium BP (Nishiaki 2010). In Central Asia², at the Neolithic site of Jeitun at Turkmenistan, sheep and goats were identified as domestic animals which were exploited for their meat as well as milk (Dobney and Jacques 2010).

The excavation and zooarchaeological investigation of the site of Mehrgarh in Pakistan suggested an alternative view on the origins of caprine domestication of the eastern side of the Middle East. The site lies in the Kachi District highland of Baluchistan where wild barley, sheep, goats, and cattle are still found. A continuous sequence of cultural development from before 8000 BP to ca. 4500 BP was revealed, and bones of *Bos*, *Ovis*, and *Capra* were securely identified since Period IA (8300-6000 BP). The sheep and cattle bones from Periods I and II were found to be larger than the contemporary materials from sites in the western part of the Middle East. Moreover, an overall gradual decrease in the size of these taxa was revealed, accompanied with an increasing representation in their frequency at the expense of wild fauna (gazelle/antelope). It was therefore interpreted as a sequence showing the local domestication of sheep and cattle, while domestic goats may have been adopted from the West (Meadow 1993; Meadow 1996). Nevertheless, the

² Central Asia: The borders of Central Asia are subject to multiple definitions. Here the delineation by UNESCO is followed, which includes Afghanistan, north-eastern Iran, Pakistan, northern India, Western China, Mongolia and the former Soviet Central Asian republics (Mayor, F. 1994).

domestic sheep might have been replaced later by the improved breeds from the West in the third millennium (Meadow 1989b), as suggested by the karyotypes of the modern domestic sheep ($2n = 54$) (Meadow 1991; Nadler et al. 1973 a,b).

1.1.4 Research Aim: the Beginnings of Sheep Husbandry in Western China

In China, Caprinae bones do not appear abundantly in archaeological sites until around 4000 BP, first numerous in the contexts of the Qijia culture in Gansu and Qinghai Province in Western China³ (see the review of Chapter 2), and then some Longshan culture contexts in the Central Plain⁴ (Figure 1.1). Since this time is much later than the earliest domestic sheep of Southwest Asia, it has been suggested that sheep and goats were not domesticated locally in China, but imported from the West (Flad et al. 2009; Flad et al. 2007; Yuan 2010).

³ Western China: western part of China. In political meaning it covers Chongqing municipality, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai provinces, and Tibet, Ningxia, Xinjiang autonomous region. It is characterised by vast region, sparse population, numerous minority nationalities, and undeveloped economic resources compared to other parts of China (Figure 1.2).

⁴ Central Plain or Zhongyuan in Chinese, is the area covers modern-day Henan, the southern part of Hebei, the southern part of Shanxi, and western part of Shandong Province. A broader interpretation of the Central Plain's extent would add the Guanzhong plain of Shaanxi, the northwestern part of Jiangsu, and parts of Anhui, and northern Hubei (Wikipedia. Zhongyuan. [online] Available at: <<https://en.wikipedia.org/wiki/Zhongyuan>> [Accessed 28 July 2015]).

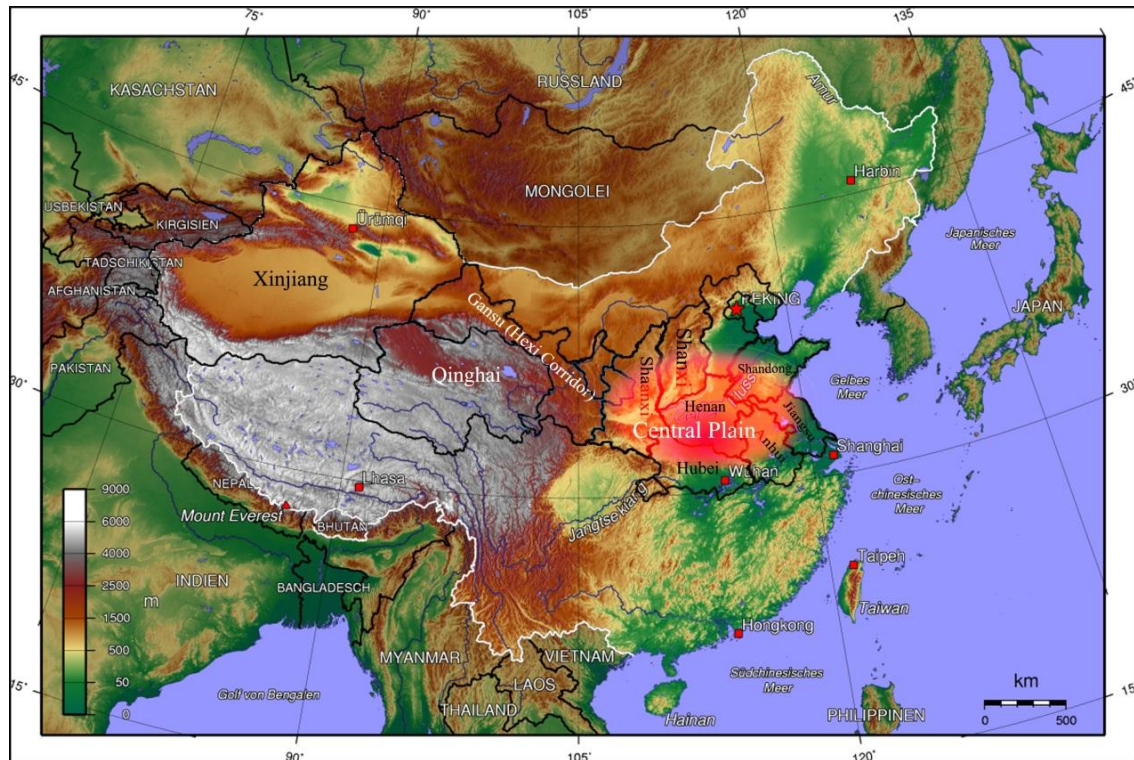


Figure 1.1 Map of China. The red circle indicates the range of the Central Plain in its broad term.

The Hexi Corridor⁵ in Gansu and the northeast margin of Qinghai (Figure 1.1) in Western China, placed at the transition zone of three major geographical and climatic zones, has long been found a route of interregional communication between the West and East for crops as well as other forms of technological exchange (Flad et al. 2007; Levine et al. 1999; Linduff and Mei 2009). Western China is also a region which lies within the natural distribution of wild sheep *Ovis ammon* (Argali) and many other Caprinae (e.g. *Pseudois*, *Nemorhaedus*, *Capricornis*, see Chapter 4 for details). Genetic research has indicated that *Ovis ammon* are not closely associated with the majority of modern domestic sheep lineages (e.g. Meadows et al. 2011), but reports also suggest that

⁵ Hexi Corridor: or Gansu Corridor; is location coincides with current Gansu Province, refers to the historical route which was the most important route from North China to the Central Asia and traders and the military. (Wikipedia. Hexi Corridor. [online] Available at: https://en.wikipedia.org/wiki/Hexi_Corridor[Accessed 28 July 2015]).

introgressions between captured Argali and domestic sheep can occur in experimental conditions (Ma et al. 2009; R. Schafberg *pers. comm.* Aug. 2014). Moreover, among the sheep in Qinghai-Tibet plateau, the ‘Tibetan Type’ breeds appear to have a larger size, be more suitable for the high latitude, low temperature, and oxygen-deficient environment, different from those in the lowlands.



Figure 1.2 "Western China" (in red) in the map of China.

The foregoing statements lead to the following questions: As for the morphologically very similar Caprinae in this region, were they correctly distinguished from domestic sheep (*Ovis aries*) and goats (*Capra hircus*) in the past and is it possible at all? How were the wild Caprinae in this region exploited and how did that relate to how domestic sheep and goats were exploited? Whence was the domestic caprine brought in and if any, how did that happen? Whence was the Tibetan breed developed and does it relate to the local *Ovis ammon*? Could the methods in recognizing caprine domestication applied in other parts of the world also be successful in this region? It might not be possible to answer all

of these questions satisfactorily in this study, but efforts will be made to answer at least some of them. In brief, the aim of the research is to contribute to our understanding of the process of the early history of sheep and goat domestication in China.

1.2 Research Design and Structure of Dissertation

Chapter 2 presents a review of the current research background of sheep and goat domestication in China. Emphasis is placed on the region that has yielded most evidence so far and has shown relatively more importance --- Gansu and Qinghai Province. The methodologies that have been applied to detecting the domestication process of sheep and goats in the world are also summarised. The natural environment and archaeological settings of the research area are provided in Chapter 3. Information about the selected archaeological sites is also given here. Chapter 4 reviews the taxonomy, distributions, ecology, and habitats of the animals in subfamily Caprinae in the research region. The complexity of the *Ovis* and *Capra* taxonomy and their changes following domestication are discussed. Chapter 5 gives the materials and method protocol. Chapter 6 presents the study of the comparative osteomorphology and osteomorphometry of the Caprinae and *Gazella* related to this research based on the modern specimens. Chapter 7 displays the taxonomic identification of the archaeological materials of the subfamily Caprinae and *Gazella*. Chapter 8 discusses the general animal economy and process of sheep and goat domestication in the research area, overviewing the whole thesis and discusses its broader implications.

2. Research Background

This chapter reviews the approaches that have been successfully used to study caprine domestication in the world and current research on caprine domestication in China.

2.1 Approaches to Studying Animal Domestication

2.1.1 Concept of Domestication

In order to discuss the approaches and methods of studying animal domestication, it is necessary to first review the concept of animal domestication.

The domestication of plants and animals is nowadays widely accepted as an evolutionary continuum of interaction between people and the plants and animals they depend on for food and other products, and during this process, people began to decreasingly depend on wild plants and animals, and increasingly depend on domesticated plants and animals (Harris 1996). There are arguments whether it should be regarded as a 'revolutionary' event or a long-term 'evolutionary' process (Rindos 1984), although the consequences of this change were no-doubt revolutionary (Barker 2006). Those who view it as a 'revolution' have a tendency to assume that there are normative situations of dichotomies, in which the animals and plants be clearly distinguished as having either 'domestic' or 'wild' forms, and human societies could be separated as either hunter-gathers or farmers/pastoralists. To recognize animal domestication is just a matter of identifying the presence of domestic animals at a site (Meadow 1989a). From another perspective, the transformation to full food production was very gradual. It may be viewed as a continuum of relationships stretching from random hunting through intentional game-cropping, herd-following, animal-penning, and pet-keeping to the breeding of genetically isolated 'domestic' stock (Hecker 1982; Higgs and Jarman 1969; Jarman and Wilkinson 1972). On the one hand, there might be no discontinuity in human-animal relationships to be expected between pre-pastoral and pastoral societies. On the other hand, there are diverse forms of human-plant and human-animal relationships which are far too

complex to be explained in terms of an elementary dichotomy as either ‘wild’ or ‘domestic’.

Inconsistency and inadequacy in the general criteria used to distinguish prehistoric wild and domestic animals have long been recognized (Jarman and Wilkinson 1972). As has been described by many authors (e.g. Vigne 2011; Zeder et al. 2016), there are multiple pathways to animal domestication. Some animals, such as reindeer, were found to have a relationship with humans via protective herding and taming (Ingold 1980; Sturdy 1972). It is difficult to conceptualize this either as ‘domestic’ or ‘wild’. Even if the deer herds were intentionally protected, moved, and culled by humans, they were not so intensively controlled for breeding and had their products exploited as the other typical domestic animals. In fact, even among the ‘typical’ domestic animals, there are different types of relationships between animals and people. For example, dogs act as companions and friends of humans, while sheep, goats, and cattle were mostly raised for their economic products such as milk, meat, and (in the case of sheep) wool etc. Domestication may include many specific forms of exploitation and management (intensive, extensive, specialized, generalised), and it is probably more useful to describe the specific characteristics of exploitation systems rather than lump them all under one term.

Furthermore, from the perspective of genetics and evolutionary biology, domestication can be viewed as an evolutionary process of selection on animals and plants for specific behavioural features promoting adaptation to the new factor, humans. Experiments on a variety of mammals, birds, and fish found that similar behavioural and morphological changes occurred when the species were domesticated (Arbuckle 2005). These changes include, for instance, a decrease in aggressive behaviour, a decline in reactivity to environmental stimuli when subject to the process of domestication, reduced brain weight, reduction in sensory systems (e.g. ear bones and eye weight), and reduction in limb structures. These widely observed ‘domestic traits’ on different animals may be significant since these indicate that animals could have been subjected to similar selective pressure and environmental stimuli when they were domesticated, under which

phenotypes of animals were affected in similar ways. In fact, most of these ‘domestic traits’ seem to be related to paedomorphy --- retentions or emergence of juvenile characteristics in an adult organism, and ‘feminization’--- morphology of domesticated adult males became somewhat more like those of females (Trut 1999), both of which are shifts in the rates of certain ontogenetic processes changes that make the animals tamer than the previous generation. In other words, domestication of animals may have triggered profound changes in the mechanisms which regulate the development of the body in response to the selection for tameness in the younger generation (Price 1984; Trut et al. 2004). This theory may be of particular interest to zooarchaeological studies since exploitation conditions might be predicted when the morphology of the animal skeletons was found altered compared to that of the earlier times.

Finally, domestication may also be comprehended in a social and symbolic sense. According to Hodder (1990), it was the conceptual change from the ‘wild’ to ‘domestic’ in the ideological world during Neolithic Revolution that made people continually bring wild plants and animals into a closer relationship to humans, leading animals and plants ultimately to the genetic change. *Domus* – a metaphor as a safe haven which provides warmth and security, a conceptual unit opposed to the wild, the dangerous and the unsocial, and a locus for food production was emphasized as the major agent promoting the process (Bogucki 1992). The adoption of more intensive food production techniques led to growing concerns for property and its maintenance through time and accumulation of the materials, which in turn ensnared people within social and economic structures that they came to depend on (Hodder 1990). In this sense, people domesticated themselves with their internalized desire for the control of individualistic, unsocial, and wild behaviours.

2.1.2 Zooarchaeological Approaches

The criteria in recognizing animal domestication in zooarchaeology have been extensively discussed (Bökönyi 1969, 1989; Davis 1987; Meadow 1989a; Vigne et al. 2005; Zeder 2006). Different methods are reviewed below, although it has long been

suggested that no single line of evidence can be relied upon as the only means to identify domestication and all these methods suffer from limitations (Legge 1996). Since the roles of the different domestic animals in human societies are different, the ways of recognizing their domestication process are also different. They can be grouped into two main categories: herd animals and house animals, with dogs different from both (Reitz and Wing 2008). In the following section, the focus will be placed on the approaches that are most applicable to the study of caprine domestication.

2.1.2.1 Taxonomy Frequency (Species Spectrum)

If there is a change within an archaeofauna sequence showing a shift from an earlier spectrum which includes many animals not known to have ever been domesticated to a later spectrum which includes ‘pro-domesticates’ could reflect an economic shift from hunting to husbandry. In the Old World, the ‘pro-domesticates’ include animals such as sheep, cattle, pigs, dogs. This method, however, is based on two assumptions: 1) As opportunists, the Pleistocene people exploited any large mammals they could get, hence a complete spectrum of larger mammals (except excessively large and ferocious species) in the local environment at that time should be represented in animal bones; 2) The animals first domesticated were the same as the domestic animals today (Davis 1987).

The limitation of this method is that it depends on recognizing a change within an archaeofaunal sequence, which is best established at a site with a continuous archaeological record. However, it is usually not easy to find such a case. Alternatively, it could be conducted at a series of sites of one region, which should be derived from a limited geographical area in order to eliminate the possibility of geographical variation (Davis 1987; Legge 1996).

2.1.2.2 Zoogeographic Evidence (the Introduction of a New Species)

If the domesticated species appears in a region which has no wild ancestors in that particular place, especially since the Pleistocene, it may be used as evidence for the introduction of that domestic species. But the limitation is that sometimes the presence of

the wild ancestors in a particular region in prehistory is arguable, such as in the case of sheep and goats in the Middle East (Uerpmann 1987).

A case in point of recognizing domestication using taxonomic frequency and zoogeographic evidence is the study in Tell Abu Hureyra, a site in Syria with a continuous sequence from Mesolithic to Neolithic, ranging from 11,500 BP to 7000 BP, which illustrates the transition from a hunting-gathering society to an agricultural-based one. The earliest caprine bones were identified in Mesolithic levels which were all diagnosed as sheep (*Ovis*) and none from goat (*Capra*). The natural setting (at the junction of the Euphrates floodplain and undulating steppe) also supports the thesis that goats were not the local fauna but sheep were. In these levels, gazelles are the most abundant, followed by onager, with caprines accounting for only about six percent. Other faunas include a small number of deer, cattle, and pig. Starting from the early aceramic levels, caprine bones increased to about 12-14 percent. In addition, the first bones of goats were identified. In the later aceramic level, caprine bones quickly increased to 65-75 percent of the fauna while gazelles rapidly declined. Such evidence of the growing proportion of caprines at the expense of gazelle was interpreted as the reduced hunting of gazelle as a result of over-exploitation, replaced by the domestication of caprines. Especially, the presence of goat as a new species in the early aceramic level was interpreted as an introduction of goat as a domestic population, while sheep were probably independently domesticated from the local fauna. This transition happened at about 8300 BP (Legge and Rowley-Conwy 2000). The interpretation of the change in human-animal relationship from the zooarchaeological evidence was supported by the other lines of evidence such as artefacts, buildings, burials, change of the overall settlement structures, and plant food remains.

2.1.2.3 Demographic Evidence (Population Structure: Mortality Profiles and Sex Ratios)

The population structure of a domestic herd is different from that normally found in wild populations since the domestic herd is manipulated by people in order to be maintained easily and provide products such as milk, meat, or wool (Davis 1987). There

are studies examining the mortality profiles of the herds for which different purpose they are raised (e.g. Payne 1973; 1987). However, it is difficult to depict a ‘normal’ wild population structure resulting from hunting (Stiner 1990). The major difference of a domestic herd from the wild one might be that there is a selective slaughter of the sub-adult males and conservation of females (Zeder 2005). If such a pattern can be observed by means of examining the teeth or post-cranial skeleton, it might be used to demonstrate domestication. One limitation of this method is that it requires sufficiently large and chronologically homogeneous samples (Davis 1987). However, there are contradictory opinions on the usefulness of this approach in detecting early domestication. Zeder (2005) suggests that sex-specific demographic profiles could provide clear evidence of herd management predating the detectable morphological changes happening in animal populations, whereas a more recent survey in Neolithic Southwest Asia found that clear evidence for young male kill-off appeared considerably later than the earliest caprine management, and the early management strategies were varied (Arbuckle and Atici 2013).

2.1.2.4 Morphological and Body Size Change

Morphological and body size change is another area that must be considered. Although body size reduction could actually be regarded as one aspect of morphological change, it was traditionally used as the main criterion in the identification of domestication. It has been widely observed that size diminution occurred in several major domestic species at their early stage of domestication, such as in sheep and goats (Legge and Rowley-Conwy 2000; Meadow 1984, 1993; Peters et al. 2014; Uerpmann 1978, 1979), *Canis* (Davis 1981; Turnbull and Reed 1974), *Bos* (Davis 1981; Meadow 1984; Peters et al. 2014), and *Sus* (Davis 1981; Wing 1978), which were found in the areas of the Near East, Northwest South Asia, Europe, and South America. Other phenotypic manifestations due to domestication include the changes in the horn cores of sheep and goats (Meadow 1989b), brain size reduction and diminution of ear bones (Arbuckle 2005), and snout shortening, tooth crowding and tooth length reduction (Albarella 2002; Ervynck et al. 2002; Morey 1994).

Different explanations were provided for these phenomena. As for the size change, according to Boessneck and von den Driesch (1978), early people may have preferred larger numbers of smaller and probably, therefore, more easily managed animals, whilst Widdowson and McCance (1975) claim that malnutrition stemming from overgrazing could lead to the smaller adult size. Belyev and collaborators found that body size reduction and other aspects in morphological change in some large mammal taxa, such as *Canis*, *Sus* and bovids, were probably associated with the selection in domestication that aimed at less aggressive behaviours towards humans (Trut 1999), but also could be a spontaneous morphogenetical response to the special anthropogenic milieu (Tchernov and Horwitz 1991).

It has also been argued that body size diminution can be attributed to other factors other than domestication, such as different environmental conditions (Vigne et al. 2005; Zeder 2006). According to Ducos (1991), Helmer (1989), and Zeder (2001, 2005), changes in kill-off patterns actually contributed more to the overall size diminution of a population than the individual size reduction. In addition, unlike the rapid changes revealed in the fox domestication experiment of Belyev, the morphological alterations in the early stage of domestication were probably very progressive and slow, as shown by the case of pig domestication in the high Tigris basin (Çayönü Hongo et al 2009), goat domestication in the Zagros Mountains (Zeder 2006), and sheep, goat, and pig domestication in Cyprus (Vigne 2013). The transition to domestication may have followed an unstable and opportunistic trajectory (Vigne 2015).

Slight morphological changes at the very beginning of domestication could be difficult to detect and measure using classical osteoscopic and osteometric techniques (Evin et al. 2013; Vigne 2015), but may be better revealed by sophisticated geometric morphometrics (GMM), which successfully integrate biology into zooarchaeological studies (Cucchi 2015; Vigne 2015). With its different technical approaches --- landmarks, outlines, sliding semi-landmarks, 3D surface (Bookstein 1991), GMM was found to be successful in the identification of anatomical features of animal remains at intraspecific

level, and the detection of morphological modifications related to intrinsic (genetic, ontogenetic) and extrinsic (geography, climate, diseases, foods, etc) factors within a species (Cucchi 2015). In archaeozoology, GMM has helped to find out the introduction and dispersal of house mouse to Cyprus (Cucchi et al. 2002), to the Western Mediterranean (Valenzuela-Lamas et al. 2011), and regional differentiation of horse (Seetah et al. 2014).

With the development of mathematical and statistical processing, traditional morphometric techniques have also made progress in refining the results of detecting more detailed information, including increasing the linearity of the relations between the variables and the homogeneity of the variances (Bookstein 1991). This allows two components of form, size and shape, to be studied separately (Bookstein 1991), and comparison between different samples coming from dimorphic species using Gaussian mixture analyses (Vigne 2011). Since the application of GMM in zooarchaeology is limited, which partly result from the sophistication of its full application and fragmentation of the archaeological materials (Vigne et al. 2007), it has been recommended that GMM should be used to complement other than to replace traditional morphometric techniques (Evin et al. 2014; Vigne 2015).

2.1.3 Stable Isotope Research

Stable isotopic analysis of animal skeletal tissues can provide a direct measure of dietary intake and environmental inputs that document changes in diet and mobility of animals (Makarewicz and Sealy 2015). Since it has been amply documented that animals kept under cultural control had a dietary spectrum different from their free-ranging relatives (e.g. L \ddot{o} sch et al. 2006), stable isotopic studies are able to help distinguish between the diets of wild and husbanded animals (L \ddot{o} sch et al. 2006).

Recently, there is a trend to combine stable isotope biochemistry and zooarchaeological study in a cohesive research design, and it has been used to explore the most enduring questions including those related to the transition from hunting and

gathering to food production and the spread of this process across Eurasia (Birch 2013). Nevertheless, care needs to be taken in distinguishing human-related dietary shifts from those environmental-based ones, because isotopic signatures also vary in relation to local environmental conditions (Vigne et al. 2005). It has been advised that results derived from this technique alone should not be used as a definite marker of initial domestication (Zeder 2006), and a valid interpretation of stable isotope ratios in respect of palaeodiet has to be based on comparative analysis of human and animal bone finds from the same contexts or the same restricted geographical and ecological defined area (Grupe et al. 2003). A reconstruction of the food web by analysing as many food resources as possible in the site is required in order to interpret palaeodiet in relation to domestication (Grupe et al. 2003).

This technique still needs to be improved, since currently the relationship between metabolic pathways and the isotope values of consumer tissues is still not completely solved, and it is still challenging to clearly distinguish the energy and protein foods with different carbon isotopic compositions (Makarewicz and Sealy 2015).

2.1.4 Genetics

The relationships between domesticates and their wild ancestors, and between the ‘domestic traits’ and their underlying genetic architecture, have been increasingly decoded through the advance of genetic research (Larson et al. 2014). The different genetic techniques have provided fascinating aspects in interpreting the early steps of animal domestication. However, any work about genetics is almost automatically out of date by the time of writing. The discussion presented below should not be used to compromise the findings of any other work.

Different techniques and their use

To trace the evolutionary ancestry of domesticates, geneticists focus on neutrally evolving, non-coding loci and organellar genomes, among which the commonly used markers for animal domestication include nuclear, mitochondrial, and Y-chromosome genome, and noncoding nuclear microsatellite DNA (Zeder et al. 2006).

Mitochondrial DNA (mtDNA) and Y-chromosomes provide the matrilineal and patrilineal history respectively. Since mtDNA has a much greater mutation rate than in the nuclear genome, has multiple copies, and lacks recombination, mtDNA has been widely used for studying the divergence between wild and domestic populations and to infer the likely progenitors of the domestic species under the relatively short timescale of domestication (MacHugh and Bradley 2001). Incorporation of geographic information of the samples allows further biogeographic or phylogeographic analysis, which can discern the likely centre(s) of domestication (Bradley 2006).

Microsatellite DNA, contributed by both parents, has proven useful in the investigation of the genetic structure of domestic breeds of animals (Leroy et al. 2015). In addition, endogenous retroviruses have also been proved useful as genetic markers to detect the diversity of the domestic animal populations and trace their dispersal history (Chessa et al. 2009).

Recent advances

The non-recombining mtDNA and Y chromosome have some drawbacks in revealing the evolutionary history of domestic animals. As independent genetic loci in the genome, a single marker can only reflect a small part of past demographies (Larson and Burger 2013). With the advance of genotyping and re-sequencing technologies, recent research has focused on genome-wide association studies (Wang et al. 2014), which involve the rapid scanning of the markers across the complete sets of genomes to find genetic variations associated with domestication traits. SNPs (Single Nucleotide Polymorphisms), an abundant form of genome variation, are distinguished from the rare variations of the previously used markers and have become a focus of recent research. With the whole-genome sequencing project, large number SNPs have been discovered. While mtDNA can be replaced rapidly during a hybridization process between migrating and resident populations, the nuclear genome will retain introgression signatures over longer evolutionary timescales (Larson and Burger 2013). As the availability of genome-wide sequence data for domesticated species increases, it has become increasingly feasible to

identify between-breed differentiation and genomic regions that have been targets of selection during domestication (Larson et al. 2014; Rubin et al. 2010; Wang et al. 2014; Wiener and Wilkinson 2011).

Many SNPs have been identified that associate with diverse traits (Wang et al. 2014). These genome and SNP data provide an unparalleled opportunity for the researchers to explore the molecular mechanisms involved in morphological and behavioural traits within individual genomes in domesticated animals under selection (Karlsson and Lindblad-Toh 2008; Karlsson et al. 2007; Marsden et al. 2016; Gouveia et al. 2014; Wiener and Wilkinson 2011). The identification of ‘domestication genes’ in animals enabled the detection of the causative mutations for several monogenic traits, such as those for coat colour (Ponsuksili et al. 2011) and dwarfism (Orr et al. 2010). Through the development of sequencing technologies and assembly tools, additional genomes from various domesticated animals and their closely related wild relatives and even wild ancestors can be known (Wang et al. 2014).

Ancient DNA

It has been increasingly realized that the analysis of ancient DNA is a critical direction of future study (Larson et al. 2014; Zeder et al. 2006). The pictures shown through modern population genetics on the early steps of domestication are incomplete and sometimes biased (Asplund et al. 2010; Flink et al. 2014), since the long-term gene flow within and between wild and domestic populations and intensive breeding practices may have resulted in modern populations bearing ambiguous resemblance to their early progenitors (Larson et al. 2012). Nevertheless, ancient DNA extractions and amplifications are facing challenges of DNA degradation during fossilization and laboratory-based contamination (Rizzi et al. 2012). Current ancient DNA studies have been mostly focused on mtDNA (e.g. Beja-Pereira et al. 2006; Leonard et al. 2002) and not many other markers. Therefore, although informative, the power of these studies so far to infer the complex demographics of domestication is still limited, and larger ancient genomic analysis holds great promise for the study of the history of domestic animals

(Larson and Burger 2013).

Attention points

One thing that needs particular attention is the interpretation and use of the term ‘domestication’. Larson et al. (2014) proposed that “domestication” should be reserved only for the initial independent process, and not to refer to the subsequent admixtures that incorporated genetic and morphological characteristics of wild local populations, even though they also formed important parts of the ongoing domestication phenomenon (Larson and Burger 2013; Marshall et al. 2014). Nevertheless, the slow pace of domestication and the long period before fully biologically modified domesticated cereals and animals appeared (Brown et al. 2009; Fuller et al. 2011; Vigne et al. 2009; Vigne et al. 2011), together with the considerable gene flow between wild and early managed animals (Larson and Burger 2013), has been widely recognized. This has led to increased scepticism about the traditional models of rapid transition to domestication and when exactly to call archaeological remains ‘domesticated’ (Larson et al. 2014; Vigne 2015).

2.2 Current Research Status of Caprine Domestication in China

Academic interest in the question of the origins of domestic sheep/goats in China has been in a trend of development. In the following section, the current research status from zooarchaeological and genetic studies will be reviewed. There is also some discussion of this topic from the ethnic anthropological perspective.

2.2.1 Zooarchaeology

Just as correctly pointed out by Flad et al. (2007), most archaeological work in China in the last few decades has failed to systematically collect and analyse faunal data to allow for rigorous examination of animal domestication from the various lines of zooarchaeological approaches, although this has been gradually changing in recent years. The following section reviews the corpus of published material relating to early caprines

and their domestication in China. Since the existing archaeological data point to the Upper Yellow River Valley in Gansu and Qinghai as the most critical region in containing the earliest and most abundant Caprinae remains in China (Figure 2.1), the data in this region will be presented in detail. The details of the data of the Caprinae evidence in other parts of China are provided in Appendix A. The cultural sequence and the chronology are shown in Figure 2.2.

By the Zhou Dynasty (3046-2771BP), sheep/goats (Chinese: Yang 羊) was regarded as one of the six major domestic animals of people as recorded in Zhou Li literature 周禮 (Sun 1987) and was used for sacrifice for the ritual ceremony. The sheep bones excavated from Yinxu (殷墟), and Anyang (3600-3100 BP), the capital of the Shang Dynasty, were identified by De Chardin and Yang (1936) as surely domestic sheep of typical Shang breed and were named as *Ovis* Shang. The goats from there were identified as *Capra* sp. Hence the archaeological evidence of sheep/goats is reviewed from the Paleolithic to the Bronze Age (9000-3000 BP). The chronology and geographical regions of major Chinese archaeological cultures are presented in Figure 2.2.

Fossils of *Ovis* were found in many Paleolithic sites in North China (Qi 1989), indicating that the wild Argali sheep were hunted by people (Xie 1985). Among the sites dating to 8000-6000 BP, only very few caprine bones have been reported in North China, and the taxonomy status is doubtful (Flad et al. 2007; Luo 2009; Zhou 1984), let alone the domestication status. In the Northwest, there were hardly any bones identified to sheep/goats, including Layihai (拉乙亥) (ca. 7000-6500 BP) (Gai and Wang 1983) in Qinghai-Tibet Plateau and Dadiwan (大地湾) at the mid-upper range of Yellow River Valley on the western part of the Loess Plateau. Dadiwan contains a continuous archaeological sequence from the early to the late period (7800-4900 BP) and represents a millet-based agricultural society. Although two bone artefacts were reported as made from caprine bones and one specimen was suggested *Ovis ammon* in the second phase (Qi et al. 2006), the taxonomic status is doubted here. A close examination of the picture of the 'Ovis' horn core specimen in the report indicates that it was a Bos (Qi et al. 2006: Plate

302: 1). Also, in a Chinese paper by the then leader of the archaeology team (Lang and Cheng 2002) of Dadiwan, more than ten juvenile sheep/goat skulls in an ash pit from the first phase (7800-7350 BP) were claimed as identified by Professor Lamberg-Karlovsky of Harvard University. However, Professor Lamberg informed me through a personal communication that he was simply curious whether there were sheep/goat remains and he did not actually identify the materials.

In contrast to Xie (1985), who proposed that sheep in China were domesticated based on the wild Argali, there have long been suggestions that sheep and goats were brought into China from the Northwest. For example, Epstein (1969) suggested that Chinese sheep were not evolved from local *Ovis*, but more likely were imported from Inner Mongolia and Tibet. In recent years, Flad et al. (2009) suggest that domestic sheep might have first appeared in Majiayao (马家窑) cultural contexts as early as 5600 BP in Gansu and Qinghai provinces. They cited the archaeological report that in Shizhaocun (师赵村), Gansu province, a sheep/goat mandible was found buried in the tomb of an adult male (1999); in Hetaozhuang (核桃庄), Minghe county, Qinghai province, sheep/goat skeletons and pig skulls were discovered in the tomb (ATQP 1979); in ash pits of the Shilingxia (石岭下) cultural complex at Fujiamen (傅家门) site, several sheep/goat scapulae and pelvis were discovered made into oracle bones (IACASS 1995; Xie and Zhao 2006). Although some of these sites contain multiple archaeological sequences, those remains were found from the Majiayao (马家窑) cultural phase, which should be earlier than 5000 BP according to the relative archaeological culture sequence. Another Majiayao culture site reported with sheep/goat remains is Linjia (林家) in Gansu (ca. 4900-4700 BP), where the bones were discovered together with other materials including millets, barley, and a bronze knife (GPCRT et al. 1984). However, these data are from the previous archaeological reports in which no direct radiocarbon dates of these specimens were available. Furthermore, there is no scientific nomenclature of the species identified, and the caprine remains were just presented as ‘Yang’ (羊) in Chinese, which can mean any goat-like animals including several locally-existing wild Caprinae species.

Mogou (磨沟) is another important site in Gansu province excavated in 2010 and contains probably hundreds of sheep/goat bones according to my rough examination of the materials in 2012. But the assemblages belong to two time periods - Majiayao (ca. 5000 BP) and Qijia (ca. 4000 BP). It was not certain from which context the materials were, and the exact taxonomic status of those caprine remains unclear.

The abundance of caprine remains increased significantly at about 4000 BP in Qijia (齐家) cultural contexts in Gansu and Qinghai province, and also in the North China Plain. Securely identified *Capra hircus* was reported at this period in Erlitou (二里头), Henan (Yang 2006) and Zhukaigou (朱开沟) in Inner Mongolia (Huang 1996). Again many of those from Gansu and Qinghai seem to be related to ritual significance. In the cemeteries of Qinweijia (秦魏家) (ca. 4250-4000 BP), 50 caprine mandibles were found, second to pigs and followed by cattle and interpreted as domestic sheep without further evidence (GTIACASS 1975). In Dahezhuang (大何庄), which is also around 4000 BP, 56 caprine bones were identified, and 14 of them are mandibles buried in the tomb while the rest are found in ash pits (GTIACASS 1974). In both sites, caprine scapulae were found made into oracle bones with burning and drilling marks. In Huangniangniangtai (皇娘娘台), oracle bones made from sheep were buried in the tomb (MGP 1978; Zhang 1987). Moreover, in the Qijia context of Shizhaocun (continuing to the Majiayao phase), caprines were also found in large amounts, and it was believed that they were domestic sheep (IACASS 1999). However, again in these cases only the Chinese character 'Yang' is presented for taxonomic identification but were directly interpreted as sheep.

Developed later than Qijia, the Siba culture (3900-3400 BP) in the middle and west of the Hexi corridor, Kayue (3600-2800 BP) and Xindian culture (3600-2600 BP) in the west part, and the Shajing culture (3000-2500 BP). They were reported containing large amounts of caprine bones, and the ratio of caprine to pigs became larger than Qijia

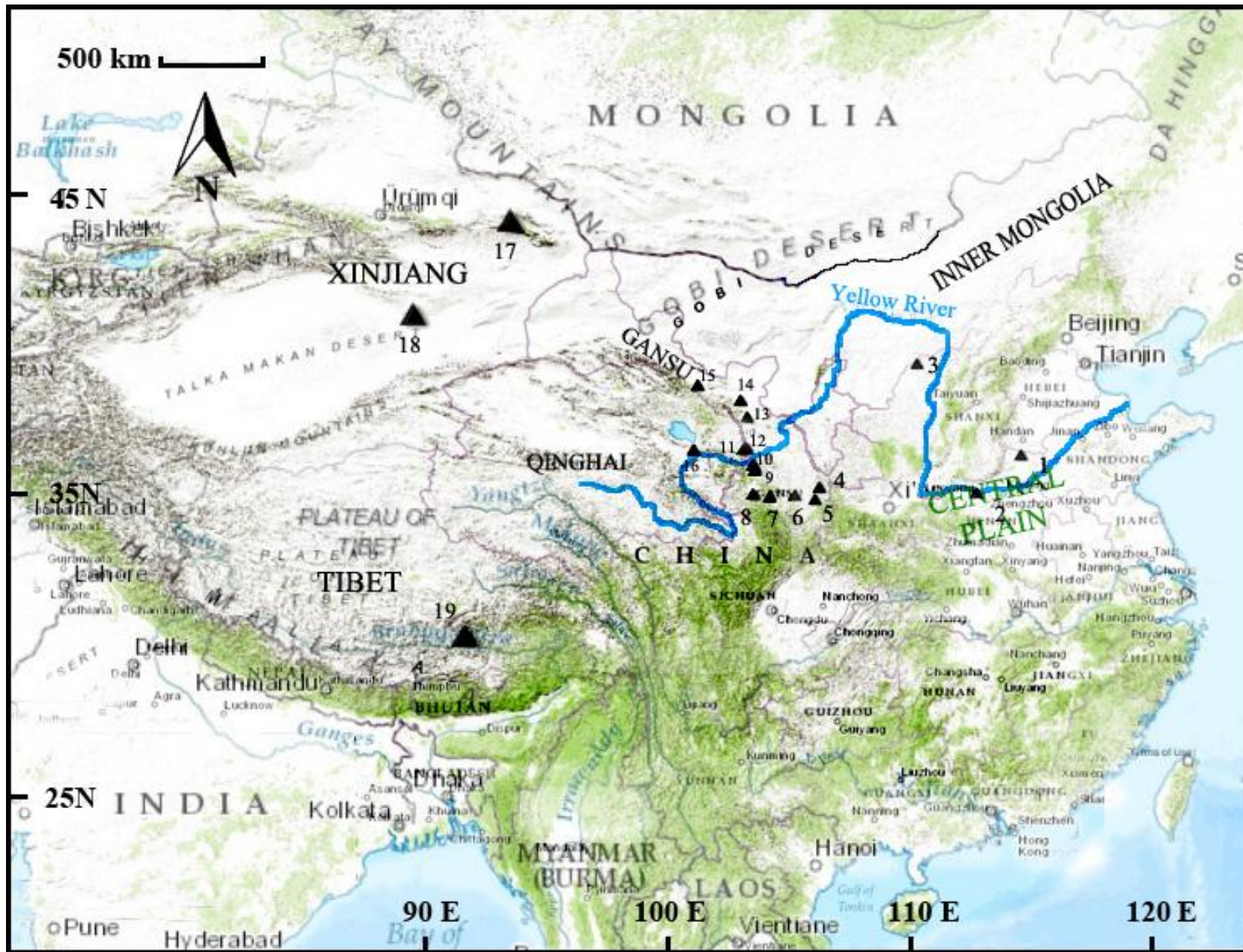


Figure 2.1 Map of China showing principal regions and sites mentioned in Chapter 2. 1. Yinxu (殷墟); 2. Erlitou (二里头); 3. Zhukaigou (朱开沟); 4. Dadiwan (大地湾); 5. Shizhaocun (师赵村); 6. Fujiamen (傅家门); 7. Mogou (磨沟); 8. Dahezhuang (大何庄); 9. Linjia (林家); 10. Qi nweijia (秦魏家); 11. H Hetaozhuang (核桃庄); 12. Xiahaishi (下海石); 13. Huoshaogou (火烧沟); 14. Huangniangniangtai (皇娘娘台); 15. Donghuishan (东灰山); 16. Layihai (拉乙亥); 17. Balikun (巴里坤); 18. Kongque River (孔雀河); 19. Qugong (曲贡).

(Yan 1998). In Huoshaogou (火烧沟) (around 3600 BP), a significant amount of caprine bones was found buried in the tomb as tomb goods (personal communication with the investigator Prof. Yunping Huang and examination of the materials). In Donghuishan (东灰山) (3720-3600 BP), sheep remains were also identified (presented as *Ovis* sp.) (Qi 1998). In Xiahaishi (下海石), Honggu (红古) (about 3500 BP), sheep and pig bones were found in the pottery vessels in the tombs (IARGP 2008).

Elsewhere in China, Tibetan sites began to have sheep bones since about 4000 BP, starting with Qugong (曲贡) (Zhou 1999), the sheep there were recognised as Tibetan domestic sheep based on the large dimensions indicated by metric data. Xinjiang sites did not begin to contain sheep bones until 3900 BP in the tombs of the Kongque River (孔雀河) and Balikun (巴里坤) (Han 2007; Wang 1983), and after 3600 BP sheep remains became numerous and should be related to the nomad people from central Asia as suggested by other material culture (Chang 1985; Huang and Dai 1986; Yang 1982). In Southeast China, it seems that domestic caprine was imported into this region only since the Shang Dynasty (Wu and Luo 2008).

Date (BP)	Chronology	Gansu & Qinghai	Central plain	Shandong	Xinjiang	Inner Mongolia	Tibet
9000	Early Neolithic	Laoguantai culture	Cishan culture	Beixin culture			
8000							
7000							
6000	Late Neolithic		Yangshao culture	Dawenkou culture			
5000							
4000	Chalcolithic	Majiayao culture (including successfully Shilingxia style, Majiayao style, Banshan style, Machang style)	Longshan culture	Longshan culture			Karoo culture
		Qijia culture					
3000	Bronze Age	Siba culture	Erlitou culture	Yueshi culture	Bronze Age culture	Zhukaigou culture	Qugong culture
		Kayue/Xindian/Siwa culture					

Figure 2.1 Major Chinese archaeological cultures from Neolithic to Bronze Age in Northern and Western part of China (converted from Li 1990; Yan 1987).

2.2.2 Stable Isotopes

Up to now, not many stable isotopic studies have been conducted on sheep and goat

remains before 4500 BP, probably due to the scarcity of the materials and the difficulty in taxonomic identification (See section 2.3.1). But a few exceptional cases also exist. The research conducted by Dodson et al. (2014) secured the taxonomic status of the sample as *Ovis* from the cultural context equivalent to the Zhukaigou culture (the bone was directly dated to cal.4292–4029 BP using DNA sequencing at North Shaanxi Province of China. $\delta^{13}\text{C}$ values indicate the sheep had a diet based mainly on C3 plants but are also close to the boundary of diets based on C3 and C4 plants (Dodson et al. 2014). Two samples at Wayaogou (ca 6500–6000 BP) were identified as ovicaprid and were found to have $\delta^{13}\text{C}$ values showing a mixed C3/C4 diet, although with more C4 grasses being consumed than C3 plants (Chen et al. 2016). Caprine samples later than 4500BP and before 1600 BP (Longshan period~Xia Dynasty) from the central plain (Dai et al. 2015), Wei River Valley (Chen et al. 2016), west Loess Plateau (Ma et al. 2015), and Hexi corridor (Atahan et al. 2011) are mostly identified as sheep rather than goat, and also showed a mixed C3/C4 diet. It was suggested that the sheep likely mainly had grazed on grassland.

In North China, where the millets are the C4 plants featured with high $\delta^{13}\text{C}$ values, heavy millet consumers will stand out by their elevated C4 signature. Many studies were hence carried out to interpret the diet of the animals concerning whether they were domesticated and fed by people with millets (e.g., Barton et al. 2009). High $\delta^{13}\text{C}$ values in bone collagen alone do not confirm domestication behaviour towards animals as resulting from feeding with the crop millets, or even cultivation of C4 plants, but in northwest China they are likely to reveal the human selection on otherwise rare plant populations as C4 plants are rare in northern latitudes (Gu et al. 2003), growing mostly only during summer months and comprising <10% of perennial, terrestrial vegetation (Wang 2003). Nevertheless, as discussed, not only the animals which are the research target of domestication in the site should be tested, but also many other animals, human bones, and archaeobotanical data of the specific site need to be analysed in order to reconstruct the food web and get the reliable interpretation in terms of palaeodiet and domestication.

2.2.3 Genetic Study

In recent decades, remarkable analytical advances in molecular genetics have provided significant insights into the understanding of the origins, regional expansion and migration of domestic sheep and goats in Eurasia.

Origins of domestic sheep

Different wild sheep have been proposed as potential ancestors of domestic sheep, such as the Urial (*Ovis vignei*), Argali (*Ovis ammon*) and Mouflon (*Ovis orientalis*). Recent studies on the whole mitochondrial genome phylogeny globally revealed that Argali-derived and Urial-derived mitogenome displayed highest divergence to domestic sheep sequences, least likely to be ancestral for the majority of the current domestic sheep, while European Mouflon (*O. musimon*) and Asian Mouflon (*O. orientalis*) shared the most recent female ancestry with the domestic sheep (Demirci et al. 2013; Lv et al. 2015; Meadows et al. 2011; Sanna et al. 2015). Among them, *Ovis musimon* sequences were immediately adjacent to haplogroup B in domestic sheep, very probable representing a remnant from early domestication events instead of genuinely wild sheep (Chessa et al. 2009; Hiendleder et al. 2002; Meadows et al. 2011; Pedrosa et al. 2005; Tapio et al. 2006). The Asian Mouflon, *O. orientalis*, is less well-characterized and thought to be the next closest extant *Ovis* species to domestic sheep based on cytB sequence (Bunch et al. 2006; Tapio et al. 2006). The haplogroups observed in Anatolian wild sheep (*Ovis gmelinii anatolica*) through the mtDNA control region and partial cytB sequences were suggested as remaining from the early existing broader population ancestral to the initial domestication process (Demirci et al. 2013; Demirci 2012). Microsatellite-based nuclear DNA variations also confirmed that wild Punjab Urial sheep (*Ovis vignei*) did not share any recent ancestry with Asian domestic sheep (Pichler et al. 2016).

One study that needs particular mention is Dodson et al. 2014, in which ancient mtDNA sequencing was performed on directly dated sheep bones in China. The amplification has been successful in one sample, a bone directly dated to ca. 4000 BP from a context equivalent to the Zhukaigou Culture period from Northern Shaanxi of China.

The amplification products showed 100% identity with *Ovis aries* and also 100% identity of *O. orientalis anatolica*, *O. vignei*, and *O. ammon*, being inadequate to reveal the ancestry of the specimen and its domestication status. It reflects the limitation of the genetic approach attributed to the difficulty of obtaining sufficient materials. But this study may have unfolded a direction worth more research of this kind to be carried out.

The male-mediated pattern revealed through Y-chromosomal markers also showed that the European mouflon (*Ovis musimon*) is the only species that share a haplotype with domestic animals, which agrees with the *O. musimon*'s status as feral domesticated indicated by mtDNA and leaves the male progenitors of this species still a mystery (Meadows and Kijas 2008). After all, genetic erosion and loss of haplogroups in the modern wild sheep population are evident (Demirci et al. 2013; Meadows et al. 2007). More research (especially on ancient samples) is still necessary to clarify the evolutionary history of domestic sheep.

Domestication process of sheep

Among domestic sheep, six maternal lineages – Haplogroups A, B, C, D, E, and X - have been identified through global surveys of mitochondrial sequence variation (by partial control region, the *cytB* gene, and complete mitogenome) (Demirci et al. 2013; Lv et al. 2015; Meadows et al. 2007; Meadows et al. 2011; Pedrosa et al. 2005; Sanna et al. 2015). Three of them (Haplogroups A, B, and C) have been identified among Chinese mainland sheep breeds (Niu et al. 2008; Zhao et al. 2013). In contrast to the sheep in Europe and West Asia, which are dominated by lineage B, the majority of the sheep in China and other parts of East Asia belong to lineage A (Hiendleder et al. 2002; Lv et al. 2015; Pedrosa et al. 2005). This pattern is even apparent in ancient samples (Cai 2010; Gabbianelli et al. 2015). Eleven patrilineal haplotypes were revealed in Eurasian sheep (Meadows and Kijas 2008; Meadows et al. 2006), and seven of them were found in Chinese sheep (Wang et al. 2015). The five mitochondrial haplogroups were characterized as branching independently (Meadows et al. 2011; Sanna et al. 2015), which greatly predates the domestication events in Near East dated approximately to 10,500-11,000 BP

(Peters et al. 2005; Zeder 2008). This was suggested by some authors as representing multiple separated domestication events (Bruford and Townsend 2006; Hiendleder et al. 2002; Hiendleder et al. 1998; Pedrosa et al. 2005), but scepticism arose over the so-called ‘domestication’ revealed by the mtDNA marker (Larson and Burger 2013). It was argued that the different lineages might be viewed as representing the introduction of several founder groups from different wild populations (Lv et al. 2015; Meadows et al. 2007; Meadows et al. 2011; Zeder 2006). Nevertheless, the gene flow between wild and managed animals as a part of the complex history of domestication needs to be considered. It is likely to have occurred at a broad genetic base involving a diverse ancestral population, as is indicated by the genome-wide analysis of the world’s sheep breeds (Kijas et al. 2012).

Features in sheep population genetics

Compared with other animals such as cattle or dogs, sheep appear to have a weak phylogeographic structure and low genetic differentiation, indicating a high rate of intercontinental dispersal (Kijas et al. 2012, 2009). Frequent genetic exchange and introgression were suggested as having played a significant part during the development of different breeds, as evidenced by autosomal microsatellite, mtDNA, and SNPs (Kijas et al. 2012; Leroy et al. 2015). A scenario that includes several consecutive migrations of sheep populations was revealed using genome-wide analysis (Kijas et al. 2012), endogenous retroviruses (Chessa et al. 2009), and whole mitochondrial genomes (Lv et al. 2015).

Goats

The similar but slightly different situations have been revealed in goat samples. Wild goats (*Capra aegagrus*) in West Asia were found embedding all five highly divergent maternal haplogroups in modern goats (*Capra hircus*, A, B, C, D, F, and G), indicating *Capra aegagrus* as the likely ancestors of domestic goats (Naderi et al. 2008). A weak phylogeographic structure compatible with high levels of gene flow was also identified among domestic goats (Azor et al. 2005; Luikart et al. 2001; Sardina et al. 2006).

Although multiple maternal lineages were found, this may not necessarily indicate independent origins of goat domestication east of the Iranian Plateau, since *Capra aegagrus* in other regions do not carry domesticated haplogroups (Naderi et al. 2008), corresponding to the archaeological finds (Zeder and Hesse 2000). Haplogroup A, the most abundant lineage among the domestic goats, was detected from the ancient samples in western Iran dated to the ninth millennium BC (Mazdarani et al. 2014), further indicating the importance of this region. Geographic expansion of the different lineages from the areas of initial domestication to surrounding areas that include Europe, the Caucasus, Africa, and Asia was found by sequencing a large number of modern and ancient samples (Kadowaki et al. 2017; Naderi et al. 2008)

Among the indigenous Chinese goats, lineage A, B, C, and D were found (Chen et al. 2005; Liu et al. 2006). Although lineages A is predominant, lineage B which includes two subclades was found occurring only in eastern and southern Asia and is also present in ancient samples dated to 2500 years ago (Chen et al. 2005; Han et al. 2010; Liu et al. 2006).

2.3 Discussion and Summary

In sum, there are different ways of conceptualizing ‘domestication’, which will lead to different attitudes toward studying them. For the purpose of this dissertation, which is to contribute to our understanding of the early history of sheep and goat domestication in China, domestication will be mainly conceptualized as an evolutionary process in terms of human-animal relationships rather than a revolutionary event, whether or not some or all of original domestic stock were introduced to China from elsewhere.

Different methods can provide valuable information about animal domestication. The selection of the methods depends on the nature of the archaeological materials. Some methods might provide more reliable evidence than the others if applied correctly. It is assumed here that morphological changes in animal bones are likely to reflect the nature of domestication processes under the selection pressures of new anthropogenic

environments, hence could happen in the earliest generations of animals in domestication. Therefore, the morphological study of animal bones is used in this research as the main methodological approach for detecting process of early caprine domestication.

Compared with research on animal domestication in the Near East, there is a lot more work needs to be done in zooarchaeological research in China. There is not sufficient evidence yet to depict a detailed process and the nature of sheep and goat domestication. Most zooarchaeological work dealing with the early sheep domestication simply focuses on separating bones in normative situations of assumed dichotomies between domestic and wild.

Based on the bulk of the zooarchaeological evidence, it has generally been accepted among Chinese archaeologists that sheep and goats were domestic in Qijia cultural contexts in Gansu and Qinghai Provinces and the Longshan culture period in the central plain, at about 4500 BP onwards (e.g., Yan 1998). Caprine remains seem already to have become the second or third important animal taxon, accounting for a significant portion of the total fauna. Among them, sheep (*Ovis*) are always more positively identified than goat (*Capra*). As for the earlier periods, there was probably a small number *Caprinae* remains contained in Majiayao cultural contexts in Gansu and Qinghai Province, and Yangshao culture contexts in the Central Plain. Those from Majiayao contexts might be of ritual meaning. However, the taxonomic identification and presentation of the caprine remains are problematic. Simply using ‘Yang’ to describe caprine remains renders little assistance in the clarification of the issue of their domestication. In Chinese, ‘Yang’ represent anything including locally wild *Caprinae* and gazelle that probably have morphologically very similar skeletons and teeth. It constitutes big problems for zooarchaeological research in this area especially in the sites of early periods when hunting was still an important part of subsistence strategies. Another problem is the interpretation of the caprine remains as domestic. For some Majiayao remains, the ‘Yang’ found with ritual meaning were directly interpreted as domestic sheep, but as discussed above, using the cultural context on its own to diagnose domestication is not warranted. For the later periods, the relative

abundance of caprine remains was used as major evidence for arguing for domestication status, but usually, no detailed information of the changing taxonomic frequency in the different contexts is available. Even we accept that caprines were domestic during this period, it may not be the initial stage of domestication during which time the taxa may have only constituted a small part of the fauna.

Genetic studies have provided tremendous new insights into the evolutionary history of sheep and goat domestication in Eurasia. The combination of direct radiocarbon dating, genetic sequencing, and stable isotopes in ancient samples shows promising research directions, but are costly. The number of the samples analysed so far is too small, and there are still limitations in suggesting domestication status and ancestry. Currently, the majority of the investigations on the origins of domestic sheep are based mtDNA markers based on modern specimens due to a series of factors.

Although rough sketches of the evolutionary history of sheep and goat domestication have been outlined, some basic questions are actually far from being settled, such as the exact ancestral population(s), area(s), and number of times that sheep were ‘domesticated’, and how the different domestication traits emerged and were maintained in various breeds. Parts of the questions are probably involved with the controversial conceptualisation of the term ‘domestication’. As discussed, not only the initial independent domestication process but also the subsequent continuous and multi-directional gene flow formed important parts of the ongoing domestication phenomenon. The genetic and morphological traits revealed in the world’s sheep breeds today are a consequence of intensive breeding, human-driven migration and admixture, coupled with the loss of ancient genetic traits. Furthermore, as a single locus, mtDNA may only infer part of past demographics (Larson and Burger 2013), being sensitive to genetic drift (Meiklejohn et al. 2007), and could be replaced rapidly during a hybridization process between migrating and resident populations. The pictures revealed so far about the domestication histories of sheep and goats need more and deeper investigations, especially combining ancient samples and genome-wide analysis. There need to be more collaborations between

researchers in archaeology and genetics to interpret genetic bottlenecks and molecular sequences regarding their possible archaeological significance, and thus to understand the complex and multifaceted processes of domestication (Zeder et al. 2006).

In sum, the review in this chapter of the current research status has helped identify the key research area --- the Hexi Corridor and Northeast Qinghai --- and the key period --- from the Epipaleolithic to the Bronze Age. It also indicates that some controversies might be related to the complex nature of the history of sheep and goat domestication in Eurasia. A clarification on Caprinae taxonomy and a systematic comparative osteomorphological study of these animals is needed, which will be tackled in Chapter 4 and Chapter 6 respectively. Before coming to this, however, in Chapter 3, I introduce the settings of the archaeological sites from which archaeological faunal remains were studied in this research.

3. Settings of the Research Area

3.1 Introduction

The research aim of this study is to contribute to our understanding of the process of the early history of sheep and goat domestication in China, whether or not some or all of original domestic stock were introduced to China from elsewhere, through a detailed study of sites in the Hexi Corridor and Northeast Qinghai. As shown in Chapter 2, this region from the Epipaleolithic to the Bronze Age has yielded the earliest and largest amount of caprine remains in China, so is important for the early domestication history of sheep and goats. Also, this is the region where evidence of early communication between China and the West first emerged, such as crops and bronze, and regarded as a route of interregional communication between the West and East (Flad et al. 2007; Levine et al. 1999; Linduff and Mei 2009). For these reasons, this region has been selected as the research area within the broader ‘Western China’. Five archaeological sites ranging from Epipaleolithic to Bronze Age are chosen, and the faunal remains from them are studied.

Natural environmental and archaeological settings of the research area and the sites will be addressed in the following sections. There are no rigid topographic boundaries that define the extent of the study area, which cross-cuts several geographical and political borders⁶. The five selected sites form a long strip in a northwest-southeast direction along the north-eastern range of the Qinghai-Tibet Plateau and roughly coincide with the eastern end of the ancient Silk Road (Figure 3.1).

⁶The region of the five sites belongs to ‘Northwest China’ region, a political concept which includes Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang provinces. According to geographic and environmental divisions, the region cross-cuts Northwest region and Qinghai-Tibet Plateau (see below).



Figure 3.1 The studied archaeological sites in Western China: 1. Jiangxigou 2 (8000-5000 BP); 2. Andaqiha (c. 5000 BP); 3. Jinchankou (c. 4200-3700 BP); 4. Shannashuzha (c. 5300-4900 BP); 5. Sanbadongzi (c. 3900-3400 BP). Map of the routes of ancient Silk Road follow Mark (nd)

3.2 Natural Environmental Settings of the Studied Sites

Regarding geographical and environmental zones, the study region locates just at the junction between the Qinghai-Tibet Plateau, Northwest region, and the humid or sub-humid North region of China⁷. Topographically, the study region is at the border of the third and second levels of the country (Figure 3.2, Figure 3.3).⁸

7 The entire country of China can be divided into four major geographic and environmental areas (Zhao 1983): the humid or subhumid monsoonal North and South region, the arid or semi-arid Northwest region, and the alpine cold and dry Qinghai-Tibet Plateau.

8 Within China, three distinct topographic levels were divided, exhibiting stepped decreases in altitude from the Qinghai Tibet Plateau to the eastern low alluvial plain. First level: Qinghai-Tibet Plateau average > 4,000 above sea level; second level: Inner Mongolia Plateau, the Loess Plateau, the Yunnan-Guizhou Plateau, the Tarim Basin, the Junggar Basin and the Sichuan Basin, average elevation 1,000 m -2,000 m; third level: Northeast Plain, the North China Plain and the Middle-Lower Yangtze Plain. Interspersed amongst the plains are hills and foothills, average 500-1000m (Zhao 1995).

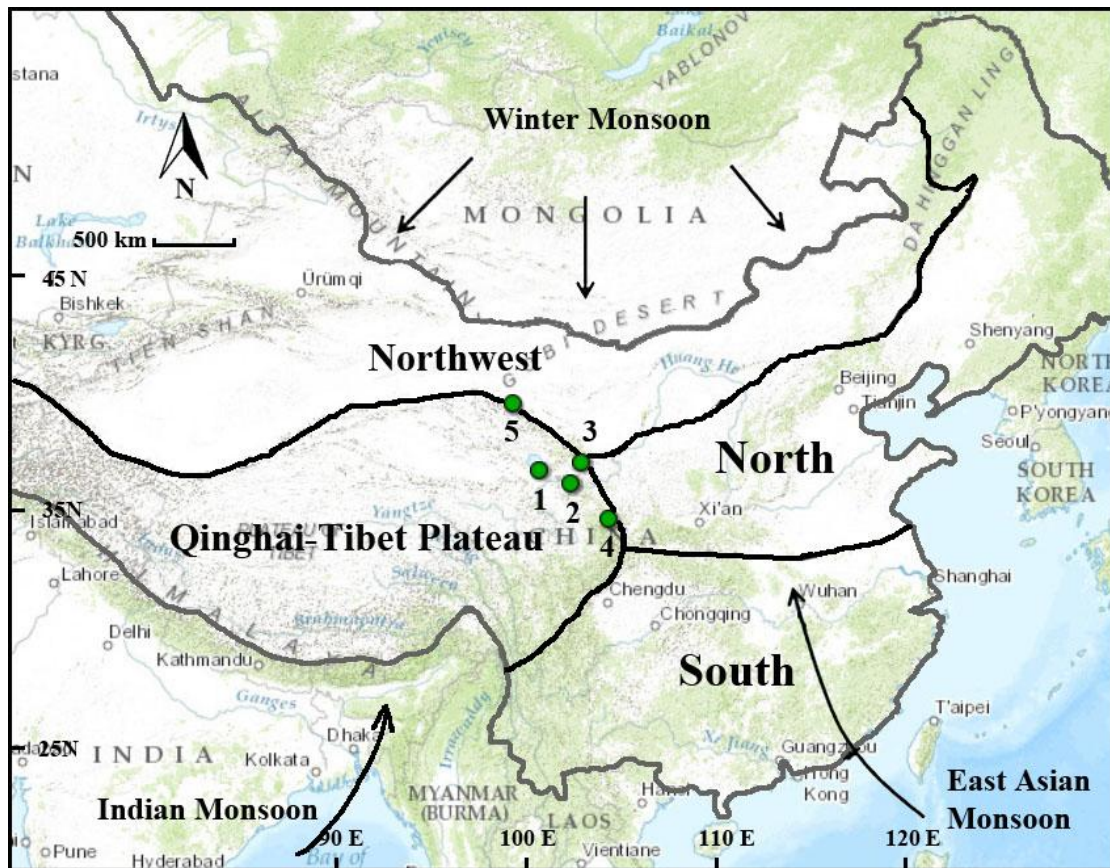


Figure 3.2 The studied archaeological sites in the map of China showing its four major geographic and ecological zones. 1. Jiangxigou 2 (江西沟); 2. Andaqiha (安达其哈); 3. Jinchankou (金禅口); 4. Shannashuzha (山那树扎); 5. Sanbadongzi (三坝洞子). The arrows indicate the Asian monsoon system.

The climatic conditions of the country are primarily controlled by the Asian monsoon system and exhibit strong seasonal and spatial contrasts in temperature and precipitation. In winter, the winter monsoon from the North brings cold and dry continental air southward and most of the country experiences low temperatures and drought; in summer, the warm and wet maritime air flows inland from the Pacific and the Indian Ocean, producing rainfalls. Due to the northwestward attenuation of summer monsoon winds, precipitation declines noticeably with increased distance from the ocean. Except for the Qinghai-Tibet Plateau, summer temperatures are universally high throughout most of the country (Zhao 1995).

The study area is not strongly influenced by the ocean airflow and has lower annual

precipitation than the areas east to it, being more characterized with plateau climate than the East, showing stronger solar radiation and lower oxygen density than the eastern Loess Plateau, but when compared with the other parts of Qinghai-Tibet Plateau, the plateau climate characters here are weaker (Zhang 2009).

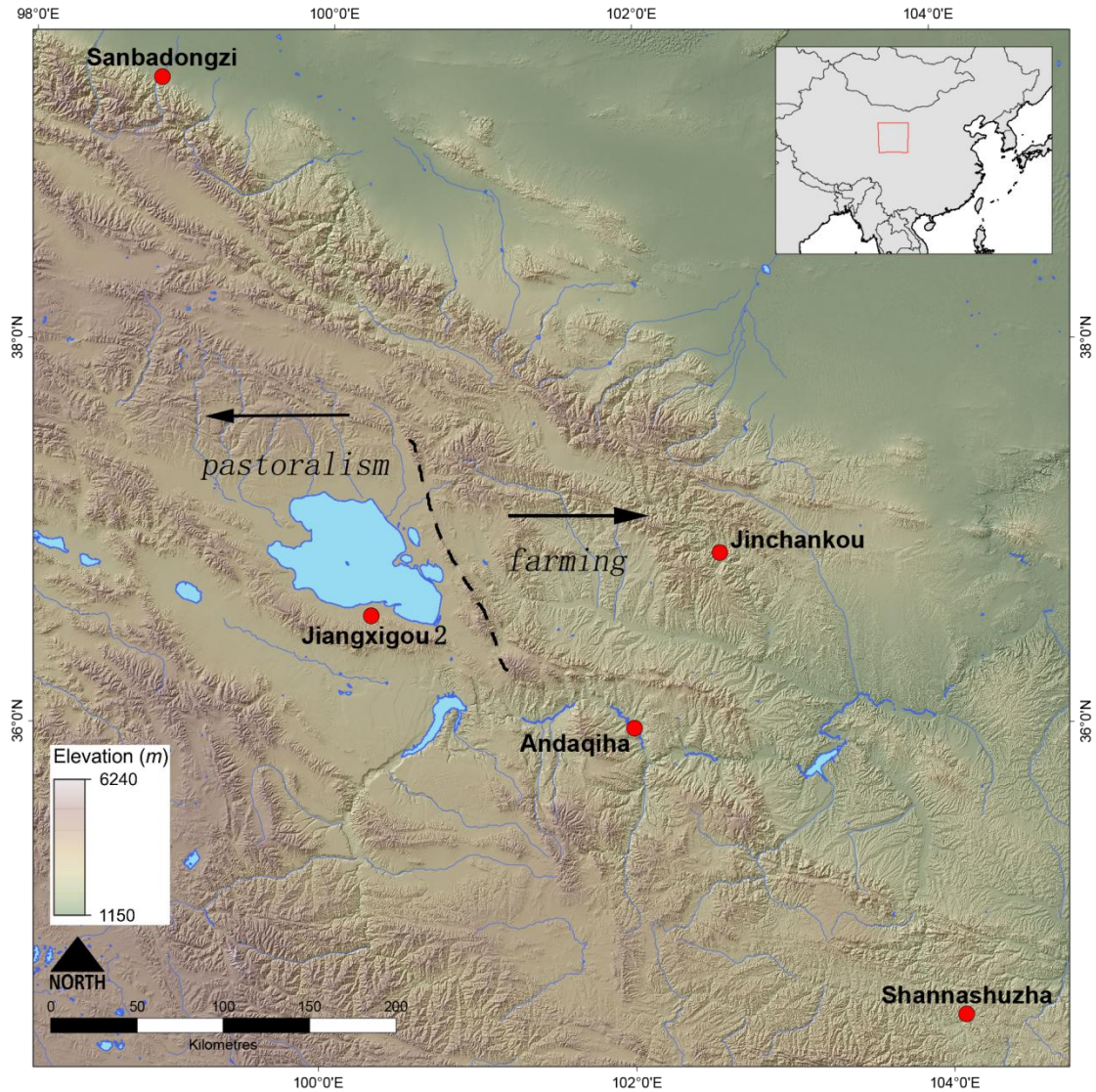


Figure 3.3 Regional topography of the five archaeological sites.

The natural environmental conditions are different among the five sites and could be mainly divided into three parts: the northeast margin of the Qinghai-Tibet Plateau (Jiangxigou 2, Andaqiha, and Jinchankou); Eastern Gansu (Shannashuzha); and Western Gansu (Sanbadongzi). In the following sections of this chapter, the climate and each

regional physiographic unit of the five sites will be described, in order to place the archaeological sites in their proper natural environmental contexts.

3.2.1 Current Environmental Setting

The environmental settings are given for the five sites in the following sections. The information is provided in terms of relative locations, topographic features, vegetations, climate, modern agriculture/pastoralism, and populations.

3.2.1.1 Jiangxigou 2: The Qinghai Lake Basin

Jiangxigou 2 is located on the southern shore of Qinghai Lake, at the junction between the southern lake plains and the Qinghai Nan Shan Mountains (36°35'25''N, 100°17'47''E, 3312m) (Figure 3.3, Figure 3.4; Figure 3.5). The landform zone Jianxigou 2 belongs to is Qinghai Lake Basin (Zhang 2009).The deposit of Jiangxigou 2 is exposed in several small cutbanks on the margin of the terrace.

Qinghai Lake, on the northeastern margin of the Qinghai-Tibetan Plateau, is a vast (4278 km²) but shallow (<27 m depth) closed saline lake. The Qinghai Lake basin floor varies between 3200 and 3400 m. There are higher mountains reaching elevations well above 4500 m surrounding it. To the south of the lake, these are Qinghai Nan Shan; to the east, the Riyue Shan; and to the northwest and northeast the Datong Shan and Daban Shan. These latter ranges are part of the extensive Qilian Mountains and most of the water feeding the lake is derived from these northern sources. Qinghai Lake is fed by more than 100 small streams, but its principal tributary is the Buha River which supplies more than half of its water (Jun and Kelts 2002; Liu et al. 2002; Shen et al. 2005).



Figure 3.4 Location and topography of Jiangxigou 2.



Figure 3.5 The site of Jiangxigou 2 (JXG) is on the east side of a stream flowing into Qinghai Lake, at the western slope of a hill, looking to the east. The stream terrace is approximately 2~3 metres higher than the present depth of the stream. Photograph: Yiru Wang.

The southern margin of Qinghai Lake is now grassland meadow, changing to shrub meadow above ~3400 m (Gong and Jiang 1999). The northern and eastern lake margins are dominated by dry steppe vegetation. At the west of the site, there is a small tributary of the Qinghai Lake flowing from the south to the north (Madsen et al. 2006).

Currently, the Qinghai Lake basin has a cold, semi-arid climate with an average annual temperature of about 0.7 °C. The annual precipitation is 417 mm with the wind from the south blowing all year round at an average of 3.4m/s. It has long but relatively dry and quite cold winters, and short, mild summers, with the majority of precipitation falling in the late summer months (Jun and Kelts 2002).

Most part of the surrounding area is pastoral lands. Tibetans, Han, Mongols, and Hui are the major populations here.

3.2.1.2 Andaqiha: Upper Yellow River and Huangshui River Valley

Andaqiha is located in Qunke town, Hualong County (36°00'27''N, 101°59'51''E, 2030 m) (Figure 3.6). It occupies a fairly level land on the second river terrace on the

junction of the Yellow River and the Yishaer rivulet, approximately 100 m north to the Yellow River and within 50 m east of Yishaer rivulet. The site is edged by some subalpine hills at its northeast side (Zhang 2009). The landform zone Andaqiha belongs to is the Upper Yellow River and Huangshui River Valley (Zhang 2009).

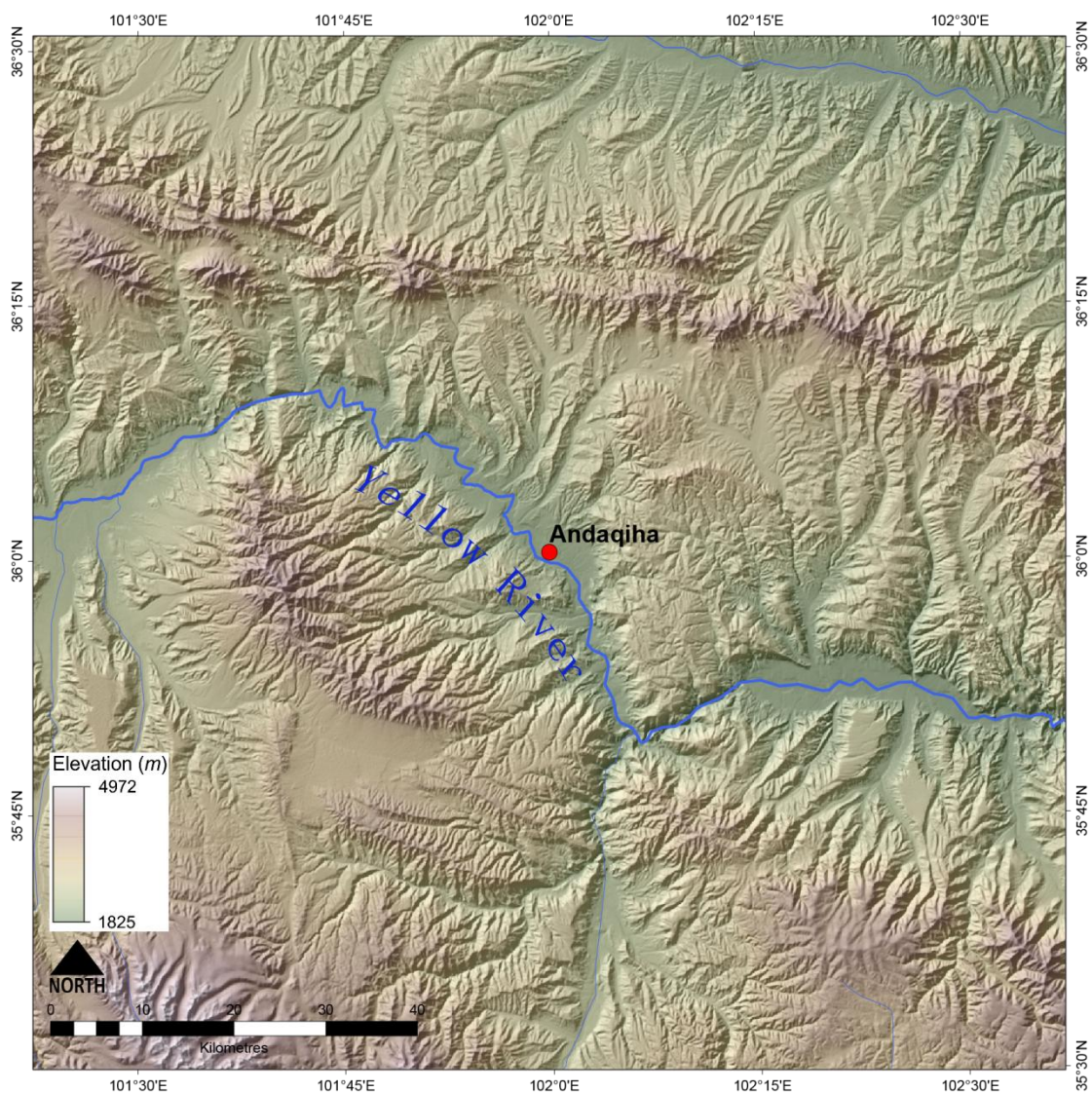


Figure 3.6 Location and topography of Andaqiha.

The Upper Yellow River and Huangshui River valley are located at the most northeastern margin of the Qinghai-Tibet plateau and also on the most western edge of the Loess Plateau that extends from the Central Plain (Figure 3.3, Figure 3.6). The elevation of this region ranges from 1650 m to 3500 m, with the mean below 2500 m. It is the region of the lowest altitude in Qinghai Province.

This region has a semi-arid temperate plateau climate with about 450 mm average annual precipitation mainly concentrated in the summer. The average annual temperature is around 8°C. During the warmest summer months it reaches above 16°C, sometimes beyond 20°C; during the winter it is generally above -8°C. The frost-free growing season is 120 days (Zhang 2009). Wild animals include hare, mice, snakes, and pheasants (Xiao 2013).

The natural environmental condition of the Upper Yellow River and Huangshui River valley is among the most favourable in the Qinghai-Tibet Plateau for farming, and the region is the major crop and fruits production area in Qinghai today. The temperature here is relatively high, and sunshine duration is long with around 110 days of summer⁹. It has more precipitation days but lower annual precipitation than the east (Zhang 2009). In addition, the irrigation condition is favourable. Wheat, rape, fruits, pigs, cattle, and sheep are kept. The villagers of Andaqiha are mostly Hui and Tibetans. Altogether there were 717 people and 180 households in Andaqiha Village in 2010 (Xiao 2013).

Most of the other regions of Qinghai Province are characterized by the more typical plateau climate of very long winters and short summers and low temperatures. To the north of the Upper Yellow River and Huangshui River region is the mountain terrain of Qilian with an average elevation of 4000 m, where there are around 250 days of winter per year. To the west, the Chaidamu Basin is characterized by a dry and extremely dry plateau climate with only 20~60 days of summer. To the south is the Southern Qinghai Plateau region, surrounded by the Kunlun mountain ranges and Tanggula Mountain ranges, which is the highest mountainous region of Qinghai with an average elevation above 4200 m and has more than 250 days of winter. Pastoralism rather than farming is the major lifestyle in these high altitude regions today, although many parts are uninhabitable. The boundary

⁹ It is specially fixed that for the Qinghai-Tibet plateau the summer means those days with average temperature of 7 days above 15 oC, spring and autumn is 3~5 oC, and winter is below 3 oC. However, for all the other regions of China it is regulated that summer is the average temperature of 7 days above 22 oC --- in that sense, there will be no real summer in Qinghai-Tibet Plateau (Zhang 2009).

between the farming and pastoralism regions in Qinghai is at the Riyue Shan Mountains, east of the Qinghai Lake (Figure 3.3; Figure 3.4), which is located within the valley of the Upper Yellow River and the Huangshui River(Zhang 2009).

3.2.1.3 Shannashuzha (Southeast Gansu)

Shannashuzha (34°29'33''N,104°04'46''E, 2845m) is on the second fluvial terrace to the west of the Tao River, which is a tributary of the Yellow River. It is 10 km north of Min county, Dingxi city, Gansu province. The region is at the junction region between the eastern range of Qinghai-Tibet plateau and the western range of Qingling Mountain (Figure 3.8), belonging to a mountainous or semi-mountainous area. The site is surrounded by high mountains to the northeast and southwest.

The vegetation coverage is quite good, especially in the mountains. The climate here is at the transition between the sub-humid and temperate zones to alpine humid zones. The majority of the area consists of pastoral grasslands(Zhou and Yang 2000).The average summer temperature of this region is 16°C, and the winter temperature is -6~-10°C. The annual precipitation is about 600 mm. The average frost-free period is 120 days. Because of the high latitude, the site is dominated by a moist and cold climate year-round. The majority of the people here are Han. Cattle, yak, cattle yak, horse, donkey, pigs, sheep,rabbits, dogs, and cats are the domestic animals of these people.

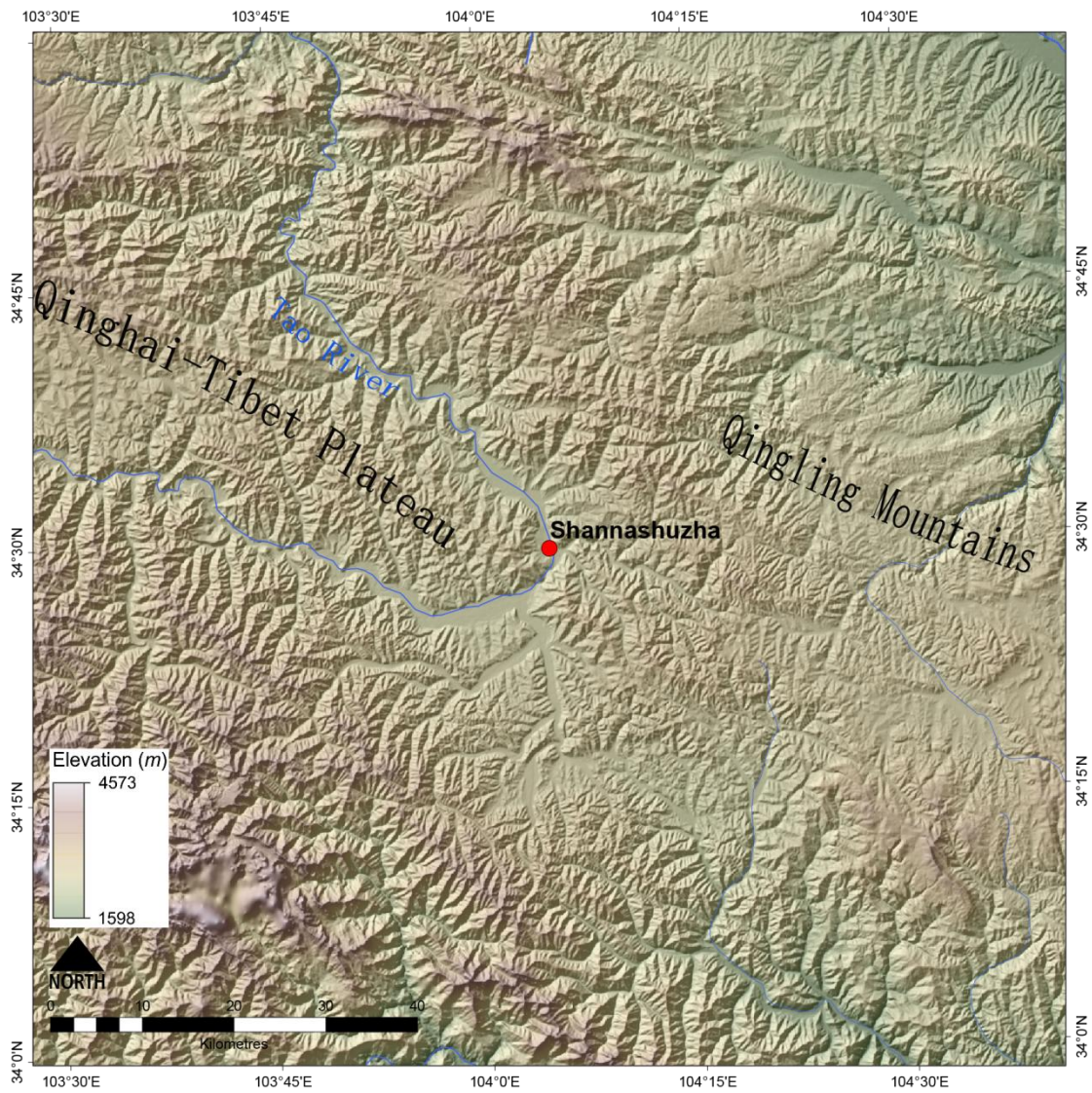


Figure 3.7 Location and topography of Shannashuzha.

3.2.1.4 Jinchankou: Eastern Qilian Mountain Area

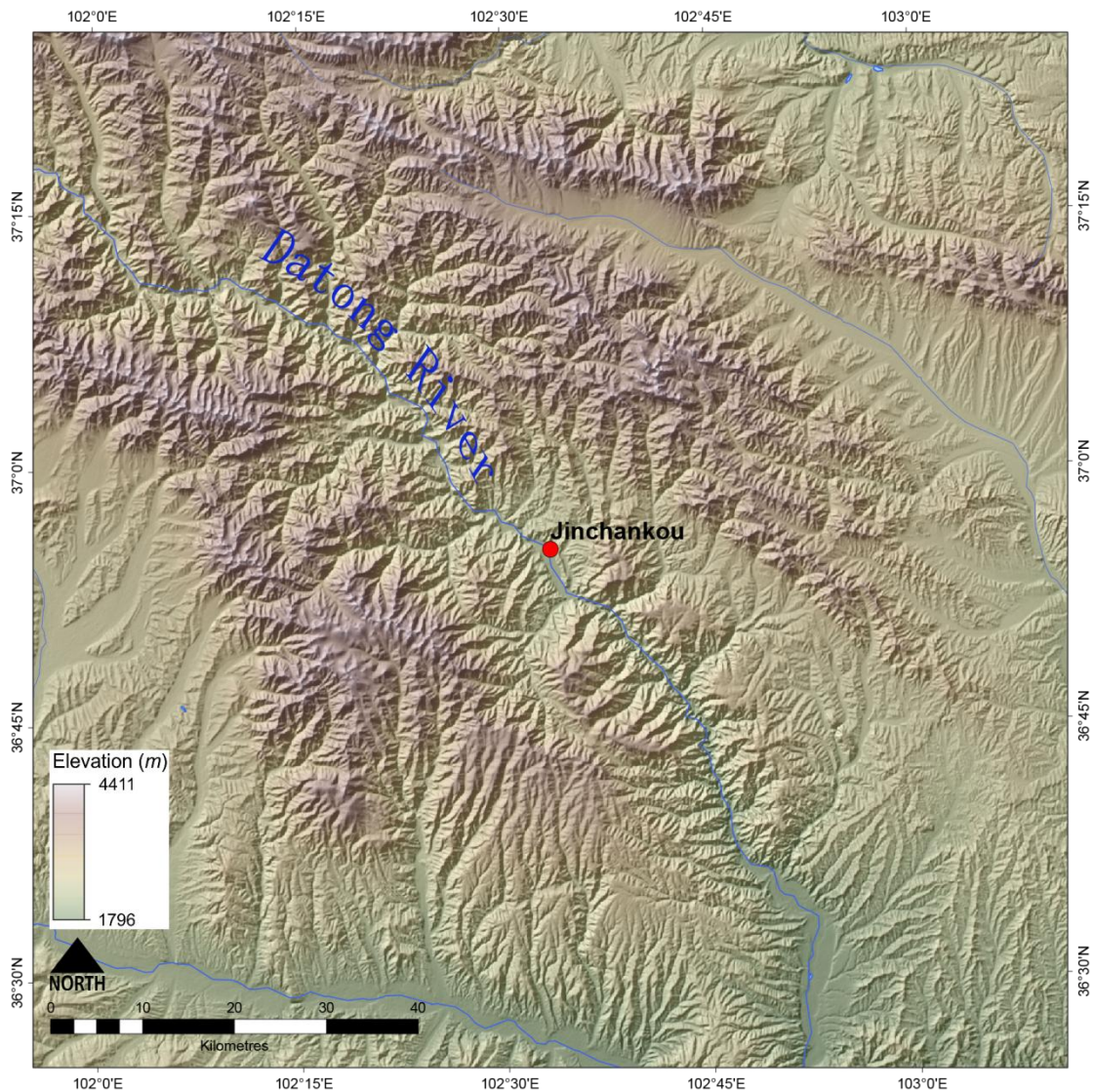


Figure 3.8 Location and topography of Jinchankou.

Jinchankou is located in the Datong River basin (36°55'12"N, 102°32'24"E, 2309m) (Figure 3.7) and belongs to the landform zone of the Eastern Qilian Mountain Area (Zhang 2009), at the third river terrace of the Datong River --- a second level of tributary of the Yellow River and about 400 m south from the Datong River. This area is also located at the eastern margin of the Loess Plateau, and the transitional zone between the Loess Plateau and the Qinghai-Tibet Plateau.

The Datong River (36.75 ~38.33 N, 98.83 ~103 E) is a tributary of the Huangshui River. The river valley is surrounded by the Qilian Mountain in the north and east, and the Datong Mountain and Daban Mountain in the south. The vegetation is mainly bushes and

forests, and there are good irrigation systems. The terrain around the site is broad and flat.

The climate in the Datong River range is continental and plateau type. The average annual temperature in this region is 3.4°C, and the annual precipitation is 400-600 mm. The streams flowing from the mountain ice caps are very important for the irrigation of agriculture in the Hexi Corridor and Northeastern Qinghai province. With a comparatively warm and mild climate, it is traditionally a good agriculture area in Qinghai Province with a high rate of productivity. Wheat, barley, and rape are currently grown in this area. Most of the inhabitants are Han, and there are also a large number of Tu, Zang, and Hui people (Committee 2001).

3.2.1.5 Sanbadongzi (Mid-Hexi Corridor)



Figure 3.9 Location and topography of Sanbadongzi.

Sanbadongzi is located at the middle part of the Hexi Corridor (39°22'36'', 98°50'45'', 1858m), on the upper part of the alluvial fan of the Fengle River (Figure 3.9), 200 m southwest to the 8th Group of Fengle County, Jiuquan City, Gansu Province. The altitude here is comparatively higher than the neighbouring area. The landform zone here is alluvial plain.

Because of the erosion and flooding of the river, the terrace is full of huge gullies, and some of them could be as deep as 10 m. Some of the gullies have been broken through by the water at the bottom and formed connecting cellar holes. The eastern end of the site stops at the major Sanba canal, the western end is at the Fengle River, to the south, the site lies across the Sanbadongzi gullies, and to the north, it extends to the Ganguya site (GPRARI and PU 2016).

In general, this area is mostly flat land. The solar radiation is very strong --- the annual amount is 5800-6400 J/m² --- higher than the eastern parts of China of the same latitude of about 700-1000 J/m². In the coldest month (January), the temperature is about -13~-18°C, and the warmest month (July) is 19~28°C. The precipitation is very low, 200 mm annually, but there are, however, rich water resources from the streams melted from the ice caps in the mountains and underground water, together with the warm temperature, making this region very suitable for agriculture. Wheat, maize, cotton, rape, hops, and many vegetables are cultivated here. It is now a good crop production area of Gansu Province. Han, Mongols, Kazaks are the major populations. Horse, donkeys, mules, camels, cattle, and sheep are raised by the people here. (Cui 1988; Zhou and Yang 2000).

3.2.2 Climate in the Past

The broad trend of climate change in China is in concert with global trends. The climate was very cold and dry during the Last Glacial Maximum. The summer monsoon system began to develop from about 14,100-10,800 BP, bringing increases in temperature and humidity. During 10,800 - 8500 BP, as shown by the pollen of Qinghai Lake basin, the conditions began to get significantly warmer and wetter. At around 8000 BP, forests

extended in many places and the water level of the lake went up (An et al. 2003;Lister et al. 1991;Mo et al. 1996;Shen et al. 2005;Xia et al. 1998).At 8200 BP, a brief cold episode is apparent in the pollen record in Qinghai Lake basin (Shen et al. 2005), but it quickly returned to warmer and wetter conditions by about 7800 BP, as the summer monsoon strengthened over the Tibetan Plateau (Tang et al. 2000). The general climate during 7800 - 7300 BP might have become slightly cooler (Shi et al. 1992),but after 7000 it was still quite warm and humid. Forests grew around the Qinghai Lake, and broadleaf trees increased at Dadiwan (Huang 1988;Xia et al. 1998). This warm and humid climate remained and was stable until 6000 BP in the Qinghai and Gansu region (Liu et al. 2002;Shen et al. 2005). The water level of Qinghai Lake rose dramatically during this period (Lister et al. 1991). The climate fluctuated more drastically after 6000 BP. The temperature dropped down continuously during 6000-5000 BP (An et al. 2003). Climate became significantly cooler and more arid after around 4500 BP. Trees decreased in abundance and steppe vegetation came to dominate the landscape around Qinghai Lake (Xia et al. 1998). During 4000-3000 BP, the climate continuously became dryer, as shown by several different lines of evidence (An et al. 2003;Deng 1997;Yang and Suo 1996;Zhang et al. 1994). The climate conditions have been fairly stable since about 3500 BP (Shen et al. 2005).

3.3 Archaeological Settings

3.3.1 Archaeological Cultures (Figure 2.2)

The archaeological cultures reviewed in this region showed a changing course from earlier to later periods. The record starts with a small number of localities of Late Palaeolithic sites dated to 30,000 to 10,000 BP at high latitude areas on the Qinghai-Tibet Plateau, characterized of hearths, chipped stone tools, microlithic tools, and animal remains, perhaps representing small foraging parties (Brantingham and Gao 2006, Madsen et al. 2006). Microlithic sites dating to 8000-6000 BP continued in this region and show an orientation toward agriculture. Abundant lithic cores, flakes, and bone artefacts are likely to indicate that foragers occupied the upper Yellow River valley (Gai and Wang 1983).

Increasing numbers of ceramics and polished stone tools after 6000 BP probably suggest a transition from highly mobile Epipaleolithic foragers to farmer/foragers and pastoralists (Hou et al. 2013; Rhode et al. 2007).

Neolithic cultures developed firstly at the Upper Wei River valley in Eastern Gansu, dating to 8000-7000 BP. They were represented by the Laoguantai culture at Dadiwan. Polished stone tools, handmade ceramics, semi-subterranean round houses, earth tombs for adults, and urn burials for children are typical of this culture, and pigs and millets were domestic foods (Yan 1998). The following phase, the Yangshao Culture, is again typically represented at Dadiwan, continuing to the earlier phase at the site and showing similar characters to the other Yangshao Culture sites in the Central Plain (Li 2008). It has been argued that the range of the Yangshao Culture extended from the Central Plain toward the west as represented by the colourful potteries, and the further westward it extends, the more different it is from its original forms in the Central Plain (Yan 1978). The Majiayao (马家窑) culture was suggested as a result of such continuation of the Yangshao Culture in Qinghai and Gansu, while also assimilating the local microlithic traditions (Li 2009; Yan 1978). The major animals found at Majiayao sites are pigs (likely domestic) and deer (probably hunted), while Caprinae bones were identified as carrying special meaning because they were buried in tombs or made into oracle bones (see Chapter 2, Section 2.3.1).

The Banshan and Machang¹⁰ cultures flourished at about 4650-4000 BP, with a gradual decreasing influence of Yangshao from the east to the west of Gansu (Li 1998).

¹⁰The Banshan culture and Machang culture are regarded as both sub-cultures 'Styles' of theMajiayao culture (chronology exemplified in Figure 2.2). Banshan style ranges at 4650~4300 BP, distributed at the upper range of Wei River, west of Longshan Mountain, from the Yellow River valley in Gansu Province to Guide Basin in Qinghai, and surrounding many tributaries of Yellow River and in Hexi corridor. The range is slightly more westernward than the Majiayao style. The Machang style is an archaeological style developed after Banshan, although contemporary with the Banshan style in a few places.It ranges at 4300~4000 BP. Its geographical location is also similar to but slightly more westernwardto Banshan, and reached the westmost end of Hexi corridor at Yumen(Li 1998).

Bronze work was firstly discovered at Majiayao culture sites(GPCRT et al. 1984), but the bronze industry developed greatly only since the Qijia culture (4500-4000 BP), which is the earliest in China with significant numbers of bronze objects. It has been argued that the various material culture found at Qijia sites reflects a complex process of trans-regional contact between the populations of the Upper Yellow River valley and those from Central Asia areas during this time (Fitzgerald-Huber 1995;Li 2005;Mei 2003).

3.3.2 Archaeological Contexts

The information about the archaeological contexts of the five sites and their faunal remains provided in the following sections, including the excavation background, retrieval method, area and thickness of the deposits, dating of the remains, the material cultures and featured remains retrieved and identified, and information about the subsistence strategies of humans revealed by different lines of evidence so far. The information about the faunal remains is provided in terms of the general preservation condition, bone surface, cut marks, fragmentation, burning, root-etching, gnawing marks, skeletal elements, identified taxa, and the distribution of the remains when possible.

3.3.2.1 Jiangxigou 2 (JXG2)

The site has been excavated twice, in 2005 and 2011, and the results were reported in Rhode et al. (2007) and Hou et al. (2013) respectively. The investigated areas of JXG2 of both times were very limited. In the first time only the face of one exposed cutbank was cleaned, and the second time the earlier profile cut was expanded by cleaning a sampling grid of 0.5m×1m, and the profile is about 120 cm deep (Hou et al. 2013). The faunal remains analysed in this dissertation were from the second investigation in 2011.

Controlled samples of artefacts and datable materials were collected from every 10 cm stratigraphic units. Sediments were wet screened through 2 mm hardware cloth to retrieve smaller-sized items. Four main stratigraphic units are identified according to the colour and characteristics of the structure and sediments (Hou et al. 2013; Rhode et al. 2007, Figure 3.10).



Figure 3.10 Stratigraphic profile of JXG2. The picture is from Hou et al. 2013.

Each stratigraphic unit was dated (Figure 3.11), either by radiocarbon dating of the charcoal or thermoluminescence, OSL. The main period of occupation was from before 8000 BP to sometime after ca. 5000 cal BP (Hou et al. 2013). The majority of the faunal remains are from the third stratum, dated to 8000-7000 BP.

Depth (cm)	Stratum	Contents	Dating material	Dates
0~10	1	light yellow, modern soil, surficial silts and sands		
10~20	1			
20~30	1		Ceramic sherd	1970±90 cal yr BP; OSL, IRSL, TL weighted average; UW-1358, 10-20 cm (Rhode 2007)
30~40	2	dark gray-brown silty loam, abundant	Ceramic sherd	4973±254 cal yr BP; OSL, FS05-95, UW-1360; 54 cm depth (Rhode 2007)
40~50	2			
50~60	2			
60~70	2	artifacts including lithics, fragmented faunal remains, fire-affected cobbles, small number of ceramics	Charcoal	4580±40 AMS 14C yr BP, (5657-5476 cal yr BP, 2 σ) (Beta-209350)=~5950 cal a yr BP modal value, 65 cm depth (Rhode et al 2007)
70~80	3	compact loess, light to medium	Charcoal	5925±35 AMS 14C yr BP, (6900-6710 cal yr BP, 2 σ) (BA111965), 75 cm depth (Hou 2013)
80~90	3	gray-brown, carbonaceous silty loam, containing	Charcoal	7330±50 AMS 14C yr BP, (8303-8014 cal yr BP, 2 σ) (Beta-208336) =~8170 cal yr BP modal value, 81 cm depth (Rhode et al 2007)
90~100	3	significant quantities of artifacts, microlithis, fragmented faunal remains	Charcoal	8170±50 AMS 14C yr BP, (9268-9010 cal yr BP, 2 σ) (Beta-194541)=~9100 cal yr BP modal value, sample taken 60 cm east of profile, depth approximate (Rhode et al 2007)
100~110	3		Charcoal	7325±35 AMS 14C yr BP, (8250-8070 cal yr BP, 2 σ) (BA111966), 108 cm depth (Hou 2013)
110~120	4	fine yellow brown, silt, sand and clay, containing scant artifacts		
120~130	4			

Figure 3.11 Dating results of the stratigraphic profile of Jiangxigou 2 (converted from Hou et al. 2013 and Rhode et al. 2007)

The materials retrieved from this site include abundant microblades fragments, microblade cores, core fragments, ceramic sherds, and faunal remains (Figure 3.11). A well-formed and well-used two-sided handstone presumably used for milling and ceramic sherds were located in the upper strata. More importantly, thermoluminescence and AMS ¹⁴C dating of the ceramics and charcoals at JXC2 suggest there existed the earliest pottery (around 7000 BP) and earliest painted pottery pieces (~5500 BP) (Hou et al. 2015). Furthermore, the painted potteries were found bearing features similar to that of the Yangshao Culture or the Loess Plateau (Hou et al. 2015).

The remains were highly fragmented, and appear to represent primarily medium-sized mammals. The surface preservation conditions of the faunal remains were quite poor. Most of the bones appear to have been heavily affected by root etching, alternate wet/dry conditions, temperature, and soil PH. Half of the observed remains were recorded as 'poor', appearing porous and amorphous, and nearly 40% lost most part of the bone surface. The normal cut marks and gnawing marks could not be seen, but multiple chop marks were clearly observed on one specimen probably produced by flint tools. No traces of burning were observed on the bones from the 2011 retrieval. However, a small proportion of bones (<5%) were burnt or calcined in the faunal remains excavated in 2005, suggesting that the animals were for consumption by people (Rhode et al. 2007). All these made taxonomic identification very difficult.

Skeletal parts represented include limb fragments, ribs, vertebrae, scapula, pelvic fragments, skull fragments, and loose teeth, suggesting that the animals may have been processed for grease or marrow extraction. Combined with the results from the 2005 excavation, the taxa identified include small rodents, Caprinae, small mammal, deer, and gazelle.¹¹ In sum, although derived from a meticulous screen sieving, since the total excavated area is very small and the preservation of the faunal remains is very poor, the identified animal remains could only represent a small part of the animals exploited by

¹¹A list of the identified taxa at Jiangxigou 2 is provided in Appendix S.

humans. Fragile bones and small animals such as birds and fish may have been completely lost.

Ancient starch grains and pollen were extracted from ceramics, indicating that millets were cultivated at over 3000 m since 5600 cal BP, the earliest on the Qinghai-Tibet Plateau (Hou et al. 2015).

Combining all the different evidence together, it has been suggested that the microlithic industry revealed at Jiangxigou 2 might represent parties employing a seasonally transhumant mobility system presumably based on hunting (Rhode et al. 2007). The ceramics at the later period probably indicate that the site was affected by the Neolithic Yangshao culture from around 7000 BP (Hou et al. 2015). Despite the small numbers, the presence of the oldest ceramics of the Qinghai-Tibet plateau at this site (nearly 1000 years older than the Zongri culture sites on the upper Yellow River, and more than 500 years older than the Neolithic village site of Karuo located on the southeastern Tibetan Plateau) is significant. The change of the distribution of the material culture across the strata appeared to be indicating a shift in resource procurement strategies from hunting to agriculture (Hou et al. 2013; Hou et al. 2015 Rhode et al. 2007).

3.3.2.2 Andaqiha

The Andaqiha site was revealed during the rescue excavation in 2003 before the construction of the Gongboxia hydropower (Figure 3.12). The total area of the Andaqiha deposit is quite large, estimated 24000 m², although the excavated area was only 240 m², accounting for less than 2 percent of the total. The deposits are approximately 4 metres thick. All the retrieved materials were from hand collection.

The early period of the deposits was called Shalongka, containing Epipaleolithic microlithics but no pottery remains, dated back to 8300-8150 BP according to two AMS radiocarbon dates of charcoals collected from the stratum (Dong et al. 2013). Above the microlithic deposits, there are Neolithic culture deposits, Andaqiha. This is the earliest large-scale Neolithic site in Qinghai Province (Xiao 2013).



Figure 3.12 The site of Andaqiha in Hualong, looking to the north. Currently, there is farmland. The archaeological remains were once buried in front of the trees. Photograph courtesy of Zhancang Zhang, 2009.

Two excavation areas containing eighteen grids were excavated, with each grid measuring 5×5m. Area I contained the majority of the remains. Altogether six strata were divided. The first three strata of Area I are modern soils containing very little ancient remains. The fourth stratum was a dark grey-brownish silty loam and was diagnosed as from the Wei and Jin Dynasty (AD 220-589) period. The major period of the deposit was Neolithic and represented by Stratum 5. The sixth stratum maybe slightly older and contained very little remains (H. Qiao *pers. comm.* 2013).

The Neolithic stratum 5 is a thick layer appearing as a dark grey, brownish, silty loam. It was divided into 5 sub-layers: 5a~5f. Stratum 5a and 5b contained the majority of the remains, and both covered the whole excavated area. 5c~5d are all small layers and covered only parts of the excavated area, and they might be of the same age. Table 3.2 provides the distribution of the strata at the different grids in Area I (Qiao. *pers. comm.* 2013; Xiao 2013).

	T0101	T0102	T0103	T0104	T0302	T0303	T0304	T0402	T0403	T0404
5a	√	√	√	√	√	√	√	√	√	√
5b	√	√	√	√	√	√	√	√	√	√
5c	√								√	
5d								√		√
5e	√				√					
5f	√									
6		√	√					√	√	

Table 3.1. Distribution of the different layers of Andaqiha in the grids.

Calibrated radiocarbon dates of the site were obtained from plant remains. One unidentified wood charcoal and one charred millet seed from the same flotation sample collected in the Neolithic stratum of the site were dated (Table 3.3, Dong et al. 2014). Considering the old-wood effect (Dean 1978; Schiffer 1983), the ^{14}C date of the unidentified charcoal (LUG10-185), which is much older than that of charred seeds from the same flotation samples (Beta-292119), may not accurately reflect the date of the contemporary cultural remains of the site. Moreover, the date of the unidentified charcoal is evidently older than that of the other Majiayao sites in the region. Hence it should be abandoned (Dong et al. 2014). Therefore, the date of the Neolithic Andaqiha deposits should be around 5000 BP.

Lab nr	Dating material	Meth od	^{14}C age (BP)	Cal BP 1σ (IntCal13)	cal BP 2σ (IntCal13)	Referenc e
Beta-292119	Charred millet seeds	AMS	4340 ± 40	4906 ± 54	4937 ± 98	Chen et al. 2015

LUG10-185	Charcoal	LQC	5121 ± 88	5864 ± 118	5914 ± 262	Dong et al. 2012b
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Table 3.2. Radiocarbon dates of Andaqiha.

Numerous materials were discovered from Stratum 5, including large numbers of pottery sherds and microlithic tools, nineteen house bases (including both semi-subterranean and the above ground styles), six cooking pits, 30 ash pits, and some kilns. The pottery sherds discovered are mostly coarse, burnished red ceramics, and a small number are burnished-orange, sand-tempered brown and grey. The surfaces are decorated with black curves, lines, triangles, triangular net figures, grey ceramic rings, and cord-marked patterns. Especially, sherds of vases with small mouths and a pointed base, and basins with curved bodies are typical characteristics of the mid-late Yaoshao culture (Miaodigou style) (Qiao. *pers. comm.* August 2013), corresponding to the early-mid Majiayao culture (Dong et al. 2013).

Flotation has been conducted on this site. Altogether 9.5 L earth samples were sampled and 484 plant seeds were found, including 7 foxtail millet (*Setaria italica*), 111 Proso millet (*Panicum miliaceum*), and 366 other seeds, among which 363 are *Setaria* (*Setaria* sp.), indicating that at least two types of millets were cultivated here whilst no wheat nor barley was identified (Jia 2012).

The faunal remains were not preserved well at this site. Most parts of the bone surface were lost, and apart from very large ones normal cut marks cannot be seen. The level of fragmentation is high. About 25% of the bones were burnt. Among the burnt bones, most of them were lightly burnt. Heavily burnt specimens appearing grey or calcined accounted for about ten percent, and about thirty percent were charred or carbonized. Most of the burnt specimens are from the major ash pit (H2), accounting for >70% of burnt faunal assemblage). Root etching is observed, and on some specimens, they cover all of the bone surfaces, but in general, it's not as heavy as that at Jiangxigou 2. Gnawing marks are observed on 1.4% of the identified specimens. The elements recovered include teeth and

almost all different skeletal parts of the mammal (antler, teeth, scapula, humerus, radius, ulna, metapodials, femur, tibia, tarsal bones, phalanx, and vertebrae). The identified taxa include deer (red deer, roe deer, musk deer), Caprinae, gazelle, rodents, birds, and a small number of domestic pigs and dogs. The faunal remains were discarded all over the site, and the ash pit H2 was the major disposal point¹². The taphonomic pattern indicates that the faunal remains were not moved after being discarded and that the carcasses of the animals were disarticulated, roasted, and the bones explored for marrow by humans.

Being similar to Jiangxigou 2, the millet cultivation, structured houses, and the potteries at Andaqiha are viewed as evidence of the influence from the Yangshao Culture on the Loess Plateau, while the microlithic tools and large numbers of wild animal carcass were interpreted as the local hunting-gathering tradition (H. Qiao *pers. comm.* 2016, Xiao 2013). The existence of both types of material cultures might be interpreted as a cultural integration between the Neolithic Yaoshao culture spread from the loess plateau and the local hunting-gathering tradition (Xiao 2013). Compared with JXG2, Andaqiha is a site of a much larger scale and has developed into a village, suggesting that millet-based cultivation agriculture was quite developed at this site.

3.3.2.3 Shannashuzha

¹²The animal taxa identified at the different units of Andaqiha are provided in Appendix T.



Figure 3.13 The Shannashuzha site at Min County, looking to the east. Photo courtesy of Gansu Archaeological Institute, 2012.

Shannashuzha was excavated during a rescue archaeology project before the construction of the Lanzhou-Chongqing Railway in 2012~2013 that now passes through the site. Altogether 1400 m² were excavated, and the total area of the site was estimated as 50,000 m² (X. Zhao *pers. comm.* 2013). The excavated area accounts for 2.8% of the total estimated area of the site (Figure 3.13).

All materials were hand collected. 111 ash pits, 2 house remains, and 3 ash trenches were revealed. According to the shape and decorative patterns, the remains were diagnosed as belonging to the early Majiayao culture (Shilingxia and Majiayao style), with mid-to-late the Yangshao Culture relics (Miaodigou style) sporadically found (X. Zhao *pers. comm.* 2013). AMS 14C dating was conducted on two bamboo samples, considering that bamboo has a relatively short lifespan (Dong et al. 2016). The results are listed in Table 3.4. The dates correspond to the Majiayao culture.

Lab nr	Provenience	Method	14C age (BP)	Cal BP 1 σ (IntCal13)	cal BP 2 σ (IntCal13)	Reference
LZU1564	T0309H113	AMS	4460 \pm 25	4979-5270	4973-5282	Dong et al. 2016
LZU1565	T0110H17	AMS	4400 \pm 25	4881-5035	4874-5041	Dong et al. 2016

Table 3.3. AMS dates of Shannashuzha.

Large amount of pottery, stone tools and bone tools were collected. House F2 had been repaired and maintained for many times. Pottery tools such as a ceramic ring and a pottery basin were found. Many of them are painted potteries with black decorations, and a small number were decorated with birds and frog patterns. Stone knives, stone balls, bone knives, and bone knives were discovered. Shannashuzhais interpreted as a long-term resident base of people (X. Zhao *pers. comm.*2013).

The faunal remains were preserved quite well, with the majority of the bone surface kept intact or just slightly eroded. Cut marks can be clearly observed, which were recorded on about a quarter of the Caprinae remains. The level of fragmentation is high, with mostly just the articulation joints recognisable to taxonomy. Traces of burning were not as common as at Andaqiha, and only about 6-7% of the Caprinae specimens were found with slight traces of burning. Root-etching is slight, and gnawing marks were observed on 3% of the observed remains. The skeletal elements represented in Caprinae include cranium, maxilla, scapula, humerus, radius, femur, tibia, metacarpal, tarsal bones, phalanx, and vertebra.

A wide range of animals was identified, including a small portion of domestic animals --- pigs and dogs --- and a large number of wild animals, which consisted of *Bos*, deer, gorals, badgers, bamboo rats, hare, gazelles, monkeys, fox, and bears¹³. Among them, the

¹³ The animal taxa identified at Shannashuzh are provided in Appendix U.

majority of the identified remains are deer (L. Ren *pers. comm.*2013).

According to the extraction by flotation of the seeds in Majiayao deposits of Shannashuzha, millet seeds were pervasively found among all the units of this site. They consist of the largest proportion of the plant remains and were believed to be the staple of this community (Hu 2015). This result is in agreement with the large-scale archaeobotanical study of the Majiayao sites in Qinghai (Jia et al. 2013), which suggests that during this period rain-fed millet agriculture was fully developed and commonly practised amongst Majiayao cultural sites.

Stable carbon and nitrogen isotopes analyses were conducted on the bone collagen extracted from the identified faunal remains (Dong et al. 2016). It was found that pigs mainly relied on a C4-based diet, likely including human food waste with millets. *Bos*, Chinese goral, and deer are relied mainly on C3-based food, very probably as a result of the animals being grazed on the natural pastures. In addition, bamboo rat and badger mainly consumed a C3-based diet. In contrast, the hares also ate some millet-related food apart from C3 plants, which provides a hint of the near-site activity. In sum, combined with the agriculturally oriented stone tools found at the site, it was suggested that whilst people here had practised a millet-based agriculture, diverse economic strategies were developed at this site (Dong et al. 2016; Hu 2015).

3.3.2.4 Jinchankou



Figure 3.14 The site of Jinchankou, looking to the south. Photograph: Yiru Wang, 2013. The archaeological remains were buried under the ground at the front.

The investigation of Jinchankou was conducted in 2012 as a small-scale research excavation. The total area of the site was estimated as 8000 m², although the actual excavation area was around 285 m² with nine 5×5m grids, accounting for 3.56% of the total (Figure 3.14). All the remains were collected by hand. According to the pottery styles, it was identified as a Qijia Culture site (Q. Wang *pers. comm.* 2013).

Ten charred seeds were radiocarbon dated using the AMS method at Peking University. The detailed information is shown in Table 3.5. As can be seen, the site dates to 3721~4146 cal BP, corresponding to the age of Qijia culture.

Lab nr	Materials	Provenience	Method	14C age (BP)	Cal BP 1σ (IntCal13)	cal BP 2σ (IntCal13)	Reference
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BA130843	common millet	12HJT0304F1③	AMS	3555±25	3831-3890	3725-3955	Yang 2014
BA130844	Barley	12HJT0105F1③	AMS	3565±20	3841-3885	3777-3957	Yang 2014
BA130845	Wheat	12HJT0305F1③	AMS	3605±25	3875-3964	3846-3976	Yang 2014
BA130846	Wheat	12HJ0305F1③	AMS	3515±25	3725-3838	3704-3861	Yang 2014
BA130847	foxtail millet	12HJT1103T110 2F2	AMS	3705±25	3988-4087	3976-4145	Yang 2014
BA130848	foxtail millet	12HJT1103T1102 F2	AMS	3705±25	3988-4088	3976-4146	Yang 2014
BA130849	foxtail millet	12HJT0906F3	AMS	3585±20	3848-3904	3836-3963	Yang 2014
BA130850	Barley	12HJT0405F4③	AMS	3545±25	3734-3885	3723-3901	Yang 2014
BA130851	Barley	12HJT0105H6	AMS	3535±25	3729-3869	3721-3891	Yang 2014
BA130852	Barley	12HJ105H6	AMS	3560±25	3834-3889	3728-3959	Yang 2014

Table 3.4. AMS dates of the site Jinchankou (data from Yang 2014).

The preliminary results revealed one tomb, two kilns, five houses, and eighteen ash pits. In addition, large numbers of bone tools, stone tools, potteries, and a small amount of bronze tools were retrieved (Q. Wang *pers. comm.* 2013).

The faunal remains were preserved quite well at Jinchankou. Most of the bone surface is just lightly eroded, and cut marks could be observed. On 32% of the Caprinae remains hack marks or fine cut marks were observed. The level of fragmentation is medium-high, similar to the situation of Andaqiha and Shannashuzha, and not as severe as Jiangxigou 2. Traces of burning were not observed on any Caprinae remains, but occasionally found on the specimens of the other taxa (unpublished material). The level of root etching is light-medium, which is not as high as Andaqiha but slightly heavier than Shannashuzha. Gnawing marks were observed on about 1% of the Caprinae specimens. The elements

represented in the Caprinae remains include horn core, cranium, scapula, humerus, radius, metacarpals, metatarsals, femur, tibia, phalanx, and tarsal bones.

The taxa identified include *Sus*, dogs, and deer (red deer, roe deer, musk deer), sheep, blue sheep, gazelle, bear, fox, badger, rats etc (Li et al. 2014). Among them, the majority of the remains are deer, which accounts for more than 50% of the total identified animals. Dogs and sheep were thought as domestic, but the domestication status of *Sus* was not clear (Li et al. 2014).

The flotation of the plant remains from 1213L soil at the site unearthed 1,1243 charred plant remains (Yang 2014). 10,163 of them are crop seeds, including foxtail millet (*Setaria italic*) (n=7055), common millet (*Panicum*) (n=2821), barley (*Hordeum vulgare*) (n=275), wheat (*Triticum aestivum*) (n=15), and *Cannabis sativa*, and another 818 are wild plants seeds (Yang 2014). As can be seen, the crops consumed by people were mainly millets, which might represent an agricultural influence inherited from the Majiayao culture and the Yangshao culture. A small amounts are wheat and barley, indicating that the crops first cultivated in the west had been adopted here and consisted of a small part of the agricultural crops (Yang 2014).

3.3.2.5 Sanbadongzi



Figure 3.15 The site of Sanbadongzi, looking to the northwest. Photo courtesy of Shuicheng Li. The archaeological remains were once buried behind the pebble road.

The site was investigated and test-excavated in 1987 by the joint team of the Gansu Archaeological Research Institute and the Department of Archaeology of Peking University. Two small areas were excavated --- one beside the river terrace and another one at the southern side of the Ganguya, and each area was 4m^2 (2×2 m), with the archaeological deposit of about 30-45 cm thick. The site was lower at the southwest and higher at the northeast, and all materials were hand collected (Figure 3.15; GPRARI and PU 2016).

The styles of the potteries here indicate an affiliation with the Siba Culture, although one red coarse cooking tripod (87JFS-117) is evidently older than the age of Siba (GPRARI and PU 2016). There is no direct radiocarbon dating of this site yet, but radiocarbon dates conducted on Siba-culture material from the site of Huoshaogou and Donghuishan at mid and west of Gansu indicate that the Siba culture falls approximately within the period 3900-3400 cal. BP (S. Li *pers. comm.* 2015; Flad et al. 2010).

The deposits are black-grey and brownish silty layer, which cannot be further divided.

There are large numbers of pebbles on the ground around the site, and also scattered some stone tools and a small number of potteries. A pillar hole with the diameter of 10-12 cm was identified. Considering the regular-arranged structure of the pebbles, it was a house built of wood and earth, and a courtyard built with pebbles. A number of stone tools, potteries, and animal bones were collected. Based on the material culture from the site, it was suggested to be a residential settlement (GPRARI and PU 2016).

The preservation conditions of the faunal remains are not very good. Less than half of the remains have the surfaces slightly eroded, and the others have lost most of the surface. Normal cut marks cannot be seen, apart from quite large ones. The fragmentation level is also medium-high; 223 articulation joints and element units allowed taxonomic identification to at least Order (Flad 2016). Butchery marks were found on 33% of the Caprinae bones, including both hack marks and fine cut marks, indicating marrow extraction. No traces of burning were found, and slight root etchings were observed occasionally, whilst gnawing marks are observed on 9% of the Caprinae samples. This indicates that the faunal remains were not removed after deposition. The elements retrieved include horn cores, craniums, loose teeth, mandibles, scapula, humerus, radius, ulna, pelvis, femur, tibia, phalanx, and metatarsals, etc, and the taxa identified contained carnivore, horse, Caprinae, gazelle, cattle, pigs, and deer (Flad 2016). However, since the excavated area was very small, it might only represent part of the fauna exploited by people at the site.

Plant flotation has been conducted at Sanbadongzi (GPRARI and PU 2016). 490mL soil samples revealed 3.18g of carbonized plant remains. The crops identified include seeds and spike-stalk of wheat (*Triticum* spp) and barley (*Hordeum vulgare* L.), spike-stalk of rye (*Secale cereale*), and seeds of foxtail millet (*Setaria italic*) and broomcorn millet (*Panicum miliaceum*). The weeds found are the normal species of the drylands. This result indicates that wheat, barley, and rye had been an integral part of the crop cultivation system at this area during Siba culture period (around 3600-3400 BP), although it is still uncertain where the rye originated from (GPRARI and PU 2016).

Stable carbon and nitrogen isotopes analysis were conducted on the bone collagen extracted from the faunal and human remains from the residential part and the tombs of this site (GPRARI and PU 2016). It was found that, apart from two cattle and one pig, which mainly relied on C4-based diet, all the other animals (7 pigs, 7 cattle, 2 horses, 13 sheep/goats, 7 deer) mainly relied on C3 foods ($\delta^{13}\text{C}$ -19.7‰~-16‰). As for humans, the $\delta^{13}\text{C}$ signatures were between -12.9‰~-18.7‰, lower than the general $\delta^{13}\text{C}$ signature level of the Neolithic northern Chinese whose diet mostly consisted of the C4 crop millets. The distinguished C3 signature in nearly all humans (not only those of high social status) diets were interpreted as widely incorporating more C3 crops like wheat and barley among common people than the eastern part of China, further illustrating the importance of this area in adopting western crops (GPRARI and PU 2016).

3.4 Discussion and Summary

In general, the research area is at the border between the farming area and pastoralism area in China, and at the junction between three major geographical and environmental zones. Each small region of the studied sites has some unique environmental characters. Comparatively, Andaqiha and Jinchankou are more suitable for farming nowadays. The archaeological culture in this region suggested a contact between the local foraging people and the agricultural populations from the Yangshao culture at an early stage (5000 BP, Majiayao culture), and interactions between the early Chinese agriculturalists and Eurasian steppe pastoralists at a later stage (4500-4000 BP, Qijia culture).

The study of the climate of this region since the last glacial shows there are several periods of climate fluctuations in the Holocene. It has been suggested that the development of human societies in this area has been greatly influenced by changes in climate, with the archaeological sites being more abundant when the climate was more favourable to human life (warm and more humid), and less abundant when the climate was less favourable (cold and dry). Especially, the deterioration of the climate at around 4000 BP was suggested as the cause for the populations' occupation range reducing to the more eastern region and pastoralism becoming increasingly more common in this region (Dong

et al. 2013;Liu et al. 2010). It was also indicated that the introduction of sheep/goats was likely to be related to the climatic condition which is more favourable to pastoralism (Liu and Chen, 2012).

The information of the archaeological contexts and the faunal remains has not been given in a balanced manner for all the five sites due to varied aspects and the amount of research conducted at the different sites. However, a zooarchaeological study has to be carried out with the information available so far, while it has to bear in mind that the information gathered is still partial and the conclusions to be reached are always subject to changes when new archaeological evidence about the sites is revealed.

The materials of all the five sites have been subjected to transportation and washing after retrieval, which could also have resulted in some loss. When the five sites are compared, it is found that the remains at Jiangxigou 2 appear to have been most heavily affected by the biotic and abiotic processes after burial (e.g. root etching, alternate wet/dry conditions, temperature, and soil PH). The remains from Andaqiha received the second most severe weathering, and those from Shannashuzha, Jinchankou, and Sanbadongzi experienced more constant conditions. The burning and butchery marks on these assemblages indicate that the carcasses were mostly processed on site. People disarticulated, butchered, and roasted animals for consumption, and the animal carcasses were more directly on the fire at Andaqiha and Jiangxigou 2 than other sites. This information and the associated archaeological contexts suggest that the faunal remains were disposed of *in situ* and not removed afterwards.

Based on the current information, it can also be seen that small sized bones and the late-fusing elements of the young animals may have been systematically under-represented in the assemblages of all five sites, since four of them were retrieved without sieving (Payne 1972), whilst Jiangxigou 2 is particularly poorly preserved due to long taphonomic processes. Therefore caution should be exercised during the analysis of the general pattern of the economy based on the taxonomic frequency identified.

4. Taxonomy, Distributions, and Ecology of Caprinae and Gazella in Western China

4.1 Introduction

Domestic sheep and goats today derive from their wild ancestors, which belong to subfamily Caprinae. The animals of this subfamily range from the relatively primitive and little-known forest dwelling Goral (*Naemorhedus* sp.), weighing around 30 kg, to the Musk Ox (*Ovibos moschatus*) of the Arctic tundra which reaches over 350 kg. With such diversity, they adapt well to harsh mountain environments in the Eurasia and North America (Schaller 1977).

China, with one of the greatest ranges of the ecological diversity of any country and containing almost all Holarctic types, is one of the most important countries for Caprinae in the world in terms of diversity (IUCN/SSC 1997; Schaller 1977). Nine species are currently considered to occur in China, and these have been divided into as many as 32 subspecies by some authorities. In particular, the region of Western China contains up to 70% of the Caprinae of China (IUCN/SSC 1997) and contains my research area.

The practice of animal domestication is closely associated with the natural environments and ecological preference of the animals. However, the biological diversity of Caprinae has long been overlooked among prehistoric Chinese zooarchaeological studies. Fragmentary fossil remains have always been labelled as 'Yang' (羊) as long as found likely to be Caprinae and were often interpreted as domestic sheep in the literature (reviewed in Chapter 2). Hence the purpose of this chapter is to review the taxonomy, distributions, and ecologies of the animals in the subfamily Caprinae in Western China.

4.2 Caprinae and Gazelle of the Research Area

The Caprinae genera naturally distributed in my research area include *Ovis*, *Pseudois*, *Naemorhedus*, *Capricornis*, and five species of gazelle. It should be remembered that the habitats of some species may have changed from what they were in the past, which could be due to the modification of the environments, but more importantly, man has had a tremendous impact. Many species were forced to change their habitats under the pressure of humans' behaviour (Schaller 1977).

4.2.1 *Ovis*

Domestic sheep today derived from the wild *Ovis* distributed in the mountainous areas in the southern part of Eurasia. The taxonomy, geographical distributions, ecology and habitats of *Ovis* are reviewed below.

4.2.1.1 Taxonomy and Geographical Distribution (Table 4.1; Figure 4.1)

Wild sheep (genus *Ovis*) now range in mountainous areas in Asia and North America and is one of the most complex mammalian genera with regard to its evolution and systematics (IUCN/SSC 1997). Many wild sheep classification and revisions have been proposed according to morphological criteria, chromosome diploid number, and geographic distribution (Table 4.1 in Rezaei et al. 2010). Some authors follow the classification which proposes two species (*Ovis ammon*, *Ovis nivicola/canadensis*) (Tsalkin 1951) or even a single polymorphic species (*Ovis ammon*) (Haltenorth 1963), but up to twenty *Ovis* species are recognized when the phylogenetic species concept is applied (Groves and Grubb 2011). These disagreements are the result of multiple historical identifications and ill-defined taxonomic criteria (Bruford and Townsend 2006).

Biomolecular studies have confirmed that there are two major clades in the genus *Ovis*: Old World sheep, including *Ovis ammon*, *Ovis vignei*, and *Ovis orientalis*, and New World sheep, including *Ovis nivicola*, *Ovis dalli* and *Ovis canadensis* (Hassanin et

al. 1999; Rezaei et al. 2010). Domestic sheep lives in anthropogenic environments worldwide and clearly a group with the Old World sheep (Ropiquet and Hassanin 2005).

Among the Old World sheep, morphological traits (body size, horn morphology, colour and pattern of the coat) (Fedosenko and Blank 2005; Schaller 1977), chromosome diploid number (Bunch et al. 2006; Nadler et al. 1973b), and mtDNA data (Hiendleder et al. 1998, Hiendleder et al. 2002) have been used to study their phylogenetic relationships and taxonomy. The molecular study by Rezaei et al. (2010) based on cytochrome *b* and nuclear sequences confirmed the previous classification based on morphological criteria and chromosome diploid number, classifying them into three distinct species: *Ovis orientalis* (Western Asian Mouflon), *Ovis vignei* (Urial), and *Ovis ammon* (Argali). *Ovis orientalis* (2n=54) lives in South Central Turkey, in the mountains from Armenia and Azerbeidjan, and the southeastern end of the Zagros. *Ovis vignei* (2n=58) ranges from Turkmenistan to Eastern Iran, Afghanistan, Pakistan and Northwest India (Kashmir). *Ovis ammon* (2n=56) is distributed across the Qinghai-Tibet Plateau and the Tien-ShanAltai Mountains (Figure 4.1). High gene flow across international borders at Afghanistan and Tajikistan were observed among different subspecies of *Ovis ammon*(Luikart et al. 2011). In the overlapping distribution zones,*orientalis* × *vignei* hybrids in central, northern and southeastern Iran display intermediate chromosome numbers between 54 and 58 (Bunch et al. 1990; Nadler et al. 1971; Valdez et al. 1978,). These species show mitochondrial allele sharing and the nomenclatures used were found confusing in some cases (Bruford and Townsend 2006; Hiendleder et al. 2002; Rezaei et al. 2010).

The *Ovis orientalis musimon* (European Mouflon)is distributed in Europe. Although it was found genetically closely related to *Ovis orientalis* (Hiendleder et al. 1998, 2002; Rezaei 2010), it is no longer regarded as the potential wild ancestral source of domestic sheep, but rather a feral remnant of the first domestic populations to enter Europe (Guerrini et al. 2015; Vigne 1999). Currently, there are still hybridizations

between *Ovis musimon* and *Ovis aries*(Schröder et al. 2016).

Taxon	Common name	Range
<i>O. ammon</i>	Argali	China, Kazakstan, Pakistan, Tadjikistan, Northern India, Eastern Kazakhstan, Kyrgyzstan, Mongolia, Nepal, Pamir Range, South Central Siberia
<i>O. vignei</i>	Urial	Afghanistan, Northwest India, Northeast Iran, Southwest Kazakhstan, Pakistan, Tajikistan Turkmenistan, Uzbekistan
<i>O. orientalis</i>	Western Asian Mouflon	Armenia, Southern Azerbaijan, Northern Iraq, Western Iran, South Central and Eastern Turkey
<i>O. musimon</i>	European Mouflon	Europe
<i>O. aries</i>	Domestic Sheep	Anthropogenic environments throughout the world

Table 4.1 The classification adopted for Eurasian *Ovis*.The range is adopted from the classification in IUCN/SSC (1997: 13).



Figure 4.1The approximate range of modern *Ovis* in Eurasia (shown in light green and dark green): 1. *Ovis ammon* (Argali); 2. *Ovis vignei* (Urial); 3. *Ovis orientalis* (West Asian Mouflon); 4. *O. musimon* (European Mouflon). The range of *Ovis* compiled from Harris and Read(2008). The dotted circle shows approximately the research area.

The classification of *Ovis* followed in this dissertation is illustrated in Table 4.1.

4.2.1.2 Ecological Distributions and Body Characters

The range of *O. ammon* (Argali) today extends almost to 5750 m (Stockley 1928) near the ultimate limit of vegetation. They live in severe climates, where it is extremely cold and windy. On the Qinghai-Tibet Plateau, they inhabit the rolling terrain at high altitude, but they have not been reported in woodlands. In Northern Xinjiang, *Ovis ammon* are distributed on the low mountains and foothills of the Altai Mountains along the Mongolian border. The most easterly range of *Ovis ammon* today is the Shansi province and middle areas of Inner Mongolia. Currently, there are more animals of this species in Northern Xinjiang than in other regions in China (IUCN/SSC 1997).

Ovis ammon is the largest species in the genus (Figure 4.2). They are stout animals with a short body, thick neck, and lightly boned but robust legs. Their leg bones are much longer than those of the *Ovis vignei* (Urial) and West Asian Mouflon (*O. orientalis*). With relatively long legs, they are fast runners and may flee from predators. For adult male *Ovis ammon*, head-tail length (HB) is 177-200 cm, body weight is 110-182 kg, maximum 216 kg. *Ovis ammon* is also the most sexually dimorphic of species of wild sheep. Females are much smaller, weighing about a third that of males. The horns of *Ovis ammon* are the longest, thickest, and heaviest of all wild species of sheep. In the males, the horns curve down and forward for more than 360 degrees, with heavy annuli and a broad base that increase in length and mass with age. The facial part of the skull of *Ovis ammon* is elongated. The occiput of *Ovis ammon* protrudes little beyond the rear margins of horn cores and drops almost vertically, and is considerably shorter than in *Ovis orientalis* and *Ovis vignei* (Fedosenko and Blank 2005).



Figure 4.2 Photos of *Ovis ammon*. Left: *Ovis ammon* in still (Argali_sheep, n.d.); Right: *Ovis ammon* sheep in the run (Mountain_sheep, n.d.).

As noted before, *Ovis vignei* (Urial) and West Asian Mouflon (*Ovis orientalis*) have adapted to a variety of ecological conditions and are very difficult to be separated clearly. Their altitudinal range stretches from sea level to above 5000 m. Apart from *Ovis vignei* in Ladak (the region of Northwest India lying between the Kunlun mountain range in the north and the main Great Himalayans to the south), where they ascend to 4200 m, most of the others were found at relatively low altitudes. Currently, they live on gently to steeply rolling, but not precipitous, terrain, in open habitats where trees are sparse or absent (Schaller 1977). In KysylKum in Russia, *Ovis vignei* were found where there were only small eroded buttes rising 100 to 200 m above the sands (Heptner et al. 1996); in Kavir Protected Region of the Siah Koh (Iran), they were observed in a barren expanse of sand with crumbly rock being covered with only occasional herbs (Schaller 1977). In Chitral, however, the Ladak *Ovis vignei* was once found in oak forests, according to villagers who once hunted them, and the Punjab *Ovis vignei* in Kalabagh may frequent dense thickets. It has been suggested that dense forests were major barriers to *Ovis vignei* movements along some mountain ranges, enabling them to evolve into different subspecies (Schaller 1977). On the island of Corsica, *Ovis musimon* were found in fairly dense evergreen forests (Clark 1964; Pfeffer 1967). The body characteristics of the *Ovis vignei* (Urial), *Ovis orientalis* (Western Asian Mouflon), *Ovis musimon* (European Mouflon), and *Ovis aries* (domestic sheep) are illustrated in Figure 4.3.



1



2



3



4

Figure 4.3 *Ovis* in Eurasia: 1. Male *Ovis vignei* (Urial) (Urial n.d.); 2. Male *Ovis orientalis* (Western Asian Mouflon) (Mouflon n.d.); 3. *Ovis musimon* (European Mouflon) in Cyprus; 4. *Ovis aries* (Domestic sheep) (Crawford 2011).

Being adapted to flat or undulating habitats, *Ovis vignei* are stout-bodied but not heavily muscled, and they have light-boned legs. The body size of *Ovis vignei* and Western Asian Mouflon is very variable both within and between populations. The *Ovis vignei* in the eastern range mostly belong to an intermediate size range of from 50 to 100 kg, with shoulder height > 90 cm, while Western Asiatic sheep are generally smaller in size (Schaller 1977). But geographical variety exists, with those in the south being smaller than those in the north. For example, Panjab *Ovis vignei* are of small size, whereas sheep to the west in Kopet Dagh (the mountain range at the northern frontier of Iran) are bigger. This size difference should be due to the Bergmann rule (1847) of large size being an adaptation to cold climate regimes. Female *Ovis vignei* are smaller than males. Armenian *Ovis vignei* ewes are about 62% of the weight of the rams. In

some western populations, the females lack horns. *Ovis vignei* have distinctive throat ruffs and lose their ruffs annually during the spring moult. Among the *Ovis orientalis* on Cyprus and Armenia, the smallest males weigh fewer than 50 kg, and their shoulder height ranges from 66 to 84 cm (Schaller 1977). The detailed information of the body characters and habitats of Eurasian *Ovis* is summarized in Table 4.2.

Taxonomy	Body characters	Habitats/Ecology
<i>Ovis ammon</i>	Males: SH=106-135; Wt =110-182 kg, maximum 216 kg. Horns of males: massive, curve down and forward for more than 360 degrees; long leg bones	Rolling terrain of high altitude ascending to >5000m; low mountain and foothills; fast runners; never reported in woodland
<i>Ovis vignei</i>	Males: SH > 90 cm; Wt=50-100 kg, stout-bodied but not heavily muscled; light-boned legs	Terrains gently to steeply rolling but not precipitous; open habitats where trees are sparse or absent, most on relatively low altitudes <4000m; oak forest and dense thickets.
<i>Ovis orientalis</i>	Similar to <i>Ovis vignei</i> , some females lack horns	Sterile desert, sand and crumbly rock covered with only occasional herbs, flat or undulating habitats, lower altitudes
<i>Ovis aries</i>	Varied body size and structure, reduced brain size and eye socket, shortened limb bones, increased frequency of pathological lesions on toes	Closely confined to certain ranges by man, less access to rugged terrains, less agile and less active in jumping and running

Table 4.2 Summary of the body characters and habitats of Eurasian *Ovis* (Clark 1964; Fedosenko and Blank 2005; IUCN/SSC 1997; Pfeffer 1967; Ryder 1983; Schaller 1977; Stockley 1928; Zohary et al. 1998). SH: shoulder height; Wt: weight.

4.2.1.3 Other Characteristics

Wild *Ovis* prefer grass when it is available, but they consume a wide variety of forbs and leaves from shrubs and trees. They follow a diurnal pattern in the daily activity of feeding but do not have a pattern of seasonal migration like some other Caprinae and ungulates. The extent of movement in sheep varies considerably from population to population even within a species. The territory of *Ovis vignei* in Kalabagh

encompasses about 40 sq km (Schaller 1977). They are highly social animals living in herds consisting of variable numbers of males, females, and young. The sexes segregate more completely among *Ovis ammon* than *Ovis vignei* and *Ovis orientalis*. *Ovis ammon* stay in separate ram and ewe herds throughout the year apart from during the mating season (Cobbold 1900; Darrah 1898; Demidov 1900; Dunmore 1893; Macintyre 1891). The main mating season of *Ovis* occurs in autumn and winter, and it varies amongst the different populations. *Ovis ammon* have a later and shorter mating period (from December to early January) (Heptner et al. 1966; Lambden 1966) than *Ovis vignei*. Few *Ovis orientalis* live longer than 9 years in the wild (Pfeffer 1967), while *Ovis ammon* have a longer lifespan (Heptner et al. 1966).

4.2.2 *Capra*

Today the genus *Capra* includes several forms of wild goats present in mountain habitats from Northern Mongolia and Russia to Western Europe and Ethiopia, as well as the 'cosmopolitan' domestic form. Three species of wild *Capra* are commonly recognized: *Capra aegagrus*, *Capra ibex*, and *Capra falconeri*. Unlike sheep, although all goats also interbreed freely in captivity (Corbet 1978; Couturier 1962; Gray 1954), when two kinds of goat colonize the same range naturally, they evolve at least a partial reproductive barrier and hybrids are rare; this was supposed to represent a valid criterion for a species (Schaller 1977). A recent bimolecular study found discrepancies between the phylogenetic patterns of these different *Capra* groups according to their Y-chromosome and mtDNA data, which might be explained by the hybridization between the ancestral Bezoar (*Capra aegagrus*) and Ibex type (*Capra ibex*) (Pidancier et al. 2006).

As discussed in Chapter 2, *C. aegagrus* was the ancestor of the domestic goat *C. hircus*. The horns of wild goats are scimitar-shaped with a sharp anterior keel, their sweep broke by occasional knobs on the anterior surface (Figure 4.5). Today these animals are distributed discontinuously from Central Afghanistan and Southern Pakistan, west through Iran, Western Turkmenistan, Northern Iraq, and the Caucasus

region as far as Northwestern Turkey (Weinberg et al. 2008) (Figure 4.4). They used to occur in Jordan, Lebanon and Syria, but are now extinct in these areas (Grubb 2005), and also occurred in Israel before 10,000 years ago (Dayan et al. 1986).

The horns of *Capra ibex* are scimitar-shaped as in the wild goat, but the anterior surface is relatively flat and broken by prominent transverse ridges. There are different opinions on the classification of this species, but generally, six subspecies are recognized. They occur in Alpine regions, Sudan, Egypt, Syria, Israel, the Arabian Peninsula, Ethiopia, and the Western Caucasus. The only *Capra* species in China is the Asiatic or Siberian ibex (*C. i. Sibirica*), which ranges over vast areas of Central Asia and China, including Gansu, Inner Mongolia, Tibet and Xinjiang (IUCN/SSC 1997) (Figure 4.4).

C. falconeri, commonly called Markhor, have sharp-keeled horns twisted into an open or tight spiral. These creatures live in India, Pakistan, Afghanistan, Tajikistan, Turkmenistan, and Uzbekistan. Their ranges in India and Pakistan are close to but do not penetrate into, China (Figure 4.4). Hybridizations of Markhor (*C. falconeri*) and wild goat (*C. aegagrus*) have been reported (Corbet 1978; Couturier 1962).

As Figure 4.4 shows, none of the wild goat species are distributed in my research area, hence, their ecology and behaviours are only presented briefly here. Goats eat the leaves of most shrubs and trees as well as various grasses and forbs depending on local conditions and visit rocky depressions filled with water. They are expert climbers and retreat to cliffs when seriously threatened. They devote more time to browsing than sheep, reaching the vegetation on cliffs. All *Capra* become mature enough to mate in two to three years (Schaller 1977).



Figure 4.4 The approximate range of modern *Capra* in Eurasia (shown in light green, dark green, and red): 1. *Capra aegagrus*; 2. *Capra falconeri*; 3. *Capra sibirica*. Compiled from Michel and Rosen Michel (2015), Reading and Shank (2008) and Weimar et al. 2008. The dotted circle shows approximately the research area.



Figure 4.5 Left photo: wild goat (*Capra aegagrus*) (cretanwildgoat n.d.); right photo: domestic goat (*Capra hircus*) (Fir0002/Flagstaffotos 2007).

4.2.3 Domestic Sheep and Goats

Ovis aries and *Capra hircus*, domestic sheep and goats, are derived from their wild ancestors and currently live in anthropogenic environments of even broader areas and environments distributed all over the world. There are lots of different breeds today.

The domestication behaviours of sheep and goats are related to inbreeding,

outbreeding, and selective breeding (Ryder 1983). Inbreeding might be firstly caused by herding or fencing (Lush 1945), which may result in a smaller breeding unit than in the wild state, and soon all the animals of a community become related. In order to slow down the movement toward uniformity and discard any undesired results, people could have introduced outside stock. Ryder (1983) suggested that it would mainly have been from neighbouring areas, and moreover that there would have been much greater outbreeding --- human migrations would have transported animals far beyond the areas over which they would have wandered before they were domesticated, letting very different races interbreed. Long ago Lush (1945) pointed out that a combination of moderate inbreeding and occasional outbreeding has the effect of producing many distinct families which are moderately uniform within themselves.

Reed (1959) and Ryder (1983) postulated that selective breeding might have been carried out by the preferential killing of males and later by castration, as rams are often aggressive, especially during the rut, and hence more difficult to keep. Under domestication, only a few rams and a large number of breeding ewes are required to ensure the continuity of the herd. Selection under human domestication usually acts in an opposite manner to natural selection, as humans tend to emphasize characters that are of no value in the wild state such as passivity and submissiveness (Reed 1959; Ryder 1983), as already discussed in Chapter 2, *Ovis aries* are closely confined to a certain range set by people and protected from natural predators. Thus they are less agile and less active in jumping and running than wild sheep (Zohary et al. 1998). Also, domestic sheep and goats have a much higher reproductive rate and more offspring than their wild relatives, and in temperate Europe, for example, are commonly provided with extra feed during the winter (Ryder 1983).

The changing ecology of the animals under domestication resulted in changes in body characteristics. The selective culling of young males initiated a reduction in sexual dimorphism. Domestic rams have marked reductions in body and horn size, which is accompanied by a change in the shape and angulation of horns, including

helically twisted horns in goats (Zohary et al. 1998). In some breeds of modern domestic sheep both sexes are horned, in others, only the rams are horned or both sexes are polled (Figure 4.3). In general, loss of horns in livestock is one of the consequences of domestication, as is also evident in cattle (Ryder 1983).

In sum, there are marked reductions in body size and change in shape in domestic sheep and goats compared with their wild counterparts. The changes can be evidenced zooarchaeological include a shortening of the extremities, a reduced brain capacity, a reduced robustness of the bones, decreasing size of sensory functional organs (e.g. eye sockets, ear bones) and increased frequency of pathological lesions on toes (Zohary et al. 1998). The change in the orientation of the crystallites of the bone minerals makes the bones of domestic sheep often feel smooth to touch (Drew et al. 1971), though the conditions vary in different breeds. Increase in the size of sheep between the Neolithic and Bronze Ages in Europe was evidenced by metapodial length/width ratios (Bökönny 1977).

4.2.4 Pseudois

4.2.4.1 Taxonomy and Geographical Distributions

The common name of *Pseudois* is Blue Sheep, Bharal in Hindi, and Yan Yang (岩羊) in Chinese. It is a small genus under the Tribe Caprini, subfamily of Caprinae. Only one species, *Pseudois nayaur*, is accepted in this dissertation following Schaller (1977), although some people also recognize a (sub)species of dwarf form (Feng et al. 2001; Schaefer 1937; Wang and Hoffmann 1987; Zeng et al. 2008). Nevertheless, in the early days when *Pseudois nayaur* was first recognized, it was described under the genus *Ovis*, being recorded as *Ovis na hoor* (Hodgson, 1834), *Ovis na hura* (Gray, 1843) and *Ovis burhel* (Gray, 1863) (Wang and Hoffmann 1987). In some current museum collections and literature, they are still regarded in this way and confused with *Ovis* (e.g. Xie and Zhang 1994).

The range of *Pseudois nayaur* includes the Qinghai-Tibet Plateau, Gansu,

InnerMongolia andWest Sichuan.In the south and west, they have also penetrated the Himalayas into Nepal, northern India and the Pamir mountains (Schaller 1977; Smith et al. 2010) (Figure 4.6).

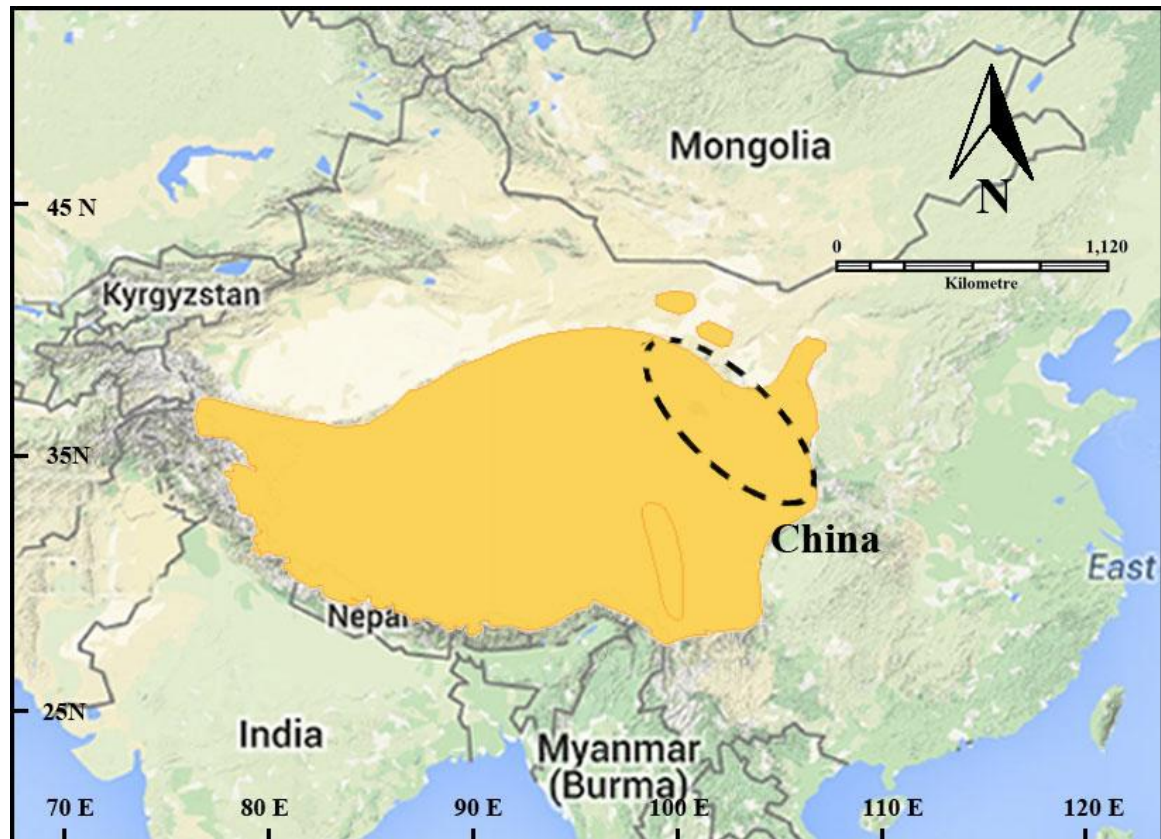


Figure 4.6The approximate range of the modern Blue Sheep (*Pseudois nayaur*, shown as yellow shading) distributed close to the research area (the approximate range shown in dotted circle).Compiled from Harris (2014).

A phylogenetic analysis based on mtDNA fragment suggested that *Pseudois nayaur* along with true goats represent an evolutionary lineage that separated from true sheep and *Ammotragusa* long time ago (Ludwig and Fischer 1998). Experiments found that *Pseudois nayaur* and *Ovis aries* did not interbreed, and across between a male *Pseudois nayaur* and domestic goats produced full-term but stillborn twins (Schaller 1977).

4.2.4.2 Ecological Distributions and Body Characters

Pseudois nayaur live above the timberline, from 3500 m upward to the limit of

vegetation at around 5500 m, except in the eastern range where some populations descend to 2600 m in the gorge of the Yangtse River (Schaefer 1937). They are found grazing on the ground in the immediate vicinity of rocky fastnesses (Kinloch 1892; Schaller 1977; Sheldon 1975). They forage on grasses, shrubs, and forbs, and move on the lower slopes, alpine meadows, as well as over steep and broken cliffs. The steeply rolling hills are places where they graze while the cliffs are used as retreats in times of danger (Schaller 1977).

Pseudois nayaur are medium-sized animals showing a bewildering combination of sheep- and goat-like traits (Schaller 1977) (Figure 4.7). They are similar to *Ovis* and *Capra* in a series of characteristics but differ in horn structure and some morphological characteristics (Schaller 1977; Smith et al. 2010). Their horns are comparatively smooth, without distinct transverse wrinkles, and do not spiral but rather twist outward from the head, and are roughly subquad rangular in cross-section at base for males and suboval for females (Wang and Hoffmann 1987).

The weights of the animals range from 50-70 kg for males, and 35-45 kg for females, with that of females being 0.65 percent that of males (shoulder height = 69-91 cm; head-tail length = 120-165 cm). The figures for dwarf Blue Sheep are slightly smaller: weight 28-65 kg for males and 17-40 kg for female (shoulder height 50-80 kg; head-tail length = 109-160 cm) (Smith et al. 2010).



Figure 4.7 Blue Sheep (*Pseudois nayaur*): (left) Blue Sheep on cliffs (Bluesheep 2008; (right) Blue Sheep in the Himalayas (Jankovoy n.d.).

4.2.4.3 Other Characteristics

Blue Sheep feed on grass, alpine herbs, shrubs, dead forbs and lichens. The herds may be up to 200 in size (Stockley 1928) and even 400 (Schaefer 1937), but the measure now 4.8-18.4 based on Schaller's observation in Shey. They have active curves offending the mornings and afternoon. Males sometimes form all-male herds, and sometimes mix with family herds (Schaller 1977). The fossils of *Pseudois* are identified in Late Pleistocene localities in Northern China (Wang and Hoffmann 1987), and also in Neolithic site such as Anban, situated in the Central Plain and dating to around 5000 years ago (DANU 2000; Parrini et al. 2009).

4.2.5 *Nemorhaedus* and *Capricornis*

4.2.5.1 Taxonomy and Geographical Distributions

The common name of *Nemorhaedus* is Goral. In Chinese, they are called BanLing (斑羚) or Qing Yang (青羊). The common name of *Capricornis* is serow, and SuMenLing (苏门羚) or Lie Ling (鬣羚) in Chinese. They are both genera under the Tribe Rupicaprini. The chromosome number of long-tailed Goral is reported as $2n=56$, most closely related to *Capricornis sumatrensis*. Nucleolar Organizer Region also

indicates a close relationship between *Capricornis* and *Nemorhaedus* (Soma et al. 1987). Therefore these two genera are presented together.

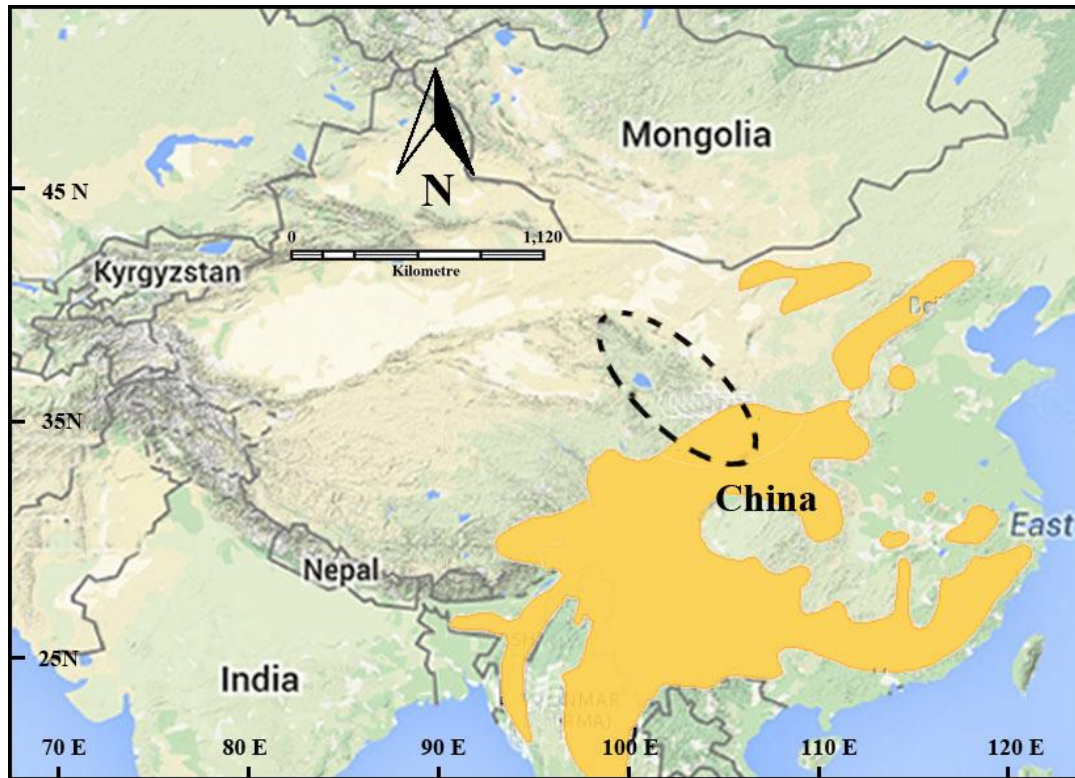


Figure 4.8 The range of the modern Goral (*Nemorhaedus baileyi* and *Nemorhaedus griseus*, shown as yellow shading) distributed close to the research area (the approximate range shown in dotted circle). Compiled from Duckworth and MacKinnon (2008) and Duckworth et al. (2008a).

Gorals (*Nemorhaedus*) are widely found in China and Southeast Asia and also extended along the southern flanks of the Himalayas, crossing the Indus into Northern Pakistan (Mead 1989). Among them, only the Red Goral *Nemorhaedus baileyi* and the Chinese Goral *Nemorhaedus griseus* are distributed close to the research area, ranging across southeast Tibet, Northwest Yunnan, and Central South China (Figure 4.8). The Long-tailed Goral is found in Eastern China, and the Himalayan goral is present along the northern flanks of the Himalayas (Smith et al. 2010), so both are far away from my research area, in different ecologies, though the current range is believed to be considerably reduced compared with earlier times (IUCN/SSC 1997).

The Serow (*Capricornis*) now extends as far north as Japan and is found widely

distributed in the forested areas of mainland China, Southeast Asia, Malaysia and Sumatra as well as Taiwan (Schaller 1977). Among six species of *Capricornis* only one species is likely to have occurred in the research area: *Capricornis milneedwardsii* (Chinese Serow). They were distributed across Central and much of South China (Figure 4.9). The *Capricornis tahr*, Himalayan Serow, currently ranges only on the south slope of Qomolangma on the border with the Nepalese Himalayas (IUCN/SSC 1997), is not likely to have occurred in the research area in the past because the ecology there is different from Qinghai and Gansu.

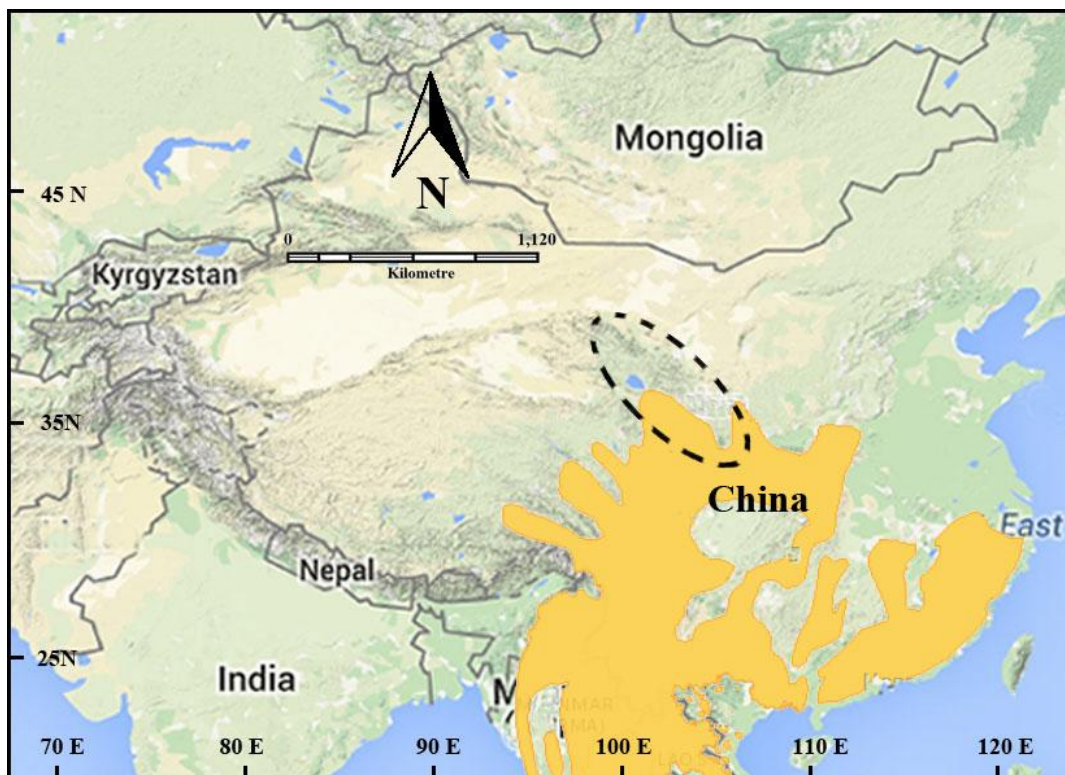


Figure 4.9 The range of the modern Serow (*Capricornis milneedwardsii*, shown as yellow shading) distributed close to the research area (the approximate range shown in dotted circle). Compiled from Duckworth et al. (2008b).

It should be noted that some sources consider Serows in China as *C. sumatraensis* and five subspecies are recognized (e.g. IUCN/SSC 1997). Besides, this form has commonly been included in the genus *Nemorhaedus* (Smith et al. 2010).

4.2.5.2 Ecologies and Body Characters

Both Serow and Goral are forest animals and quite well adapted to rugged, steep, and mountainous terrains. Serows also move on low mountains and foothills and are much larger than the Goral in body size. The ecological and body characters are shown in Table 4.3, Figure 4.10, and Figure 4.11.

Taxonomy	Elevation (m)	Ecology	Appearance	Wt (kg)	HB (cm)	SH (cm)
Goral (<i>Nemorhaedus</i>)	500-4500	Wooded, rugged, mountainous terrain; dryer conditions	Goat-antelope like, coarse, shaggy hair, short mane, grey to dark brown and foxy red	20-32	88-118	50-78
Serow (<i>Capricornis</i>)	200-4000	Steep areas and alpine cliffs, low mountains foothills, tropical rainforests	Blackish, greyish, reddish, goat-like, stocky, stiff and shaggy mane	61-140	140-170	90-100

Table 4.3 Summary of the ecology and body appearance of the Serow and Goral. (Data compiled from Mead 1989; Schaller 1977; Shackleton 1997; Smith et al. 2010). Wt = weight; HB= head-tail length; SH= shoulder height.



Figure 4.10(Left) young Red Goral (*Nemorhaedus baileyi*) feeding (Cubitt n.d.); (Right) Chinese Goral (*Neamorhedus griseus*) (Aidehua2013 2011).



Figure 4.11 Chinese Serow (*Capricornis milneedwardsii*) feeding in the forest (Smithsonian 2008).

4.2.5.3 Other Characteristics

Fossil records of Goral were reported in seven locations of Pleistocene Asia. In China, bones of Goral of middle Pleistocene age were identified in Sichuan province (Colbert et al. 1953), and of early Pleistocene age at Tam Yang (Arambourg and Fromaget 1938). Gorals have been widely identified at Neolithic sites in China such as Karuo dated to 5000–4000 years ago (Huang and Leng 1985), Tangzigou in Yunnan province around 7000 years ago (Ji et al. 2004), and Guantaoyuan 6000 years ago (Hu 2007). No Serows have been identified in Chinese archaeological reports up to now, but this might be due to the use of the nomenclature *Nemorhaedus* for *Capricornis* as mentioned before.

4.2.6 Gazelle

4.2.6.1 Taxonomy and Geographical Distributions

Apart from Caprinae, five species of Gazelles are distributed at, or close to the

research area today or in the recent past. Three of them belong to the genus *Procapra*, and the other two to *Gazella* and *Pantholops*. The taxonomy, their common name, and geographical distributions are summarized in Table 4.4.

Both *Gazella* and *Procapra* are placed within the Subfamily Antilopinae, Family Bovidae. The Tibetan antelopes *Pantholops* are either placed with *Saigata tarica* under the subfamily Caprinae or under the subfamily Antilopinae (Bannikov et al. 1961; Gentry 1992; Simpson 1945). The mtDNA sequence analysis tends to place it under Caprinae (Gatesy et al. 1997; Hassanin and Douzery 1999), but it is highly distinctive in morphology from other species within the Caprini (Gentry 1992; Lei et al. 2003). All gazelles are commonly referred to as Huang Yang (黄羊 = yellow sheep) by Chinese in some areas.

Gazella subgutturosa is commonly called the Goitered Gazelle. In Chinese, its scientific name is E-hou-ling (鹅喉羚). *Procapra* is commonly called the Central Asian Gazelle. In Chinese their scientific name is Yuan Ling (原羚). *Procapra picticaudata*, the Tibetan Gazelle or Zang Yuan Ling (藏原羚) in Chinese, and *Pantholops hogsonii*, the Tibetan Antelope or Zang Ling Yang (藏羚羊) in Chinese, are both distributed in Qinghai-Tibet Plateau and sometimes confused with each other. Due to the similar conditions, Goitered Gazelle and Mongolian Gazelle are discussed together, and the two Tibetan species together below.

Goitered Gazelle has a very wide distribution across the Middle East and Asia (Kingswood and Blank 1996). Since the beginning of the 20th century, their range has contracted drastically. In China, they range in Xinjiang, North Qinghai, Gansu, and Inner Mongolia (Smith et al. 2008) (Figure 4.12). The range is quite similar to that of the Mongolian Gazelle (*Procapra gutturosa*), which was once widely spread across the Central Asiatic steppe belt and Northern China, but sharply reduced in the area during the second half of the last century. Currently, Mongolian Gazelles do not occur beyond the Great Wall, surviving in the Mongolian steppes and Transbalkalia (Russia) (Sokolov and Lushchekina 1997; Wilson and Reeder 2005).

Taxonomy		Geographical distribution (recent historical)
<i>Gazella subgutturosa</i>	Goitered Gazelle	Arabian Peninsula to Northwestern China, Southern Mongolia
<i>Procapra gutturosa</i>	Mongolian Gazelle	Widespread in Central Asia steppe belt, Northern China
<i>Procapra przewalskii</i>	Przewalski's Gazelle	Eastern Qinghai, Inner Mongolia, Ningxia, Shanxi
<i>Procapra picticaudata</i>	Tibetan Gazelle	Qinghai-Tibet Plateau
<i>Panthalops hodgsonii</i>	Tibetan Antelope/Chiru	Qinghai-Tibet Plateau, Xinjiang

Table 4.4 Taxonomy and recent geographical distributions of gazelles in the research area (Leslie Jr 2010; Sokolov and Lushchekina 1997; Wilson and Reeder 2005).

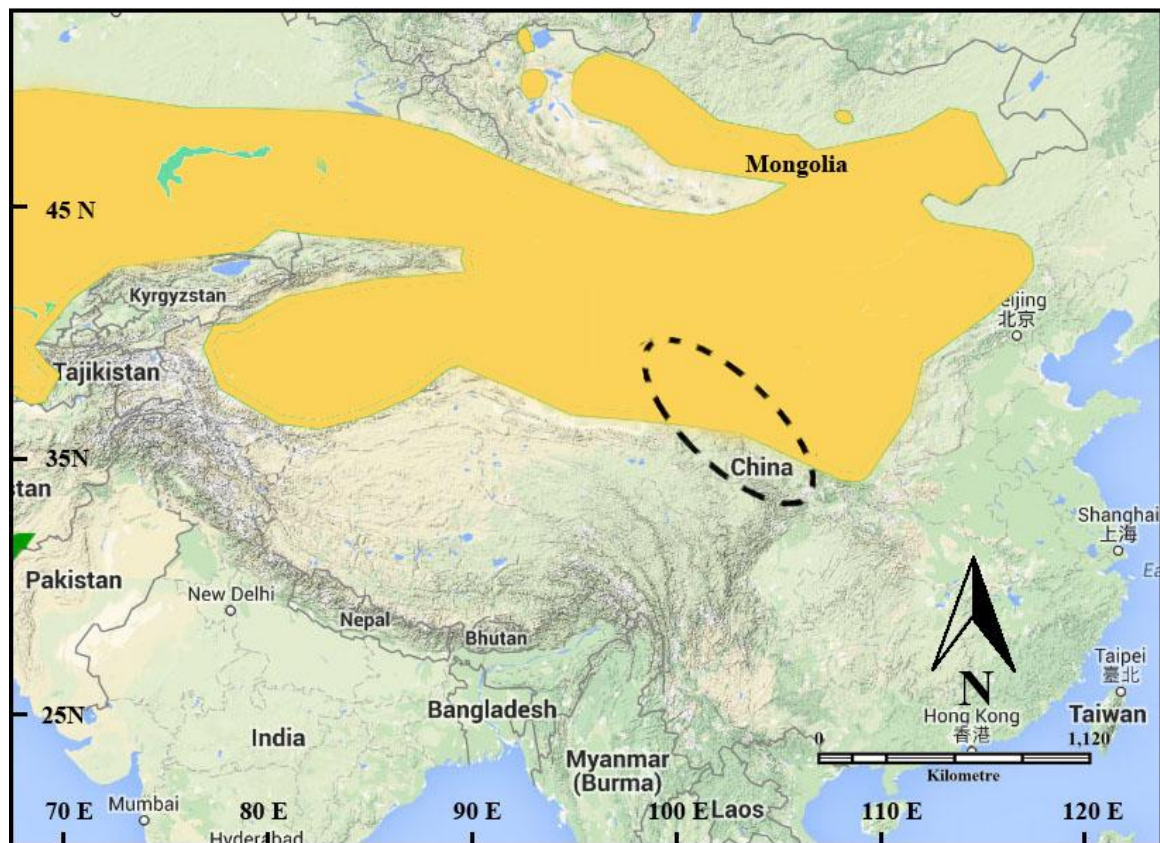


Figure 4.12 Range of Goitered Gazelle (*Gazella subgutturosa*, shown as yellow shading) distributed close to the research area (the approximate range shown in dotted circle). Compiled from Mallon (2008).

Both *Procapra picticaudata* and *Pantholops hodgsonii* are endemic to Qinghai-Tibet Plateau (Figure 4.13; Figure 4.14). Their ranges include the Chinese provinces of Gansu, Qinghai, Sichuan, Tibet and Xinjiang. Currently, they occur only on the Plateau higher than 3000 metres above sea level, but this range should have already been reduced to higher elevations due to the development of human society (Leslie Jr 2010; Leslie Jr and Schaller 2008; Smith et al. 2010).

P. przewalskii were historically widespread, but now are restricted to very small and isolated areas in the vicinity of Qinghai Lake, north of Qinghai Province, and are nearly extinct. Historically, they occurred in Eastern Qinghai, Inner Mongolia, Ningxia, and Shanxi (Leslie Jr 2010).

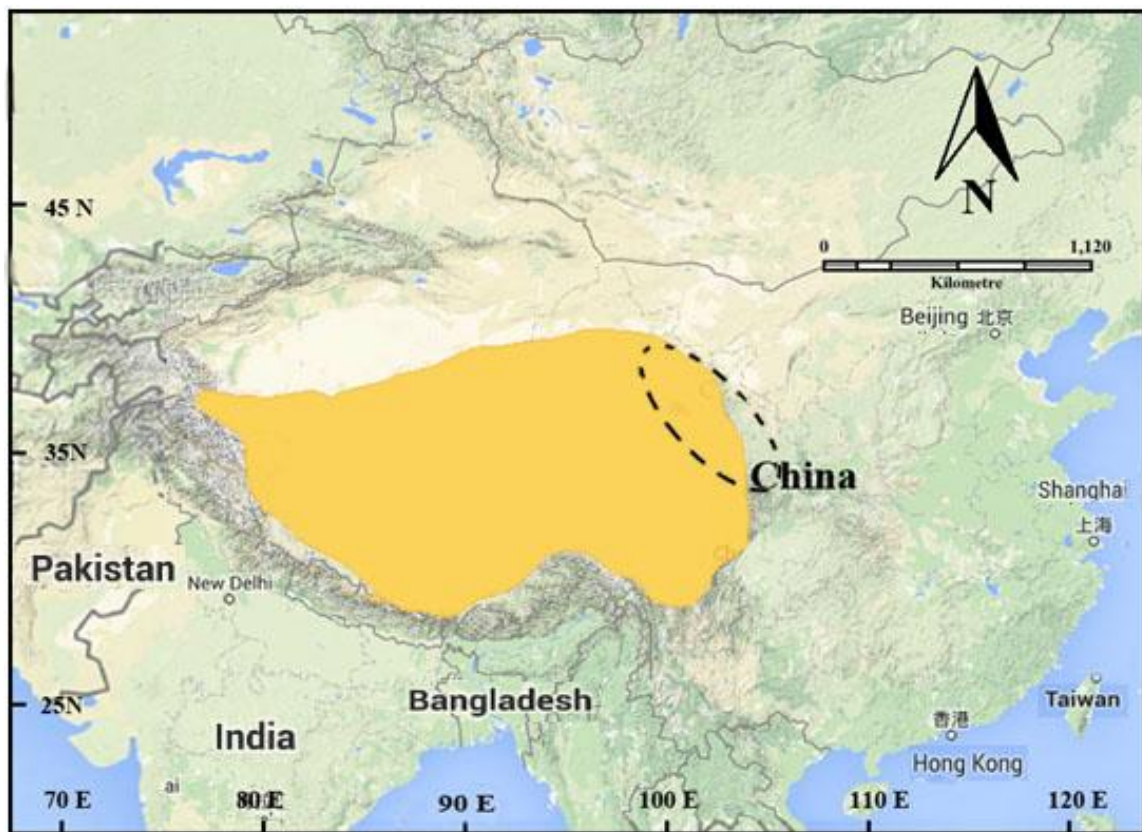


Figure 4.13 Range of Tibetan Gazelle (*Procapra picticaudata*, shown as yellow shading). Compiled from Mallon and Bhatnagar (2008). The dotted circle shows the approximate research area

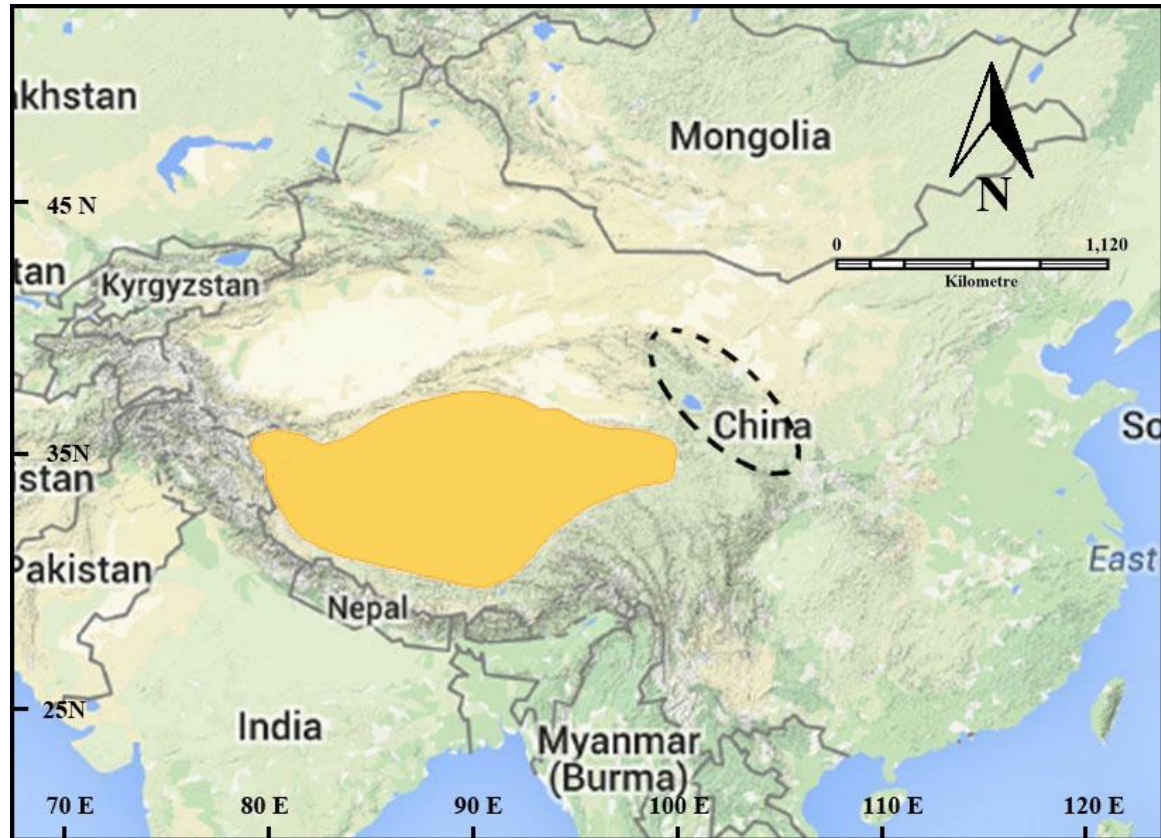


Figure 4.14 Current range of Tibetan Antelope (*Pantholops hodgsonii*, shown as yellow shading) Compiled from Mallon (2008). The dotted circle shows the approximate research area.

4.2.6.2 Ecological Distributions and Body Characters

Goitered Gazelle and Przewalski's Gazelle are both distributed at elevations of about 1000-3000 m on the desert, alpine grasslands, and semiarid grasslands (Cai et al. 1990; Heptner et al. 1966; Leslie Jr 2010). The Mongolian Gazelle is distributed lower on the zonal steppes (Sokolov and Lushchekina 1997; Wilson and Reeder 2005). The two species endemic to the Qinghai-Tibet Plateau are both distributed on open alpine meadows and steppes with high elevation, but their former range might have been larger and lower (Kingswood and Blank 1996; Leslie Jr et al. 2010).

Apart from the Tibetan Gazelle (*Procapra picticaudata*) having a diminutive body size, most of the others are medium-sized antelopes (Table 4.5). In general, gazelles are lightly built animals with elegant shape and slender legs (Heptner et al. 1966;

Kingswood and Blank 1996; Smith et al. 2010) (Figure 4.15, Figure 4.16, Figure 4.17).

Taxonomy	Wt (kg)	HB (cm)	SH (cm)	Ecological distribution	Elevation (m)
<i>Gazella subgutturosa</i>	18-34	94-126	56-79	Desert, steppes, alpine grasslands	1000-3500
<i>Procapra gutturosa</i>	20-39	105-160	54-84	Zonal steppes, dry, small-root, mat-grass	800-1000
<i>Procapra przewalskii</i>	17-32	109-160	50-70	Semiarid grassland steppe	1000-3000
<i>Procapra picticaudata</i>	13-16	91-105	54-65	Open alpine meadows and steppe	3000-5750
<i>Pantholops hodgsonii</i>	24-42	100-140	79-94	Open alpine and desert steppes	3250-5500

Table 4.5 Body features and ecological distributions of gazelle in the research. (Wt= body mass; HB= head-tail length; SH= shoulder height) (Heptner et al. 1966; Kingswood and Blank 1996; Leslie Jr 2010; Leslie Jr and Schaller 2008, Leslie Jr et al. 2010; Smith et al. 2010; Sokolov and Lushchekina 1997).



Figure 4.15 Group of Goitered Gazelles (*Gazella subgutturosa*) running (Ševčík n.d.).



Figure 4.16 Tibetan Gazelle (*Procapra picticaudata*): (left) a group of males (NZMC n.d.); (right) newborn baby in hiding posture (Schaller 1997: 119).

Gazelles are among the fastest ungulate species. When chased, Mongolian Gazelle can run parallel to a moving vehicle at a speed of 60-70 km/hr, maintaining that speed for 12-15 km (Sokolov and Lushchekina 2012). Przewalski's Gazelle was noted as 'marvellously' swift by Przewalski (Leslie Jr et al. 2010). They are capable of jumping fences of 90-100 cm high (Leslie Jr 2010).



Figure 4.17 Tibetan Antelopes (*Pantholops hodgsonii*) (Agency 2007).

4.2.6.3 Other Characteristics

The basic product obtained from the gazelles is excellent high-caloric meat (Leslie Jr 2010; Sokolov and Lushchekina 1997). The development of human society has degraded the life of the gazelles. The animals have declined or have been extirpated in many parts of their range. Poaching, loss of prime habitat to agriculture and extensive fencing for livestock are the major problems for their degradation (Kingswood and Blank 1996; Leslie Jr 2010)

In China, Mongolian Gazelle were identified in Neolithic deposits in the Baijiacun site (Zhou 1994) dating to 8500-7000 years ago, and at the Jiangzhai site in the Central Plain of China 6700 years ago (Qi 1988). Tibetan Gazelle has been identified at the Neolithic site of Karuo in Tibet dating to 5000 years ago (Huang and Leng 1985). There is no secure archaeological record of other gazelles.

4.3 Current Caprine Herding Practice in Northeastern Qinghai

During two seasons of fieldwork in the summer of 2012 and 2013, I made ten visits to five areas in Qinghai to make a study of current (traditional) sheep herding practice, to help inform my understanding. The places were at Hualong (化隆), Haiyan (海晏), Huzhu (互助), Qilian (祁连), and Henan (河南), which are mostly concentrated in the northeast of the province (Figure 4.18) and close to the research area. Among them, Hualong and Huzhu are mainly agricultural economic regions, Haiyan is a half agricultural and half herding region, and Qilian and Henan are pure herding regions. Valuable information about the current sheep herding practices was obtained from these regions.

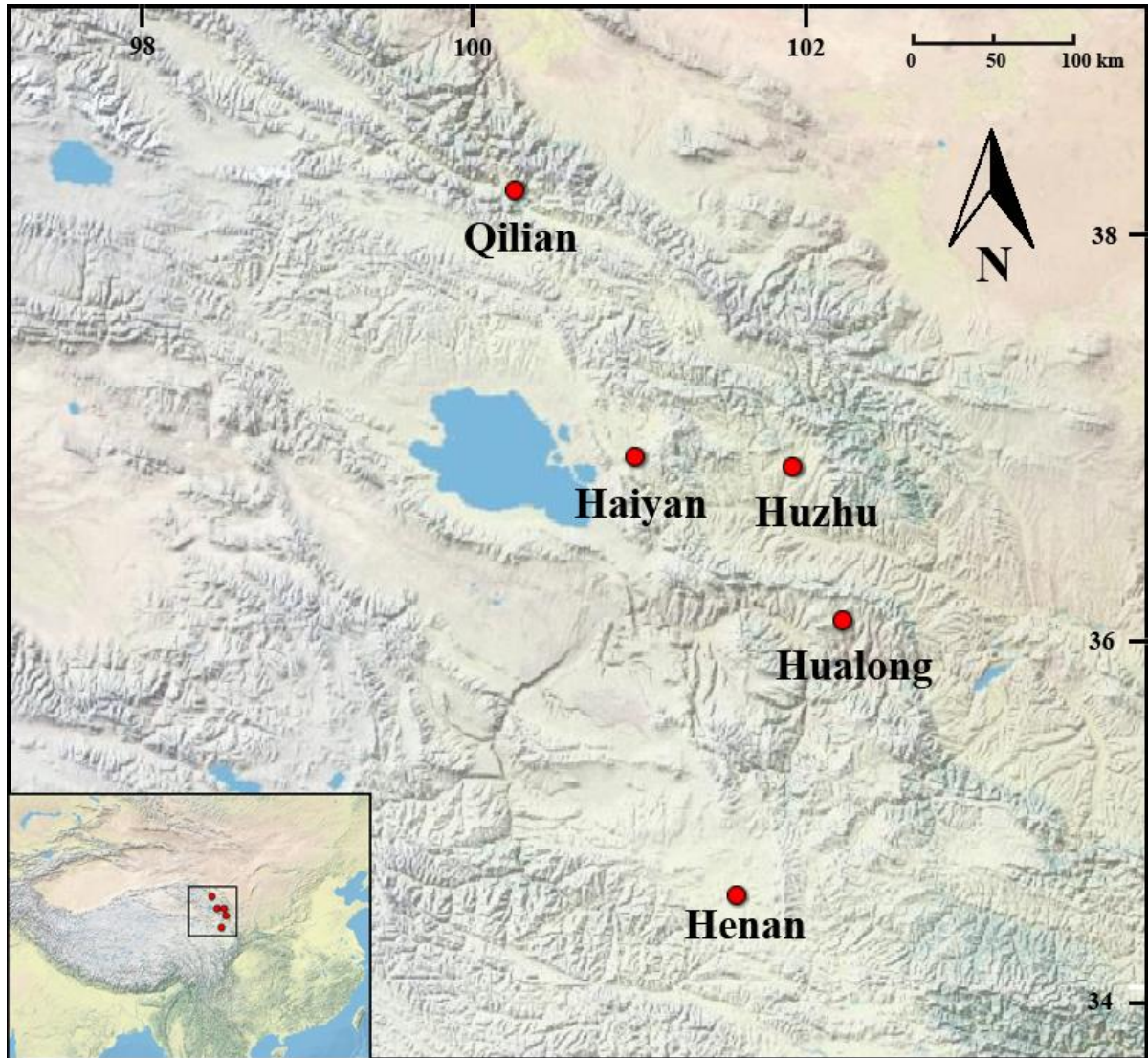


Figure 4.18 Map of the areas I visited to study current caprine herding practices.

4.3.1 Sheep Breeds

I discovered that different breeds of sheep are kept in the different regions. In Northeast Qinghai, two types of sheep are currently most common: ‘Tibetan Type Sheep’ (藏系羊) from the Qinghai-Tibet Plateau, and ‘Xinjiang Thin Wool Sheep’ (新疆细毛羊)/‘Small Tail Han Sheep’ (小尾寒羊) imported from Xinjiang and the Central Plain of China. In addition, there are some so-called ‘Local Breeds’ (本地羊), which were described differently in different regions, likely the crossbreeds of the different breeds or regional types of domestic sheep which have been raised locally for a long time. In Henan county of Southeast Qinghai, the typical breed there is Oula

Sheep (欧拉羊) (Figure 4.20), the largest sheep breed adapted to the high latitude environment in Qinghai, and which is regarded as a sub-breed of Tibetan Type Sheep.

Among these breeds, Tibetan Type Sheep and Xinjiang Thin Wool/Small Tail Han are strongly contrasted in many ways, as summarized in Table 4.6. The crossbreeds of Tibetan Type and Xinjiang Thin Wool sheep have the characteristics of both.

	Tibetan Type	Xinjiang Thin Wool/Small Tail Han
Origin	Qinghai-Tibet Plateau	Originated from Xinjiang, also popular in Central Plain China
Adaptation	Mountains of high elevation, cold temperature	Grasslands of low altitude, warm temperature
Region	Hualong, Huzhu, Haiyan, Qilian, Henan	Hualong
Feed	Do not like fodder, feed on grass	Eat lots of fodder
Character	Agile, active; males like to fight; jump high; difficult to be fenced and controlled; strong and survive well in harsh climates, like yak	Reluctant to move; eat a lot; need lots of care; fragile and delicate, like pigs
Horn	Large curved horns in male	Small horns or no horn in male
Weight	Adult male: 50.5-75kg; adult Oula sheep of Henan: 70-75kg, some reach 100 kg	Vary
Breed	Once a year	Two to three times a year
Usage	Very thick wool, could make Tibetan blankets	Good quality lambs and wool

Table 4.6 Typical features of the Tibetan Type Sheep and Xinjiang Thin Wool/Small Tail Han sheep currently raised in Eastern Qinghai.

Tibetan-Type Sheep probably originated on the Qinghai-Tibet Plateau. They are raised in almost every household and every grassland in the four regions I visited, but they are not common in Xinjiang and the Central Plain of China according to a sheep herding specialist at the Nadamu Meeting (那达慕大会), the annual meeting held in Haiyan county for showing off the different breeds of domestic animals of Qinghai. Tibetan-Type sheep have the largest body size among the different sheep breeds, have big curved horns in males, are aggressive, agile, jump high, and are difficult to control and fence (Figure 4.19).



Figure 4.19 Male Tibetan-Type Sheep on the Nadamu Meeting in Haiyan County. Photograph was taken by me at the end of August 2013. Since it was very sunny and warm on the day, many Tibetan-Type Sheep were languid.

In Henan county, where only Oula Sheep (Figure 4.20) are raised, the fences are higher than in all other regions of Qinghai because the sheep jump much higher there. Tibetan-Type sheep survive well in the cold and harsh climate and are well adapted to the high latitudes, but they do not like the hot temperature in the agricultural zones.



Figure 4.20 Female Oula Sheep in Henan County. Photograph was taken by me at the end of August 2013.

In contrast, Xinjiang Thin Wool (Figure 4.21) and Small Tail Han Sheep are thought to have come originally from Xinjiang and are also popular in the Central Plain of China. Some of them were brought from the Central Plain of China and raised in the agricultural zones and mixed agriculture/herding zones in Qinghai. However, they are not kept in the pure herding regions such as Qilian and Henan County, since they could not adapt to the high latitudes and are not able to survive in cold climate. They eat lots of fodder, which is composed of maize, wheat/barley straw, flour etc. In contrast, Tibetan-Type Sheep do not feed on fodder but favour grass. But this situation also varies. The amount of fodder given to some breeds of Tibetan-Type Sheep was gradually increased resulting in them being able to breed three times in two years rather than, as normal, only once a year. In contrast, a crossbreed of wild Argali and a Tibetan-Type sheep that had just been brought back home, reported by the herder in Henan County, refused to eat anything for 2-3 days after being fed with fodder.

Xinjiang Thin Wool Sheep produce good quality wool and lamb, and breed 2-3 times a year, much more frequently than the Tibetan-Type. The hairs of Tibetan-Type Sheep are very thick, and some are hollow, which can only be used to make Tibetan blankets. The hair of Oula Sheep in Henan County is not white but usually consists of black and brown patches on their head or body. Their hair sheds naturally, never needing to be shared.



Figure 4.21 Male ‘Half Thin Wool sheep’ (a developed breed from Xinjiang Thin Wool Sheep in Haiyan County adapted to the local environment in high latitude) in Haiyan County. Photograph was taken by me at the end of August 2013.

In general, Thin Wool Sheep are weak and delicate, reluctant to move and need lots of care by people, whereas the Tibetan-Type Sheep are strong and harsher, wilder and do not like to be controlled by people, more like the wild *Ovis ammon*, and are well adapted to the high latitude. In the words of the herder specialist I spoke to, Xinjiang Thin Wool are more like pigs, and Tibetan Sheep are closer in nature to yaks. In different areas, people raise different breeds that are suitable for the local environment and their needs. Crossbreeding is commonly practised.

4.3.2 Ways of Herding and Managing

The ways of herding and managing sheep also vary in different regions and by different peoples. The herders I visited are mostly Hui, Tibetans, and Mongolians.



Figure 4.22A herder and his sheep in Niuxin Mountain, Qilian County. Photograph was taken by me in August 2013.

In the small-scale households in the agricultural zone, 3-5 or more than ten sheep were kept in the house, together with several pigs, cattle, and dogs. Normally sheep are reared in pens beside the house, fed with home-made fodder. During the summer sheep are herded on the nearby mountains in the daytime. As discussed before, suitable breeds are raised for the local conditions. A small amount of fruit trees, wheat, rape flowers and maize were grown by the household depending on their conditions. The residues of maize, wheat and barley can be used to feed cattle and sheep.



Figure 4.23 Tibetan-Type Sheep herded on the Qilian Mountains at an altitude higher than 3000 m. Photograph was taken by me in August 2013 in Alaidusuo, Qilian County.

In the large-scale herding practised in the agricultural and half agricultural/half herding zone, when more than 40 or 100 sheep are kept, sheep are normally herded on the mountains during the summer by a hired herder and are enclosed in the large brick house during the winter and fodder, grass are provided. When herding in the mountains during the summer (Figure 4.22, Figure 4.23), the herder follows the sheep and will make a small tent for him/herself to live during the night. The ratio of male to females in a herd varies. Normally there are 4-5 males in 100 heads. Males are normally castrated at 4-6 months old. The amount of castrated sheep depends on the wealth status of the people.

In the pure herding zones at high latitudes, only large-scale herding is practised

(Figure 4.24). In Henan County, no crops are grown, and the local economy consists only of the herding of sheep, yak, and horses. There are extensive areas of high-quality grasslands, such as the Mengqi Grassland (蒙旗草原), the richest grassland in Qinghai. Sheep here are herded on ‘summer land’ during May-September and move to ‘winter land’ from October to April. The winter lands are the grasslands where the snow melts easily after the winter, while the summer grasslands are the place where the snow does not melt easily. As discussed before, since Oula Sheep are wilder and jump higher than other breeds, the fences are higher than in other regions of Qinghai.



Figure 4.24 Oula Sheep being herded on the Mengqi Grassland in Henan County. Photograph was taken by me in August 2013.



Figure 4.25 Domestic goats herded on the mountains in Huzhu County. Photograph was taken by me in August 2013.

Goats were not as common as sheep in Qinghai. A group of domestic goats was observed feeding on the mountains in Huzhu County (Figure 4.25).

4.3.3 Relationships with Wild Sheep

According to the local county annual of Henan County, the Tibetan-Type domestic sheep is developed based on the local *Ovis ammon*, a conclusion based on morphological similarities (CCLHHMAC 1996), though without genetic studies it is uncertain whether the latter are genuinely wild stock or derived at some time in the past from feral animals. Wild Caprinae still exist in Qinghai today, including both *Pseudois nayaur* (Blue Sheep) and *Ovis ammon* (Argali), although they are not very common. They range over the mountains at high elevation and do not normally come down. Crossbreeding of domestic sheep with (presently) wild *Ovis ammon* is practised in the herding zones of Qinghai in order to improve the meat quality and make the herds better adapt to the harsh environments, similar to that has been reported in Xinjiang

(Aniwashiet al. 2011). I visited typical cases in Henan County and Qilian County.

In Henan County, crossbreeding is intentionally practised. The Oula Sheep is a sub-clade of Tibetan-Type Sheep, which resemble wild sheep more than other Tibetan sheep, and they are still crossbred with (presumed) *Ovis ammon*. Tradition has it that they also contain some inheritance of Mongolian sheep, from when the Mongolians migrated here in the early Qing Dynasty, bringing lots of sheep from Mongolia with them (CCLHHMAC 1996).

Although (presumed) wild *Ovis ammon* are not very common in this area now, Zhaxi Ruizhi (扎西瑞智), a Mongolian herder I visited who put a male '*Ovis ammon*' together with the female domestic Oula Sheep, told me that he brought that '*Ovis ammon*' (Figure 4.26) from Tashi area in Xinjiang. However, although he claimed it is an *Ovis ammon* to the other villagers, he confessed to me it is actually an offspring of a wild *Ovis ammon* with a Baishi Sheep (a local domestic sheep) from the Tashi area. He brought this male in Taishi and transported it to back to Henan, to improve his sheep breed.



Figure 4.26A (presently) wild '*Ovis ammon*' herded with Oula Sheep in Henan County. Photograph was taken by me in August 2013.

The kids of a cross with a wild *Ovis ammon* (Figure 4.27) will not easily get sick like domestic sheep, nor become lame after stumbling; and the newborn baby can get up by itself within half an hour of being born, while the newborn of domestic sheep won't be able to get up within two hours. Zhaxi Ruizhi personally favours the crossbreed offspring with (assumed) wild *Ovis ammon* because they are healthy, look pretty, agile, and can grow to a larger size and help him win village competitions (there are competitions for the largest sheep, yak, horse etc. in this area).

The most common season for the crossbreeding between domestic sheep with *Ovis ammon* is August-September, although it occasionally happens from September-January. They do not normally mate in February or March because *Ovis ammon* are active for their rut in October but languid in spring. The domestic sheep are active in August-September for mating. The kids of a cross between *Ovis ammon* male and a domestic sheep have 60-70% of their features resembling the female domestic

sheep.



Figure 4.27A female offspring of the crossbreeding between the ‘*Ovis ammon*’ and Oula Sheep by Zhaxi Ruizhi. Note that it is brown in colour all over the body. Photograph was taken by me in August 2013.

In Qilian County, which is mainly a herding region with a small amount of crops being grown, sheep here have been reported crossbreeding with wild *Ovis ammon* coincidentally. When the domestic sheep are herded on the mountains, the wild male *Ovis ammon* occasionally cross with the female domestic sheep, but not very often because their rutting seasons are different – *Ovis ammon* sheep normally rut in autumn-winter, while the domestic sheep rut normally in summer or spring. The kids of a crossing with the wild sheep are agile, wild, and suitable for high altitudes and a cold climate.

In summary, my study in the different regions of Eastern Qinghai clearly shows that the Tibetan-Type domestic sheep is quite different from the ‘normal’ domestic sheep in the lowlands. They are closer to the local (presumed) wild *Ovis ammon* on the Qinghai-Tibet Plateau in many ways and are especially adapted to the local environments. Crossbreeding between domestic sheep and the local wild (or feral?)

Ovis ammon is carried out intentionally or unintentionally in the herding zones of Qinghai today.

4.4 Discussion and Summary

4.4.1 Different Caprinae and Gazelle

As shown above, a systematic review of the Caprinae and gazelle species in Western China shows all the possible species of these two categories that were once distributed in the research area, which include: *Ovis ammon* (Argali), *Pseudois nayaur* (Blue Sheep), *Nemorhaedus* (Goral, *Nemorhaedus bailey* and *Neamorhedus griseus*), *Capricornis milneedwardsii* (Chinese Serow), and five species of gazelle under genus *Gazella*, *Procapra* and *Pantholops*, as well as, of course, *Ovis aries* (domestic sheep) and *Capra hircus* (domestic goat) once they were present. Considering the likelihood that the current range of all these species (except domestic sheep and goats) is smaller than in the past due to the pressure on them of human society, it is possible that some species were distributed in the research area in the past even if their current range does not cover it, such as with the *Nemorhaedus bailey* and *Pantholops hodgsonii*. Another two genera belonging to Caprinae were also examined originally, Tahr (*Hemitragus*) and Takin (*Budorcas taxicolor*), but they are not included in this study because it was found later that they could not have been distributed in the research area. The only species of *Hemitragus* in China is *Hemitragus jemlahicus*, Himalayan Tahr, which inhabits only a narrow strip along the southern flanks of Himalaya. Takin is currently distributed in Sichuan and Yunnan province of China, covering a slight flank of the Southeast Tibetan plateau. Their natural habitats in those regions are quite different from the research area in Northwest Qinghai-Tibet Plateau and Gansu.

Apart from *Capricornis* and some subspecies of *Ovis ammon*, which are large-sized ungulates, most of the others are medium-sized ungulates of overlapping size sharing similarities in their ecology and adaptations. With so many different species of Caprinae and gazelle likely distributed in my research area in the past, the

implication is that their very similar fragmentary remains could occur in archaeological faunal assemblages, making them very difficult to distinguish. Yet it is, of course, essential to identify the fragmentary remains of these species correctly in order to trace the origins and early history of sheep and goat domestication in China. Especially, it is important to separate *Ovis aries* and *Capra* remains from the others, though up to now there has been little systematic work on the comparative osteomorphological study of these animals in China. Taxonomic identification, therefore, becomes the most challenging part of this project.

4.4.2 Ecology and Body Characters

The thorough review of the geographical and ecological distributions, characters and behaviours of the different species has provided me with a deeper understanding of the biology of the animals. According to Schaller (1977), habitat is a factor shaping size and build and certainly those Caprinae partial to flat or undulating habitats are lighter in build with longer and thinner legs than those inhabiting steep hills and precipices. Besides, species whose existence depends on their ability to escape predators through speed need a slender frame. *Ovis ammon* are apparently more adapted to flat terrains than the *Ovis vignei* and *Ovis orientalis* and depend heavily on speed to travel and escape so have longer and light-boned legs. Wild sheep are good runners adapted to open terrain and depend on their ability to escape predators through speed, while goats are more cliff dwellers. Therefore sheep have a slender frame with long legs, and goats are stocky in build with more powerful legs. Domestic sheep and goats are more closely confined to a certain range set by people and are protected by them from their natural predators. Thus they are less agile and less active in jumping and running than their wild counterparts, resulting in changes in the size and proportion of limbs, especially a shortening of the extremities, a reduced robustness, and an increased frequency of pathological lesions on toes (Zohary et al. 1998).

4.4.3 Sheep, Goats and Domestication

As discussed, wild *Ovis* are distributed widely in Asia, from the Qinghai-Tibet Plateau in the east to the Mediterranean islands in the west. They differ in a number of ways: morphology, habitats, and biomolecular composition. Although existing genetic studies clearly indicate that the majority of wild *Ovis ammon* (Argali) are not closely associated with the majority of modern domestic sheep, it is striking that some local Tibetan-type domestic sheep in Qinghai resemble *Ovis ammon* in a number of ways. The interbreeding between the local domestic sheep and what are presumed to be wild Argalis that I observed in Qinghai corresponds to the human practice of mating domestic ewes with wild rams documented in Central Asia and North China (Carruthers 1949). Although it is not sure if the ‘Argali sheep’ that is referred to by the herders I met is the real wild *Ovis ammon* and not in fact feral examples of animals that escaped in the past from domestic populations, the reported hybridizations between the Argali and Bashibay sheep (a breed of domestic sheep in Xinjiang) through human-interfered electro-ejaculation were successful (Aniwashi et al. 2011; Kuerman et al. 2012; Ma et al. 2009; Zhu et al. 2009), and the Argali, Bashibay, and hybrids of Argali × Bashibay sheep have been tested genetically (Aniwashi et al. 2010; Polat et al. 2015). More interestingly, the ‘Baishi sheep’ that Zhaxi Ruizhi described to me is from ‘Tashi Area’ in Xinjiang. The name ‘Baishi’ sounds similar to ‘Bashibay’ sheep from Tacheng described in those papers, and they might be from the same source. Similar to what I have observed, the reports also revealed that the hybrids of the Argali sheep and Bashibay sheep could retain the properties favoured by people from both sides of the parents, and they performed best on the second generation --- 105% of total fertility rate, weight up to an average of 35.8kg for 4.5 months, and the percent of infection by common diseases being 3.3% (Kuerman et al. 2012). In addition, they could grow fast and have a strong body to adapt to the harsh environment, reduced fat rump and increase lean meat, which are desired by people (Aniwashi et al. 2011; Kuerman et al. 2012).

However, although this has potential implications for the possibility of similar

practices in the past especially in early phases of sheep domestication history, without independent confirmation on ancient samples, we cannot be certain if it could really happen in the past and when. In this light, it is fascinating to investigate if such practices of crossbreeding could be evidenced osteomorphologically or genetically on the ancient samples of *Ovis*, but the latter is beyond the scope of this dissertation.

None of the wild *Capra* are currently distributed in the research area of this study. It is unlikely that any *Capra ibex sibirica*, the only *Capra* species in China, was distributed in the research area in prehistory. The environments that they adapted to, the very arid climate and bare rocky terrain with rubble and cliffs like today's Altai and Tien Shan Mountains, are very different from those of Qinghai and Gansu today and in the past. Hence bones of *Capra* identified in the prehistoric sites I studied should represent domestic goat (*Capra hircus*) imported from the West.

4.4.4 Summary

This chapter has presented the taxonomy, distribution, physical characters and ecology of the animals of the subfamily Caprinae and gazelle in my research area. It has been found that there is a very complex distribution of Caprinae and gazelle in the research region. They share similar characters but are also different from each other in ecology. The change of the body characters of sheep and goats under domestication are likely to have been related to changing ecological habitats of the animals. Some of the species discussed in this chapter have been reported at prehistoric sites in China, but given how similar many of them are in their general morphology, the possibility exists that the fragmentary bones typical in faunal assemblages on archaeological sites may not have been identified correctly because of the lack of systematic comparative osteomorphological study, the focus of the following chapters. My interviews with the local herders in Qinghai showed that some local Tibetan-Type domestic sheep appear to be closely related to what are presumed to be wild Argali sheep and correspond to the tradition recorded of crossbreeding the wild ram and domestic ewes in this area to improve the breeds, but there is also a possibility that the modern 'wild Argalis'

involved in cross-breeding are in fact the descendants of once feral animals. Hence we need comparative genetic tests on both modern and ancient samples in this area in order to test if that the practice of backcross occurred in the past. In sum, the biological diversity of the sub-family Caprinae and gazelle in my research area necessitates a systematic study of the comparative osteomorphology of these animals. In the case of widely distributed genera *Ovis*, intra-specific variation in osteomorphology due to differences in ecological conditions might be expected and might be used to see if there are local wild Argalis or the domestic sheep in the past.

5. Materials, Approaches, Methods

5.1 Introduction

As has been discussed in Chapter 4, the biological diversity of the sub-family Caprinae and gazelle in the research area necessitates a systematic study of the comparative osteomorphology of these animals, as the correct taxonomic identification of animal remains for archaeological sites is the basis for all further zooarchaeological analysis. Compounding this problem is the occurrence of different species/populations of *Ovis*. Since the origin of caprine domestication in the research area might be a complex development from local foraging to the adoption of caprine pastoralism/husbandry, involving several species/populations of *Ovis* in Eurasia, variation in morphology of *Ovis* may be expected and needs to be considered during identification. As noted (e.g. Buitenhuis 1995; Gillis et al. 2011), biological and morphological variation is an issue of considerable importance for zooarchaeologists studying caprine populations from diverse geographic regions and during their evolution through domestication. Therefore, an attempt has been made to develop osteoscopic and osteometric discriminating criteria between the different genus of Caprinae and gazelle in Western China and *Ovis* in Eurasia based on the useful groundwork distinguishing different genera of Caprinae in previous literature.

The materials, approaches, and methods used in this research will be presented in this Chapter, which comprises two parts --- those of the modern comparative skeletons, and the faunal remains from the archaeological sites. The criteria developed for distinguishing the Caprinae and gazelle based on the modern specimens will be applied to the archaeological materials.

5.2 Materials, Approaches, and Methods for Modern Samples

5.2.1 Materials

The materials of the modern skeletal samples of the Caprinae and *Gazella* come from

museums and collections in the UK, Europe and America. As shown in Table 5.1, Table 5.2, and Table 5.3, a total of 185 records of non-*Ovis* Caprinae and *Gazella*, and 185 records of *Ovis* specimens were investigated in this study.

Scientific Name	Common Name	Total	Adult			Subadult			Juv
			M	F	U	M	F	U	
<i>Pseudois nayaur</i>	Blue Sheep	40	8	12	5	6	4	2	3
<i>Nemorhaedus</i>	Goral	31	11	10	4	0	1	3	2
<i>Capricornis</i>	Serow	28	7	7	7	3	1	2	1
<i>Capra sibirica</i>	Siberian Ibex	25	12	4	3	0	2	2	2
<i>Gazella & Procapra</i>	Gazelle	31	15	12	0	3	1	0	0
<i>Capra hircus</i>	Goat	30	3	5	7	2	3	1	9

Table 5.1 The number of the modern comparative specimens studied of the non-*Ovis* Caprinae and *Gazella*. M: male; F: female; U: unknown; Ad: adult; Sub: sub-adult; Juv: juvenile.

Scientific Name	Common Name	Total	Zoo-bred			Wild			Ad	Sub
			M	F	U	M	F	U		
<i>O. ammon</i>	Argali	38	3	3	1	21	10	0	28	10
<i>O. vignei</i>	Urial	18	2	5	0	8	2	1	16	2
<i>O. orientalis</i>	West Asian Mouflon	29	0	0	0	9	9	11	26	3
<i>O. musimon</i>	European Mouflon	40	10	9	4	7	6	4	29	9

Table 5.2 The number of the modern comparative specimens studied for the wild *Ovis* distributed across Eurasia. M: male; F: female; U: unknown; Ad: adult; Sub: sub-adult.

Groups	Total	Adult			Subadult		
		M	F	U	M	F	U
Country Sheep	26	4	10	6	1	0	5
Rambouillet Sheep	13	4	9	0	0	0	0
Argali × Domestic Sheep	21	16	5	0	0	0	0

Table 5.3 The number of the modern comparative specimens studied for the different breeds of domestic sheep from the different sources. M: male; F: female; U: unknown; Ad: adult; Sub: sub-adult

The museums and collections holding these specimens are: The Grahame Clark Laboratory for Zooarchaeology (GCZ), Cambridge; the University Museum of Zoology, Cambridge (CUMZ); the Staatssammlung für Anthropologie und Paläoanatomie,

München (SAPM); the Berlin Museum für Naturkunde (BMN); the Muséum national d'Histoire naturelle, Paris (MNHN); the collection of the Zooarchaeology Laboratory of the University of Tübingen (TBG); the Museum für Haustierkunde “Julius Kühn”, Martin-Luther University of Halle-Wittenberg (MHJ); the American Museum of Natural History, New York (AMNH); the Smithsonian National Museum of Natural History (USNM); the Museum of Comparative Zoology, Harvard (MCZ); and the Field Museum, Chicago (FMNH).

Apart from the bones examined by myself, some metric data of *Pseudois* from Götze (1998) are added for osteometric analysis. Although *Capra sibirica* are not distributed in my research region currently, 25 specimens of this species were examined, since it was not sure if this species was distributed in the research area in prehistory and the osteometric data of *Capra sibirica* are found meaningful for this research.

Since a vital question of the research is whether domestic and/or wild sheep (species) are in my sample, it would have been ideal if a good sample of definite prehistoric domestic sheep (e.g. those of the Iron Age) from the study region could have been compared, because it would be safer to assume that they are morphologically similar to the Neolithic and Bronze Age sheep from the sites. However, due to the limited zooarchaeological work in this region, such specimens were not obtained. Instead, modern *Ovis aries* in the UK and Europe (country sheep and Rambouillet sheep) were compared; the assumption had to be that they are similar to the domestic sheep in prehistoric Western China.

Furthermore, although the only wild *Ovis* in this region is *Ovis ammon*, the modern specimens of other wild *Ovis* in Eurasia are also incorporated in the study, as well as the crossbreeds of *Ovis ammon* and *Ovis aries*. This is because the origins of domestic sheep in Western China likely involved *Ovis aries* spread from the west, but whether there was any gene flow with different populations of wild *Ovis* during the long-distance movement to China is unclear (some domestic sheep may have gone feral and appear to be ‘wild’, (cross)bred with the wild and/or domestic sheep). In addition, the routes of migration(s)

are unclear and may have taken the course through the areas where *Ovis orientalis* and/or *Ovis vignei* were distributed. As evidenced by the movements of crops and other material cultures in prehistory, there was more than one route along which domestication dispersed into and out of China (Boivin et al. 2012, Fuller and Boivin 2009).

Therefore, the archaeological specimens were analysed in comparison with the modern specimens of all wild Caprinae, gazelle in Western China and *Ovis* in Eurasia and domestic sheep and goats, including *Pseudois nayaur*, *Nemorhaedus*, *Capricornis*, *Capra hircus*, *O. ammon*, *O. orientalis*, *O. vignei*, *O. aries*, and *O. musimon*. Although *O. musimon* is feral domestic sheep in Europe, it represents a segment in the evolutionary history of domestic sheep from Near East to other areas and would be useful for comparison.

Three groups of *Ovis aries* were examined (country sheep, Rambouillet sheep, and crossbreeds of Argali × domestic sheep) in order to check their difference compared with the wild Eurasian *Ovis* and the effect on the osteomorphology caused by crossbreeding between the domestic sheep and *Ovis ammon* (Argali). In the country sheep group, the majority are from England, including Soay domestic and some of the unknown-breed country sheep, while a small part were labelled as domestic sheep descended *Ovis musimon* in the zoos of Germany, France, and the US. The Rambouillet sheep¹⁴ are those kept at Halle farm in an early twentieth century. The crossbred sheep Argali × domestic sheep are products of the experiments of hybridization also at Halle farm in the early twentieth century. Most of these sheep were with one of their parents from a Rambouillet or a country sheep, and the other one a crossbred of Rambouillet and *Ovis ammon*¹⁵

¹⁴ Rambouillet sheep: a breed of sheep developed since eighteenth century on the experimental Royal farm of France. It is now a well-known dual-purpose breed for its superior wool and meat.

¹⁵ Ten *Ovis ammon* in Halle were captured wild animals transported through Asia by Carl Hagenbeck (1844-1913), an important animal dealer who undertook expeditions mainly to Altai Mountains and Mongolia to capture wild animals for selling them to the world. However, the real origins of these '*O. ammon*' might be complex and there is no other evidence supporting their identity. These animals were brought to Germany in the beginning of the 20th century and the journey took 2-3 months. During this period, the sheep were not fed well enough. The

(usually a multiple crosses, which means an offspring of the offspring of Rambouillet × *Ovis ammon* and Rambouillet or country sheep). In general, the gene of most of the crossbreds in the samples include only a small proportion of *Ovis ammon* and a big portion of Rambouillet and country sheep from central Europe in the early twentieth century. The one with the largest proportion (1/4) of *Ovis ammon* is the sample ‘Ramb × Argali 811/92’; its pedigree is illustrated in Figure 5.1. All the other Argali × domestic sheep in the study contained less than 1/4 *Ovis ammon* inheritance.

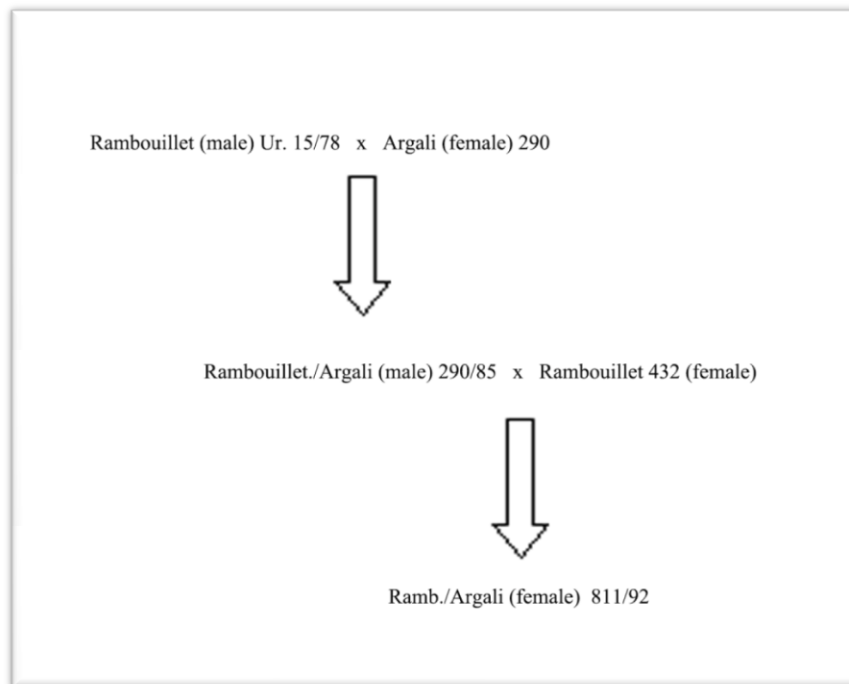


Figure 5.1 The pedigree chart of the sample ‘Ramb × Argali 811/92’. As can be seen, it has 1/4 portion of inheritance from *Ovis ammon*.

In order to control dimorphism due to age and sexual difference, the specimens of different age and sex categories were compared. According to the epiphysis fusion dates, three age groups in the study can be distinguished. The criteria to classify the specimens are based on Bökönyi (1970) and Greenfield (1986).

- Juvenile:

animals became very thin if they arrive alive. Stress factors like captive condition, starving, the different feeding and new groups may play a role. A high amount of them died in captivity (usually after a few months or 1-3 years) (R. Schafbergers. comm. October 2014).

- the bones are much smaller than those of sub-adult;
- acetabulum (ilium, ischium and pubis) and proximal radius fuse in the early stage of the juvenile;
- distal epiphyseal of humerus, tibia and metapodials fuse in the late stage;
- proximal phalanges fuse in late stage;
- carpals and tarsals fuse in late stage.
- Sub-adult:
 - bones from this age group are larger than those of juveniles and have almost reached, but not quite, their adult size;
 - proximal humerus, ulna, femur, tibia, calcaneum, and fibula fuse in the late stage of subadult;
 - distal radius, ulna, femur, fibula fused in late stage.
- Adult:
 - bones in this group have grown to the full size;
 - all long bones fused.

While the majority of specimens of domestic animals (*Ovis aries* and *Capra hircus*) held the collections are from females, for most wild species male and female specimens are kept in a balanced number. Ideally, at least twenty specimens should be examined for each species (J. Peters, *pers. comm.* March 2013). However, due to the limitation of the research, this number was more or less reached only for the humeri and metapodials.

The status of wild (feral) or zoo-bred animals was noted for each specimen wherever possible. Ideally, only the wild animals should be studied for the Caprinae and gazelle in Western China. However, in order to enhance the number of the specimens, a number of zoo animals are included in this study, as it is known that the skeletons of these zoo specimens do not differ osteoscopically from those of free-ranging individuals, although zoo animals can be smaller than their relatives living in the wild (J. Peters *pers. comm.* March 2014).

Originally, cranium, all dentition, and most of the skeletal elements were studied. However, it was found subsequently that the distinctive features on skulls are not particularly useful due to the low frequency of complete preservation of the diagnostic element in the archaeological samples. Furthermore, the distinctions on dentition between the different genus/species are small whilst the individual variations are striking. The focus is therefore placed on selected skeletal elements, including distal scapula, distal humerus, proximal radius, distal metacarpals, proximal femur, distal tibia, distal metatarsals, and first phalanges. Some other skeletal elements were also studied, but they are not presented since it was found that the criteria on them were of very little use for archaeological identification in this research. The criteria derived from the previous literature are annotated.

The information on the collection number, age group, sex, origin, wild/zoo status of the examined specimens, which are available as a result of the information given in the collections of the respective museums, can be found in Appendices B and C.

5.2.2 Approaches

The present work is largely based on the approaches developed in previous studies to the investigation of the osteological features distinguishing sheep, goats, and the relevant genera.

The characters distinguishing between the skeletons of the genera *Ovis* and *Capra* have been explored by many previous authors. Gromova (1953) focused on the morphological distinctions of the wild members classified at that time as *O. orientalis/gmelini* and *Capra aegagrus*. Based on this groundwork, Boessneck et al. (1964) and Boessneck (1969) elaborated carefully the observations for distinguishing the skulls and postcranial skeletons of domestic sheep (*Ovis aries*) and goats (*Capra hircus*), noted that many features in Gromova (1953) could also be used for distinguishing their domestic forms. Boessneck et al. (1964) studied a comprehensive collection of material, which included more than 70 goats and 100~200 sheep specimens. They derived mainly from the

animals in central Europe, including the extinct breeds of the 18th century, and the modern improved breeds. Since the publications of the criteria by Boessneck et al., new criteria have been identified to diagnose some specific skeletal parts (e.g. Buitenhuis 1995; Kratochvil 1969; Payne 1969; Prummel and Frisch 1986) and to distinguish between sheep, goats, and other closely related small ruminants (Fernandez 2001; Gabler 1985; Helmer and Rocheteau 1994; Hildebrand 1955). It has been shown based on the European and North American materials that some of the criteria developed originally by Boessneck et al. (1964) are quite reliable while others are less so. Clutton-Brock et al. (1990) systematically checked those features against a large collection of the bones of a primitive breed --- the Soay sheep from Scotland, identifying which of these criteria are absolutely reliable and which are not when applied on Soay sheep. Zeder and Lapham (2010) assessed the criteria noted by the previous authors and some commonly used by zooarchaeologists on ten skeletal elements using a large collection of samples of sheep and goats held in museums of US, concluding that the majority of those criteria are quite reliable regardless of sex, domestic status, age groups, and geographic or temporal context of the assemblage. In addition to the cranial and postcranial skeletons, a lot of work has been carried out to distinguish between the teeth of sheep, goats, and other small ruminants (Balasse and Ambrose 2005; Gillis et al 2011; Halstead et al. 2002; Helmer 2000; Hillson 2005; Payne 1985; Zeder and Pilaar 2010). These works, which include the description of the distinctive characteristics and their expressions, drawings elaborating the diagnostic features, quantitative methods of differentiation, and diagrams illustrating the differences in sizes and ratios, are fundamental to the work developed in this dissertation. They have demonstrated how the distinctive characteristics that are reflected over time in the literature are applicable in different materials.

In spite of all these valuable works, there have been very few investigations examining the osteomorphological differences between the various Caprinae and *Gazella* distributed in Western China and how they can be differentiated against domestic sheep and goats. Götze's (1998) work is an exception and of great value. It examined the

distinguishing features of the skulls and skeletons of *Pseudois nayaur* against domestic sheep and goats based on 59 specimens including 46 adults and 13 sub-adults of both sexes of captured wild and zoo-bred animals held in different collections in Europe and UK, based on the criteria developed in Boessneck et al. (1964). Skulls of *Ovis ammon* and *Pseudois nayaur* were compared and studied, but the osteomorphology of the skeletal elements of *Pseudois* was not checked against the wild Caprinae distributed in Western China (e.g. *Ovis ammon*, *Neamorphedus goral*).

Some previous studies have included wild sheep (e.g. Gromova 1953; Zeder and Lapham 2010) or examined some particular breeds of sheep in their research (e.g. Clutton-Brock et al. 1990). However, wild *Ovis* distributed in different geographic regions of Eurasia were not statistically examined, and it is still uncertain how the osteomorphology of post-cranial skeletons altered under the evolution of domestication and hybridization in Western China.

Measurements

The elements were measured with an accuracy of 0.1mm by electronic vernier callipers. The measurements taken are mostly the standard ones defined by von den Driesch (1976). The rest are illustrated in the figures of each element. The majority of them are those discussed in the previous literature and generally agreed by zooarchaeologists. In some particular situations, new measurements had to be defined to document the features. A study was conducted to establish and quantify ‘reliability’ of the newly developed measurements, and thus provide an indication of the consistency or repeatability of those measurements. As has been suggested by Bruton et al. (2000), no single estimate is sufficient to provide the full picture about reliability and universally appropriate, and that different types of estimations should be used in accordance to the specific situation. The issue important to decide is what level of reliability is considered to be acceptable. The detailed procedure and the result of conducting the inter-rater and intra-rater repeatability study are provided in Appendix D. In general it is found that the newly developed measurements can be regarded as reliable, especially those repeatedly

taken by myself.

In recent years, geometric morphometrics (GMM) has been proved to be a technique that provides greater resolution than traditional biometry in the study of shape (e.g. Evin et al. 2014). However, due to the limitation of the PhD, GMM is not applied in this study.

Formality

The majority of the anatomical nomenclature used here is in Volume I of the animal anatomical textbooks of Nickel, Schummer and Seiferle (5th edition, 1984).

Zoo-bred samples and captured wild samples were evaluated separately when assessing the size, but were grouped together when assessing the osteoscopic characteristics. Due to the limitation of sample size, the different age classes will be discussed separately only when the sample is large enough, as will be shown in the case of *Pseudois nayaur*. The issue of sexual dimorphism will be addressed occasionally. But since it is difficult to assess the sex of the animals when analysing archaeological samples, mixing the male and female groups replicates the conditions when confronting archaeological materials. Measurements for each sample with sex and age information can be found in Appendices E and F.

All the drawings are original unless otherwise noted.

Statistical analysis

SPSS (Statistics Package for Social Science) was used to undertake statistical analysis. Linear discriminate function analyses¹⁶ are performed based shape indices (explained in Section 5.2.3 of this Chapter) in order to codify the osteometric variations between the target taxa/populations and to provide a functional template capable of being applied to

¹⁶ In each discriminant analysis, all independents (shape indices) are entered together, and the dependents are the species to be classified (e.g. 1. *Pseudois*; 2. *Nemorhaedus*, etc). Fisher's function coefficients are selected. The matrix chosen is the 'within group correlation'. Prior probabilities are set as 'all group equal', and casewise result and summary table are displayed. The covariant matrix is 'within-groups', 'combined-groups', 'separate-groups', and 'territorial map' are plotted.

archaeological datasets.

5.2.3 Methods

Several different methods were applied to study the comparative osteomorphology of various Caprinae and gazelle in this study, involving two types: osteoscopic criteria and osteometric criteria, and in each type two methods are included.

5.2.3.1 Osteoscopic Criteria

Descriptive criteria

The modern skeletal specimens of the Caprinae and *Gazella* in the collections described above were examined in terms of the expression of the distinguishing features between them, referring to those described in the previous literature. Special attention was paid to distinguishing between the local Caprinae and gazelle taxa of Western China from *Ovis aries* and *Capra hircus*. The criteria developed in Götze (1998) were checked against a large collection of the bones held in the collections in Europe and the US. They were compared with domestic sheep and goats, and also with other taxa of Western China distributed in the study area. New criteria were elaborated when found valid to distinguish between the different taxa.

Since the number of each taxa/population examined is smaller than 50, which is not large enough for establish reliable criteria, the observations and data presented here should be regarded with caution and as preliminary until a larger dataset can be obtained and analysed.

Except for distal humerus and distal metapodials, all the selected elements discussed before are elaborated for their diagnostic features to distinguish between them, which is presented in Appendices G, H, J, L, M, O.

Numerical scores of osteoscopic characters

The morphoscopic criteria identified by Boessneck et al. (1964) and the subsequent

developments by various authors distinguishing between sheep and goats made it possible for many researchers to differentiate the two taxa, but lots of researchers are still hindered by lack of directly available comparison material and lack of precision in their identification (Buitenhuis 1995). Though based on rather objective criteria, the identifications are always subjective judgments if no quantification of the morphoscopic criteria is executed.

As has been realised, ‘the osteomorphological differences between sheep and goats may be expressed only as variations in the average or typical expression of characters for which extreme values overlap’ (Hildebrand 1955). Variations among the different individuals of the same species can be caused by many factors and are greater than previously expected. Strictly speaking, the descriptive morphoscopic criteria developed to distinguish the target taxa/populations are not quantifiable and are not discriminated.

In order to make the identification more objective, an attempt has been made to set up a scoring system and produce semi-quantitative data on three skeletal elements --- distal humerus, distal metacarpal and distal metatarsal, presented in Chapter 6. It partly follows Gillis (2011) and partly Buitenhuis (1995). Those found reasonably useful for species separation are presented in this study. Each osteoscopic character was defined, and the different features/phases of the character were scored. However, due to the original design decisions, not all the specimens were scored at the first place when observing them. Parts of the specimens were photographed and were scored based on their photos later.

The characters were scored not so much in terms of sheep-like or goat-like, but more in their own terms, like strongly arched, curved, or straight. When the features are found exclusive of one or several taxa, they are specially noted.

5.2.3.2 Osteometric Criteria

Another attempt to quantify the morphological variations is to use osteometric data. The traditional linear measurements taken on the bones contain two components: shape (the property of an object invariant under scaling, rotation, or translation), and size (a

scalar, based on distances or coordinates of points specified on the object)(Claude 2008; Vigne 2015; Vigne et al. 2005). The shape is determined more by genetically inherited traits, and size is determined more by diet or environment such as moisture level (Cardini and Elton 2009; Meiri and Dayan 2003). There are several different ways of reducing a form into size and shape components. In my case, two methods are adopted.

Ratios of pairs of measurements

Metric ratios calculated by pairs of measurements express shape. Hildebrand (1955) used ratios of measurements and statistical analysis to illustrate how deer, sheep, and goats were distinguished based on skeletal elements. By plotting pairs of measurements on scatter diagrams, Payne (1969) was able to demonstrate how the distal condyles of sheep and goats metapodials can be differentiated by taking measurements and plotting such diagrams. Eisenmann (1986) separated different horses, half-asses, and asses. Albarella et al. (1997) separated different populations of cattle by considering separately the variables size and shape through ratios between different measurements, and demonstrated that the impact of the different breeds on the variation of shape is greater than that of sex. In brief, considering metric ratios as shape information to distinguish different taxa and breeds is a well-established technique.

In the present study, ratios of pairs of measurements were calculated and compared to analyze the morphological variations among the different taxa on all the selected elements discussed above, presented in Appendices G-O. For each metric ratio on humeri and metacarpals, a high-low chart is presented to show the domain of variation and the mean for the different species. However, the simple calculation of metric ratios does not completely remove the effect of size. The shape will be difficult to assess independently, and the effect of size will always dominate the statistical analysis when using ratios to evaluate the shape (*pers. comm.* N. Pöllath, January 2017).

Log-shape ratios approach (LSR)

The log-shape ratios approach is described in Vigne (2015) and Mosiman (1970).

This method increases the linearity of the relations between the variables and the homogeneity of the variance, and thus improves the quality of the comparisons between them (Bookstein 1991). It has been applied to evaluate the effect of sexes, species, and localities on the osteomorphology of two commensal rat species in South-East Asia (Claude 2013), and to the metric measurements of the tali of *Sus scrofa* ssp. in Klimonas on Cyprus (Vigne 2015). As a routinely used technique in mammal evolution and systematics, the computation is simple, and it is easy to be interpreted in geometric terms, but the expression of shape is also dependent on the choice of the linear measurements, and it introduces spurious correlations between variables (Claude 2008). The correlations between the size and shape could be revealed, and the effect of allometry could be removed using statistical methods (*pers. comm.* N. Pöllath, January 2017; Claude 2008), although it is not applied in this study.

In my study, the linear measurements taken on the distal humerus, distal metacarpal, and distal metatarsal were reduced into one size (isometric size) and several shape components (shape indices) following Vigne (2015). The shape indices (SI)¹⁷ were analysed to examine the shape variation among the different species/groups. This is presented in Chapter 6.

5.3 Materials, Approaches, and Methods for Archaeological Materials

5.3.1 Materials

The archaeological materials come from the five archaeological sites, which were discussed in Chapter 3.

5.3.2 Approaches and Methods

The approaches taken in analysing the archaeological specimens include two parts:

¹⁷On humerus, there six shape indices were used - SI BT, SI HT, SI SHT, SI BTM, SI BTI, SI LHT; On metacarpal and metatarsal, eleven are used— SI Bd, SI DpBV, SI DBV, SI 1, SI 2, SI 3, SI 4, SI 5, SI 6, SI 7, SI 8. Each of the shape indices corresponds to a linear measurement (e.g. SI Bd corresponds to Bd).

those for analysing the general faunal remains and those only for the Caprinae and gazelle specimens.

5.3.2.1 General Faunal Remains

All the faunal remains were analysed at local institutes without the aid of modern comparative specimens. The following were used for aiding taxonomic identification: Schmid 1972, 3D animal bone illustrations from the website of the Max Plank Institute, modern comparative skeletal pictures by Barbara Wilkens of Department of History in the University of Sassari, and the photographs of the skeletal elements of the modern Caprinae and gazelle specimens of Western China taken by myself. All the bones were weighed with the scale of 0.1 gram accuracy. Each specimen with an identified taxonomic identity was recorded for its side and taphonomic information (see below). The un-identified fragments were grouped together and recorded for their taphonomic information and weighed. Standard measurements were taken following von den Driesch (1976) for all identified specimens.

In the laboratory analysis, firstly the taphonomic processes on the bones were examined. Taphonomy is the study of the changes that influence a deposit. It involves the forces that form an archaeological deposit throughout the history of the site, including the initial disturbance of the location as it became a locus of human affairs, the activities that occurred at the site while it was the scene of purposeful human activity, and what happened once people “abandoned” it (Davis 1987; Huntley and Stallibrass 2000; Koch 1989; Lyman 1994; Schiffer 1983). It is essential to understand the taphonomy of an archaeological assemblage because it modified the records by superimposing other patterns, affecting any interpretation of the remains.

Models of taphonomic history from the life assemblage to the collected bones and/or published data have been constructed by different authors since the 1960s (Andrews and Cook 1985; Behrensmeyer and Kidwell 1985; Clark and Kietzke 1967; Hesse and Wapnish 1985; Lawrence 1968; Meadow 1981; Medlock 1975). Since taphonomic

processes are cumulative, the processes that happened later will increase, mask, or remove the information that might otherwise be derived from the bone assemblage in the early stage (Lyman 1994). Therefore, the taphonomic processes were examined following the sequence from the late to the early times as follows, and the relevant information is provided in Chapter 3 (Section 3.3.2):

1. Collect the information about the excavation, including excavation background (rescue *vs* research excavation); retrieval method of the faunal samples (hand collection *vs* screen sieving) (Payne 1972); alteration of the bones after retrieval and before been analysed (e.g. washing and transportation).
2. Collect information and understanding the excavation contexts where the faunal samples were retrieved, including: obtaining the information of the other materials and remains from the same contexts; compare the size of excavation area to the estimated total area of the site. This reflects how representative the samples are for the whole range of animals exploited at the site (Payne 1972).
3. Surface preservation conditions were assessed using three scales: 1. good: the surface of the bone smooth to lightly eroded with cut marks can be observed; 2. average: most of the surface lost and normal cut marks cannot be seen apart from very large ones; 3. poor: the bone appears porous and amorphous. These stages were designed considering the specific condition of this study and developed based on the five weathering stages of Behresmeyer (1978). Illustrations of the three scales of surface preservation are in Appendix R.
4. Burning was studied by observing and recording traces of burning on each specimen. Four levels were recorded: 0. no traces of burning; 1. light traces of burning; 2. medium burnt: appearing charred or carbonized; 3. heavily burnt: appearing grey and calcified. These stages were designed considering the specific condition in this study and developed based on the six burning stages of Stiner et al. (1995).

5. Butchery marks (hack marks and fine cut marks) (Binford 1981) were observed and recorded once they were discovered.
6. Root etching (Binford 1981) is observed and recorded.
7. Gnawing marks by mammals (Binford 1981; White 1992) were observed and recorded if noticed.

In the second place, whereas possible, specimens were assigned to a taxonomic entity and skeletal element. For NISPs (number of identified specimens), all specimens that could be assigned to both a taxon and element were counted. However, the level of the identified taxonomic level varies. There are many specimens that could only be assigned to a higher level than genus. For example, in the case it could not be identified as *Pseudois* or *Nemorhaedus* it was recorded as ‘Caprinae’ but still counted for NISP. Specimens that were assigned to ‘large/middle/small sized mammals’ were not taken into account for NISPs.

Taxonomic frequencies of the total fauna of a site were calculated based on NISP. Together with the taphonomic analysis, this gives a general picture of the animal economy of this area.

The assemblages of the five sites were not analysed equally. All faunal specimens from Jiangxigou 2, Andaqiha and Sanbadongzi were examined by myself, although the Jiangxigou 2 and Sanbadongzi fauna have been analysed before and the previous analysis results were provided for reference. Only the Caprinae remains from Jinchankou and Sanbadongzi were analysed by me, and the general remains were analysed by other researchers and the results were kindly shared with me. Hence the taphonomic analysis of Jinchankou and Sanbadongzi in this study was based only on the Caprinae remains.

5.3.2.2 Caprinae and *Gazella* Remains

Apart from the approach adopted to analyse the general faunal remains, different approaches were applied to the Caprinae and *Gazella* remains, involving both osteoscopic

and osteometric criteria developed on modern materials.

Both osteoscopic criteria and osteometric criteria have their own advantages and limitations in analysing the taxonomic identity of archaeological specimens. In general, the osteoscopic criteria are less subjective than the osteometric criteria, but it also depends on the specific situations of analysis.

The success of the osteoscopic characters depends on the accuracy of the criteria and on the practice a zooarchaeologist has. The success of the osteometric method and then statistical analysis depends on the good choice of measurements that precisely capture the morphology of the bone, and the suitability of these measurements to be manipulated. Ideally, measurement error should be calculated for every measurement to ensure that the error will not bias the result of statistical analysis. However, this is rarely done in the traditional osteometric analysis, as opposed to geometric morphometrics where it is part of the protocol. In addition, the sample size is also important in statistical analysis. Ideal sample size would be 30-40 specimens for each targeted group, although the larger number the better. Also, in the linear discriminate analysis, which was utilized in this study, the sample size of the different groups should not differ to a great extent. Finally, the choice of the sample is also crucial, and only the sample of the specific species in question should be incorporated (*pers. comm.* N. Pöllath, January 2017).

In the present study, all the newly developed measurements were tested for repeatability, and relative errors were calculated in order to provide a quantitative measure of the reliability. But the previously developed measurements were not tested, considering that they had already been well applied in numerous cases.

Different methods were applied to different skeletal elements during the fieldwork and during the laboratory analysis. During the fieldwork, all the selected skeletal elements of Caprinae and gazelle (dentition, scapula, humerus, radius, ulna, metacarpal, pelvis, femur, tibia, metatarsal, phalanx 1, 2, and 3, astragalus, and calcaneus) were analysed using the descriptive osteoscopic criteria and ratios of pairs of measurements. Most of the

specimens identified as Caprinae or *Gazella* were photographed from different angles to show the diagnostic criteria. Standard and newly developed measurements were taken. In the laboratory analysis, three elements --- distal humerus, distal metacarpal and metatarsal --- were analysed in more detail based on linear discriminant analysis with shape indices, criteria of ratios of pairs of measurements, and scored osteoscopic characters. The original shape and taphonomic information were checked in the photographs and records once needed. The other elements were not analysed in the laboratory.

As will be shown in Chapter 6, the numbers of the specimens available for each measurement taken on the modern comparative groups are not large --- apart from *Capra sibirica*, which has only 5 specimens on humerus, it ranges from 11 (*Pseudois* sub/juv) to 33 (*Ovis ammon*) on the humerus, and 12 (*Ovis vignei*) to 33 (*Ovis ammon*, *Ovis musimon*) on metacarpals and metatarsals. Hence, in the statistical analysis for archaeological specimens, *Capra sibirica* is excluded, as this species were not distributed the research area, and its sample sizes are too small. In addition, the zoo-bred and captured wild specimens of *Ovis ammon* are grouped together, as it was found that apart from the size difference, the osteometric data of these two groups are very similar, confirming what J. Peters suggested. The sub/juv group and adult group of *Pseudois nayaur* are also grouped together: although slight differences between the two groups are detected, they are not huge (around 0.1 in each ratio), and when combined it reaches the number of more than twenty. Nevertheless, there are still many taxa with specimen numbers less than twenty in many measurements. Hence, the results based on the osteometric analysis should be regarded with caution.

Because of erosion and fragmentation, many samples were not available for multivariate discriminate analysis based on various measurements. In addition, the multivariate discriminate analysis could not always produce satisfactory results for analysing the archaeological specimens. There were cases when the posterior probability of separating various taxa/groups was lower than 70% and even lower than 60%, as will be shown in Chapter 6 and 7. Ratios of pairs of linear measurements and osteoscopic

characters were utilized in many of these cases. For example, when the bones were homogeneously eroded, and when not all the measurements are operable to be taken on an element. The ratios and osteoscopic characters could be used at least to provide suggestions for taxonomic identity. Nevertheless, one should be aware of the limitation of the information.

As such, multiple lines of evidence were integrated into the study: the results produced through individual methods had to be regarded with caution, but more confidence could be placed in multiple lines of evidence being integrated.

The results produced in fieldwork and the laboratory analysis are both valued. Although the field analysis appeared to be rough and more preliminary compared to the laboratory work, the direct examination of the archaeological samples provided a live record of the bones with all the taphonomic information available. As discussed, for the analysis of archaeological samples, taphonomic processes is very important.

6. Comparative Osteoscopic Characters and Osteometry of the Caprinae and *Gazella* of Western China and *Ovis* of Eurasia

6.1 Introduction

This chapter discusses the comparative osteoscopic characters and osteometry of the distal humeri and metapodials of Caprinae and *Gazella* that are distributed in the research area today. Only the numerical scored characters and discriminate analysis of log-shape ratios on distal humeri and metapodials are presented here.

6.2 Humerus, Distal End

6.2.1 Osteoscopic and Osteometric Studies

A series of quite diagnostic features were developed between the different species of *Ovis* and other Caprinae on this element, making it a most diagnostic element in the species identification guide.

Anatomical terms

In the description of the morphology of the distal humerus, the following terms are used: 1. trochlea; 2. condylus; 3. fossa radialis; 4. epicondylus medialis. (Figure 6.1)

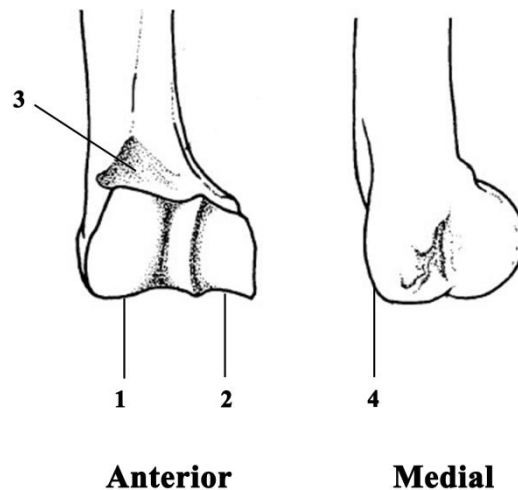


Figure 6.1 Anatomical terms addressed on distal humerus. 1. trochlea; 2. condylus; 3. fossa radialis; 4. epicondylus medialis. The drawing is reproduced from Helmer and Rocheteau (1994): Figure 5.

Measurements (Figure 6.2)

BT = (Greatest) breadth of the trochlea, taken following von den Driesch (1976: 77).

HT = (Greatest) height of the trochlea (Adopted from ‘HTm’ in Göze 1998: 179; ‘HMT’ in Fernandez 2001: 2).

SHT = Smallest height of the trochlea. The measurement is taken on the sagittal groove (Adopted from ‘HTC’ in Davis 1996; ‘HT’ in Fernandez 2001, volume II: 2; ‘HTF’ in Göze 1998: 179).

LHT = Height of the condylus. The measurement is taken midway between the sagittal ridge and the lateral edge of the condylus and parallel to the sagittal ridge. (Adopted from ‘HTI’ in Götze 1998: 179).

BTm = Breadth of the trochlea

BTl = Breadth of the condylus. The measurement is taken from the sagittal ridge to the most lateral edge of the condylus (Adopted from ‘BTI’ in Götze 1998: 179).

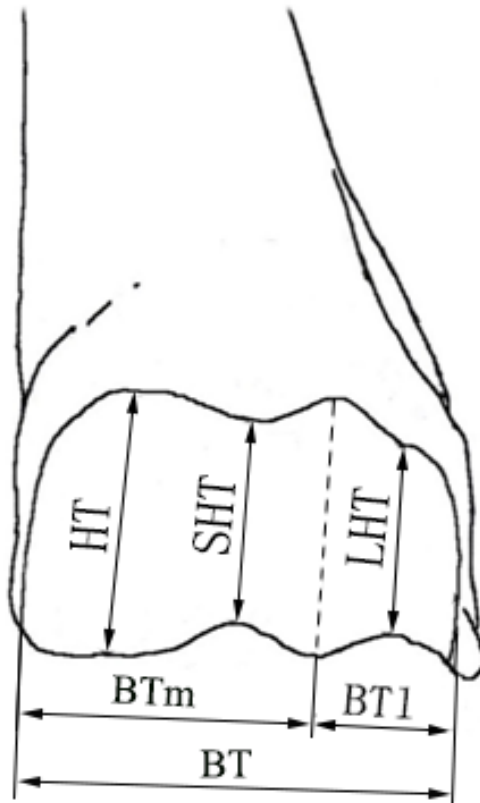


Figure 6.2 Measurements taken on the distal humerus.

6.2.1.1 All Caprinae and *Gazella*

Absolute Size

As can be seen in Table 6.1, wild *O. ammon* is among the largest species in all the measured samples, and then followed by *Capricornis* and *Capra sibirica*. These three species are the large-sized animals with the mean of BT scales above 40 mm. This fits with the body size described in Schaller (1977).

The size of *Pseudois* is similar to zoo *O. ammon* (Table 6.1), and they are larger than all the other middle-sized Caprinae and *Gazella*. The size of sub-adult *Pseudois* overlaps with the other species of *Ovis* and Caprinae; *Capra hircus* and *Nemorhaedus* are at a lower position in the size and overlap with *O. vignei* and *O. orientalis* and *O. musimon*. *Gazella* and *Procapra* are the smallest amongst all the taxa analyzed.

Taxon	Common Name	N	Range	Mean	SD
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<i>O. ammon</i> (wild)	Argali (wild)*	17	38.6-50.5	44.0	3.09
<i>C. serow</i>	Serow	15	39.3-52.9	46.3	3.87
<i>C. sibirica</i>	Siberian Ibex	5	39.6-43.7	41.3	1.79
<i>P. nayaur</i> (ad)	Blue Sheep (ad)	13	35.8-38.3	36.7	1.31
<i>O. ammon</i> (zoobred)	Argali (zoobred)	7	32.0-37.2	35.4	1.72
<i>P. nayaur</i> (sub-ad)	Blue Sheep (sub-ad)	13	31.3-39.2	34.8	2.63
<i>O. orientalis</i>	West Asian Mouflon	17	27.7-35.8	30.9	2.41
<i>C. hircus</i>	Goat	16	20.9-35.0	31.0	3.33
<i>O. vignei</i>	Urial	14	26.6-33.7	30.0	2.31
<i>N. goral</i>	Goral	23	23.6-33.0	29.8	1.91
<i>O. aries</i>	Domestic Sheep	51	23.3-42.4	29.3	3.69
<i>O. musimon</i>	European Mouflon	35	25.2-34.0	28.5	2.40
<i>P. gutturosa</i>	Mongolian Gazelle	2	28.2-28.3	28.3	0.06
<i>G. gazella</i>	Mountain Gazelle	13	19.2-25.1	21.7	1.92

Table 6.1 Osteometrics of Caprinae and *Gazella* studied. Number of specimens measured (N), range, mean, and standard deviation (SD). Values are given for breadth of the trochlea (BT) of the humerus in millimetres (mm). * 'wild' refers to the captured wild animals.

Comparative Osteoscopic Characters

The drawings of the typical morphology of the different species are presented in Figure 6.3. Originally 9 characters were considered in separating the different Caprinae and *Gazella*, but finally, only four (all in anterior view) were numerically scored in the study of comparative osteoscopic characters of Caprinae and *Gazella*.

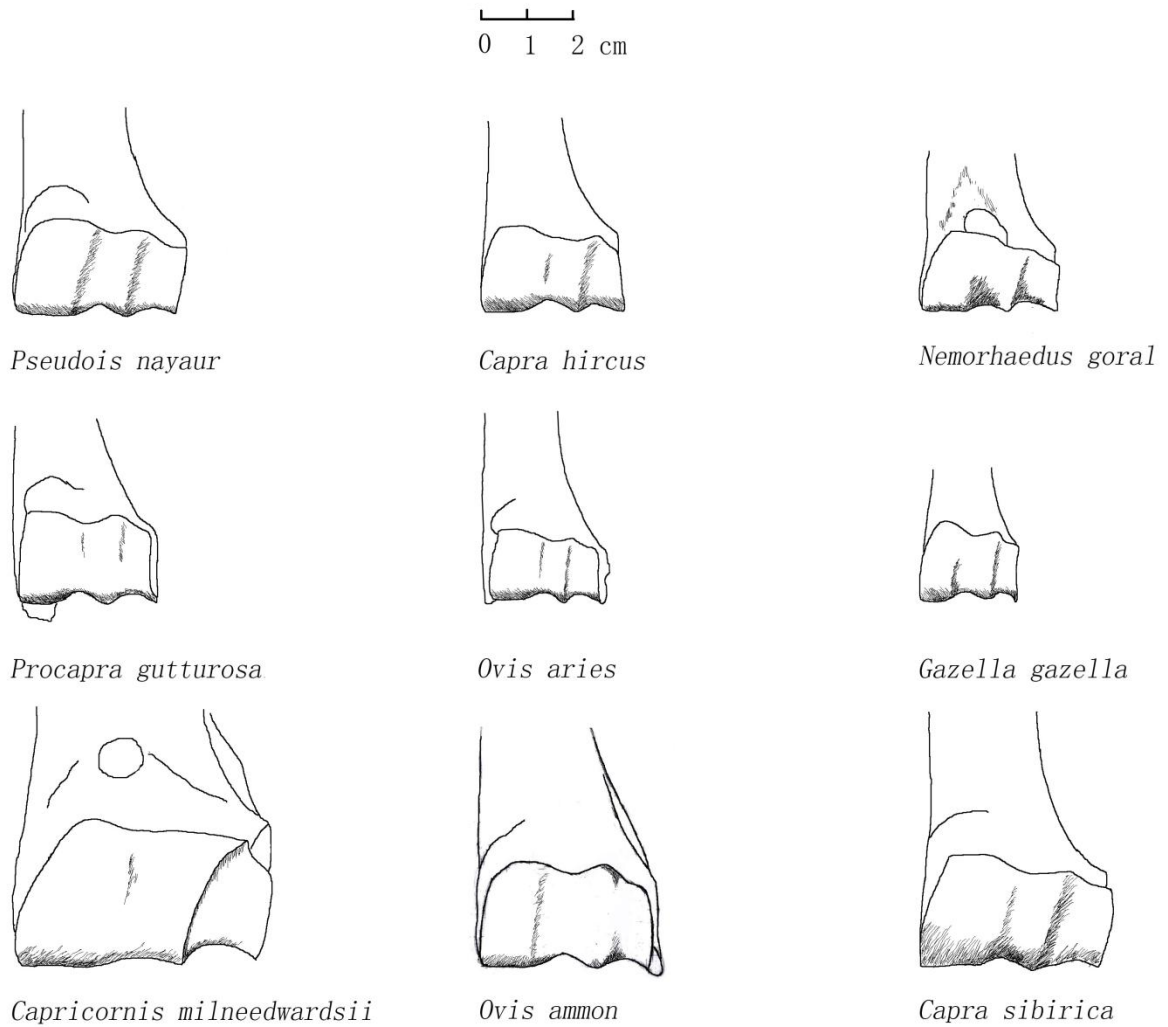


Figure 6.3 *Pseudois nayaur* (Blue Sheep), *Capra hircus* (Goat), *Nemorhaedus* (Goral), *Procapra* (Mongolian Gazelle), *Ovis aries* (Domestic Sheep), *Gazella* (Gazelle), *Capricornis* (Serow), *Ovis ammon* (Argali), *Capra sibirica* (Siberian Ibex). Typical morphology of the distal humerus, anterior view.

1. The superior edge of the condylus

As shown in Figure 6.4, the specimens are scored according to the degrees of the obliqueness of the superior edge of the condylus. With the distal margin of the trochlea and the distal-lateral points of condylus kept in the same level, those running rather parallel to the inferior edge are scored 1; those rather oblique are scored as 3; the intermediate are scored 2.

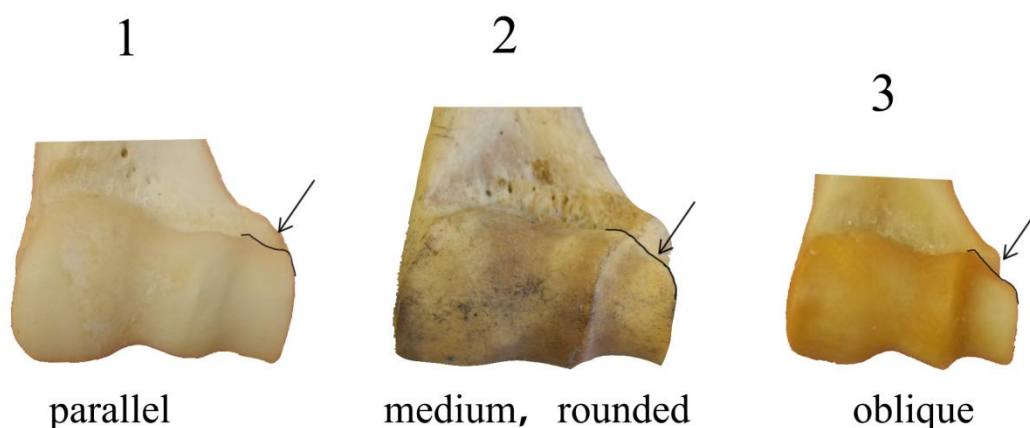


Figure 6.4 Scored Character 1 on distal humerus of Caprinae and *Gazella*, shown on three specimens, scored 1, 2, and 3 respectively.

As can be seen in Table 6.2, in most of the species the superior edge of the condylus is parallel to the inferior edge; including *Pseudois* (score 1 accounts for 83.3%), *Ovis* (score 1 accounts for 75%), while quite oblique in *Capra hircus* (score 2 accounts for 73.7% and score 3 accounts for 26.3%). The number of the specimens observed for this character is very small in *Capricornis* (N=4), *Nemorhaedus* (N=5), and *Gazella/Procapra* (N=3), and not large in *Pseudois* (N=12) and *Capra hircus* (N=19) either. There is no feature in this character exclusive to any species. It may be used to distinguish *C. hircus* from others, although this is still awaited to be tested on more samples. This character is not discussed in any previous literature to distinguish different Caprinae.

Species		Score 1		Score 2		Score 3		Total
Scientific Name	Common Name	count	%	count	%	count	%	
<i>Pseudois</i>	Blue Sheep	10	83.3	2	16.7	0	0.0	12
<i>Capricornis</i>	Serow	3	75.0	1	25.0	0	0.0	4
<i>Nemorhaedus</i>	Goral	3	60.0	1	20.0	1	20.0	5
<i>C. hircus</i>	Goat	0	0.0	14	73.7	5	26.3	19
<i>Gazella/Procapra</i>	Gazelle	3	100.0	0	0.0	0	0.0	3
<i>Ovis</i>	Sheep	83	78.3	20	18.9	3	2.8	106

Table 6.2 Scored counts of the Caprinae and *Gazella* studied, distal humeri, Character 1, the superior edge of condylus.

2. The distal margin of the condylus

The specimens are scored according to the relative location of the distal margin of the condylus. Keeping the distal margin of the trochlea and the distal point of the sagittal ridge at the same level, those with distal margins of the condylus located more proximally compared to the distal rim of the sagittal groove are scored as 1; those with distal margins of the condylus located more at the same level or lower than the sagittal groove are scored as 2 (Figure 6.5).

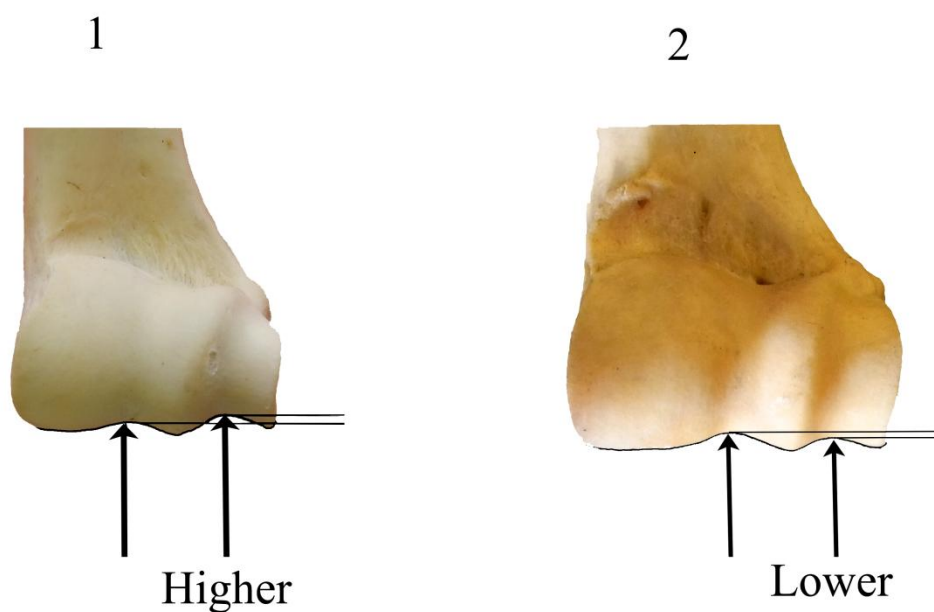


Figure 6.5 Scored Character 2 on distal humeri of Caprinae and *Gazella*, shown on two specimens, scored 1 and 2 respectively.

As can be seen in Table 6.3, in the majority of the specimens of *Capricornis* and *Nemorhaedus* the distal margin of the condylus is higher than the distal margin of the sagittal groove (score 1 accounts for 94.1% and 88.9% respectively), while parallel or lower than the distal margin of the sagittal groove in the other species. The number of the specimens observed for this character is not large among non-*Ovis* specimens in general, and particularly small in *Gazella/Procapra* (N=6). There is no feature in this character exclusive to any species, but it may be used to distinguish *Capricornis* and *Nemorhaedus* from others. This character is not discussed in any previous literature to distinguish

different Caprinae.

Species		Score 1		Score 2		Total
Scientific Name	Common Name	count	%	count	%	
<i>Pseudois</i>	Blue Sheep	1	8.3	11	91.7	12
<i>Capricornis</i>	Serow	16	94.1	1	5.9	17
<i>Nemorhaedus</i>	Goral	16	88.9	2	11.1	18
<i>C. hircus</i>	Goat	0	0.0	15	100.0	15
<i>Gazella/Procapra</i>	Gazelle	1	16.7	5	83.3	6
<i>Ovis</i>	Sheep	1	0.5	94	98.9	95

Table 6.3 Scored counts of the Caprinae and Gazella studied, distal humeri, Character 2, the distal margin of the condylus.

3. The obliquity of the sagittal ridge

The specimens are scored according to the ubiquity of the sagittal ridge. With the distal margin of the trochlea and the distal-lateral points of the condylus kept in the same level, those sagittal ridges which appeared quite straight are scored as 1, those intermediate are scored 2, and those quite oblique are scored as 3 (Figure 6.6).

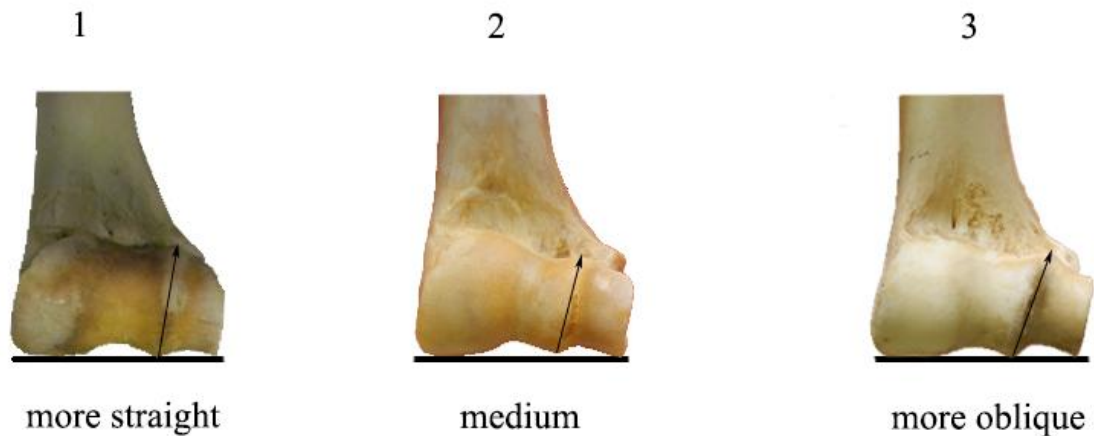


Figure 6.6 Scored Character 3 on distal humeri of Caprinae and *Gazella*, shown on three specimens, scored 1, 2, and 3 respectively.

As can be seen in Table 6.4, the direction of the sagittal ridge is mostly quite straight in *Ovis* (score 1 accounts for 98.9%). The numbers of the specimens observed for other

species are quite small. Nevertheless, among the limited samples observed, *C. hircus* (N=11) and *Gazella/Procapra* (N=6) are quite straight in this character (score 1 accounts for 100% in both species); *Capricornis* (N=10) is quite oblique in the majority of the specimens (90%); while about half of the *Nemorhaedus* (N=15) (46.7%) have a straighter sagittal ridge. In 12 Pseudois more than half of the specimens have a quite straight sagittal ridge (58.3%), and one quarter is intermediate; others (16.7%) have a quite oblique sagittal ridge. There is no feature in this character exclusive to any species. This feature is not discussed in previous literature.

Species		Score 1		Score 2		Score 3		Total
Scientific Name	Common Name	count	%	count	%	count	%	
<i>Pseudois</i>	Blue Sheep	7	58.3	3	25.0	2	16.7	12
<i>Capricornis</i>	Serow	1	10.0	0	0.0	9	90.0	10
<i>Nemorhaedus</i>	Goral	7	46.7	0	0.0	8	53.3	15
<i>C. hircus</i>	Goat	11	100.0	0	0.0	0	0.0	11
<i>Gazella/Procapra</i>	Gazelle	6	100.0	0	0.0	0	0.0	6
<i>Ovis</i>	Sheep	87	98.9	1	1.1	0	0.0	88

Table 6.4 Scored counts of the Caprinae and Gazella studied, distal humeri, Character 3, the direction of the sagittal ridge

4. Foramen of fossa radialis

The specimens are scored according to whether a foramen exists or not at the fossa radialis (Figure 6.7). Those with a foramen that communicates between the anterior and posterior sides at the fossa radialis are scored 2, and those without such a foramen are scored 1.



Figure 6.7 Character 4 on distal humeri of Caprinae and *Gazella*, shown on two specimens, scored 1 and 2 respectively.

As can be seen in Table 6.5, the foramen is not observed in any specimens of *Ovis*, *C. hircus*, or *Pseudois*, although the number of the specimens observed for *Pseudois* and *C. hircus* is quite small (N=7 and 11 respectively). In *Capricornis* and *Nemorhaedus*, while the majority (80%) are without the foramen, nearly 20% are found with a foramen (N=17 for both species). In *Gazella/Procapra* (N=13), two specimens are found with a foramen, accounting for 13.3%. There is no feature in this character exclusive to any species. This character is not discussed in any previous literature to distinguish different Caprinaes.

Species		Score 1		Score 2		Total
Scientific Name	Common Name	count	%	count	%	
<i>Pseudois</i>	Blue Sheep	7	100.0	0	0.0	7
<i>Capricornis</i>	Serow	17	81.0	4	19.0	21
<i>Nemorhaedus</i>	Goral	17	81.0	4	19.0	21
<i>C. hircus</i>	Goat	11	100.0	0	0.0	11
<i>Gazella/Procapra</i>	Gazelle	13	86.7	2	13.3	15
<i>Ovis</i>	Sheep	87	100.0	0	0.0	87

Table 6.5 Scored counts of the Caprinae and *Gazella* studied, distal humeri, Character 4, foramen of the fossa radialis.

6.2.1.2 *Ovis*

Absolute Size

Table 6.6 shows the size differentiation of different *Ovis* in Eurasia. The size range is the largest in *Ovis ammon* and smallest in *O. musimon* sheep confined to zoos, and there is a gradual descending size gradient from the East to the West across Eurasia, although zoo animals and wild *Ovis* should be considered separately. This size gradient between them agrees with the body size variation that has been described for these species in the literature (see Chapter 4). Expectedly the range and variance of domestic sheep are the largest amongst all the sheep groups.

Species		N	BT	Mean	SD
Scientific Name	Common Name				
<i>Ovis ammon</i> (wild)	Argali (wild)*	17	38.6-50.5	44.0	3.09
<i>Ovis ammon</i> (zoobred)	Argali (zoobred)	7	32.0-37.2	35.4	1.72
<i>Ovis orientalis</i>	West Asian Mouflon	17	27.7-35.8	30.9	2.41
<i>Ovis vignei</i>	Urial	14	26.6-33.7	30.0	2.31
<i>Ovis aries</i>	Domestic Sheep	51	23.3-42.4	29.3	3.69
<i>Ovis musimon</i> (wild)	European Mouflon (feral)	15	26.5-34.0	29.5	2.43
<i>Ovis musimon</i> (zoo)	European Mouflon (zoobred)	20	25.2-31.6	27.7	2.14

Table 6.6 Osteometrics of *Ovis*. Number of specimens measured (N), range, mean, and standard deviation (SD). Values are given for proximal breadth (BT) of the humeri in millimetres (mm). * 'wild' refers to the captured wild animals.

Expectedly, the wild animals tend to be larger than zoo animals for the same species, as can be seen from the two groups of *O. ammon* and *O. musimon*. Despite distributed further west, the majority of wild *O. orientalis* are larger than the *O. vignei*, but the mean values are close to each other. It should be noted, though, that nearly half of the latter are zoo animals.

Comparative Osteoscopic Characters

Originally ten features were analysed but only one was finally incorporated and presented here.

The transition from the shaft to the lateral epicondyle

The specimens are scored according to the form of the transitional part from the shaft

Species	Score 1	Score 2	Score 3	Total
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to the lateral epicondyle (Figure 6.8). Those exhibiting a rather straight transition are scored '1'; those with a much arched transition are scored '3'; the intermediate between the above two are scored '2'.

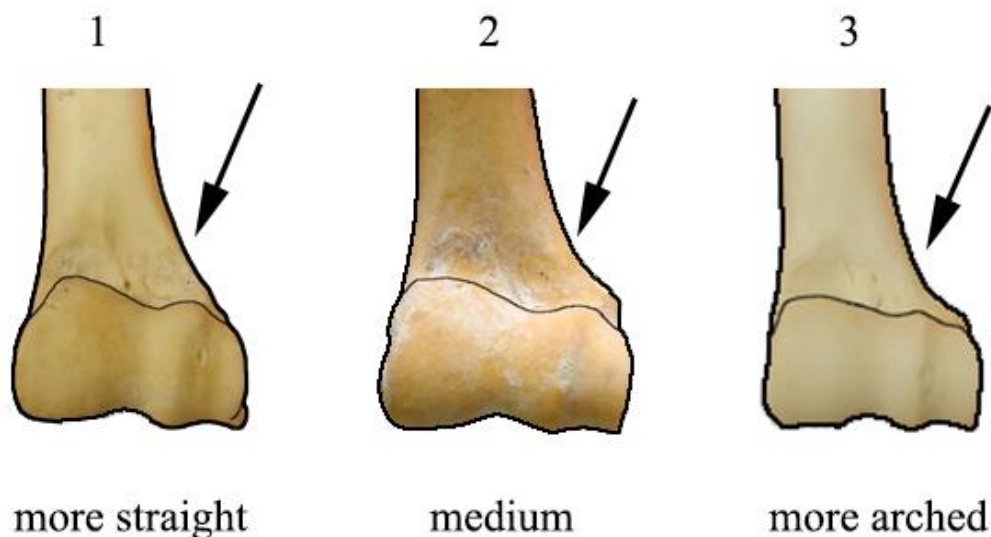


Figure 6.8 The Scored character of different *Ovis* shown on three specimens, scored 1, 2, and 3 respectively.

As can be seen in Table 6.7, most *Ovis ammon* are characterised by a quite straight transition from the shaft to the lateral epicondyle (score 1 accounts for 75%); most *Ovis musimon* and country sheep (*Ovis aries* from the UK and Europe) have more arched transitions (score 3 accounts for 68.8% and 86.7% respectively) than those from regions located further east. Score 1 accounts for 35% and 25% in *O. vignei* and *O. orientalis* respectively, compared with 0% on both *O. musimon* and country *O. aries*; score 3 accounts for 30% and 68.8% respectively in *O. vignei* and *O. orientalis* compared to 68.8% and 86.7% in *O. musimon* and *O. aries*. Rambouillet sheep and Rambouillet × Argali group are also characterised by more arched transitions (score 3 accounts for about 79% in both species). There seems to be a west-east differentiation in the osteoscopic cline among the different wild *Ovis* species. But the sample size is not large for each group, and the conclusion is awaited to be tested on more samples.

Scientific Name	Common Name	count	%	count	%	count	%	
<i>Ovis ammon</i>	Argali	15	75.0	2	10.0	3	15.0	20
<i>Ovis vignei</i>	Urial	7	35.0	7	35.0	6	30.0	20
<i>Ovis orientalis</i>	Mouflon	4	25.0	1	6.3	11	68.8	16
<i>Ovis musimon</i>	European Mouflon	0	0.0	10	31.2	22	68.8	32
<i>Ovis aries</i>	Country Sheep*	0	0.0	2	13.3	13	86.7	15
<i>Ovis aries</i>	Rambouillet sheep*	2	12.5	3	18.8	11	68.8	16
<i>Ovis aries</i>	Crossbred Sheep*	6	28.6	0	0.0	15	71.4	21

Table 6.7 Scored counts of *Ovis* studied, distal humeri, the transition from the shaft to the lateral epicondyle. *Three groups of *Ovis aries* are measured, although they are not different 'species'. Crossbred sheep is the hybrids of *Ovis ammon* (Argali) and *Ovis aries* (Country sheep and Rambouillet sheep).

This character is addressed in Boessneck et al. (1964: 66-67, Abb. 27) and Prummel and Frisch (1986: 569-570, Figure 4) as that the direction of the epicondylus in sheep makes an angle with that of the axis, while in goat it runs parallel to the longitudinal axis of the humeri. In Fernandez (2001, vol. 1: 48-49), it was found that the majority of the *R. rupicapra* have a wide lateral epicondylus and it flares out, while in goat it is mostly narrow and flat. Other literature addressing the development of the lateral epicondyles placed the focus mainly on the stoutness of the epicondyles but not the form of the transition. For example, it was noted that in the majority of *O. aries* the lateral epicondyle is broad, strong, and massif, while in majority of the *C. hircus* and *C. Capreolus* it is narrow (Boessneck 1964: 66-67, Abb. 27; Helmer and Rocheteau 1994: 17; Fernandez 2001, vol. 1: 48-49).

6.2.2 Discriminant Analysis Based on Shape Indices

A. Classification of all Caprinae and Gazella to 6 groups (Figure 6.9)

Six shape indices of the distal humeri on each measured specimen were calculated for

discriminate function analysis. *Pseudois* (N=24), *Capricornis* (N=15), *Nemorhaedus* (N=21), *C. hircus* (N=14), *Gazella/Procapra* (N=15), and all *Ovis* specimens (N=133) were classified (See Chapter Five, p. 127-128, and footnote 17 for explanation of shape indices).

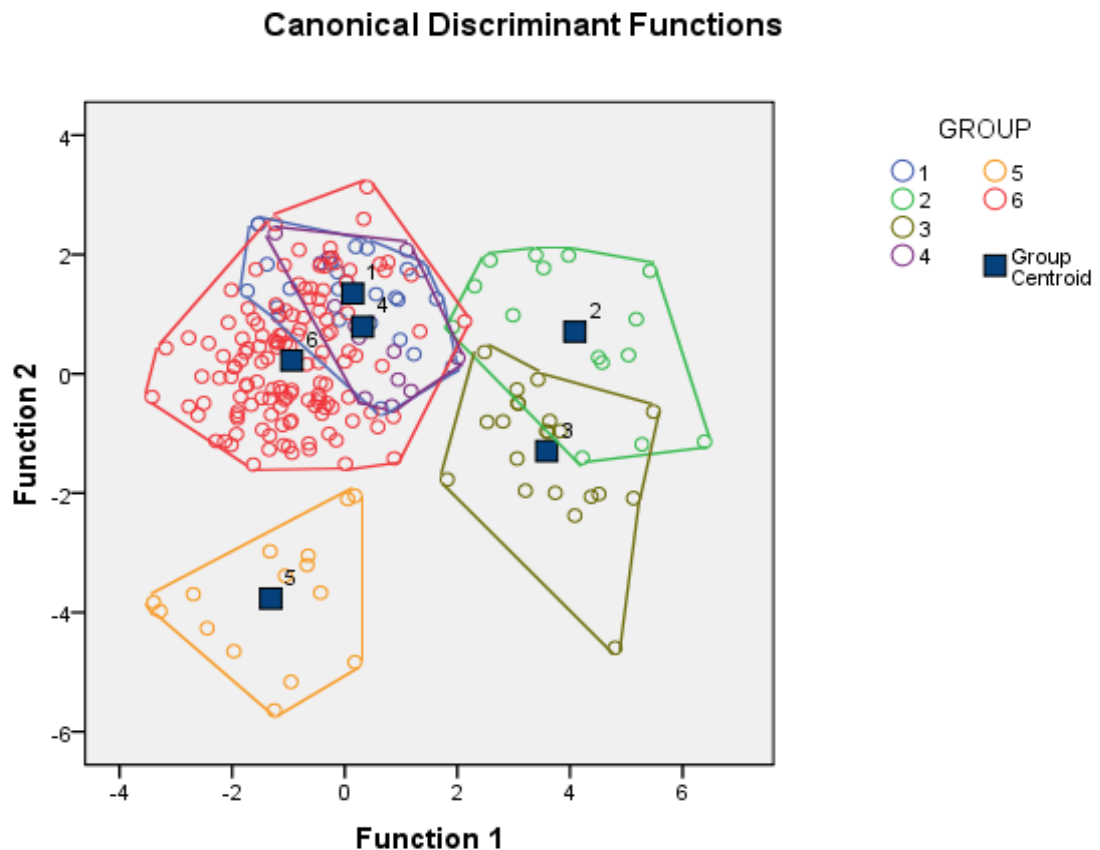


Figure 6.9 Classification results of all modern *Ovis*, non-*Ovis* Caprinae, and *Gazella* specimens (N=222) based on the first two discriminate functions using six shape indices. 1. *Pseudois* (Blue Sheep); 2. *Capricornis* (Serow); 3. *Nemorhaedus* (Goral); 4. *C. hircus* (Goat); 5. *Gazella/Procapra* (Gazelle); 6. *Ovis* (captured wild and domestic Sheep). Group Centroid: mean discriminant scores for each grouping variables. See the complete result of the canonical discriminant function analysis in Appendix P, vol. 2.

86.9% of the original grouped specimens were correctly classified to the prior groups. The convex hulls showed that *Pseudois* and *Capra hircus* largely overlap with each other, and they both fall inside the convex hull of *Ovis*. The majority of *Capricornis*, *Nemorhaedus*, and *Gazelle/Procapra* are separated quite well from

Ovis+Pseudois+C. hircus group.

B. Classification of all *Ovis* to 6 groups (Figure 6.10)

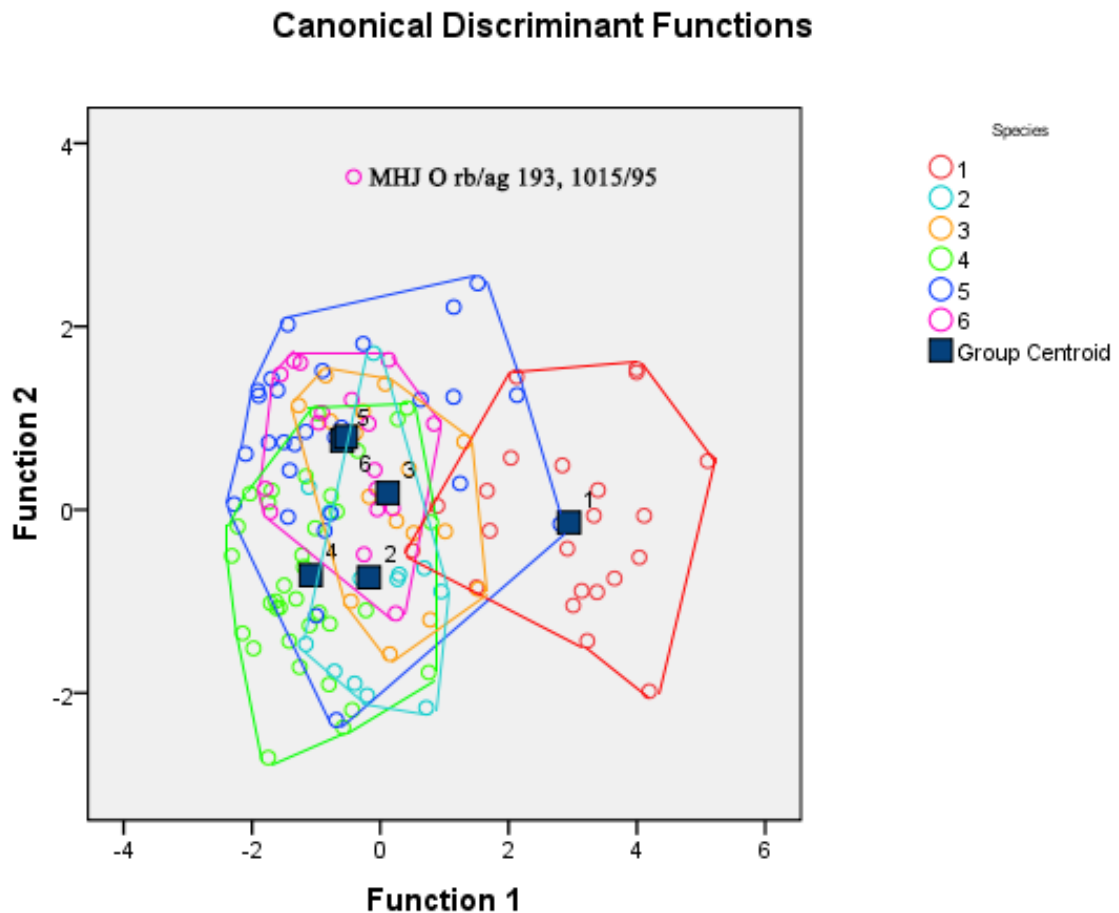


Figure 6.10 Classification results of all modern *Ovis* specimens (N=133) based on the first two discriminate functions using six shape indices. 1. *O. ammon* (Argali); 2. *O. vignei* (Urial); 3. *O. orientalis* (Western Asian Mouflon); 4. *O. musimon* (European Mouflon Sheep); 5. *O. aries* (Domestic Sheep); 6. *O. ammon* × *O. aries* (Crossbred Sheep). Group Centroid: mean discriminant scores for each grouping variables.

57.9% of the original grouped cases were correctly assigned, although there is an outlier of *O. ammon* × *O. aries* (MHJ O rb/ag 193, 1015/95) positioned quite far away from the others.

As can be seen, apart from *O. ammon* that are generally separated from the others, all the other *Ovis* (*O. vignei*, *O. orientalis*, *O. musimon*, *O. arie*, *O ammon* × *O. aries*) are clustered overlapping with each other.

O. aries are more scattered, overlapping with many *O. ammon*. This may be attributed to the fact that the *O. aries* samples in this study come from a wide source (UK, European, US domestic sheep and Rambouillet sheep).

Therefore, apart from some 'typical' *O. ammon*, it might be difficult to separate the other *Ovis* species/populations from each other in archaeological samples, particularly if fragmented.

C. Classification of all Caprinae and Gazella to 11 groups (Figure 6.11)

This time, *O. ammon* (N=22), *O. vignei* (N=14), *O. orientalis* (N=16), *O. musimon* (N=35), *O. aries* (N=28), *O. ammon* × *O. aries* (N=18) are set as separated groups and analysed together with all other Caprinae and *Gazella*.

66.2% of the original grouped cases were correctly classified. However, one extreme outlier in *O. musimon*, MNB 22772, was found, which are located very far away from the rest. It will be excluded from the analysis to predict the assignation of the archaeological specimens in the next step.

As shown in Figure 6.11, all the *Ovis* groups are generally scattered together. Two Caprinae species, *Pseudois* and *C. hircus*, are quite close to the *Ovis* groups. The others, *Capricornis*, *Nemorhaedus*, and *Gazella/Procapra*, are scattered quite separately.

Especially, as can be seen in the figure, *Pseudois* specimens overlap with a substantial portion of *O. ammon*, some *O. vignei*, *O. orientalis*, and some *O. aries*, while. *C. hircus* overlaps with the majority of *O. vignei*, some *O. ammon*, some *O. orientalis* and *O. aries*, and a few of *O. musimon* and *O. ammon* × *O. aries*.

Therefore, it might be difficult to distinguish between *Ovis*, *Pseudois*, and *Capra hircus* in archaeological samples using this method.

Canonical Discriminant Functions

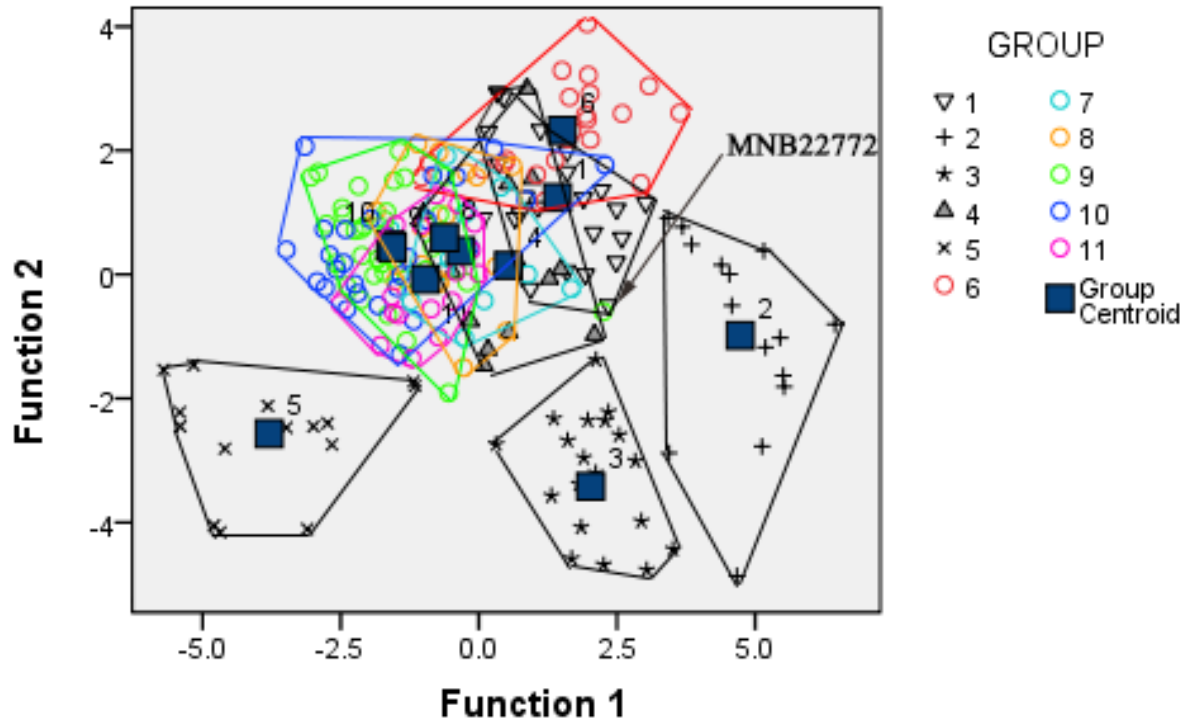


Figure 6.11 Classification results of all modern Caprinae and gazelle specimens (N=222) based on the first two discriminate functions using six shape indices. 1. *Pseudois* (Blue Sheep); 2. *Capricornis* (Serow); 3. *Nemorhaedus* (Goral); 4. *C. hircus* (Goat); 5. *Gazella/Procapra* (Gazelle); 6. *O. ammon* (Argali); 7. *O. vignei* (Urial); 8. *O. orientalis* (Western Asian Mouflon); 9. *O. musimon* (European Mouflon Sheep); 10. *O. aries* (Domestic Sheep); 11. *O. ammon* × *O. aries* (Crossbred Sheep). Group centroid: mean discriminant scores for each grouping variables.

6.3 Metapodials, Distal End

6.3.1 Osteoscopic and Osteometric Study

The metacarpal and metatarsal exhibit very clear distinction patterns between the different species studied. Because the structures of the articulation of the two bones closely resemble each other, the two elements are presented together.

Anatomical terms

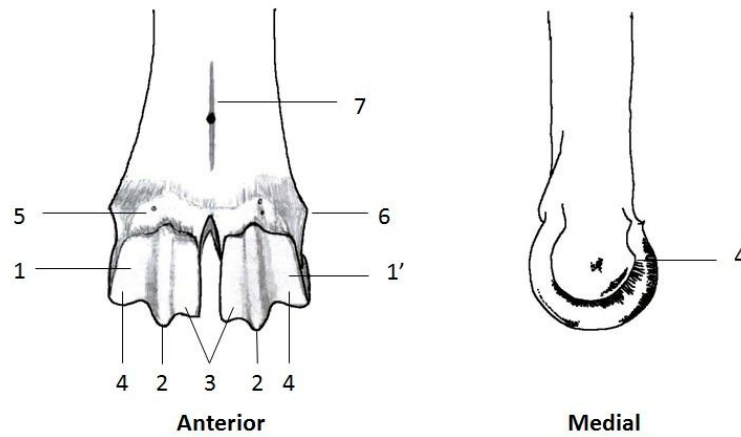


Figure 6.12 Distal metapodial: anatomical terms. 1. medial, 1' lateral (articular) condyle; 2. Verticillus of the condyle; 3. Axial section of the condyle; 4. abaxial section of the condyle; 5. depression for ligamentous attachment; 6. lateral protuberance; 7. Dorsal longitudinal groove

Measurements

Altogether 11 measurements have been taken on each specimen (Figure 6.13).

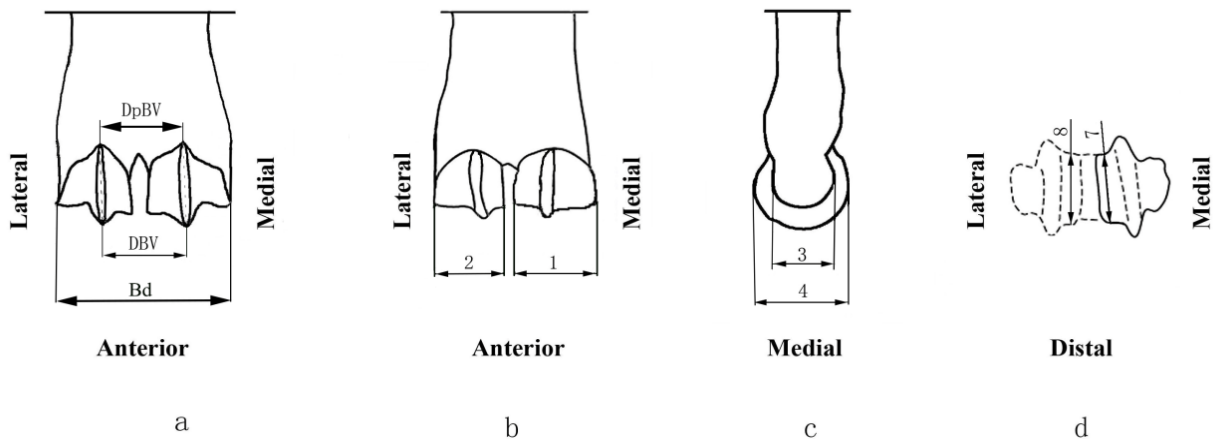


Figure 6.13 The measurements taken on distal metapodials. Picture b & c: modified from Legge (Harrison et al. 1987, Figure 71). Picture d: modified from Payne (1969, Figure 1)

Measurements 1-6 (Figure 6.13: b, c) are taken following Payne (1969): Figure 1,

Legge (Harrison et al. 1994: Figure 1), and (1969: Figure 72); Boessneck et al. (1964: Abb. 70).

1: the width of the medial condyle

2: the width of the lateral condyle

3: the dorsopalmar (Mc) or dorsoplantar (Mt) diameter of the abaxial section of the medial condyle

4: the dorsopalmar (Mc) or dorsoplantar (Mt) diameter of the verticillus in medial side.

5: the dorsopalmar (Mc) or dorsoplantar (Mt) diameter of the abaxial section of the lateral condyle

6: the dorsopalmar (Mc) or dorsoplantar (Mt) diameter of the verticillus in the lateral side

Measurements 7-8 (Figure 6.13: d) are adopted from 'DIM' and 'DIL' in Davis 1996: 597, Figure 1.

7: the dorsopalmar (Mc) or dorsoplantar (Mt) depth of the axial section of the medial condyle

8: the dorsopalmar (Mc) or dorsoplantar (Mt) depth of the axial section of the lateral condyle.

Two additional measurements are proposed (Figure 6.13: a):

DBV: Distal breadth across the verticilli, measurements always taken from the two most distal points of the verticillus.

DpBV: The dorsoproximal breadth across the verticilli, measurements always taken from the two most proximal points of the articular surface of the verticillus in anterior view.

The breadth of the distal end (Bd) is always taken across the condyles, never on the

distal diaphysis, following Rowley-Conwy (1998) (Figure 6.13: a).

6.3.1.1 Caprinae and *Gazella*

Absolute Size

As can be seen in Table 6.8 and Table 6.9, the size range of different species of Caprinae and *Gazella* follows almost the same sequence of these two elements. It is also quite similar to the sequence observed in humeri, although some individual positions in the sequence are different.

Species		N	Range	Mean	SD
Scientific Name	Common Name				
<i>Capricornis</i>	Serow	20	27.3-45.6	39.9	4.6
<i>O. ammon</i> (wild)	Argali (wild)	27	30.0-41.9	36.6	2.7
<i>Capra sibirica</i>	Siberian Ibex	20	29.6-39.6	35.0	3.1
<i>Pseudois</i>	Blue Sheep	28	25.8-34.9	30.4	2.3
<i>Ovis ammon</i> (zoobred)	Argali (zoobred)	6	27.0-32.7	30.3	2.3
<i>Capra hircus</i>	Goat	18	23.7-35.6	28.6	3.4
<i>Ovis orientalis</i>	West Asian Mouflon	21	24.9-31.5	27.1	1.9
<i>Nemorhaedus</i>	Goral	21	20.8-33.3	27.0	2.6
<i>Ovis aries</i>	Domestic Sheep	49	21.0-37.8	26.0	3.3
<i>Ovis vignei</i>	Urial	12	21.6-28.6	25.4	2.2
<i>Ovis musimon</i>	European Mouflon	33	21.6-32.7	24.9	2.2
<i>Gazella & Procapra</i>	Gazelle	17	15.1-21.6	18.4	1.9

Table 6.8 Absolute size of the Caprinae and *Gazella* studied. Number of specimens measured (N), range, mean, and standard deviation (SD). Values are given for distal breadth (Bd) of the metacarpal in millimetre (mm).

Species		N	Range	Mean	SD
Scientific Name	Common Name				
<i>Capricornis</i>	Serow	23	30.1-41.8	36.5	3.64
<i>Ovis ammon</i>	Argali (wild)*	26	28.7-39.0	33.8	2.24
<i>Ovis orientalis</i>	West Asian Mouflon	22	24.5-44.3	34.4	6.07
<i>Capra sibirica</i>	Siberian Ibex	16	26.6-35.4	31.1	2.43
<i>Ovis aries</i>	Domestic Sheep	38	20.3-43.9	29.8	7.02
<i>Ovis ammon zoo</i>	Argali (zoobred)	7	26.4-31.7	29.1	2.2
<i>Pseudois (ad)</i>	Blue Sheep (ad)	20	23.7-31.5	28.0	2.37
<i>Pseudois (sub/juv)</i>	Blue Sheep	10	16.8-31.0	26.4	3.84

	(sub/juv)				
<i>Ovis vignei</i>	Urial	13	19.9-28.0	24.1	2.27
<i>Capra hircus</i>	Goat	18	19.9-31.2	24.9	2.89
<i>Nemorhaedus</i>	Goral	19	20.9-27.6	24.4	1.84
<i>Ovis musimon</i>	European Mouflon	27	20.6-29.0	23.6	1.92
<i>Gazella & Procapra</i>	Gazelle	17	17.1-22.3	19.8	1.67

Table 6.9 Absolute size of the Caprinae and *Gazella* studied. Number of specimens measured (N), range, mean, and standard deviation (SD). Values are given for distal breadth (Bd) of the metatarsal in millimetres (mm). ad: adult; sub: sub-adult; juv: juvenile. Argali (wild): captured wild Argali sheep.

The differences of absolute size between metacarpals and metatarsals have been compared statistically by One-way ANOVA in SPSS. It was found that there are lots of overlaps as well as significant differences between the series of studied taxa in Bd in both metacarpals and metatarsals (Appendix P).

Comparative Osteoscopic Characters

The drawings of the typical morphology of the different species on metacarpal and metatarsals are presented in Figures 6.14 and 6.15 respectively. Four characters were numerically scored in the study of comparative osteoscopic characters of Caprinae and *Gazella*.

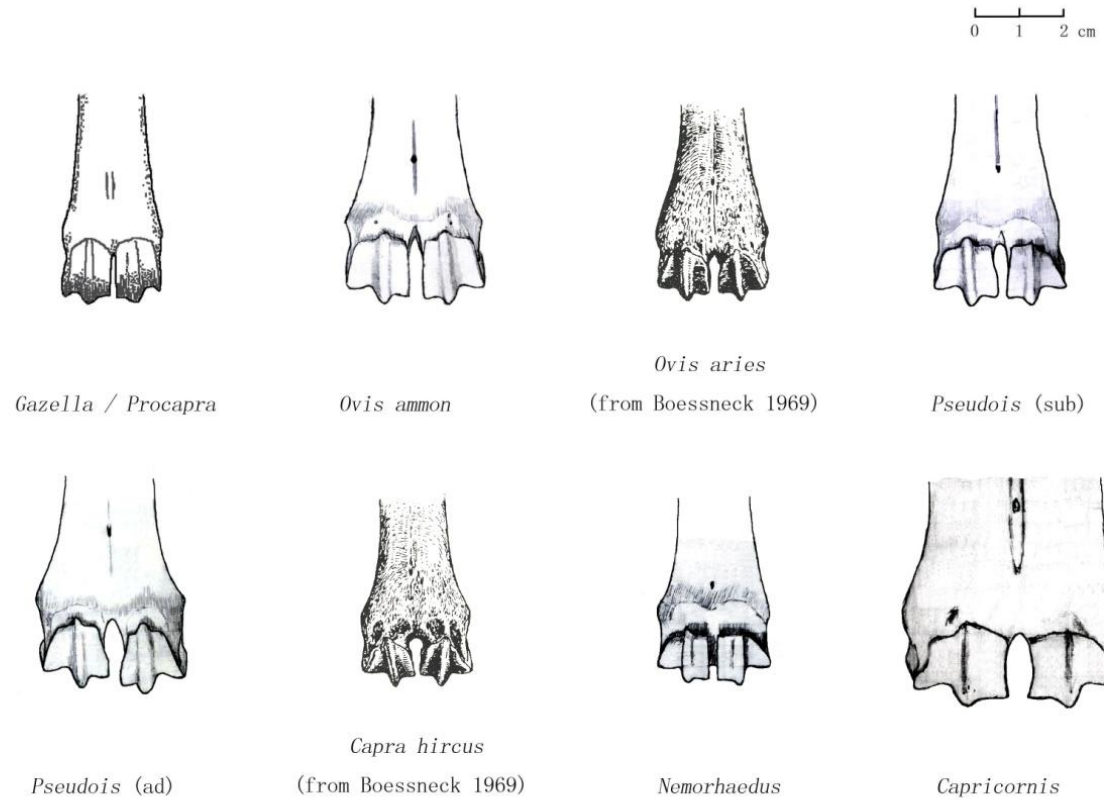


Figure 6.14 *Gazella/Procapra* (Gazelle), *Ovis ammon* (Argali), *Ovis aries* (Domestic Sheep), *Pseudois* (Blue Sheep), *Capra hircus* (Goat), *Nemorhaedus* (Goral), *Capricornis* (Serow), Comparative osteomorphology, distal metacarpal, dorsal view.

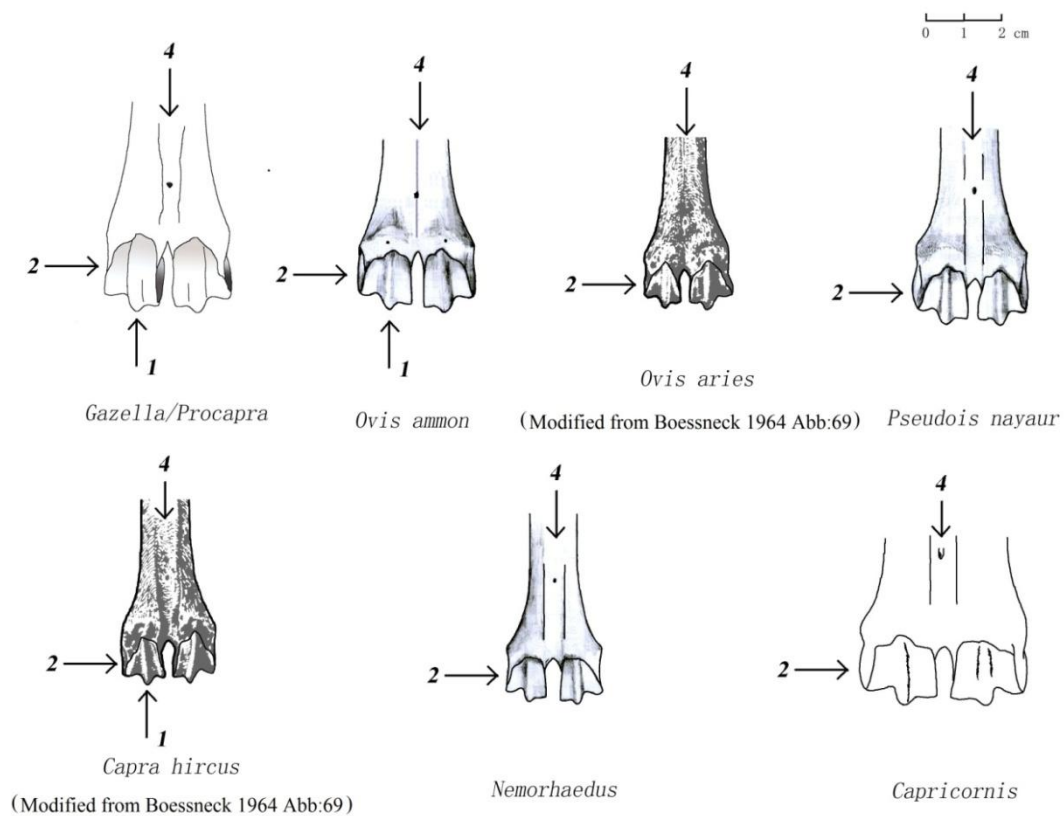


Figure 6.15 *Gazella/Procapra* (Gazelle), *Ovis ammon* (Argali), *Ovis aries* (Domestic Sheep), *Pseudois* (Blue Sheep), *Capra hircus* (Goat), *Nemorhaedus* (Goral), *Capricornis* (Serow), Comparative osteomorphology, distal metatarsal, dorsal view. The arrows are to note the distinctive features.

1. The development of the distal edge of the abaxial part of the condyle

The specimens are scored according to the development of the distal edge of the abaxial part of the condyle (Figure 6.16). Those with the distal edge of this part quite levelled are scored 1, those oblique and steep are scored 3, those intermediate are scored 2.

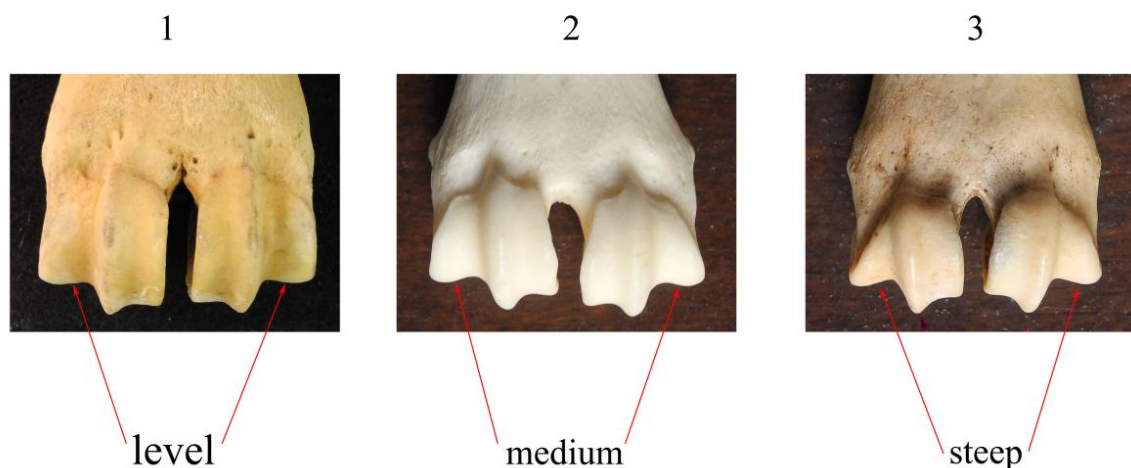


Figure 6.16 Caprinae, distal metacarpal, Character 1 shown on three specimens scored 1, 2, and 3 respectively.

Species		Score 1		Score 2		Score 3		Total
Scientific Name	Common Name	count	%	count	%	count	%	
<i>Pseudois</i>	Blue Sheep	1	16.7	5	83.3	0	0.0	6
<i>Capricornis</i>	Serow	6	85.7	1	14.3	0	0.0	7
<i>Nemorhaedus</i>	Goral	2	50.0	1	25.0	1	25.0	4
<i>Capra hircus</i>	Goat	1	10.0	2	20.0	7	70.0	10
<i>Gazella/Procapra</i>	Gazelle	0	0.0	0	0.0	4	100.0	4
<i>Ovis</i>	Sheep	25	59.5	17	40.5	0	0.0	42

Table 6.10 Caprinae, distal metacarpal, Character 1, development of the distal edge of the abaxial part of the condyle, scored counts.

This feature is noted by Zeder and Lapham (2010): that the peripheral part of the trochlea condyle flares outward from the axial part of the bone. As can be seen in Table 6.10, in metacarpals the distal edge of the abaxial part of the condyle is mostly quite level in *Capricornis* (score 1 accounts for 85.7%), quite steep and oblique in

Gazella/Procapra(score 3 accounts for 100%) and *C. hircus*(score 3 accounts for 70%), but the number of the specimens observed for *Capricornis* and *Gazella/Procapra* is quite small (N=7,4 respectively). Among the limited number of specimens that were observed for *Pseudois* (N=6), the majority (83.3%) are intermediate. For other taxa, this feature is not characterized.

In metatarsals (Table 6.11), the situation for *Capricornis* and *Pseudois* mirrors that on metacarpal --- 94.4% of the 18 specimens of *Capricornis* have the flat abaxial part of the condyle and 60% of the *Pseudois* are intermediate. But the number of the specimens observed for *Pseudois* is very small (N=5). The majority of the *Ovis* (76.9%) also have quite levelled peripheral part in this character. For the other taxa, this feature is not distinctive.

Species		Score 1		Score 2		Score 3		Total
Scientific Name	Common Name	count	%	count	%	count	%	
<i>Pseudois</i>	Blue Sheep	0	0.0	3	60.0	2	40.0	5
<i>Capricornis</i>	Serow	17	94.4	1	5.6	0	0.0	18
<i>Nemorhaedus</i>	Goral	3	60.0	1	20.0	1	20.0	5
<i>Capra hircus</i>	Goat	3	37.5	3	37.5	2	25.0	8
<i>Gazella/Procapra</i>	Gazelle	0	0.0	2	66.7	1	33.3	3
<i>Ovis</i>	Sheep	60	76.9	17	21.8	1	1.3	78

Table 6.11Caprinae, distal metatarsal, Character 1, development of the distal edge of the abaxial part of the condyle, scored counts.

2. The shape of the condyles in a dorsal view

The specimens are scored according to the shape of the medial condyles in a dorsal view (Figure 6.17). Those with the long and narrow condyles are scored 1; those comparatively short and wide are scored 3; those intermediate are scored 2.

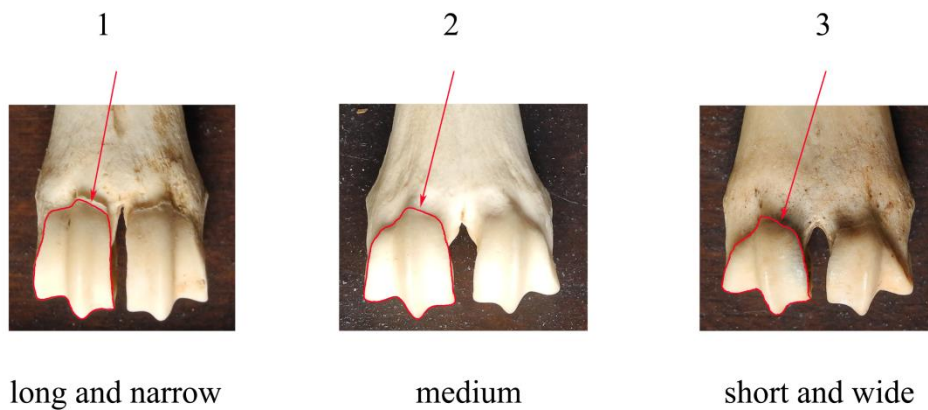


Figure 6.17 Caprinae, distal metacarpal, Character 2 shown on three specimens scored 1, 2, and 3 respectively.

Species		Score 1		Score 2		Score 3		Total
Scientific Name	Common Name	count	%	count	%	count	%	
<i>Pseudois</i>	Blue Sheep	0	0.0	6	100.0	0	0.0	6
<i>Capricornis</i>	Serow	0	0.0	7	100.0	0	0.0	7
<i>Nemorhaedus</i>	Goral	0	0.0	4	100.0	0	0.0	4
<i>Capra hircus</i>	Goat	0	0.0	0	0.0	10	100.0	10
<i>Gazella/Procapra</i>	Gazelle	4	100.0	0	0.0	0	0.0	4
<i>Ovis</i>	Sheep	0	0.0	2	4.8	40	95.2	42

Table 6.12 Caprinae, distal metacarpal, Character 2, The shape of the condyles in a dorsal view, scored counts.

Species		Score 1		Score 2		Score 3		Total
Scientific Name	Common Name	count	%	count	%	count	%	
<i>Pseudois</i>	Blue Sheep	0	0.0	2	40.0	3	60.0	5
<i>Capricornis</i>	Serow	0	0.0	0	0.0	18	100.0	18
<i>Nemorhaedus</i>	Goral	0	0.0	0	0.0	5	100.0	5
<i>Capra hircus</i>	Goat	0	0.0	0	0.0	8	100.0	8
<i>Gazella/Procapra</i>	Gazelle	2	66.7	1	33.3	0	0.0	3
<i>Ovis</i>	Sheep	0	0.0	17	21.8	61	78.2	78

Table 6.13 Caprinae, distal metatarsal, Character 2, the shape of the condyles in a dorsal view, scored counts.

It was noted by Clutton-Brock et al. (1990) that the complete metapodials of sheep are rather easy to be distinguished from goat by their long and slender proportions. When only distal parts are present, it was found the same --- as can be seen in Table 6.12 and 6.13, all condyles in *C. hircus* in both metacarpals and metatarsals are scored 3 which are wide and short while a smaller proportion in *Ovis* is scored 3. Gazelles are characterised by the longest and narrowest condyles (100% of the 4 specimens in metacarpals and 66.7% of metatarsals are scored 1). All the specimens in *Pseudois*, *Capricornis* and *Nemorhaedus* are intermediate in this feature in metacarpals. In metatarsals, the condyles are shorter and wider and more specimens are scored 3 (60% in *Pseudois* and 100% for both *Capricornis* and *Nemorhaedus*). But the number of the specimens observed is very small. In *Ovis*, the majority of the specimens are short and wide in this feature (95.2% in metacarpal and 78.2% in metatarsal are scored 3).

3. The direction of the dorsolateral margin delineating the abaxial part of the lateral condyle

The specimens are scored according to the direction of the dorsolateral margin delineating the abaxial part of the lateral condyle (Figure 6.18). Those more straight are scored 1, those more oblique are scored 3, and those intermediate are scored 2.

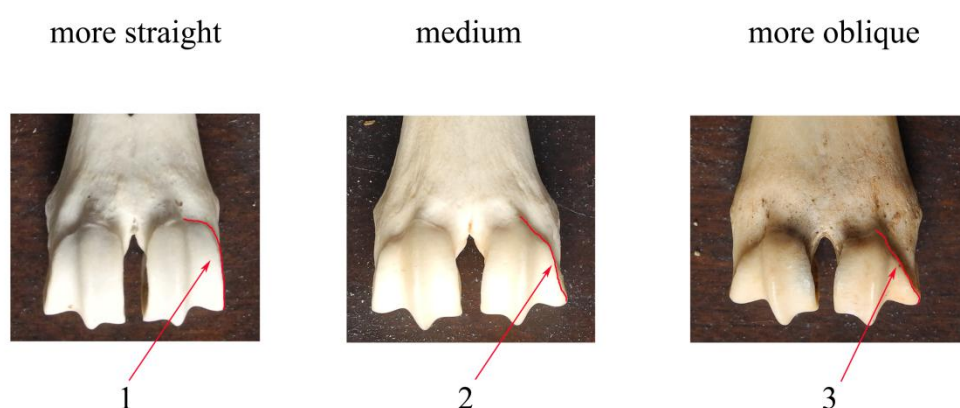


Figure 6.18 Caprinae, distal metacarpal, Character 3 shown on three specimens scored 1, 2, and 3 respectively.

Species		Score 1		Score 2		Score 3		Total
Scientific Name	Common Name	count	%	count	%	count	%	
<i>Pseudois</i>	Blue Sheep	1	20.0	4	80.0	0	0.0	5
<i>Capricornis</i>	Serow	0	0.0	0	0.0	7	100.0	7
<i>Nemorhaedus</i>	Goral	0	0.0	0	0.0	4	100.0	4
<i>Capra hircus</i>	Goat	0	0.0	7	70.0	3	30.0	10
<i>Gazella/Procapra</i>	Gazelle	4	100.0	0	0.0	0	0.0	4
<i>Ovis</i>	Sheep	15	39.4	21	55.3	2	5.3	38

Table 6.14 Caprinae, distal metacarpal, Character 3, the direction of the dorsal lateral margin delineating the abaxial part of the lateral condyle, scored counts.

As can be seen in Table 6.14, in metacarpal gazelles are characterised by a quite straight dorsolateral margin of the abaxial part of the lateral condyle (100% of the 4 specimens are scored 1). All the specimens in *Capricornis* and *Nemorhaedus* have a very oblique margin in this feature (both 100% scored 3). The majority of the specimens in *Pseudois* and *C. hircus* are intermediate in this feature (80% and 70% are scored 2 respectively), but for the rest 20% of the *Pseudois* are scored 1 while 30% of the *C. hircus* are scored 3. *Ovis* is characterized by an intermediate (55.3%) or straighter margin (39.4%) in this feature. The specimens observed for *Pseudois*, *Capricornis*, *Nemorhaedus*, and *Gazella/Procapra* are very small. There is no previous literature discussing this character.

In metatarsals, this character is less marked (Table 6.15). Mirroring that of metacarpals, the majority of the *Ovis* are intermediate in this feature (66.2%). But unlike metacarpals, the majority of the *Pseudois* and *C. hircus* are oblique (80% and 75% respectively). More than half of the *Capricornis* are intermediate (55.5%). On other taxa, this feature is not distinctive.

Species		Score 1		Score 2		Score 3		Total
Scientific Name	Common Name	count	%	count	%	count	%	
<i>Pseudois</i>	Blue Sheep	0	0.0	1	20.0	4	80.0	5
<i>Capricornis</i>	Serow	5	27.8	10	55.5	3	16.7	18
<i>Nemorhaedus</i>	Goral	1	20.0	3	60.0	1	20.0	5
<i>Capra hircus</i>	Goat	0	0.0	2	25.0	6	75.0	8
<i>Gazella/Procapra</i>	Gazelle	1	33.3	2	66.7	0	0.0	3

<i>Ovis</i>	Sheep	3	4.0	51	66.2	23	29.8	77
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Table 6.15 Caprinae, distal metatarsal, Character 3, the direction of the dorsolateral margin delineating the abaxial part of the condyle, scored counts.

4. Form of the sulcus at the anterior surface in distal end (metatarsal only)

The specimens are scored according to the sulcus at the anterior surface in distal end beside the foramen on metatarsal (Figure 6.19). Those with a deep sulcus are scored as 1, those with a shallow sulcus are scored 2, and those without such a sulcus are scored 3.

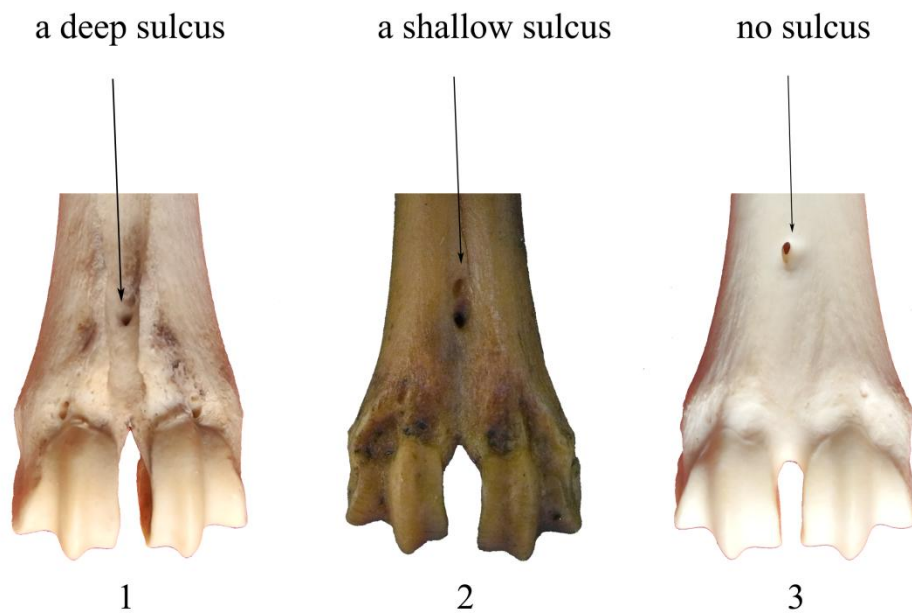


Figure 6.19 Caprinae, distal metatarsal, Character 4 shown on three specimens scored 1, 2, and 3.

Species		Score 1		Score 2		Score 3		Total
Scientific Name	Common Name	count	%	count	%	count	%	
<i>Pseudois</i>	Blue Sheep	0	0.0	4	80.0	1	20.0	5
<i>Capricornis</i>	Serow	2	11.1	9	50.0	7	38.9	18
<i>Nemorhaedus</i>	Goral	0	0.0	3	60.0	2	40.0	5
<i>Capra hircus</i>	Goat	0	0.0	3	37.5	5	62.5	8
<i>Gazella/Procapra</i>	Gazelle	2	66.7	1	33.3	0	0.0	3
<i>Ovis</i>	Sheep	0	0.0	5	8.5	54	91.5	59

Table 6.16 Caprinae, distal metatarsal, Character 4, sulcus at the anterior surface in the distal end, scored counts.

It was noted by Boessneck et al. (1964) and Zeder and Lapham (2010) that the junction between the 3rd and 4th on the anterior aspect of the distal diaphysis of metatarsals is grooved with two prominent ridges in *Capra hircus* while it is flat and indented in *Ovis*. As can be seen in Table 6.16, it was observed that the majority of the *Ovis* specimens are flat in this feature (91.5%), while 8.5% had a shallow indent. 62.5% of *Capra hircus* are found flat beside the foramen, though the prominent ridges characterize the groove right above the distal epiphysis. The majority of the gazelles were found with a deep sulcus (66.7%), but the number observed is very small (3). Most of the *Capricornis* and *Nemorhaedus* are found with a shallow sulcus or flat (Table. 6.16).

6.3.1.2 *Ovis*

The differences in size noted in the metacarpal and metatarsal of different *Ovis* species (Table 6.17; Table 6.18) show the same trend as that already observed in other elements: there is, in general, a gradual descending size gradient from the species in the East to the West of the Eurasia (apart from *O. vignei* and *O. orientalis*). However, animals living in the wild are larger than their relatives kept in zoos. Rambouillet sheep exhibit quite large mean values, being close to the *O. orientalis*. This might have resulted from the fact that they were a 'royal' breed developed for meat, which usually has quite a large scale in the breadth of the bones (Ryder 1983). The Rambouillet × Argali is smaller in scale than either Rambouillet or Argali. This might be due to multiple crossings with the country sheep of Europe.

Species		N	Range	mean	SD
Scientific Name	Common Name				
<i>Ovis ammon-wild</i>	Argali (wild)*	27	30.0-41.9	36.6	2.68
<i>Ovis ammon-zoo</i>	Argali (zoobred)	6	27.0-32.7	30.3	2.32
<i>Ovis orientalis</i>	West Asian Mouflon	12	21.6-28.6	25.9	2.15
<i>Ovis vignei</i>	Urrial	21	24.9-31.5	27.1	1.95
<i>Ovis musimon-wild</i>	European Mouflon (feral)	10	22.7-32.7	26.2	2.79
<i>Ovis musimon-zoo</i>	European Mouflon (zoobred)	23	21.6-27.1	24.4	1.59
<i>Ovis aries</i>	Country Sheep*	16	21.0-37.8	25.0	4.12
<i>Ovis aries</i>	Rambouillet Sheep*	13	23.2-33.6	27.2	3.65
<i>Ovis aries</i>	Crossbred Sheep*	20	22.4-29.4	26.1	1.84

Table 6.17 Osteometrics of *Ovis*. Number of specimens measured (N), range, mean, and standard deviation (SD). Values are given for distal breadth (Bd) of the metacarpal in millimetres (mm). *Three groups of *Ovis aries* are measured, although they are not different 'species'. Crossbred sheep is the hybrids of *Ovis ammon* (Argali) and *Ovis aries* (Country sheep and Rambouillet sheep). * 'wild' refers to the captured wild animals.

Species		N	Range	mean	SD
Scientific Name	Common Name				
<i>Ovis ammon-wild</i>	Argali (wild)*	26	28.7-39.0	33.79	2.24
<i>Ovis ammon-zoo</i>	Argali (zoobred)	7	26.4-31.7	29.14	2.20
<i>Ovis orientalis</i>	West Asian Mouflon	15	19.9-37.8	25.22	4.16
<i>Ovis vignei</i>	Urrial	20	24.5-44.3	34.6	6.13
<i>Ovis musimon-wild</i>	European Mouflon (feral)	8	22.4-29.0	25.17	2.19
<i>Ovis musimon-zoo</i>	European Mouflon (zoobred)	19	20.6-26.9	22.94	1.39
<i>Ovis aries</i>	Country Sheep*	15	20.3-33.4	24.36	3.81
<i>Ovis aries</i>	Rambouillet*	13	31.9-43.9	37.94	3.89
<i>Ovis aries</i>	Crossbred Sheep*	10	23.1-32.1	27.59	3.03

Table 6.18 Osteometrics of *Ovis*. Number of specimens measured (N), range, mean, and standard deviation (SD). Values are given for distal breadth (Bd) of the metatarsal in millimetres (mm). *Three groups of *Ovis aries* are measured, although they are not different 'species'. Crossbred sheep is the hybrids of *Ovis ammon* (Argali) and *Ovis aries* (Country sheep and Rambouillet sheep). * 'wild' refers to the captured wild animals.

In the group of *O. vignei*, there is one metatarsal showing an unusual large dimension of Bd of 37.8, while the others all range from 22.0-28.0. This exceptional one is a wild *Ovis arkal*, which is originally from Transcaspian Region. As discussed in Chapter 4, wild sheep at this region are sometimes confused with their taxonomy status, and some people regarded them as Western Asian Mouflon or Argali. They are of larger scales than the Urials in India which range further south where most of the other Urrial specimens come from.

As for the metatarsal in wild *O. ammon*, although most individuals come originally from Central Asia, five specimens from China and Mongolia (four from Shanxi Province of China, and another one from actual Mongolia) were measured. The latter is obviously smaller than the other wild Argali from Xinjiang (Western China) and the Pamir

Mountains, especially the female and juvenile individuals. This information is relevant for my research because of the distribution of the archaeological sites studied in China.

Comparative Osteoscopic Characters

Differences are observed between the osteoscopic characters of *Ovis ammon*, *Ovis vignei*, *Ovis orientalis*, *Ovis musimon*, and *Ovis aries* on distal metatarsals. There seems to be an osteoscopic cline among them, as described below. But these criteria are not discriminant.

Distal end of metacarpal, *Ovis*

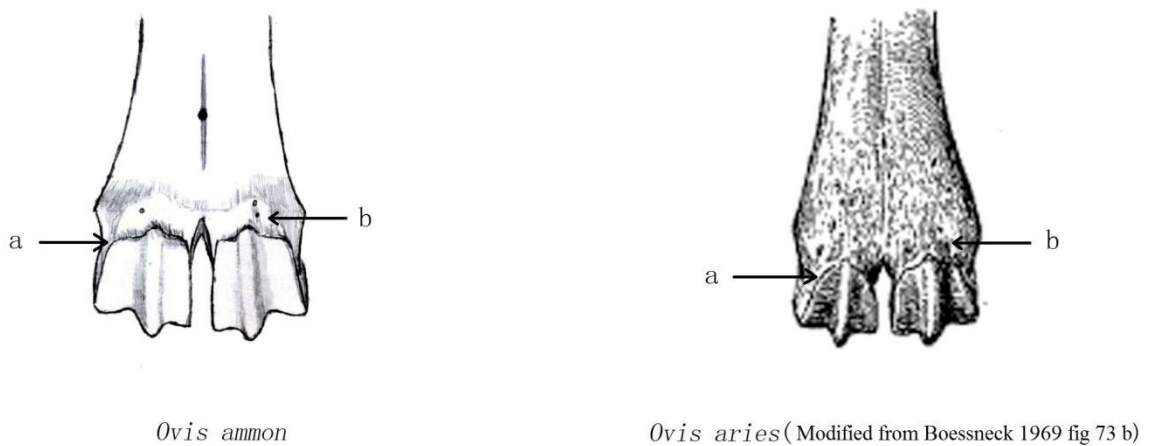


Figure 6.20 *Ovis ammon* (Argali) and *Ovis musimon* (European Mouflon), Comparative osteomorphology.

1. The dorsolateral margin delineating the abaxial part of the lateral condyle

In metacarpals: in *Ovis ammon* the lateral margin of the abaxial part of the lateral condyle runs more or less parallel to the main axis of the bone, whilst the transition to its dorsoproximal margin is characterized by an angle. In *Ovis musimon* and *Ovis aries*, the lateral margin runs more oblique, and the transition between the lateral and dorsoproximal parts lacks the angular aspect observed in *O. ammon* (Figure 6.20, a). There seems to be a West-East gradient in the variation of this feature. In Rambouillet, the degree is close to wild European Mouflon; in the crossbreed of Rambouillet and Argali, its degree is closer to zoo *Ovis musimon*. In metatarsals, reliable differences in this feature could not be

found.

2. The ratio length to width in the condyles in a dorsal view

In both metacarpal and metatarsals, condyles are proportionately longer in Eastern *Ovis* and in wild animals compared to Mouflon and domestic sheep in Europe. However, there is considerable overlap between the different groups. Sub-adult individuals exhibit shorter and wider condyles than adults. This feature is quite difficult to discern with the naked eye if the different groups of *Ovis* are not presented together.

3. The depression for the ligamentous attachment anterior-proximal of the condyles

In both metacarpals and metatarsals, it is observed that this depression is more strongly developed and deeper in wild *Ovis* compared to zoo European Mouflon and domestic sheep (Figure 6.20, b). However, sometimes the differences are subtle. In addition, sub-adults in a late fusing stage at the distal end also exhibit deeper depressions. Sometimes the feature seems even deeper in sub-adult domestic sheep even deeper than their adult wild relatives.

6.3.2 Discriminant Analysis Based on Shape Indices

6.3.2.1 Metacarpals

A. Classification of all Ovis, Caprinae, and Gazella to 6 groups (Figure 6.21)

Firstly, all *Ovis* specimens (N=134) are put together as a single group, and analysed with the other five Caprinae and *Gazella* species (Figure 6.21), including *Pseudois* (N=20), *Capricornis* (N=20), *Nemorhaedus* (N=21), *Capra hircus* (N=16), *Gazella/Procapra* (N=15) (Figure 6.21).

Canonical Discriminant Functions

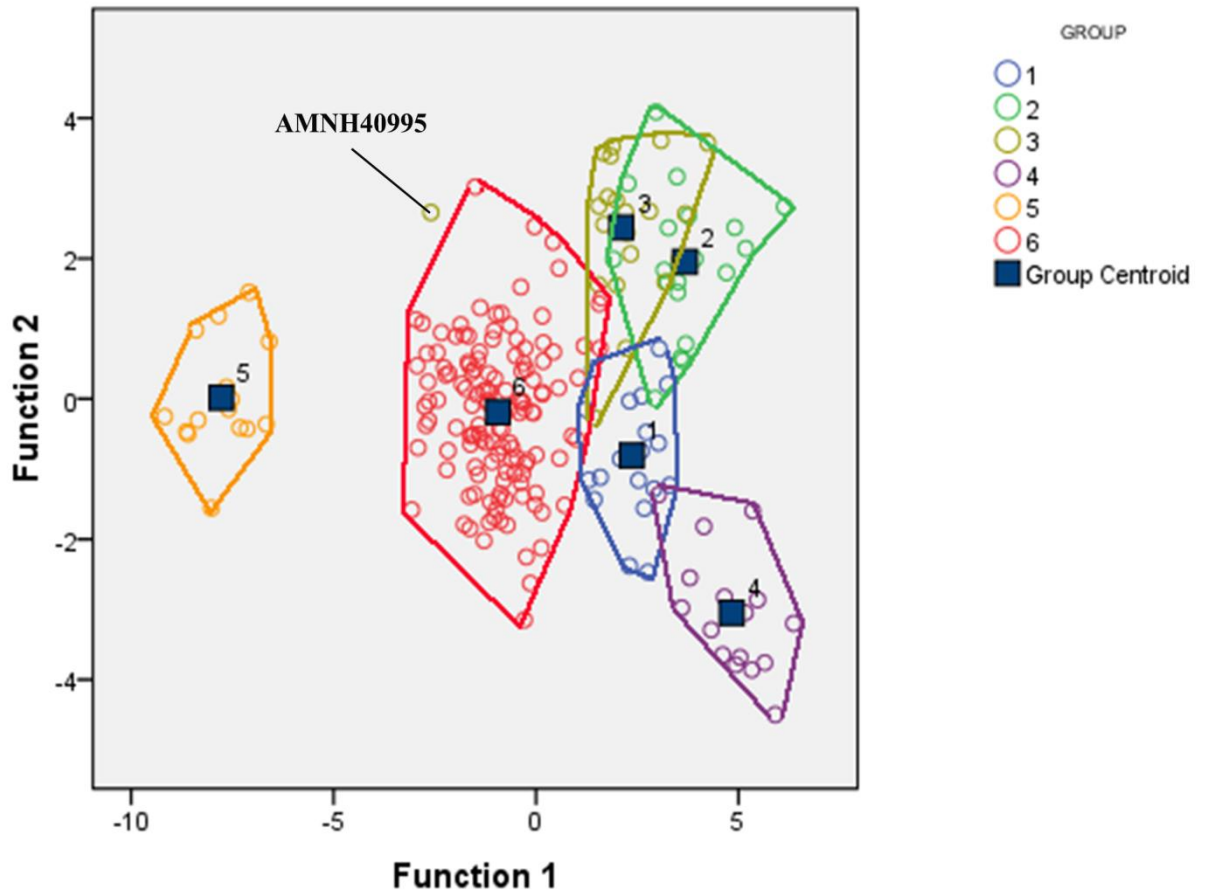


Figure 6.21 Classification results of all modern *Ovis*, Caprinae, and *Gazella* specimens (N=226) based on the first two discriminate functions on metacarpals using eleven shape indices. 1. *Pseudois* (Blue Sheep); 2. *Capricornis* (Serow); 3. *Nemorhaedus* (Goral); 4. *C. hircus* (Goat); 5. *Gazella/Procapra* (Gazella); 6. *Ovis* (Sheep). Group Centroid: mean discriminant scores for each grouping variables.

92.9% of the original grouped cases were correctly classified. However, one extreme outlier in *Nemorhaedus*, AMNH 40995, was identified, which are located very far away from the rest. It will be excluded from the analysis in the next step.

As shown in Figure 6.21, the pattern on metacarpal is not entirely similar to the humerus. The majority of the *Ovis* specimens are generally clustered together. Two Caprinae species, *Pseudois* and *Nemorhaedus*, overlap with *Ovis*, but only marginally. *C.*

hircus slightly overlaps with *Pseudois* group, not as much as that on the humerus, and not close to any *Ovis*. *Capricornis* again overlaps with *Nemorhaedus*, and *Gazella/Procapra* again scattered quite far away from the rest.

B. Classification of all Ovis to 6 groups (Figure 6.22)

Figure 6.22 shows the result of the classification of discriminate analysis of all modern *Ovis* groups. Five functions are built, and the eigenvalues of the functions 1-5 are 4.173, 0.779, 0.454, 0.292, 0.181 respectively. The first two functions extracted accounted for 84.2% of the variance, and 76.1% of the original grouped cases were correctly assigned, although there is an outlier of *O. musimon* (LMU19), scattered quite far away from the others. This might be due to the error during the recording of the measurements, and it will be excluded from the further analysis.

As can be seen, again *O. ammon* is quite separated away from the others, only slightly overlapping with *O. orientalis*. All the other *Ovis* groups are quite close to each other, but still, there are some patterns: *O. vignei*, *O. orientalis*, and *O. musimon* overlap with each other in a great deal, while *O. aries* are more separated from the others, and *O. aries* × *O. ammon* is in the middle between *O. ammon* and *O. aries*, although being close to the *O. aries* and also overlapping with the Mouflon and Urial. Interestingly, this pattern seems to correspond to the evolutionary history of these animals --- *O. vignei* and *O. orientalis* are genetically and geographically closely associated and still arguably to be separated into two species, while *O. musimon* is an early feral domestic sheep derived from *O. orientalis*. This pattern mirrors that found based on the ratios of pairs of measurements

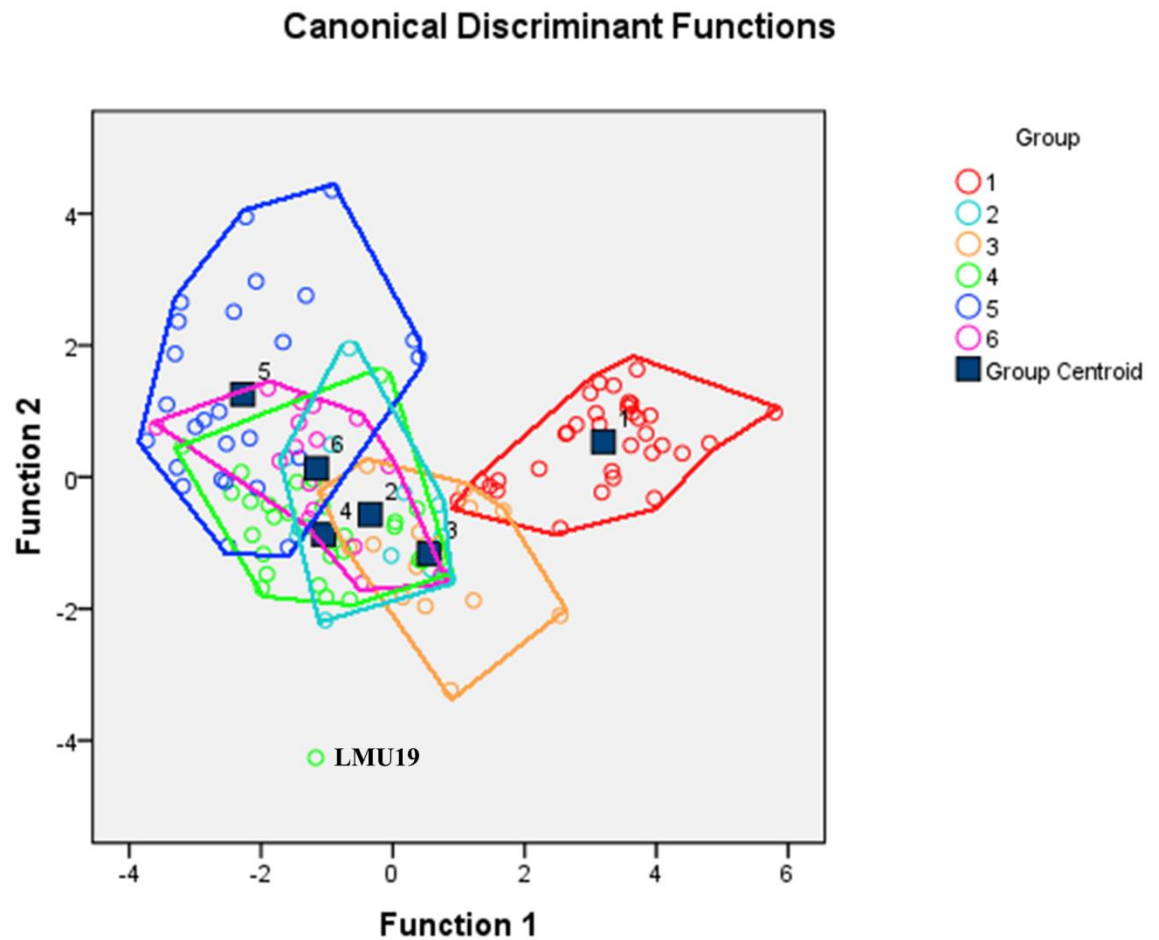


Figure 6.22 Classification results of all modern *Ovis* (N=134) based on the first two discriminate functions on metacarpals using eleven shape indices. 1. *O. ammon* (Argali); 2. *O. vignei* (Urial); 3. *O. orientalis* (Western Asian Mouflon); 4. *O. musimon* (European Mouflon Sheep); 5. *O. aries* (Domestic Sheep); 6. *O. ammon* × *O. aries* (Crossbred Sheep). Group Centroid: mean discriminant scores for each grouping variables.

Therefore, although apart from the majority of *O. ammon* and some ‘typical’ *O. aries* all the other *Ovis* might still be difficult to be separated apart from each other, there are some interesting patterns revealed in metacarpals that might be related to the evolution of these animals.

C. Classification of all Caprinae, and Gazella to 10 groups (Figure 6.23)

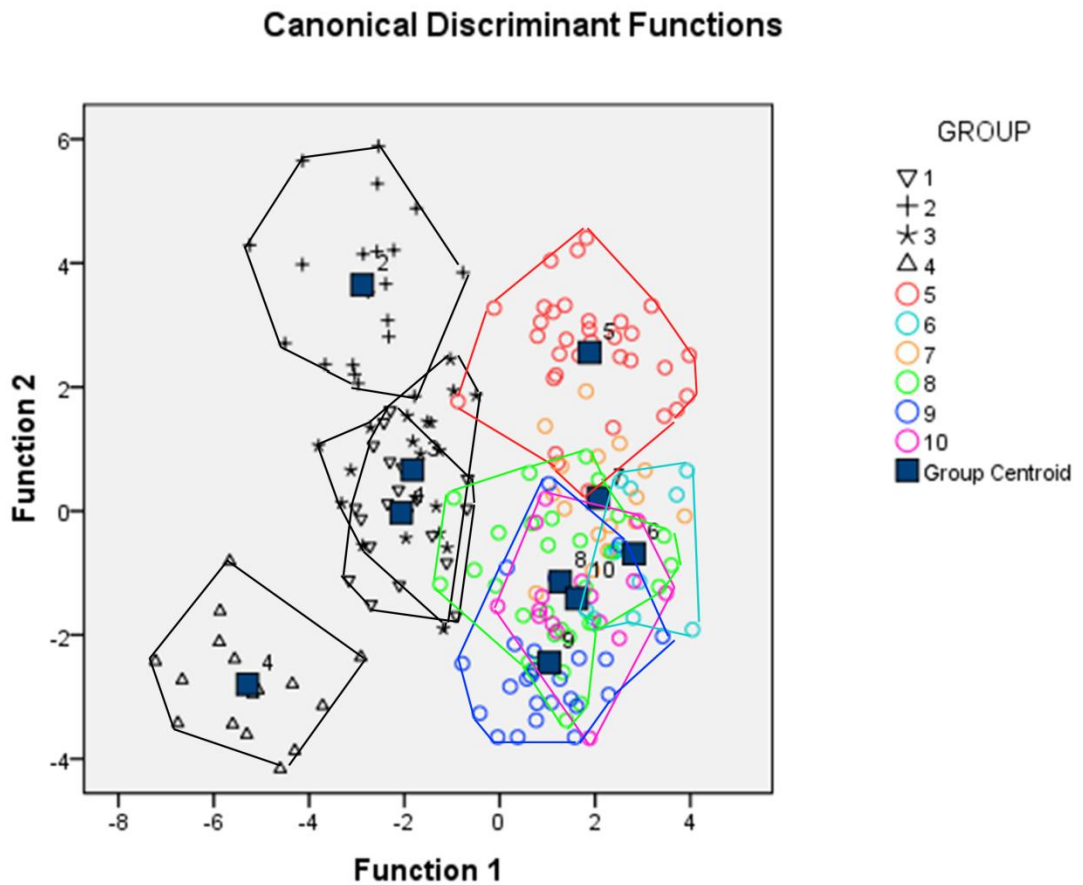


Figure 6.23 Classification results of modern Caprinae and *Gazella* specimens (N=209) based on the first two discriminate functions on metacarpals using eleven shape indices. 1. *Pseudois* (Blue Sheep); 2. *Capricornis* (Serow); 3. *Nemorhaedus* (Goral); 4. *C. hircus* (Goat); 5. *O. ammon* (Argali); 6. *O. vignei* (Urial); 7. *O. orientalis* (Western Asian Mouflon); 8. *O. musimon* (European Mouflon Sheep); 9. *O. aries* (Domestic Sheep); 10. *O. ammon* × *O. aries* (Crossbred Sheep).

In this time, different *Ovis* are analysed together with the different Caprinae. *Gazella* is excluded because as shown before they scattered quite far away from the others and could be quite easily separated. Five functions are built, and the eigenvalues of the functions 1-5 are 8.520, 1.671, 0.638, 0.264, 0.046 respectively. The first two functions extracted accounted for 91.5% of the variance, and 81.3% of the original grouped cases

were correctly classified.

As shown in Figure 6.23, *Ovis* groups slightly overlap with *Nemorhaedus* and *Pseudois*. More specifically, *O. ammon* overlaps with *Nemorhaedus* while *O. musimon* overlaps with *Pseudois* and *Nemorhaedus*. *Capricornis* and *C. hircus* are quite separated from *Ovis*, especially *C. hircus*. So based on this it might be possible to distinguish the majority of *Ovis* and *C. hircus* apart from the others, and might be possible to distinguish domestic sheep apart from the local wild sheep, *O. ammon*. As can be seen, the two sheep groups (*O. aries* and *O. aries* × *O. ammon*) are both quite clearly separated from *O. ammon*.

6.3.2.2 Metatarsal

A. Classification of all Caprinae, and Gazella to 6 groups (Figure 6.24)

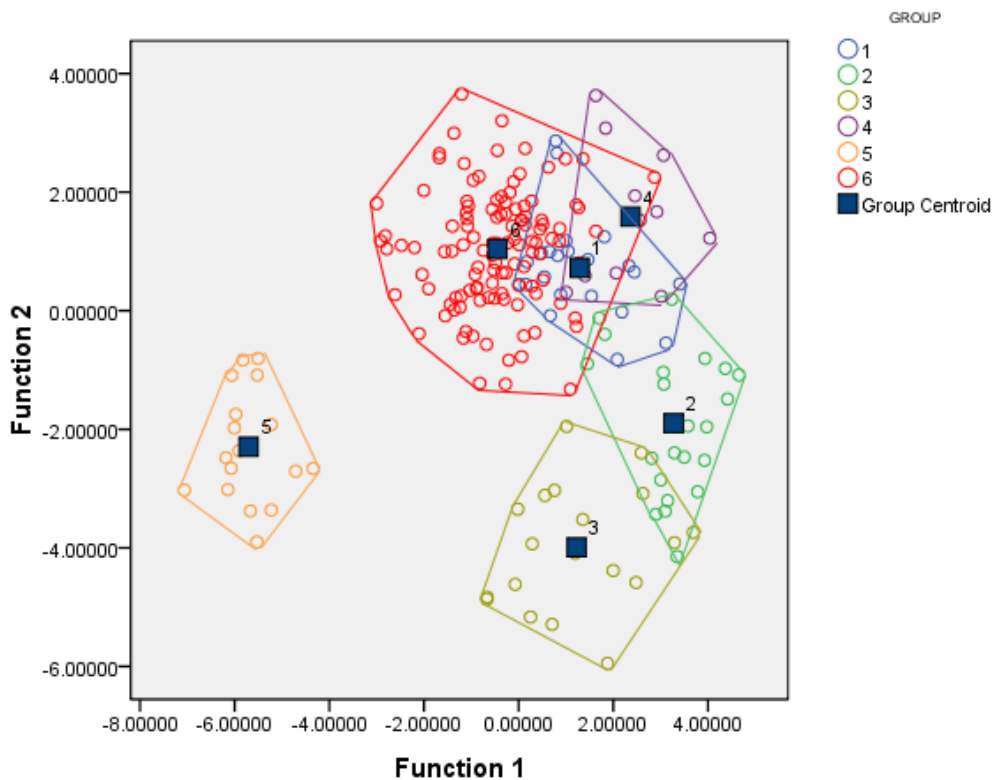


Figure 6.24 Classification results of all modern Caprinae and *Gazella* specimens (N=209) on metatarsals based on the first two discriminate functions using eleven

shape indices. 1. *Pseudois* (Blue Sheep); 2. *Capricornis* (Serow); 3. *Nemorhaedus* (Goral); 4. *C. hircus* (Goat); 5. *Gazella/Procapra* (Gazelle); 6. *Ovis* (Sheep). Group Centroid: mean discriminant scores for each grouping variables.

Altogether 209 specimens are included in the analysis, including 22 *Pseudois*, 22 *Capricornis*, 19 *Nemorhaedus*, 11 *C. hircus*, and 118 *Ovis* specimens. Five functions are built, and the eigenvalues of the functions 1-5 are 4.629, 3.146, 1.447, 0.312, and 0.108 respectively. The first two functions extracted accounted for 80.6% of the variance, and 95.2% of the original grouped cases were correctly classified. As can be seen from Figure 6.24, there are similarities and also differences between the pattern of metatarsals and the previous two elements. Again gazelles are a discrete grouping, separated from the other datasets which allows us to easily separate from the rest. *C. hircus* and *Pseudois* overlap with each other greatly, and they also overlap with *Ovis*. *Nemorhaedus* are more clearly separated from *Ovis*+*Pseudois*+*C. hircus* group than *Capricornis*.

B. Classification of all Ovis to 6 groups (Figure 6.25)

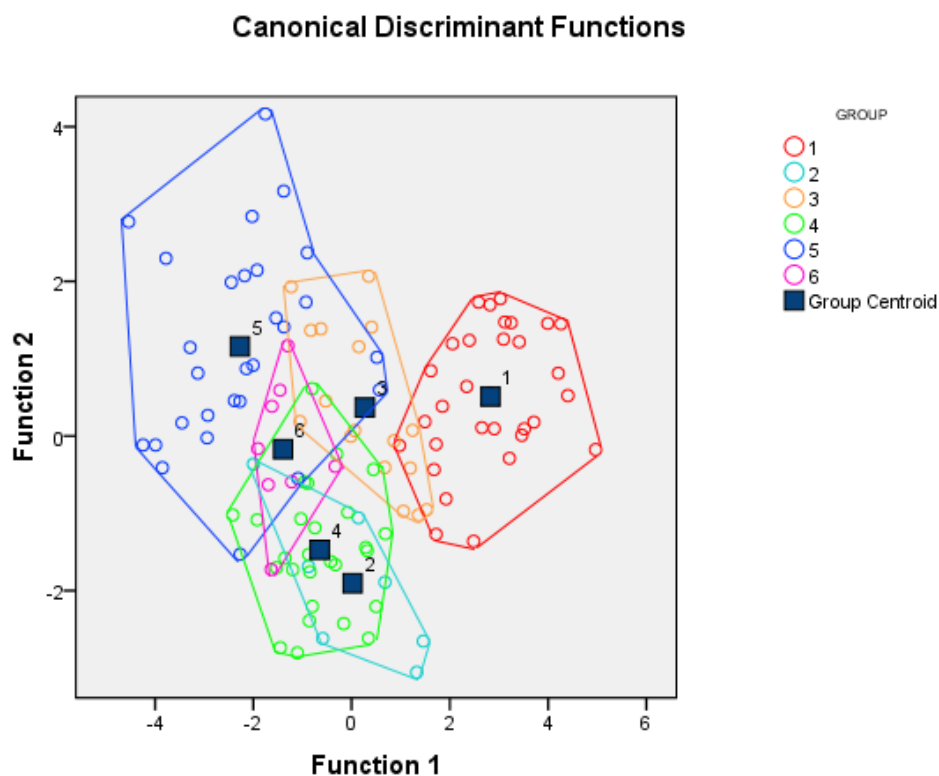


Figure 6.25 Classification results of all modern *Ovis* (N=134) based on the first two discriminate functions built on eleven shape indices on metatarsals. 1. *O. ammon* (Argali); 2. *O. vignei* (Urial); 3. *O. orientalis* (Western Asian Mouflon); 4. *O. musimon* (European Mouflon Sheep); 5. *O. aries* (Domestic Sheep); 6. *O. ammon* × *O. aries* (Crossbred Sheep). Group Centroid: mean discriminant scores for each grouping variables.

Figure 6.25 shows the result of the classification of discriminate analysis of all modern *Ovis* groups on metatarsals. Five functions are built, and the eigenvalues of the functions 1-5 are 3.757, 1.180, 0.693, 0.192, 0.100 respectively. The first two functions extracted accounted for 83.4% of the variance, and 78.0% of the original grouped cases were correctly assigned, which is higher than that on humeri and metacarpals.

As can be seen, the pattern on metatarsals is quite similar to that on metacarpals. Apart from *O. ammon* that are mostly separated from the others, all the other *Ovis* (*O. vignei*, *O. orientalis*, *O. musimon*, *O. aries*, *O. ammon* × *O. aries*) are clustered overlapping with each other. However, *Ovis aries* are scattered on a wider area, indicating larger osteometric variations in domestic sheep than other *Ovis* groups.

C. Classification of all Ovis, Caprinae, and Gazella to 10 groups (Figure 6.26)

Canonical Discriminant Functions

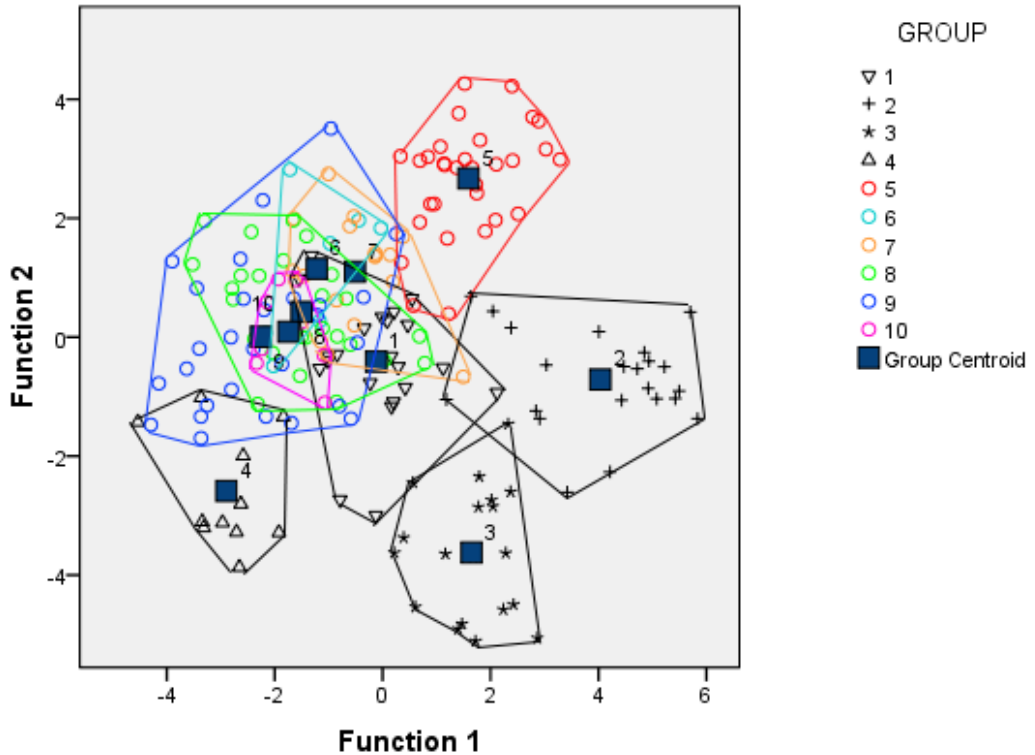


Figure 6.26 Classification results of modern *Ovis* and Caprinae specimens (N=192) based on the first two discriminate functions using eleven shape indices. 1. *Pseudois* (Blue Sheep); 2. *Capricornis* (Serow); 3. *Nemorhaedus* (Goral); 4. *C. hircus* (Goat); 5. *O. ammon* (Argali); 6. *O. vignei* (Urial); 7. *O. orientalis* (Western Asian Mouflon); 8. *O. musimon* (European Mouflon Sheep); 9. *O. aries* (Domestic Sheep); 10. *O. ammon* × *O. aries* (Crossbred Sheep). Group Centroid: mean discriminant scores for each grouping variables.

Different *Ovis* are analysed together with the different Caprinae. *Gazella* are excluded because as shown before they scattered quite far away from the others and could be quite easily separated. Nine functions are built, and the eigenvalues of the functions 1-9 are 4.520, 3.275, 1.578, 1.350, 0.588, 0.226, 0.113, 0.042, and 0.006 respectively. The first two functions extracted accounted for 66.6% of the variance, and 83.9% of the original grouped cases were correctly classified, which is slightly higher than that on metacarpals.

As shown in Figure 6.26, *Pseudois* greatly overlaps with the *Ovis* groups, especially

Western Asian Mouflon, European Mouflon, and domestic sheep. In addition, *C. hircus* partly overlaps with *O. aries*, indicating the osteometric similarities between them.

6.4 Discussion

After examining the osteoscopic and osteometric data of skeletal elements of the Caprinae and *Gazella* distributed in Western China and *Ovis* in Eurasia, the following observations can be made.

6.4.1 Absolute Size

Among the different *Ovis*, generally, the size range is largest in *Ovis ammon* and smallest in zoo specimens of *Ovis musimon*. The domestic sheep exhibit a wide range of variation in body size. The size of the feral animals is generally larger than the zoo animals in the same species, as illustrated in the two groups of *Ovis musimon*. Compared to the other Caprinae and *Gazella*, it has been found that *Ovis ammon*, *Capricornis*, and *Capra sibirica* are large-sized Caprinae, and the group of *Gazella* and *Procapra* were found to have significant differences between all the other taxa on both metacarpals and metatarsals. This could probably be used to sort out the animals of the different sizes in archaeological specimens as the first step of identification.

6.4.2 Shape

Based on the limited data, and by using osteoscopic and osteometric methods, it has generally been found that there are specific differences as well as lots of overlappings between the different wild Caprinae of Western China and *Ovis* in Eurasia in the shape of their bones.

As for the osteoscopic data (scored characters and descriptive diagnostic characters), it seems that it is really difficult to definitely separate one taxon from the others based on one single criterion, and they need be used in combination. Hardly any criteria are exclusive to one single species.

As for the osteometric data shown by the discriminate analysis based on shape indices,

generally it has been found that *Gazella/Procapra* could be better separated from the others, but more specific situations on the different elements are different. On humerus, *Ovis*, *Pseudois*, and *Capra hircus* overlap a great deal, which will make it difficult to separate these three taxa in archaeological materials. On metapodials and particularly metacarpals, the majority of the *Ovis* specimens do not overlap with the other Caprinae, and *Capra hircus* are clearly separated from the others.

Among the different *Ovis*, the different populations could be more clearly separated on metapodials and on humeri, as shown by the posterior probabilities in the discriminate analysis. But in general *O. ammon* are more clearly separated from the other *Ovis*, although this may be partly due to allometry. As discussed, *O. ammon* is the largest in size among the *Ovis* studied.

On metacarpals, in particular, two domestic sheep groups (*O. aries* and *O. aries* × *O. ammon*) are quite clearly separated from *O. ammon*. This is meaningful because it suggests that it may be possible to separate the domestic sheep and goats from the other wild ones on this element in archaeological identification, considering the domestic sheep in this area are very likely to fall within the range of the modern domestic sheep studied (which cover the areas of the majority of the other wild Eurasia sheep).

After testing, it was found that the discriminate analysis based on ratios of pairs of measurements could not separate the different Caprinae as clearly as that based on shape indices. Hence when analysing archaeological samples discriminate analysis will only be carried out using shape indices rather than ratios. However, based on the ratios of pairs of measurements, it appears that some pattern between the osteomorphology in relations with the ecologies of the species may be revealed. On a series of different ratios on metapodials (e.g. DBV/DpBV, 3/4, 5/6, 1/3, 2/5, Appendices K, N), the different species always line up in a more or less similar sequence showing a osteometric gradient (e.g. Figure 6.27) from those more adapted to climbing (*C. hircus*, *C. sibirica*, *Pseudois*) to those more adapted to running (*Ovis*, *Gazella/ Procapra*) (Appendices N, O). Among the different *Ovis*, it seems that the morphology is also corresponding to the evolutionary history of the

species (speciation, migration, and/or domestication). As some morphological traits that related to the locomotive pattern may alter under handling and/or selection in anthropogenic environments, this may have significance for the further study on the early traits of domestication. However, the data in this study are quite limited, these aspects need to be further explored with more advanced methods (e.g. to remove allometry and analyse the residues in shape indices, GMM) and more samples (e.g. more samples of the current taxa and of other small ruminants) if a firm conclusion is to be made.

The morphology showed by different sets of data generally agree with each other. For example, the range and standard deviation are always the largest in *O. aries* compared with other *Ovis* group in absolute size and different ratios, and this agrees with that in the territorial map result of discriminate analysis *Ovis* based on ratios and shape indices whereas *O. aries* also covers the largest range.

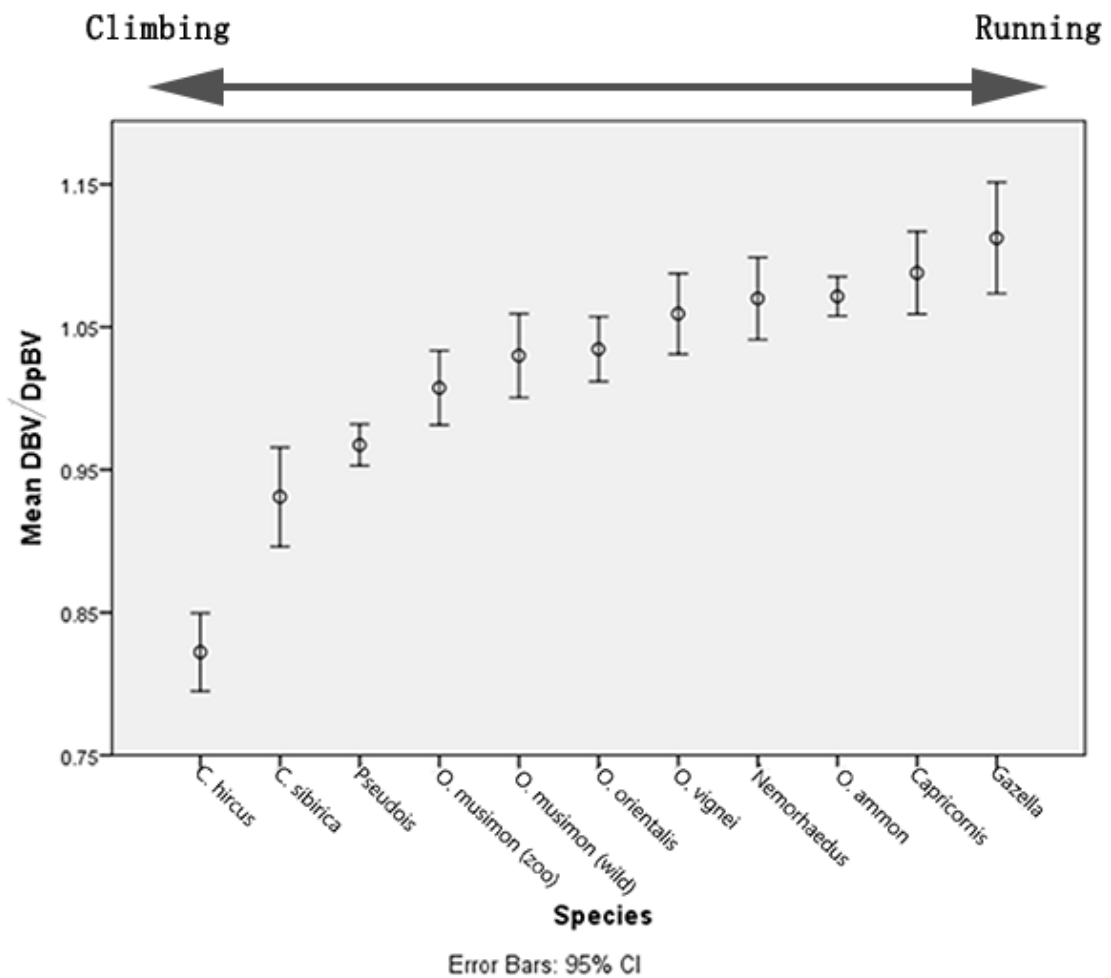


Figure 6.27 The gradient of the different species studied in the ratio DBV/DpBV on metacarpals. The circle in the middle represents the mean value; the bars above and below represent the range of 95% confidence interval.

6.5 Summary

Based on the different methods, it has generally been found that there are specific differences as well as lots of variabilities and complexities in the osteomorphological data between the various analysed species. Especially, the overlaps between the *Ovis*, *Pseudois*, and *Capra*, and those between the different *Ovis* except for the most 'typical' *O. ammon* make it difficult to separate these species on humeri. In contrast, on metacarpals, it might be possible to separate *Ovis aries* and *C. hircus* from the other wild Caprinae. In this sense, particular caution needs to be taken when attempting to identify these species in archaeological materials.

7. Morphological Analysis of the Caprinae and Gazella Remains from the Archaeological Sites

7.1 Introduction

This chapter presents the morphological analysis of the Caprinae and *Gazella* remains from the five archaeological sites. The analysis on humeri and metapodials will be presented in detail as the focus of the chapter. The analysis of the other elements will be presented briefly, and the results will be shown in Appendice Z. The original measurements and scoring of the archaeological specimens of distal humeri, distal metacarpal, and distal metatarsals are provided in Appendices V, W, X.

7.2 Taphonomic Conditions

The morphological analyses of the archaeological specimens are based on the osteomorphology that has been preserved and the metrics obtained from them. Due to taphonomic processes, archaeological specimens are eroded to different degrees and not all the original shapes of the bones are well preserved. At Andaqiha, for example, the majority of the specimens were eroded and the surface of the bones lost, hence lots of metric data obtained on the archaeological specimens are not the true original values. However, when the surface of the bone was found homogeneously eroded, it was assumed that the shape of the bone was not much affected but just the scales. Hence the osteometric analyses based on the ratios of the measurements and shape indices are still regarded as valid, but the reliability of the diagnosis based on that will not be regarded as high. In addition, some specimens were burnt and appear brackish or grey. When a specimen was found heavily burnt, and its morphology seemed distorted to an unknown degree, the identification using metric data could not be reliable.

7.3 Humerus, Distal End

7.3.1 Discriminate Function Analysis Using Shape Indices

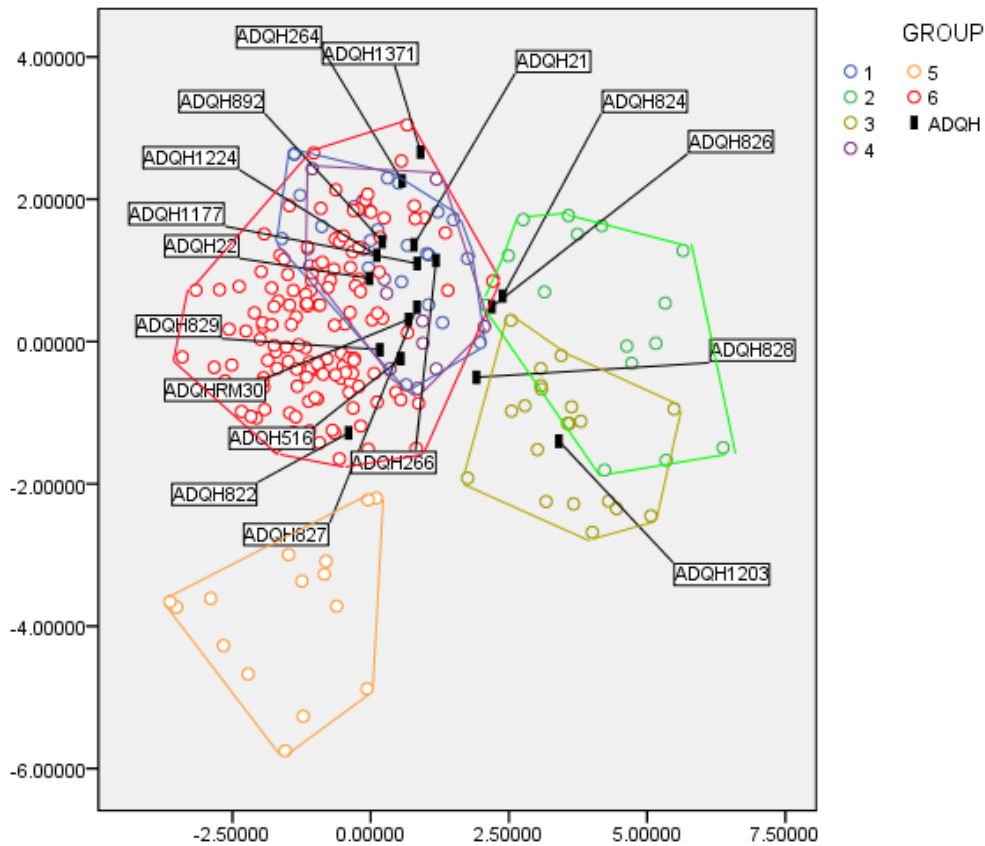


Figure 7.1 Classification of the archaeological *Caprinae/Gazella* humeri from Andaqiha against modern specimens based on the first two discriminant functions using six shape indices. 1: *Pseudois* (blue sheep); 2: *Capricornis* (serow); 3: *Nemorhaedus* (goral); 4: *Capra hircus* (domestic goat); 5: *Gazella/Procapra* (gazelle); 6: *Ovis* (wild and domestic sheep); ADQH: Andaqiha specimens.

17 specimens from Andaqiha are with complete six shape indices and were analysed with discriminate analysis (Figure 7.1). The results of the classification of Andaqiha specimens are provided in Table 7.1. Five functions are built, and the eigenvalues of the functions 1-5 are 2.995, 1.433, 0.526, 0.168, 0.013 respectively. The first two functions extracted accounted for 86.2% of the variance, and this analysis correctly identifies 85% of the original grouped cases.

As can be seen from Figure 7.1, the majority of the specimens of Andaqiha (11 out of 17) fall inside the overlapping area of the convex hulls of *Ovis*, *Pseudois*, and *Capra hircus*, and are classified as one of these taxa. In addition, three specimens which are not

inside the convex hulls of *Pseudois* are also classified as *Pseudois* (ADQH824, ADQH826, ADQH1371). Moreover, two specimens are classified as *Nemorhaedus* (ADQH828, ADQH1203), and one specimen as *Ovis* (ADQH822). However, apart from the assignation of several *Pseudois* and *Nemorhaedus*, the posterior probabilities of the highest predicted taxa for all the other specimens are lower than 80%.

Specimen Number	LDA1		LDA2
	ID	Prob	ID
ADQH21	P	0.55	Ch
ADQH22	P	0.76	Ch
ADQH264	P	0.79	Ch
ADQH266	Ch	0.70	P
ADQH516	Ch	0.60	O
ADQH824	P	0.42	N
ADQH828	N	0.51	Ch
ADQH829	Ch	0.52	P
ADQH827	P	0.76	C
ADQH826	P	0.81	C
ADQH1177	P	0.94	C
ADQH1203	N	0.96	Cpc
ADQH1371	P	0.85	C
ADQHRM30	P	0.82	C
ADQH822	O	0.55	P
ADQH892	Ch	0.50	O
ADQH1224	Ch	0.58	O

Table 7.1 Classification results of archaeological Caprinae/*Gazellahumeri* samples from Andaqiha based on the discriminant functions analysis using six shape indices. The identification result (ID) of the highest predicted assignation (LDA1), its posterior probability (Prob), and the second highest assignation (LDA2 ID) are provided. P: *Pseudois nayaur*; Ch: *Capra hircus*; O: *Ovis*.

The assignation results do not entirely in agreement with what is shown in the convex hulls. This should be attributed to the fact that only the first two functions in the discriminate analysis are plotted. Hence the assignation by the original discriminate analysis should be more reliable.

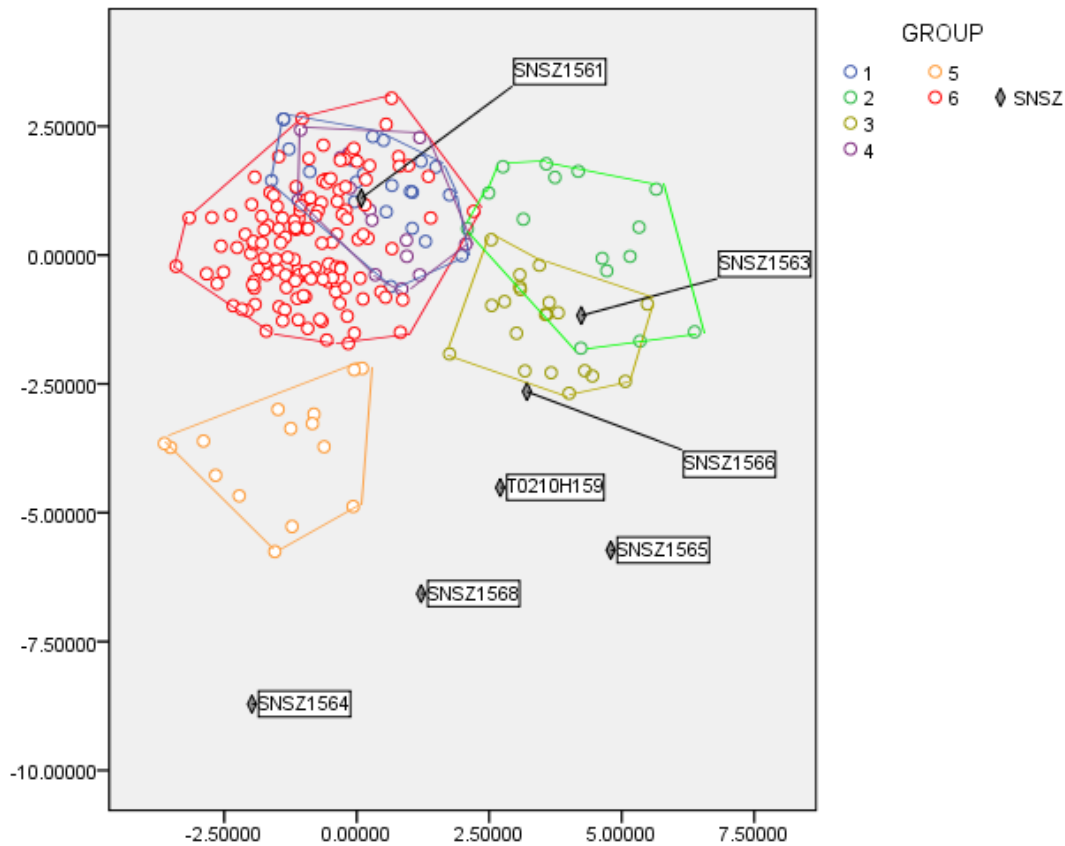


Figure 7.2 Classification of the archaeological *Caprinae/Gazella* humeri from Shannashuzha against modern specimens based on the first two discriminant functions using six shape indices. 1: *Pseudois* (blue sheep); 2: *Capricornis* (serow); 3: *Nemorhaedus* (goral); 4: *Capra hircus* (domestic goat); 5: *Gazella/Procapra* (gazelle); 6: *Ovis* (wild and domestic sheep). SNSZ: Shannashuzha specimens.

Specimen Number	LDA1		LDA2
	ID	Prob	ID
SNSZ1561	P	0.68	Ch
SNSZ1563	N	0.96	Cpc
T0210H159	N	0.82	G
SNSZ1564	G	100.00	O
SNSZ1565	N	1.00	Cpc
SNSZ1566	N	0.97	Cpc
SNSZ1568	G	100.00	N

Table 7.2 Classification results of archaeological *Caprinae/Gazella* humeri samples from Shannashuzha based on the discriminant functions analysis using six shape indices. The identification result (ID) of the highest predicted assignment (LDA1), its posterior probability (Prob), and the second highest assignment (LDA2) are provided.

P: *Pseudois nayaur*; Ch: *Capra hircus*; O: *Ovis*.

Different from Andaqiha, as can be seen in Figure 7.2, except for the specimen SNSZ1561, the humerus specimens of Shannashuzha exclusively fall inside or close to the range of *Nemorhaedus*, *Capricornis*, or *Gazelle/Procapra*. Four specimens are scattered far from the convex hulls of any taxa, but they are assigned to the group close to them (two as *Nemorhaedus*, and two as *Gazelle/Procapra*: Table 7.2). This could be attributed to the limited number of modern comparative specimens in these taxa, or to the fact that some of the specimens do not belong to any of the studied taxa in the comparative modern specimens.

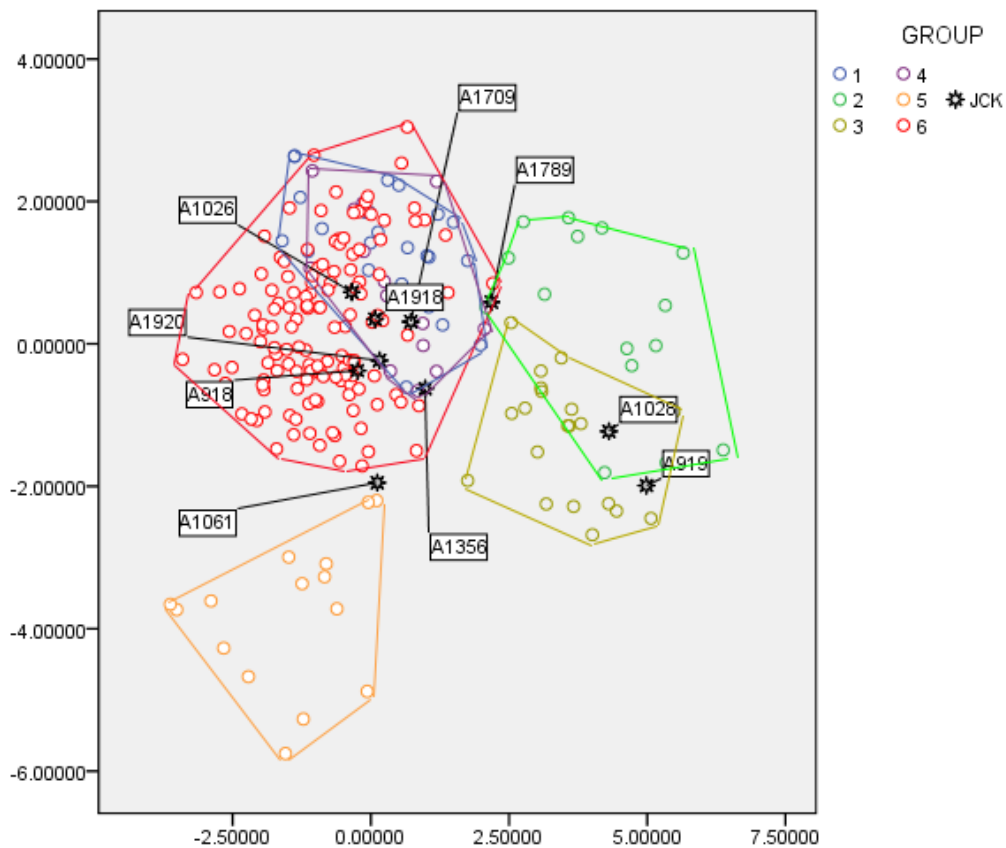


Figure 7.3 Classification of the archaeological *Caprinae/Gazella* humeri from Jinchankou against modern specimens based on the first two discriminant functions using six shape indices. 1: *Pseudois* (blue sheep); 2: *Capricornis* (serow); 3: *Nemorhaedus* (goral); 4: *Capra hircus* (domestic goat); 5: *Gazelle/Procapra* (gazelle); 6: *Ovis* (wild and domestic sheep). JCK: Jinchankou specimens.

Among the ten Jinchankou specimens, two specimens, A1028 and A919, fall inside the range of *Nemorhaedus* and *Capricornis* and are classified as *Nemorhaedus*. Six fall within the overlapping range of *Ovis*, *Pseudois*, and *Capra hircus*, and they were classified as either *Ovis* or *Capra hircus*; the other two are inside (A918) or close to (A1061) the range of *Ovis*, and were classified as *Ovis* (Figure 7.3). The probabilities of the assignments are quite high for two *Nemorhaedus* (0.99, 0.98) and three *Ovis* (>0.80), but low for the two *Capra hircus* (<=0.68) (Table 7.3).

Specimen Number	LDA1		LDA2
	ID	Prob	
A1061	O	0.68	G
A1026	O	0.88	C
A1918	O	0.50	C
A1709	Ch	0.68	O
A1028	N	0.99	Cpc
A1789	Ch	0.55	P
A1920	O	0.83	Ch
A1356	O	0.41	Ch
A918	O	0.93	Ch
A919	N	0.98	Cpc

Table 7.3 Classification results of archaeological Caprinae/*Gazellahumeri* samples from Jinchankou based on the discriminant functions analysis using six shape indices. The identification result (ID) of the highest predicted assignment (LDA1), its posterior probability (Prob), and the second highest assignment (LDA2) are provided. P: *Pseudois nayaur*; Ch: *Capra hircus*; O: *Ovis*; N: *Nemorhaedus*.

As can be seen in Figure 7.4 and Table 7.4, among the four specimens from Sanbadongzi, two are classified as *Ovis*; one is classified as *Capra hircus* and another one as *Gazella/Procapra*. But the specimen SBDZ-49-2 is located quite far from the range of modern *Ovis* specimens. Therefore this specimen is in question and needs further investigation.

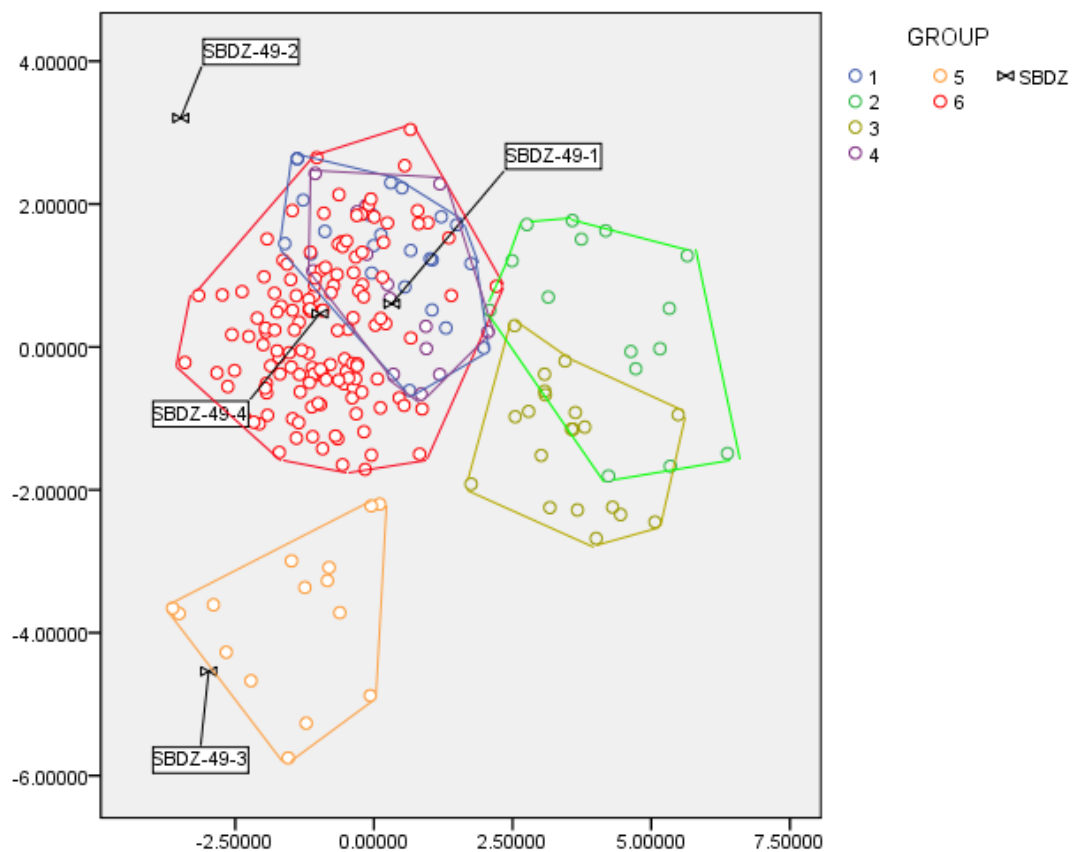


Figure 7.4 Classification of the archaeological *Caprinae/Gazella* humeri from Sanbadongzi against modern specimens based on the first two discriminant functions using six shape indices. 1: *Pseudois* (blue sheep); 2: *Capricornis* (serow); 3: *Nemorhaedus* (goral); 4: *Capra hircus* (domestic goat); 5: *Gazella/Procapra* (gazelle); 6: *Ovis* (wild and domestic sheep). SBDZ: Sanbadongzi specimens.

Specimen Number	LDA1		LDA2
	ID	Prob	
SBDZ-49-2	O	0.86	P
SBDZ-49-3	G	100.00	O
SBDZ-49-4	O	0.87	Ch
SBDZ-49-1	Ch	0.53	O

Table 7.4 Classification results of archaeological *Caprinae/Gazella* humeri samples from Sanbadongzi based on the discriminant functions analysis using six shape indices. The identification result (ID) of the highest predicted assignment (LDA1), its posterior probability (Prob), and the second highest assignment (LDA2) are provided. P: *Pseudois nayaur*; Ch: *Capra hircus*; O: *Ovis*; G: *Gazella/Procapra*.

Since the number of comparative modern specimens is not large, especially for

non-*Ovis* taxa, and only 85% of the original grouped cases were correctly classified, the discriminate power of this analysis is limited. The result produced with this analysis should not be regarded as definite. In addition, some specimens were eroded and not all the measurements are available and secure. Therefore further analysis based on the ratios and osteoscopic characters was deemed necessary, which will be presented in Section 7.3.2.

Several specimens from Jinchankou that were identified as likely to be *Ovis* based on several lines of evidence were analysed against six modern *Ovis* groups to identify the type of *Ovis* they belong to, using the discriminant analysis based on the six shape indices. The result is shown in Figure 7.5 and Table 7.5.

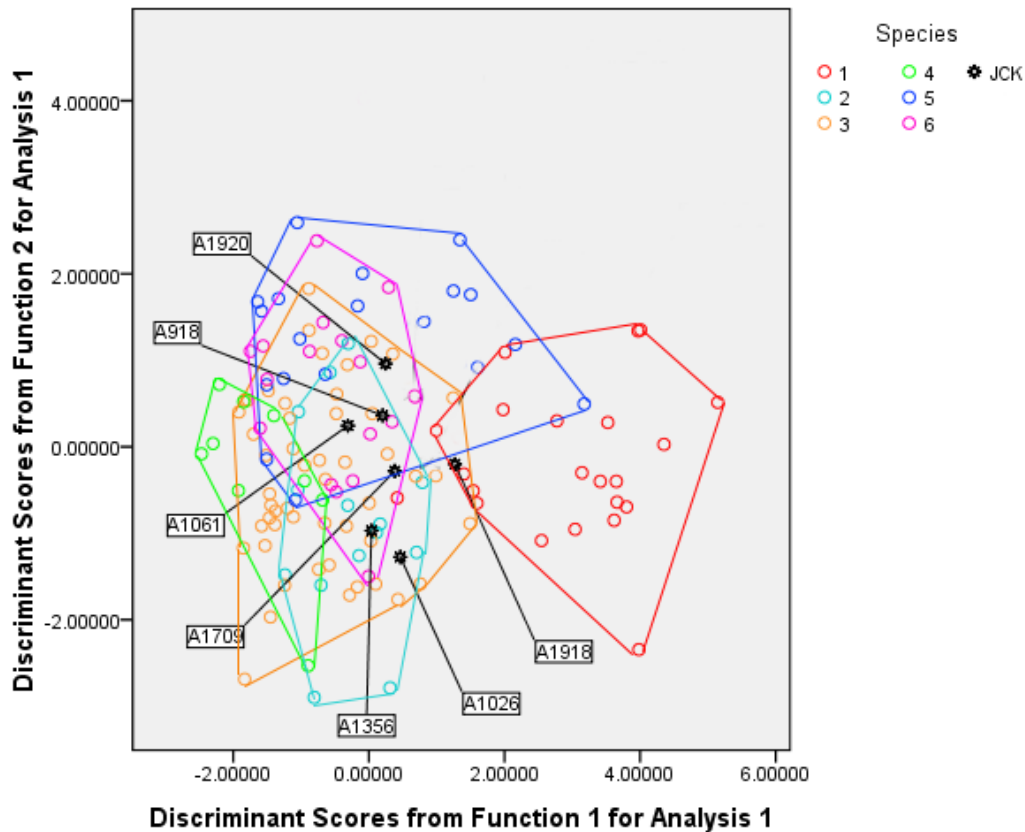


Figure 7.5 Classification of the Jinchankou humeri against modern *Ovis* specimens based on the first two discriminant functions using six shape indices. 1. *O. ammon* (Argali); 2. *O. vignei* (Urial); 3. *O. orientalis* (Western Asian Mouflon); 4. *O. musimon* (European Mouflon Sheep); 5. *O. aries* (Domestic Sheep); 6. *O. ammon* × *O. aries* (Crossbred Sheep). JCK: Jinchankou specimens.

Specimen	LDA1	
	ID	Prob.
A1061	<i>O. ammon</i> × <i>O. aries</i>	0.39
A1026	<i>O. vignei</i>	0.49
A1918	<i>O. vignei</i>	0.36
A1709	<i>O. vignei</i>	0.63
A1920	<i>O. aries</i>	0.42
A1356	<i>O. vignei</i>	0.75
A918	<i>O. ammon</i> × <i>O. aries</i>	0.31

Table 7.5 Classification results of Jinchankou humerus specimens against six modern *Ovis* groups based on the discriminant function analysis using six shape indices. The identification result (ID) of the highest predicted assignment (LDA1) and its posterior probability (Prob.) are provided.

As can be seen from the Figure 7.5 and the Table 7.5, these specimens were assigned as either *O. vignei*, *O. aries*, or *O. ammon* × *aries*, and are falling inside the overlapping areas of *O. vignei*, *O. orientalis*, *O. aries*, or *O. aries* × *O. ammon*, but not *O. ammon* or *O. musimon*. The posterior probabilities of the assignments are not high. Considering that only 57.9% of the original grouped cases were correctly classified, the assignment of the specific taxa for the archaeological samples may not be regarded as definite. However, based on the distribution of the archaeological samples in Figure 7.5, it may be interpreted that these specimens are not *O. ammon* or *O. musimon* because most of them are outside the convex hulls of these two taxa. Instead, they are more likely to be domestic sheep, because that is the only other identity for these specimens considering that they were *Ovis*, considering that *O. orientalis* (west Asian Mouflon) and *O. vignei* (Urial sheep) do not distribute in the research area. In addition, their distributions also indicate they seem to be more closely associated with sheep of the west instead of local *O. ammon*.

7.3.2 Osteoscopic and Metric Analysis with Ratios

7.3.2.1 Andaqiha

The metric data of the specimens were checked against the ratio criteria provided in Gätze (1998), Boessneck et al. (1964), Gromova (1953), and in this study.

As can be seen from Table 7.6, among the Andaqiha specimens, the diagnosis based on the ratio criteria in Göze (1998) are not entirely the same as that produced by the discriminate analysis based on the shape indices. However, the criteria in Göze (1998) are developed based on the modern specimens of *Ovis aries*, *Capra hircus*, and *Pseudois nayaur* only, not involving all the other potential Caprinae taxa that could occur at the site Andaqiha. Therefore, specimen ADQH1203 is more likely to be a *Nemorhaedus* although diagnosed as *C. hircus* in Göze criteria (Table 7.6). Based on the discriminate analysis using shape indices, it is assigned as *Nemorhaedus* with a high probability (Figure 7.1, Table 7.1). The examination of the osteoscopic characters also confirms its identity. As can be seen in Figure 7.6, the distal margin of the condylus is higher than the distal margin of the sagittal ridge (Character 2), and there is a small foramen communicating between the anterior and posterior sides (Character 4), all identical to the features developed in Chapter 6 for *Nemorhaedus* which distinguished it from *Ovis*, *Capra hircus* or *Pseudois*.

	BTI/HTF		HTF/BTR		ID
	Value	ID	Value	ID	
ADQH21	0.71	Ch/P	0.44	Ch/P	Ch/P
ADQH22	0.67	Ch/P	0.44	Ch/P	Ch/P
ADQH264	0.76	Ch/P	0.42	P	P
ADQH266	0.69	Ch/P	0.45	Ch/P	Ch/P
ADQHT0110(3)	0.67	C/P/O	0.49	Ch/P/O	Ch/P/O
ADQH824	0.67	Ch/P	0.45	Ch/P/O	Ch/P
ADQH828	0.66	Ch/P/O	0.48	Ch/P/O	Ch/P/O
ADQH829	0.66	Ch/P/O	0.48	Ch/P/O	Ch/P/O
ADQH827	0.78	Ch/P	0.45	Ch/P	Ch/P
ADQH826	0.75	Ch/P	0.41	P	P
ADQH1177	0.77	Ch/P	0.43	Ch/P	Ch/P
ADQH1203	0.63	Ch/P	0.51	Ch/O	Ch

ADQH1371	0.79	Ch/P	0.41	P	P
ADQHRM30	0.64	Ch/P/O	0.43	Ch/P	Ch/P
ADQH822	0.58	O	0.49	Ch/P/O	O
ADQH892	0.60	O	0.47	Ch/P/O	O
ADQH1224	0.59	O	0.47	Ch/P/O	O

Table 7.6 The metric data (BTI/HTF and HTF/BTR) and identification (ID) based on them for the archaeological specimens from Andaqiha, humerus distal. The identification is made based on the data provided in Götze (1998: p.88, Tab. 12) (referring to Gromova 1953; 36 ff.; Boessneck et al. 1964: 64 f) to separate *Ovis*, *Capra hircus*, and *Pseudois*.¹⁸ The last column provides the parsimonious identification results based on the two ratio criteria. O: *Ovis*, P: *Pseudois*, Ch: *Capra hircus*.

Based on the ratios in Götze (1998), three specimens (ADQH822, ADQH892, ADQH1224) were diagnosed as *Ovis* (Table 7.6). In the discriminant analysis, they either fall inside the overlapping areas of the convex hulls of *Ovis*, *Pseudois*, and *Capra hircus* (ADQH892, ADQH1224), or inside the convex hulls of *Ovis* only (ADQH822) (Figure 7.1). In addition, ADQH822 was identified as *Ovis* with the highest probability, and *Pseudois* is the second. ADQH892 and ADQH1224 were diagnosed as *Capra hircus* first, and *Ovis* as second. However, the posterior probabilities for the assignments are not high (all lower than 0.6) (Table 7.1). The diagnosis based on the ratios in this study (Appendix V) is generally in agreement with the diagnosis indicated by the convex hulls in Figure 7.1.

¹⁸ The ratio criterion 1 (BTI/HTF) and criterion 2 (HTF/BTR) in Tab.12 in Götze (1998) equals to BTI/SHT and SHT/BT in my study respectively. They have a range of 61.5%-84.5% and 42.5%-52.0% for *Capra hircus*, 61.5%-83.5% and 41.5%-50.0% for *Pseudois* (n=20); 48.5-67.0% and 45.0%-57.0% for *Ovis*, as provided by Götze (1998).



Figure 7.6 Specimen ADQH1203, from Horizon 5(a), Andaqiha.

Further checking of the surface preservation and osteoscopic characters of the specimens found that specimen ADQH822 was quite eroded with most of the bone surface lost, but overall it seems to be homogeneously eroded (Figure 7.7); ADQH892 was quite heavily burnt and the bone appeared grey and calcined (Figure 7.8); ADQH1224 was quite well preserved with almost complete bone surface and not affected by burning (Figure 7.9). Therefore, the osteometric analyses of ADQH822 and ADQH1224 were regarded as valid, while that of ADQH892 may not be because the original shape was likely to have been distorted.

Based on the morphological criteria in Götze (1998, pp. 83-90, feature 8, 9, 10, 12, 13) and in this study, the three specimens are not very likely to be *Capra hircus*. Moreover, based on Criterion 3 developed by myself, the obliqueness of the sagittal ridge is medium, scored 2, in specimen ADQH822 and ADQH892 (Table 7.7), hence there is a larger chance for them to be *Pseudois* than *Ovis*; while in specimen ADQH1224 the sagittal ridge is more straight, scored 1, hence it has a larger chance to be *Ovis* than *Pseudois*. (In Character 3, only 1 of the 88 modern *Ovis* specimens was scored as 2, 87 of the 88 modern *Ovis* specimens are scored 1; 7 of the 12 modern *Pseudois* are scored 1; and 3 of 12 *Pseudois* are scored 2, see Chapter 6, Table 6.4). However, the preservation of ADQH822 is not perfect, and the amount of modern comparative samples is not large, especially for *Pseudois*.

	C1		C2		C3		C4	
	score	ID	score	ID	score	ID	score	ID
ADQH822	2	P/Cpc/N/Ch/O	2	P/Cpc/N/Ch/O/G	2	P/O	1	P/Cpc/N/Ch/O/G
ADQH892	1	P/Cpc/N/O/G	1	P/Cpc/N/O/G	2	P/Cpc/N/O	1	P/Cpc/N/Ch/O/G
ADQH1224	1	P/Cpc/N/O/G	2	P/Cpc/N/Ch/O/G	1	P/Cpc/N/Ch/O/G	-	-

Table 7.7 Scored values of the osteoscopic characters (C1-C4) of specimens ADQH822, ADQH892, and ADQH1224, and the taxonomic diagnosis (ID) based on them. O: *Ovis*; P: *Pseudois*; N: *Nemorhaedus*; Cpc: *Capricornis*; Ch: *C. hircus*.



Figure 7.7 Specimen ADQH822, from Horizon 5(a), Andaqiha.



Figure 7.8 Specimen ADQH892, from the ash pit H2(3), Andaqiha. Note that the bone was heavily burnt and calcined. The rim of the trochlea appears blue while the inner part appears white/grey.

Overall, these three specimens could be either *Ovis* or *Pseudois*, and the diagnosis results based on the different types of evidence are not entirely in agreement with each other. Considering all the evidence together, ADQH1224 and ADQH822 are more likely to be *Ovis* to me, and the other one probably a *Pseudois*. However, as noted, the preservation conditions are not perfect, which do not allow definite diagnoses for them

based on morphology.



Figure 7.9 Specimen ADQH1224, from house F2 (2), Andaqiha.

If the specimen ADQH1224 is an *Ovis*, according to the osteoscopic criteria developed in Chapter 6 to distinguish different *Ovis* (the shape of the transition from the shaft to the lateral epicondyle), it could be *Ovis ammon*, *Ovis vignei*, *Ovis orientalis*, *Ovis aries* or crossbreeds of *Ovis ammon* and domestic sheep, but not *Ovis musimon* and country sheep in Europe. The 5 metric ratios of this specimen fall inside the criteria of all the *Ovis* studied.

The specimens which were diagnosed by the discriminate analysis as *Pseudois* with the highest possibility and *Capra hircus* as second were found mostly exhibiting osteoscopic features identical to *Pseudois*, such as specimen ADQH22 (Figure 7.10). Although heavily burnt, the morphoscopic characters of this specimen in anterior, medial, and posterior view fits with the criteria of *Pseudois* in Gätze (1998, p88, (8)) and in Chapter 6. In the discriminate analysis based on shape indices, it was identified as *Pseudois* with a probability of 0.76 (Table 7.1).



Figure 7.10ADQH22, from ash pit H2(3), Andaqiha. Note that the specimen is burnt blackish-brown.

The specimens which were diagnosed as *Capra hircus* with the highest probability and falling inside the overlapping area of *Ovis*, *Pseudois*, and *Capra hircus* (ADQH266, ADQH516, ADQH829) are with quite low posterior probabilities for the assignments (≤ 0.7) (Table 7.1). They fall into the ranges of *Capra hircus*, *Ovis*, and *Pseudois* in the

ratio criteria of Götze (1998), and were found with a poor surface condition or heavily burnt. Based on the morphological criteria in Götze (1998) and in this study, some can be excluded from being *Capra hircus*, such as ADQH266 (Figure 7.11), and are more likely to be *Pseudois*. But some could not be entirely excluded from *Capra hircus* or *Ovis* due to the very poor condition.



Figure 7.11ADQH266, from ash pit H2(1), Andaqiha. Note that the morphoscopic characters in anterior, medial, and the posterior view are more identical to *Pseudois* than to *Capra hircus*.

Overall, it can be concluded that both *Pseudois* and *Nemorhaedus* certainly existed at Andaqiha, with *Pseudois* accounting for a larger portion. *Ovis* probably also occurs, but not in a large number. *Capra hircus* has not been positively identified on the humeri. A summary of the diagnoses based on the different types of evidence for Andaqiha humerus specimens is provided in Appendix Y.

3.3.2.6 Jinchankou

The identifications based on the ratio criteria in Götze (Appendix V) are mostly in agreement with those produced by the linear discriminate analysis in this study. There are only a few exceptions.

A1028 and A919 should be *Nemorhaedus*, instead of *Ovis*. As noted before, since in Götze (1998) no *Nemorhaedus* are studied this species could not be identified using his criteria. The examining of the osteoscopic characters of the bones confirmed the identification.

A1709 is identified as *Ovis* by Götze's ratio criteria, but as *Capra hircus* with the highest probability (0.68) and secondly as *Ovis* based on the discriminate analysis using shape indices. The original morphology of the bone is preserved quite well (Figure 7.12). According to the morphological criteria used to separate between sheep and goats in previous literature and in this study, it can be diagnosed as an *Ovis* rather than *Capra hircus*. As shown in Figure 7.12, it should be scored as value '2' in Character 3, and among the modern specimens only *Ovis* and *Pseudois* were scored with this value (see Table 6.4, Chapter 6), while no *C. hircus* were scored value '2', hence specimen A1789 could be excluded from the possibility of being *C. hircus* and identified as *Ovis*.

A1789 is identified as *Capra hircus* or *Pseudois* according to the ratios in Götze (1998) and was assigned to *Capra hircus* as the highest possibility (posterior probability 0.55), and as *Pseudois* secondly. Using the osteoscopic criteria, it could be assigned as *Pseudois* instead of *C. hircus*. As shown in Figure 7.13, it should be scored as value '2' in Character 3, and among the modern specimens only *Ovis* and *Pseudois* were scored with this value (see Table 6.4, Chapter 6), while no *C. hircus* were assigned value '2', hence specimen A1789 could be excluded from the possibility of being *C. hircus*.

Overall, the osteoscopic and metric analysis identify the majority of the Caprinae specimens at Jinchankou as *Ovis*. The scored values of each specimen can be found in Appendix V and the summary of the diagnosis result is provided in Appendix Y.

The analysis of the specimens from other sites is carried out in the same manner,

although there are not many specimens available for analysis. The majority of the specimens from Shannashuzha are identified as *Nemorhaedus*, and there is one *Pseudois* and one *Gazella*. All the four specimens from Sanbadongzi are identified as *Ovis*. The detailed identification results based on the different evidence can be found in Appendices Y.



Figure 7.12 Specimen A1709, from house F3, Jinchankou.



Figure 7.13 Specimen ADQH1789, from house F3(1), Jinchankou.

7.3.3 Absolute Size

The checking of the absolute size could not invalidate the identifications made above.

7.4 Metacarpals, Distal End

7.4.1 Discriminate Function Analysis Using Shape Indices

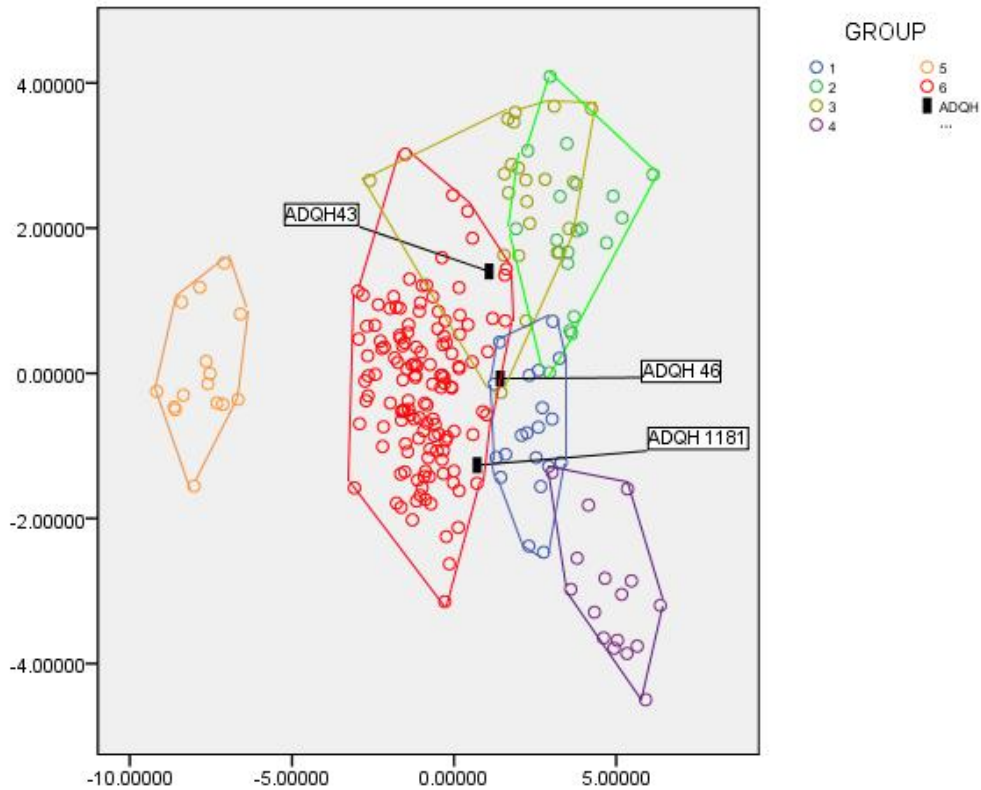


Figure 7.14 Classification of the archaeological Caprinae/*Gazella* metacarpals from Andaqiha against modern specimens based on the first two discriminant functions using six shape indices. 1: *Pseudois* (Blue Sheep); 2: *Capricornis* (Serow); 3: *Nemorhaedus* (Goral); 4: *Capra hircus* (Domestic Goat); 5: *Gazella/Procapra* (Gazelle); 6: *Ovis* (Sheep). ADQH: Andaqiha.

Only three specimens from Andaqiha are available for the analysis with all 11 shape indices (Figure 7.14). Five functions are built, and the eigenvalues of the functions 1-5 are 8.520, 1.671, 0.638, 0.264, and 0.046 respectively. The first two functions extracted accounted for 91.5% of the variance, and the results of the classification are given in Table 7.8. This analysis correctly identifies 92.9% of the original grouped cases.

As can be seen from Figure 7.14 and Table 7.8, two of the three specimens fall inside the overlapping area of the different taxa (ADQH43, ADQH46), but the third specimen falls inside the convex hull of *Ovis* only (ADQH1181). ADQH43 was assigned to *Nemorhaedus* first (with a probability of 0.87) and *Ovis* second, while both ADQH46 and

ADQH1181 are predicted as *Pseudois* first. However, the probability of ADQH1181 being *Pseudois* is not high (0.58).

	LDA1		LDA2
	ID	Prob	
ADQH43	N	0.87	O
ADQH46	P	0.92	N
ADQH1181	P	0.58	O

Table 7.8 Classification results of archaeological Caprinae/*Gazella* metacarpal samples from Andaqiha based on the discriminant analysis using eleven shape indices. The identification result (ID) of the highest predicted assignment (LDA1), its posterior probability (Prob), and the second highest assignment (LDA2 ID) are shown. P: *Pseudois nayaur*; O: *Ovis*; N: *Nemorhaedus*.

Among the specimens of Jinchankou that are available for this analysis, Figure 7.15 and Table 7.9 show that the majority are falling inside the range of *Ovis* and identified as *Ovis* with a high probability (A1065, A927, A928, A850, A868, the posterior probability is about 1). Two specimens are predicted as *Pseudois* (A1924, A858), also with quite high probabilities, indicating a high reliability of the assignments.

Specimen	LDA1		LDA2
	ID	Prob	
A1065	O	0.99	P
A1924	P	0.89	O
A858	P	0.96	Ch
A927	O	0.99	P
A928	O	0.99	P
A850	O	0.99	G
A868	O	0.99	P

Table 7.9 Classification results of archaeological Caprinae/*Gazella* metacarpal samples from Jinchankou based on the discriminant functions analysis using eleven shape indices. The identification result (ID) of the highest predicted assignment (LDA1), its posterior probability (Prob), and the second highest assignment (LDA2 ID) are provided. P: *Pseudois nayaur*; Ch: *Capra hircus*; O: *Ovis*; G: *Gazella/Procapra*.

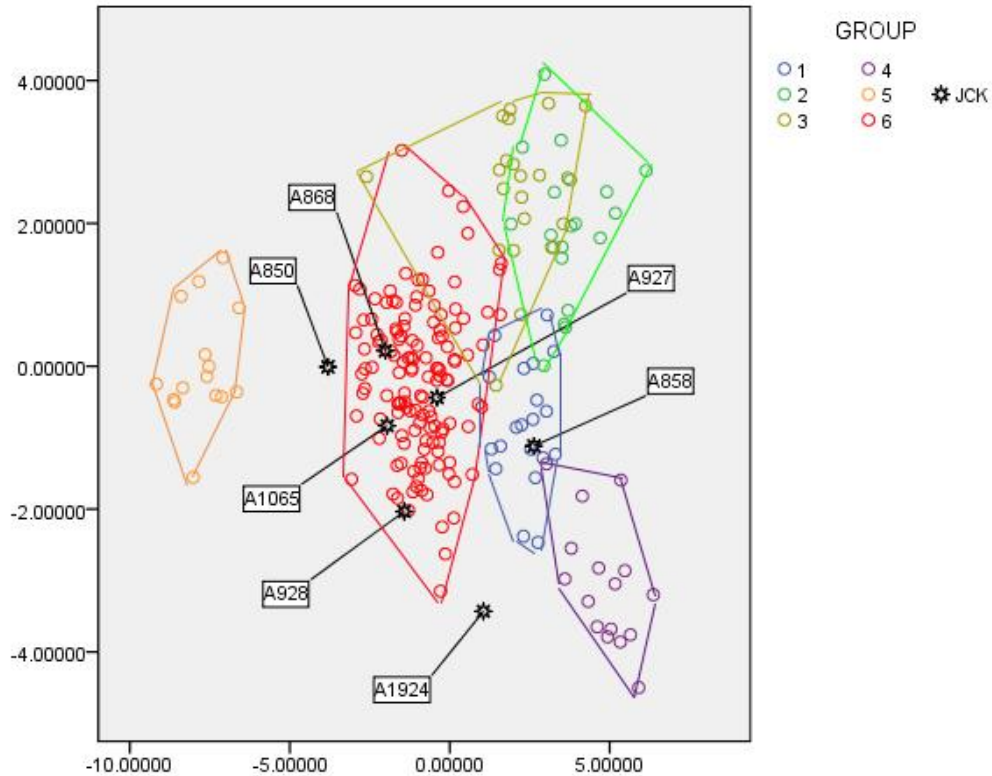


Figure 7.15 Classification of the archaeological Caprinae/*Gazella* metacarpals from Jinchankou against modern specimens based on the first two discriminant functions using eleven shape indices. 1: *Pseudois* (blue sheep); 2: *Capricornis* (serow); 3: *Nemorhaedus* (goral); 4: *Capra hircus* (domestic goat); 5: *Gazella/Procapra* (gazelle); 6: *Ovis* (wild and domestic sheep). JCK: Jinchankou.

7.4.2 Osteoscopic and Metric Analysis with Ratios

7.4.2.1 Andaqiha

According to the metric criteria ‘DabTm/DVm’ in Götze (1998: 107, criteria (5); 109, Tab. 13) and Boessneck et al. (1964: 115), the three specimens (ADQH43, ADQH46, ADQH1181) analysed in discriminate analysis based on shape indices were assigned to as either *Ovis* or *Pseudois* (Table 7.10). Apart from that, based on the ratio criteria developed in this study, one specimen was placed in *Ovis* only (ADQH43), and one as *Nemorhaedus* (ADQH47), and the others cannot be assigned to one taxon, but can be either *Ovis*, *Nemorhaedus*, or *Pseudois* (see Appendix W). A close examination of the two specimens

ADQH186 and ADQH1719 suggests that they were both heavily eroded and porous. Therefore the metric identification of these two is not quite reliable.

The scored osteoscopic characters of the specimens excluded the possibility of several of the specimens being *Pseudois* (Table 7.11). Based on the Character 2 to separate the different Caprinae and gazelle metacarpals (Chapter 6, Figure 6.17, Table 6.12), specimens ADQH43 (Figure 7.16), ADQH44, ADQH186 and ADQH1181 (Figure 7.17) are unlikely to be *Pseudois* or *Nemorhaedus*, because none of the *Pseudois* or *Nemorhaedus* modern specimens was scored 3, the value of those specimens on this character. However, this is only based on 6 and 4 modern specimens of *Pseudois* and *Nemorhaedus* respectively. In the same way, according to the score on Character 3 (Chapter 6, Figure 6.18, Table 6.14), specimen ADQH46 is unlikely to be *Pseudois*, but this is based on just 5 scored modern specimens of *Pseudois*.

	Value	ID
ADQH43	0.66	P/O
ADQH44	0.69	P/O
ADQH46	0.68	P/O
ADQH47	0.70	P/O
ADQH186	0.82	O
ADQH1719	0.79	O
ADQH941	0.64	P/O
ADQH1181	0.69	P/O

Table 7.10 The values of the metric data DabTm/DVm and identification (ID) derived from these for the distal metacarpal archaeological specimens from Andaqiha. The identification is based on the data provided in Gätze (1998: p.109, Tab. 13, referring to Boessneck et al. 1964: 115) to separate *Ovis*, *Capra hircus*, and *Pseudois*. O: *Ovis*, P: *Pseudois*.

Specimen	C1		C2		C3		ID
	score	ID	score	ID	score	ID	
ADQH43	1	P/Cpc/N/Ch/O	3	Ch/O	1	P/G/O	O
ADQH44	1	P/Cpc/N/Ch/O	3	Ch/O	2	P/Ch/O	O/Ch
ADQH46	-	-	2	P/Cpc/N/O	3	Cpc/N/Ch/O	Cpc/N/O
ADQH186	2	P/Cpc/N/Ch/O	3	Ch/O	1	P/G/O	O
ADQH1181	1	P/Cpc/N/Ch/O	3	Ch/O	1	P/G/O	O

Table 7.11 Scored values of the osteoscopic characters (C1-C3) of distal metacarpal specimens from Andaqiha, and the taxonomic diagnosis (ID) based on them. The last

column provides the parsimonious identification results based on the three characters.
P: *Pseudois*, Ch: *Capra hircus*, O: *Ovis*; G: *Gazella/Procapra*; Cpc: *Capricornis*; N:
Nemorhaedus.



Figure 7.16 Specimen ADQH43, from ash pit H2 (1) of Andaqiha site.



Figure 7.17 Specimen ADQH1181, from horizon 5(b) of Andaqiha site.

Considering all the different evidence together, the identification on metacarpals from Andaqiha (see Appendix Y) shows that *Pseudois*, *Ovis*, and *Nemorhaedus* all exist at this site, with *Nemorhaedus* probably only accounting for a small portion. However, some lines of identification are based on the very limited amount of comparative modern data available. Therefore, the identifications here are not one hundred percent certain. The unfavourable preservation conditions made it impossible to identify the specimens more precisely.

3.3.2.7 Jinchankou

	Value	ID
A1065	0.73	O
A1924	0.68	P/O
A1301	0.74	O
A858	0.67	P/O
A927	0.71	O
A928	0.72	O
A850	0.73	O
A868	0.70	P/O

Table 7.12 The value of the metric data DabTm/DVm and identification (ID) based on them for the distal metacarpal archaeological specimens from Jinchankou. The identification is based on the data provided in Göze (1998: p.109, Tab. 13) (referring to Boessneck et al. 1964: 115) to separate *Ovis*, *Capra hircus*, and *Pseudois*. O: *Ovis*, P: *Pseudois*.

Based on the metric criteria in Göze (1998) and Boessneck et al. (1964), five specimens from Jinchankou were identified as *Ovis* and three as *Ovis* or *Pseudois* (Table 7.12). These results are basically congruent with the diagnosis of the discriminate analysis based on shape indices (Table 7.9). The two specimens that were identified as *Pseudois* or *Ovis* by the Göze criteria were both identified as *Pseudois* in the discriminant analysis (A858, A1924), but the specimen A1924 does not fall inside the convex hulls of any species (Figure 7.15). Based on the scored osteoscopic criteria, A1924 (Figure 7.18) cannot be assigned to one single taxonomic identity, because there is no single consistent identity diagnosed using the three different osteoscopic characteristics (Table 7.13). In the same way, based on the different ratios in this study, A1924 could not be assigned to one single taxonomic identity either. This might be partly due to the fact that this is an unfused specimen while the modern comparative specimens are mostly fused ones. Therefore, the identity of specimen A1924 is still in question and needs further investigation.

	C1		C2		C3		ID
	score	ID	score	ID	score	ID	
A1065	1	P/Cpc/N/Ch/O	3	Ch/O	2	P/Ch/O	Ch/O
A1924	3	N/Ch/G	2	P/Cpc/N/O	2	P/Ch/O	-
A858	2	P/Cpc/N/Ch/O	2	P/Cpc/N/O	2	P/Ch/O	P/O
A927	1	P/Cpc/N/Ch/O	3	Ch/O	2	P/Ch/O	Ch/O
A926	1	P/Cpc/N/Ch/O	3	Ch/O	3	Cpc/N/Ch/O	Ch/O
A928	2	P/Cpc/N/Ch/O	3	Ch/O	2	P/Ch/O	Ch/O
A868	1	P/Cpc/N/Ch/O	3	Ch/O	2	P/Ch/O	Ch/O

Table 7.13 Scored values of the osteoscopic characters (C1-C3) of distal metacarpal specimens from Jinchankou, and the taxonomic diagnosis (ID) based on them. The last Column provides the parsimonious identification results based on the three characters.



Figure 7.18 Specimen A1924, from House F4, Jinchankou site.

In sum, considering all the evidence available, the majority of the metacarpal specimens from Jinchankou are *Ovis*, and *Pseudois* also exist. No other species have been positively identified. A summary of the identification based on different lines of evidence is provided in Appendix Y.

7.4.3 Absolute Size

Checking the absolute size of the specimens does not invalidate the identifications made above.

7.5 Metatarsal, Distal End

7.5.1 Discriminant Function Analysis Using Shape Indices

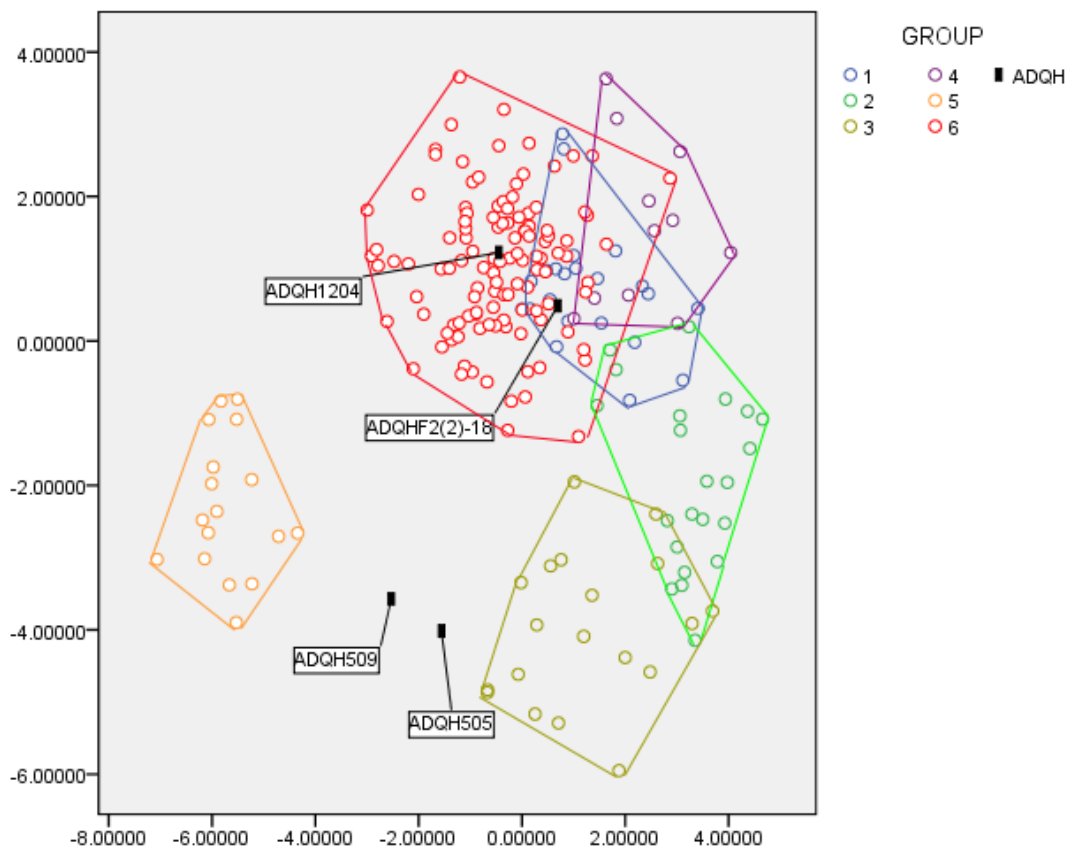


Figure 7.19 Classification of the archaeological *Caprinae/Gazella* metatarsal specimens from Andaqiha against modern specimens based on the first two

discriminant functions using six shape indices. 1: *Pseudois* (Blue Sheep); 2: *Capricornis* (Serow); 3: *Nemorhaedus* (Goral); 4: *Capra hircus* (domestic goat); 5: *Gazella/Procapra* (Gazelle); 6: *Ovis* (wild and domestic sheep). ADQH: Andaqiha specimens.

Four specimens from Andaqiha are available for the analysis with all 11 shape indices (Figure 7.19). The results of the classification are provided in Table 7.14. Five functions are built, and the eigenvalues of the functions 1-5 are 4.629, 3.146, 1.447, 0.312, and 0.108 respectively. The first two functions extracted accounted for 80.6% of the variance, and this analysis correctly identifies 95.2% of the original grouped cases.

As can be seen from Figure 7.19 and Table 7.14, two of the specimens are predicted as *Pseudois* as highest probability and *Ovis* as the second, although one specimen (ADQH1204) fall inside the convex hull of *Ovis* only and another (ADQHF2(2)-18) is inside the overlapping area of the modern *Ovis* and *Pseudois*. The remaining two specimens do not fall within the range of any taxa but are classified as *Gazella* (ADQH509) and *Nemorhaedus* (ADQH505) respectively. All the four assignments are with quite high posterior probabilities.

	LDA1		LDA2
	ID	Prob	
ADQH509	G	0.81	N
ADQH505	N	0.99	G
ADQHF2(2)-18	P	0.97	O
ADQH1204	P	0.80	O

Table 7.14 Classification results of archaeological Caprinae/*Gazella* metatarsal samples from Andaqiha based on the discriminant functions analysis using eleven shape indices. The identification result (ID) of the highest predicted assignment (LDA1), its posterior probability (Prob), and the second highest assignment (LDA2 ID) are provided. G: *Gazella*; N: *Nemorhaedus*; P: *Pseudois nayaur*; O: *Ovis*.

There are four specimens from Jinchankou available for this analysis. As can be seen from Figure 7.20 and Table 7.15, A1716 is identified as *Pseudois*, and three others are clearly identified as *Ovis* (A1925, A1571, A811). The posterior probabilities are all greater than 0.7, which may be high enough to be significant.

Considering that 95.2% of the original grouped cases are correctly predicted in the discriminate analysis, this identification is quite reliable.

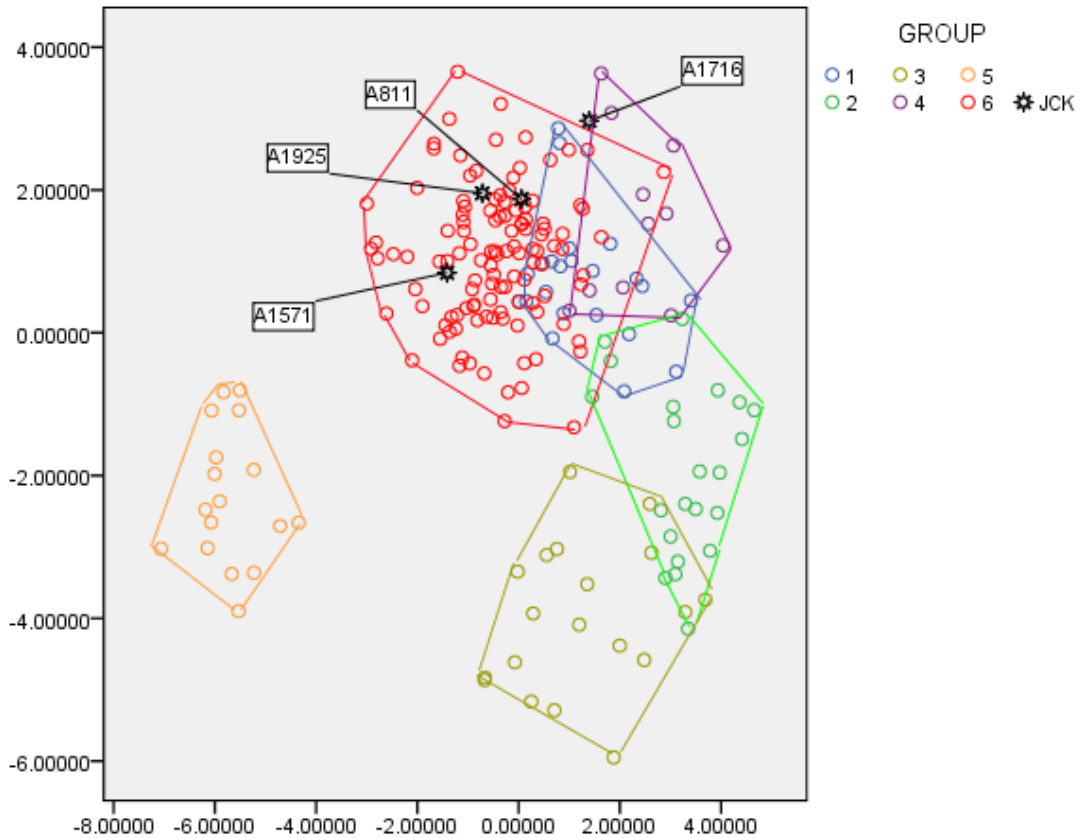


Figure 7.20 Classification of the archaeological Caprinae/*Gazella* metatarsal specimens from Jinchankou against modern specimens based on the first two discriminant functions using six shape indices. 1: *Pseudois* (blue sheep); 2: *Capricornis* (serow); 3: *Nemorhaedus* (goral); 4: *Capra hircus* (domestic goat); 5: *Gazella/Procapra* (gazelle); 6: *Ovis* (wild and domestic sheep). JCK: Jinchankou.

	LDA1		LDA2
	ID	Prob	
A1716	P	0.9	Ch
A1925	O	0.7	Ch
A1571	O	0.99	P
A811	O	0.99	P

Table 7.15 Classification results of archaeological Caprinae/*Gazella* metatarsal

samples from Jinchankou based on the discriminant functions analysis using eleven shape indices. The identification result (ID) of the highest predicted assignation (LDA1), its posterior probability (Prob), and the second highest assignation (LDA2 ID) are provided. P: *Pseudois nayaur*; Ch: *Capra hircus*; O: *Ovis*.

7.5.2 Osteoscopic and Metric Analysis with Ratios

7.5.2.1 Andaqiha

	DabTm/DVm	
	Value	ID
ADQH509	0.75	O
ADQH505	0.71	O
ADQHF2(2)-18	0.60	O/P
ADQH510	0.69	O
ADQH511	0.72	O
ADQH5b2)-21	0.78	O
ADQH1240	0.65	P/O

Table 7.16 The value of the metric data DabTm/DVm and identification (ID) based on these, for the archaeological distal metatarsal specimens from Andaqiha. The identification is made based on the data provided in Götze (1998: p.109, Tab. 13) (referring to Boessneck et al. 1964: 115) to separate *Ovis*, *Capra hircus*, and *Pseudois*. O: *Ovis*, P: *Pseudois*.

According to the metric criteria ‘DabTm/DVm’ in Götze (1998: 107, criteria (5); 109, Tab. 13) and Boessneck et al. (1964: 115), two specimens (ADQHF2(2)-18, ADQH1204) which were identified as *Pseudois* based on shape indices (Table 7.14) were diagnosed here as either *Ovis* or *Pseudois* (Table 7.16). In addition, two specimens (ADQH509, ADQH505) which were diagnosed as gazelle and *Nemorhaedus* were both identified as *Ovis* here. Considering that no comparative specimens of gazelle and *Nemorhaedus* were included in Götze’s study, the diagnosis of *Nemorhaedus* and gazelle of my study should be more valid, but the possibility that they are other wild species could not be excluded.

Specimen	C1		C2		C3		ID
	score	ID	score	ID	score	ID	
ADQH289	2	P/Cpc/N/Ch/G/O	3	P/Cpc/N/Ch/O	3	Cpc/N/Ch/O	Cpc/N/Ch/O
ADQH509	1	Cpc/N/Ch/O	3	P/Cpc/N/Ch/O	2	P/G/O	O
ADQH1182	1	Cpc/N/Ch/O	3	P/Cpc/N/Ch/O	2	P/G/O	O

Figure 7.17 Scored values of the Osteoscopic characters (C1-C3) of specimens ADQH289, ADQH509, and ADQH1182, and the taxonomic diagnosis (ID) based on them. The last column provides the parsimonious identification results based on the three characters.

Based on the scored osteoscopic characters (Table 7.17), the parsimonious identifications of two specimens (ADQH509, ADQH1182) are as *Ovis*, and another one could be any of *Capricornis*, *Nemorhaedus*, *Capra hircus*, or *Ovis*.

A close examining of the osteoscopic characters of ADQH505 clearly identifies it as a deer, because the pronounced sulcus on the coalescence sutures terminates with a clear foramen nutrition, typical of the feature of deer. It shows that deer were sometimes misidentified as Caprinae in the initial sorting of the material.

Some specimens which are only with part of the measurements available are checked against the ratio criteria in this study. The parsimonious identifications for two specimens (ADQH510, ADQH511) were *Ovis*, and one as *Ovis* or *Pseudois* (ADQH1182), while another one (ADQH1718) was identified as *Gazella/Procapra* (Appendix X).

Overall, considering the different lines of evidence, the Caprinae metatarsals of Andaqiha are identified as *Gazella*, *Pseudois*, and/or *Ovis*. Due to the overlapping features between these taxa and imperfect preservation conditions, these identifications cannot be made with a high degree of certainty (See Appendix Y for a summary of the identification based on different methods).

3.3.2.8 Jinchankou

Specimen	DabTm/DVm
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	Value	ID
A1716	0.60	P/O
A1925	0.69	O
A1571	0.69	O
A2081	0.68	O
A2068	0.65	P/O
A811	0.66	O
A925	0.69	O

Table 7.17 The value of the metric data DabTm/DVm and identification (ID) based on these, for the archaeological distal metatarsal specimens from Jinchankou. The identification is made based on the data provided in Götze (1998: p.109, Tab. 13) (referring to Boessneck et al. 1964: 115) to separate *Ovis*, *Capra hircus*, and *Pseudois*. O: *Ovis*, P: *Pseudois*, Ch: *Capra hircus*.



Figure 7.21 Specimen A1716, from House F3, Jinchankou.

Based on the metric criteria in Götze (1998) and Boessneck et al. (1964), five

specimens from Jinchankou were identified as *Ovis* and two as *Ovis* or *Pseudois* (Table 7.18). These results are basically congruent with the diagnosis of the discriminant analysis based on shape indices. One of the specimens (A1716, Figure 7.21) which was identified as *Pseudois* or *Ovis* by Götze criteria was identified as *Pseudois* in discriminant analysis with a very high probability, 0.9 (Table 7.15). Based on the different ratio criteria of this study, another three specimens which could not be analysed using complete 11 shape indices in discriminant analysis were identified as *Ovis* and *Ovis* or *Pseudois* (Table 7.19). Additional checking of the osteoscopic features does not contradict with these diagnoses (Appendix X). In sum, based on the different lines of evidence, the majority of the distal metatarsal specimens at Jinchankou are *Ovis* (e.g. specimen A811, Figure 7.22), and only one is *Pseudois*. No other taxa of Caprinae were identified (see a summary of the identification based on the different lines of evidence in Appendix Y).



Figure 7.22 Specimen A811, from House F4, Jinchankou.

Specimen	DBV/DpBV	1/3	2/5	3/4	ID
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	Value	ID	Value	ID	Value	ID	Value	ID	
A2081	0.92	Cpc/O/P	0.94	O	0.88	O/G	0.68	G/O/N	O
A2068	0.97	Cpc/O/P/N	1.01	P/O	1.02	P/O	0.65	O/Cpc/N/P/Ch	O/P
A925	0.99	N/O/P	1.01	P/O	-	-	0.69	G/O	O

Table 7.18 Values of the osteometric of specimens A2081, A2068, and A925, and the taxonomic diagnosis (ID) based on them. The identification (ID) in the last column provides the parsimonious identification results based on the three osteometrics. O: *Ovis*; P: *Pseudois*; N: *Nemorhaedus*; Ch: *Capra hircus*; Cpc: *Capricornis*.

7.5.3 Absolute Size

The checking of the absolute size does not invalidate the identifications made above.

7.6 Other Elements

Apart from humeri and metapodials, the other elements, including cheek teeth, distal scapula, proximal radius, proximal femur, distal tibia, and first phalanges were also examined based on the osteoscopic and osteometric criteria developed previously and in this study. Again, there are lots of overlaps and limitations in the identification. The preliminary identification results are set out in Appendix Z.

Among the Caprinae teeth identified from Jiangxigou 2, one specimen of upper cheek teeth was tentatively identified as *Nemorhaedus* (Figure 7.23). The form of the cingulum, the labial surface of the paracone, and metacone look identical to the *Nemorhaedus* studied in this project, and similar to some *Capra* found in Georgia at Middle to Upper Villafranchian transitional complex (Bukhsianidze and Vekua 2006).



Figure 7.23 Specimen jxg2-B11-1, identified as *Nemehedus*, from the layer 7 of Jiangxigou 2 (ca. 7,000-8,000 B.C). Scales are in centimetre.

The phalanges could not be correctly analysed without taking into account the differences between the anterior and posterior limbs. However, due to the limitation of my expertise, anterior and posterior phalanges were not successfully differentiated. They are presented in a single category as ‘First phalanges’ in the identification results.

At Shannashuzha, there is one specimen of horn core that could be tentatively identified as *Ovis* (Figure 7.24) and is more likely to be wild Argali rather than domestic sheep. The form of the specimen differs from the domestic sheep in the squared turning counter, which represents part of the original triangle form.



Figure 7.24 Specimen SNSZ1688, from Ash pit H14(2), Shannashuzha. Scales are in centimetre.

7.7 Discussion

In general, the application of the criteria to separate between the different Caprinae and *Gazella* on the archaeological materials has been successful. The following observations are noted:

No single criterion could give a definite diagnosis on its own, and the different approaches need to be used in combination. As already noted, each criterion has its own limitations. The identification results produced by the different criteria are not always

entirely congruent with each other. The imperfect preservation of the archaeological samples is one of the factors which meant that the specimens could not be confidently identified, but the overlaps in the morphology of the various species is clearly another. Therefore, one has to be cautious when applying the different approaches.

There are some very difficult cases in the taxonomic identification, such as to separate *Ovis*, *Pseudois*, and *Capra hircus* from each other, as evidenced in both humeri and metacarpals. The morphologies of these taxa are naturally very similar to each other, and the methods developed by the previous authors and in this study all have limitations. For example, only limited numbers of modern comparative specimens have been studied, and the precision to capture the morphology of the bones could be improved. The unsolved questions need to be sorted out by more advanced techniques.

It has been realised that populations from the different localities and time periods of each species may vary, and the conclusions drawn from one population could not be automatically transferred to other assemblages (Rowley-Conwy 1998). For example, the Andaqiha, Jinchankou, and Shannashuzha distal metacarpals are not comparable to the modern specimens of the Shetland sheep examined by Davis (1996), because the latter is from a single population in modern Britain and it is unknown whether the differences in metrics are due to population variation or another species. It is also not recommended by Payne (1969) to use the diagnostic ratios in his paper to identify every other individual sheep/goat metacarpal condyle. In fact, when the assemblage is larger, the bulk of materials seemed to fall into distinct clusters and can be distinguished (e.g. Figure 7.15), and when the sample is small, it is extremely difficult to identify individual bones with 100% reliability using the criteria based on the comparative specimens (e.g. Figure 7.14).

In sum, this chapter has presented the application of the identification methods reviewed and developed in Chapter 6 to archaeological specimens of humeri and metapodials. Both osteoscopic features and osteometric criteria were found useful. Although limited by the preservation conditions and a small number of both modern and archaeological specimens, the application of the methods was generally successful. These

identification results can be incorporated into the study of animal economy of this area in the next step.

8. The Animal Economy of the Studied Sites

8.1 Introduction

This chapter discusses the animal economy at the five archaeological sites, relying on the identification results of the faunal remains produced in this study and provided by the collaborators. The status of the Caprinae at the different sites will be analysed.

8.2 Jiangxigou2 (c. 10,000-7000 BP)

The faunal assemblage from Jiangxigou 2 is not large. The remains of large fauna are Caprinae, Cervidae, and *Gazella*. These species were identified from the dated stratigraphic layers from 10,000 to 7000 BP (Table 8.1). No identifiable faunal remains were obtained from the layers later than 7000 BP. As presented, the only specimen that can be tentatively identified to a genus is a loose tooth, diagnosed as *Nemorhaedus*. Besides, *Gazella* are represented by an astragalus and a first phalanges (see Appendix S). In general, Caprinae and *Gazella* are more frequently identified than Cervidae. No domestic sheep could be securely identified.

	Caprinae	<i>Gazella</i>	<i>Gazella</i> /Caprinae	Cervidae
7000 BP	1			
7000-8000 BP	1		2	1
8000 BP		2	2	
9400-10,000BP			3	

Table 8.1 Table 8.1 Large fauna identified at the different layers of Jiangxigou 2.

Because of the very limited amount of materials and poor preservation condition, it is only possible to draw a sketchy picture of the animal economy based on the faunal

remains.

Considering the archaeological contexts and other material cultures associated, where there were abundant lithic artefacts, carbonaceous silty loam, charcoal flecks, and fire-affected rock fragments (Hou 2013), the Caprinae, *Gazella*, and Cervidae should be animals intentionally obtained by people from the local environment by hunting and consumed at the site. The site has been interpreted as a long-term base camp with an economic orientation from Epipaleolithic hunting to Neolithic pastoralism/agriculture based on the other materials (Hou et al.2013; Rhode et al. 2007),but the faunal remains do not provide any evidence for domestic sheep.

8.3 Andaqiha (c. 5000 BP)

There are altogether 1196 identified specimens from Andaqiha, weighing about 12.0 kg. Absolute species frequency in NISP (number of identified specimens) was calculated for each context and each phase (Appendix T). It was found that the patterns of the relative species abundance in the different units are generally similar. The majority of the fauna are always those of the Cervidae, followed by Caprinae; possible domestic pigs and dogs account for less than 5%. Other probably hunted animals include *Gazella* (including *Gazella* and *Procarpa*). *Lepus*, *Aves*, and Rodentia all account for a small portion (Figure. 8.1).

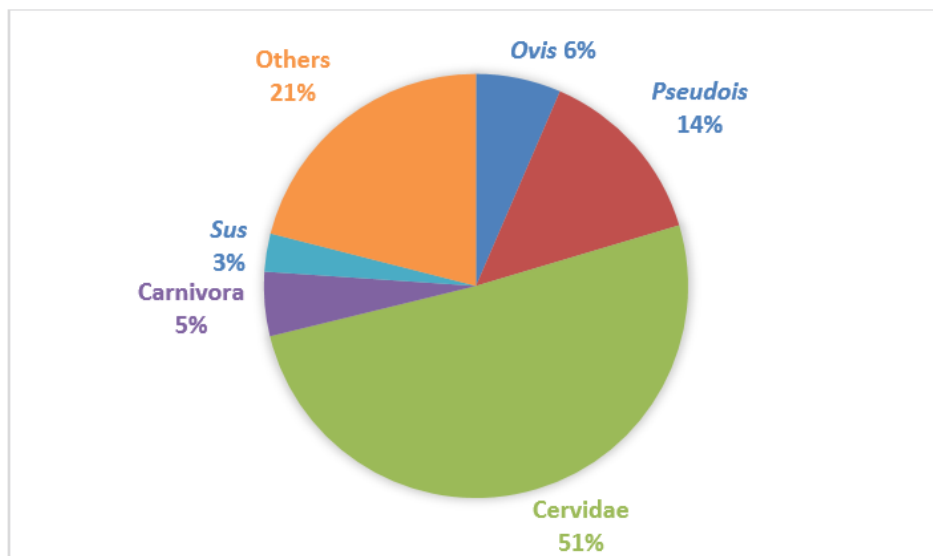


Figure 8.1 The composition of the fauna at Andaqiha.¹⁹

The abundant deer remains found in Andaqiha suggest that they were the major animal group exploited by people here. The management of deer in China has been recorded since the Western Zhou dynasty (ca. 1000-250 BC), where deer were kept in the imperial gardens for the Royals to enjoy (Cheng and Jiang 2009), and it is still practised in China today. However, since deer were not domesticated as other ‘pro-domestic’ animals such as pigs, dogs, cattle in the later times, and there is no other evidence for the management of deer, it is assumed that the Andaqiha deer represent wild animals exploited from the natural environment.

element	<i>Ovis</i>	<i>Pseudois</i>	<i>Capra</i>	<i>Nemorhaedus</i>	<i>Capricornis</i>	<i>Gazella</i>
<i>humerus</i>	2?	12	0	1	0	0
<i>metacarpal</i>	3?	2	0	1	0	0
<i>metatarsal</i>	2?	1	0	0	0	1

Table 8.2 The Caprinae and *Gazella* at Andaqiha identified on humeri, metacarpals, and metatarsals.

Among the Caprinae, as can be seen in Table 8.2, *Pseudois* account for the majority of the identified Caprinae remains, a small number of *Nemorhaedus* and *Gazella* also exists, while no *Capra hircus* and *Capricornis* were positively identified at the site, as argued in Chapter 7. There is a possibility that *Ovis* also exist here, although if so, the number seems to be very small.

Further information about the animal economy at Andaqiha has been provided by a programme of stable isotope analysis carried out by Lelel Ren (任乐乐) of Lanzhou University, whose results have been shared with me. The bone samples analysed were

¹⁹ The proportion of ‘*Ovis*’ and ‘*Pseudois*’ in the total fauna is calculated based their proportion in humeri, metacarpals, and metatarsals (e.g. ‘*Ovis*’ account for 28% in the total Caprinae remains on these three elements, and Caprinae account for 23% of the total fauna, so the proportion of *Ovis* in the total fauna is 23%×28%). The identification results on other elements for Caprinae was not used, because they were approximate identifications taken during the fieldwork and have not been verified.

those most clearly identified. Only the results of the samples with well-preserved collagen are presented here (Figure 8.2, Table 8.3.).

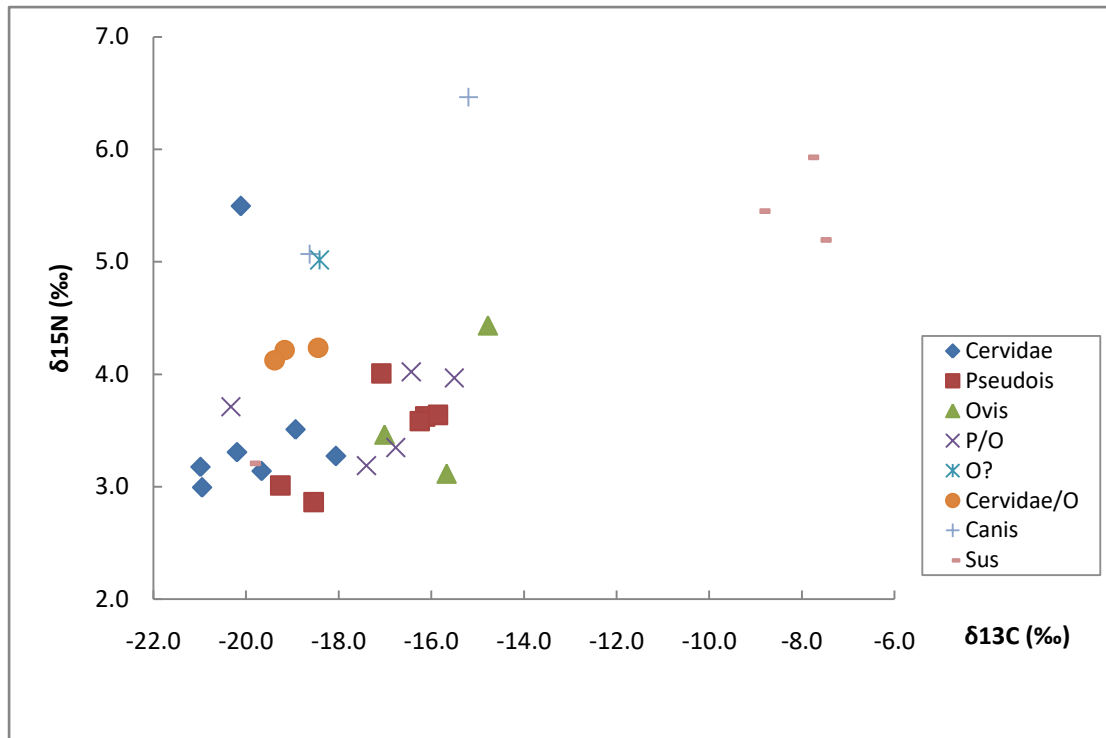


Figure 8.2 Result of stable isotope analysis on selected bones from Andaqiha. Among them, there are some specimens that could not be confirmed to one taxon. “O/P” represents the specimens that may represent *Ovis* or *Pseudois*. “O?” represents a specimen for which it was not clear if it was *Ovis* or not based on the morphology. Cervidae/O represents the specimens that may be Cervidae or *Ovis*. (Data kindly provided by Lele Ren).

First of all, there is a contrast between the three *Sus* specimens and the others in $\delta^{13}\text{C}$ value. The $\delta^{13}\text{C}$ values of the three *Sus* are at -8‰ to -9‰, while the others are lower than -14‰. The interpretation is that the *Sus* were fully domestic animals consuming a substantial amount of C4 plants, presumably to be millet provided by people as fodder.

Second, among the herbivores, there seems to be a differentiation between the deer, *Ovis*, and *Pseudois*, although there are also overlaps between them. Deer exhibit $\delta^{13}\text{C}$ values from -20.99‰ to -18.06‰, *Pseudois* are from -19.26‰ to -15.86‰, while *Ovis* are

between -17.01‰ to -14.78‰. The deer identified in the study include large sized (likely *Przewalskium albirostris*), small sized (likely *Elaphodus cephalophus*, *Moschus chrysogaster* or *Moschus berezovskii*), and medium-sized deer (likely *Capreolus pygargus*). They are mostly browsers, and the diets consist of shrubs, herbs, leaves, twigs, shoots, and bark of trees, bushes, fruits, grass, and lichens (Smith et al. 2010). As discussed in Chapter 4, wild *Ovis* are mainly grazers that prefer grass, but also consume a wide range of forbs and leaves depending on geographical ranges and vegetation available, while blue sheep are also grazers but browse more on shrubs, forbs, alpine herbs compared with *Ovis*. According to a study of the blue sheep at Helan Mountain is that close to the research area, they prefer woodland steppe and the diets are mainly composed of graminoid species (Liu et al. 2007). Whilst the samples are of course extensively small, the $\delta^{13}\text{C}$ values of the three different types of herbivores may reflect differentiation in their food habits, i.e. their overlapping preferences for grazing and browsing.

Specimen Number	Taxon	Skeletal Element	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
ADQH1267 (SI_57)	Cervidae(large)	scapula	-18.93	3.51
ADQH1237 (SI_58)	Cervidae(small)	femur	-20.12	5.49
ADQH1085 (SI_59)	Cervidae(small)	humerus	-20.95	2.99
ADQH1226 (SI_60)	Cervidae(medium)	humerus	-20.99	3.17
ADQH1227 (SI_61)	Cervidae(medium)	humerus	-20.19	3.31
ADQH1208 (SI_62)	Cervidae(small)	femur	-19.67	3.14
ADQH265 (SI_68)	Cervidae (medium)	humerus	-18.06	3.27
ADQH29 (SI_64)	<i>Pseudois</i>	radius	-17.08	4.01
ADQH46 (SI_66)	<i>Pseudois</i>	metacarpal	-16.13	3.62
ADQH1177 (SI_67)	<i>Pseudois</i>	humerus	-19.26	3.01
ADQH1165 (SI_69)	<i>Pseudois</i>	radius	-15.86	3.64
ADQH516 (SI_70)	<i>Pseudois</i>	humerus	-18.54	2.86
ADQH264 (SI_71)	<i>Pseudois</i>	humerus	-16.25	3.58
ADQH475 (SI_63)	<i>O/P</i>	radius	-17.40	3.19
ADQH942 (SI_84)	<i>O/P</i>	metacarpal	-15.51	3.97
ADQH1240 (SI_72)	<i>O/P</i>	humerus	-16.77	3.35
ADQH582 (SI_74)	<i>O/P</i>	metatarsal	-20.33	3.71
ADQH1181 (SI_89)	<i>O/P</i>	metacarpal	-16.43	4.02

ADQH1224 (SI_86)	<i>Ovis</i>	humerus	-17.01	3.46
ADQH43 (SI_87)	<i>Ovis</i>	metacarpal	-14.78	4.43
ADH551 (SI_88)	<i>Ovis</i>	tibia	-15.67	3.12
ADQH584 (SI_77)	<i>O?</i>	tibia	-18.41	5.02
ADQH1168 (SI_73)	<i>Caproleus/O</i>	tibia	-19.17	4.22
ADQH858 (SI_75)	<i>Cervidae/O</i>	tibia	-19.39	4.12
ADQH854 (SI_76)	<i>Cervidae/O</i>	tibia	-18.45	4.23
ADQH664 (SI_78)	<i>Canis</i>	femur	-18.63	5.07
ADQH553 (SI_79)	<i>Canis</i>	mandible	-15.20	6.46
ADQH1068 (SI_80)	<i>Sus</i>	humerus	-19.90	3.21
ADQH923 (SI_81)	<i>Sus</i>	scapula	-7.85	5.93
ADQH540 (SI_82)	<i>Sus</i>	calcaneus	-7.57	5.19
ADHQ541 (SI_83)	<i>Sus</i>	calcaneus	-8.90	5.45

Table 8.3 Result of stable isotope analysis on selected bones from Andaqiha. Among them, there are some specimens that could not be confirmed to one taxon. “O/P” represents the specimens that may represent *Ovis* or *Pseudois*. “O?” represents a specimen for which it was not clear if it was *Ovis* or not based on the morphology. Cervidae/O represents the specimens that may be Cervidae or *Ovis*. (Stable isotopic value data kindly provided by Lele Ren)

In North China, the natural vegetation is dominated by C3 plants and C3 cereals (Auerswald et al. 2009; Gu et al. 2003). C3 plants include almost all trees, shrubs, and cool-season grasses, while C4 plants are mostly warm-season grasses (Sage et al. 1999). C3 and C4 plants have $\delta^{13}\text{C}$ values ranging from -22‰ to -30‰ and -10‰ to -14‰, respectively (Winter et al. 1976). The relative abundance of C4 plants during the mid Holocene was likely to have reached up to 50% to 60% in the southeastern-most part of the Loess Plateau, and 30% to 40% in the northwest, while the modern C4 plant abundance is 10% to 30% on the Loess Plateau (Yao et al. 2011).

As discussed in Chapter 2, enriched $\delta^{13}\text{C}$ values in North China during the mid-Holocene have mostly been interpreted as signals of feeding domesticates with millets as fodder. For example, the pigs at the sites in the Central Plain of the Longshan period (Xinzhai, Taosi, Erlitou, 4050-3500 BP) show $\delta^{13}\text{C}$ values -13‰~-5‰, and are interpreted as being heavily reliant on the feeding of millet by people (e.g. Chen et al. 2012; Dai et al. 2015; Dai et al. 2016). Cattle at the same sites generally show higher $\delta^{13}\text{C}$

values (mean value -12‰ at Wadian, -11.3‰ at Taosi) than sheep (mean value -17.2‰ at Taosi, mean value -15‰ at Erlitou), which is interpreted as that cattle were provided with fodders including millet (Chen et al. 2012; Chen et al. 2015; Dai et al. 2015; Dai et al. 2016; Zhang and Zhao 2015). Sheep at the sites earlier than 6000 BP in the northern part of the Loess Plateau and Wei River Valley were of lower $\delta^{13}\text{C}$ values (-18.9~-19.2‰, N=2, Shihushan; -17.3~-16.9‰, N=2, Wayaogou), interpreted as having a mixed C3 and C4 plant intake (Chen et al. 2016; Dodson et al. 2014). Deer generally show values even lower with means around -20‰ to -19‰ (Erlitou, Wayaogou) (Chen et al. 2016, Zhang and Zhao 2015), interpreted as the characteristic of browsing in open grassland. However, at Xinzhai deer may have been managed and fed with millets by people since seven specimens showed the mean value at -12‰, likely provided with C4 millet foods (Zhang and Zhao 2015). In the western Loess Plateau, the pattern is almost similar to that of the Central Plain. Two Ovicaprid specimens at Xiahaishi (ca. 4000 BP) show values from -15.6 to -12.1‰ (Ma et al. 2013), and pigs at Dadiwan (7560-7160 cal BP; 6500-4900 cal BP) (Barton et al. 2009) show values between -21‰ and -8‰ (N=36).

It is interesting to compare the data of Andaqiha with the data discussed above, although the sample at Andaqiha is of course very small. Andaqiha is geographically close to Xiahaishi on the west loess plateau, and there were slightly fewer C4 plants than on the Central Plain of China in natural vegetations. Millets are also the main crop cultivated at Andaqiha, and there is no rice or wheat found. The three *Ovis* specimens showed the $\delta^{13}\text{C}$ values between -14.78‰ and -17.01‰, similar to that of the Northern Loess Plateau and Wei River Valley earlier than 6000 BP, and are lower than the Ovicaprid at 4000 BP at Xiahaishi. They have generally higher values than blue sheep at the site, which may be interpreted as that they had more C4 plants than blue sheep and even more than deer who foraged mainly in the temperate open woodlands. The differentiation is likely to be associated with the natural habitat of the animals. However, it is also possible that the wild *Ovis* and *Pseudois* had taken some millets (C4 crops) from the field cultivated by people. At Pre-Pottery Neolithic sites in the Anti-Taurus, wild sheep (*Ovis orientalis*) showed

$\delta^{13}\text{C}$ values -21.2‰ to -19.9‰, and early domestic sheep are between -20.3‰ and -19.3‰ (Lösch et al. 2006). Two *Canis* specimens at Andaqiha have much lower $\delta^{13}\text{C}$ values but generally high $\delta^{15}\text{N}$ values, indicating they had higher nutrition level.

In general, it indicates that wild deer and *Pseudois* were commonly exploited; pigs and dogs were domesticated, while some other wild Caprinae and gazelle were also utilized by people.

8.4 Shannashuzha (c. 5000 BP)

There are altogether 10,036 pieces of faunal specimens recorded from the Shannashuzha site, but the number of the identified specimens is not clear. The fauna at the site is also dominated by deer. Pigs (*Sus*) and dogs (*Canis*) were identified in small numbers, suspected to be domestic animals. In addition, large numbers of different species of wild carnivores and rodents are discovered. The faunal taxonomy identified indicates a warmer temperature at the site in prehistory than nowadays (Ren, L. 任乐乐, *pers. comm.* August 2013) and people have exploited a wide range of fauna from the local environment.

Although the exact number of NISP is unknown, based on the excavation area of the site and the information provided by the analyst, the amount of the assemblage of this site should be larger than that of Andaqiha, and the preservation condition of the bones is better. However, the number of the identified Caprinae at this site is much smaller than Andaqiha. Therefore the proportion of Caprinae at this site in the total fauna should be smaller than Andaqiha and might be less than 10%.

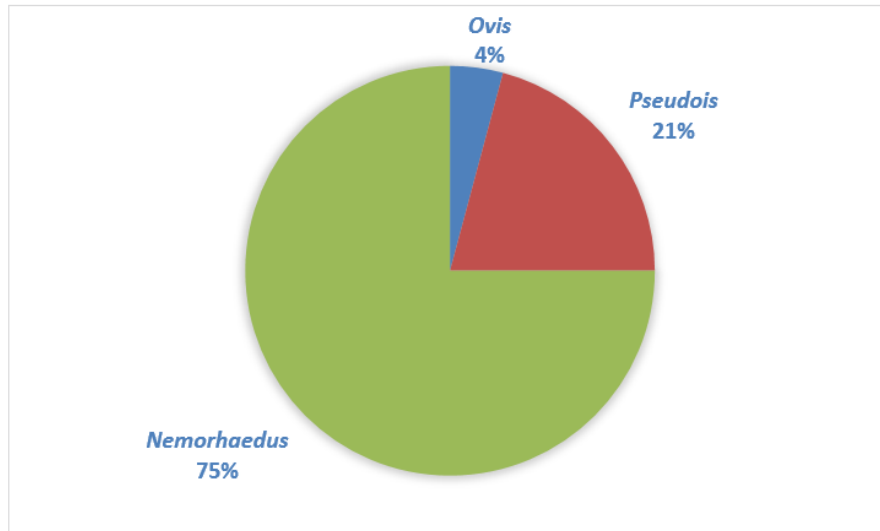


Figure 8.3 The composition of the Caprinae at Shannashuzha²⁰.

As can be seen in Figure 8.3, the Caprinae remains at this site are mostly *Nemorhaedus*, which accounted for about 74 percent. *Pseudois* accounted for about 22 per cent, and *Ovis* accounted for only 4 per cent. They likely to represent wild fauna.

element	<i>Ovis</i>	<i>Pseudois</i>	<i>Capra</i>	<i>Nemorhaedus</i>	<i>Capricornis</i>	<i>Gazella</i>
<i>humerus</i>	0	1	0	7	0	1
<i>radius</i>	0	0	0	2	0	0
<i>scapula</i>	0	2	0	7	0	0
<i>femur</i>	0	1	0	0	0	0
<i>tibia</i>	0	1	0	2	0	0
<i>horn corn</i>	1	0	0	0	0	0

Table 8.4 The Caprinae and *Gazella* at Shannasuzha identified on different elements.

²⁰ The proportion of the differeng genera of Caprinae at Shannashuzha is calculated based on the NISP of all the elements provided in Table 8.4.

8.5 Jinchankou (c. 4000 BP)

There are altogether about 2000 specimens of identified faunal remains from Jinchankou. This faunal assemblage was dominated by deer remains, which include Red Deer (*Cervus elaphus*), Sika Deer (*Cervus nippon*), Siberian Roe Deer (*Capreolus pygargus*), Hydropot Deer (*Hydropot*), and Musk Deer (*Moschus moschiferus*). The total NISP of deer accounted for more than half of the total, and the MNI accounted for about 50 percent. The second most numerous group is Caprinae, of which the NISP account for about 30 percent and the MNI more than 20 percent. Domestic dogs (*Canis lupus familiaris*) account for the third in NISP, at about 4 percent of the total. In addition, bear, fox, racoon dog, marmot, wild boar, medium-sized cats, weasels, and rats are also identified (Li et al. 2014). It was suggested by Li et al. (2014) that hunting of wild animals and pastoralism of sheep are the two major animal economic strategies at Jinchankou.

Although the proportion of Cervidae is larger than that of Caprinae based on NISP, this figure might be exaggerated. As shown in Chapter 7, the majority of the Caprinae at Jinchankou are likely to be domestic sheep. However, the Cervidae group here contains different sized taxa. Smaller sized mammals tend to be under-represented due to the hand collection method and other taphonomic processes. Thus the proportion of Cervidae might be larger than it actually was. Without knowing more detailed information of the different taxa of deer, it might be inappropriate to regard Cervidae as definitely the most important animal group at Jinchankou. It is possible that deer hunting and caprine domestication were both quite important here.

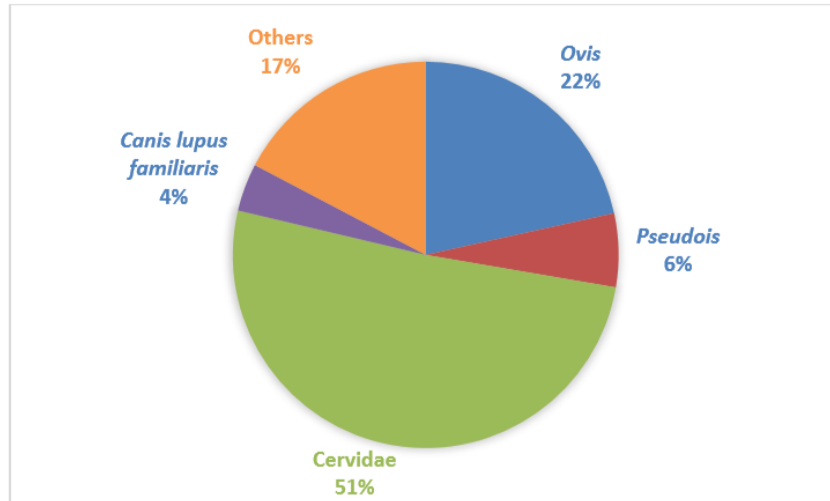


Figure 8.4 The composition of the fauna at Jinchankou.²¹

element	Ovis	Pseudois	Capra	Nemorhaedus	Capricornis	Gazella
<i>humerus</i>	7	1	0	2	0	0
<i>metacarpal</i>	6	1	0	0	0	0
<i>metatarsal</i>	6	1	0	0	0	0
<i>radius</i>	0	2	0	0	0	0
<i>scapula</i>	1	1	0	0	1	0
<i>femur</i>	1	0	0	0	0	0
<i>tibia</i>	4	1	0	0	0	0
<i>phalanx 1</i>	3	1	0	0	0	0
Total	28	8	0	2	1	0
%	72	21	0	5	3	0

Table 8.5 The Caprinae and *Gazella* at Jinchankou on different elements.

²¹ The proportion of 'Ovis' and 'Pseudois' of the total fauna are calculated based on their relative portion in the Caprinae in the total fauna reported by Li (2014) (e.g. Caprinae is reported as accounting for 30% of the total fauna, and 'Ovis' is 72% in the total Caprinae based on my identification, therefore the proportion of Ovis in the total fauna is $30\% \times 72\% = 22\%$).

As can be seen in Table 8.5, the Caprinae identified at Jinchankou are dominated by *Ovis*, being about 72 percent of the total Caprinae and 22 percent of the total fauna. The next largest group is *Pseudois*, being about only 6 percent of the total fauna, much smaller than *Ovis*. *Nemorhaedus*, *Capricornis* and *Gazelle* also present, but very small in number. This site was the first one at which *Capricornis* was identified.

The *Ovis* and *Pseudois* are reversed in their abundance compared to Andaqiha. This might suggest that people had now become more reliant on domestic sheep than on hunted wild *Pseudois* for animal protein. Since *Pseudois*, *Nemorhaedus*, *Capricornis* and gazelle are not domesticated today, and there is also no evidence that they were managed, it seems to suggest that these were wild Caprinae species and never a major component in the animal economy, although hunted occasionally. Although the modern ranges of *Nemorhaedus* and *Capricornis* do not cover this area, the appearance of these animals is clear evidence that their range in prehistoric times extended further to the northwest than today.

8.6 Sanbadongzi (c. 3500 BP)

There are in total 68 identified specimens from Sanbadongzi, weighing 1.72 kg. Based on the number of identified specimens, the Caprinae are the most numerous group, accounting for about 38 percent of the total fauna. Pigs (21 percent), cattle (20 percent), and deer (18 percent) are almost equal amongst the identified specimens. Two horse specimens were identified (Figure 8.4). According to the analysis by Flad (2016), there was also one specimen identified as *Gazella* or *Procapra* based on a fragmentary horn core base.

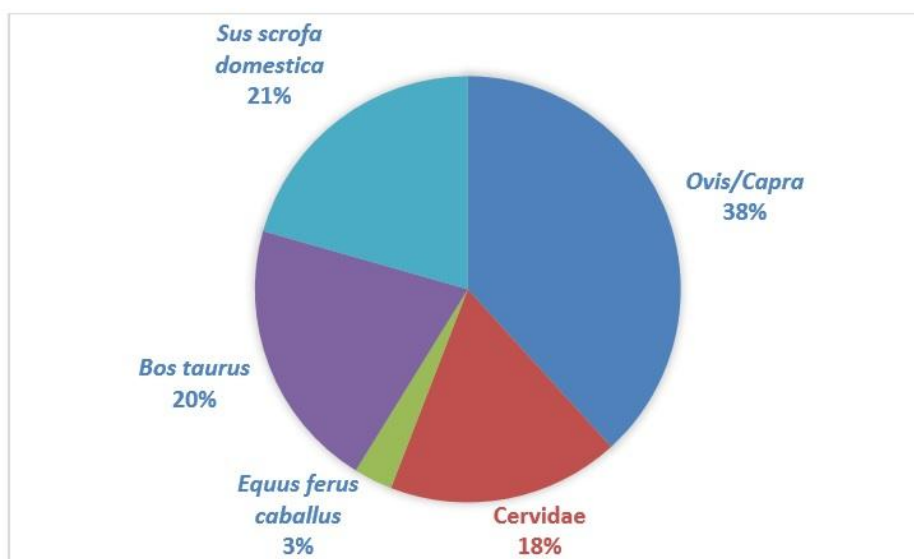


Figure 8.5 Fauna composition at Sanbadongzi²².

Among the Caprinae, all those that could be securely identified to genera are domestic sheep (*Ovis*). No other Caprinae species could be safely identified (Table 8.6).

element	<i>Ovis</i>	<i>Pseudois</i>	<i>Capra</i>	<i>Nemorhaedus</i>	<i>Capricornis</i>	<i>Gazella</i>
<i>humerus</i>	4	0	0	0	0	0
<i>metacarpal</i>	1	0	0	0	0	0

Table 8.6 The Caprinae and *Gazella* at Sanbadongzi on humeri and metacarpals.

In comparison with the spectra of fauna at the earlier sites (Jiangxigou 2, Andaqiha, Shannashuzha, Jinchankou), the fauna at Sanbadongzi are mostly the ‘pro-domestic’ species sheep, cattle, and pigs, the animals known today as domesticated animals in this

²² The proportion of the different fauna is based on my own identification, which diagnosed 26 *Ovis/Capra* (sheep/goat), 12 *Cervidae* (deer), 2 *Equus ferus caballus* (horse), 14 *Bos taurus* (cattle), and 14 *Sus scrofa domestica* (pig). All the others faunal fragments, identified as large sized and medium sized mammals, cannot be identified to genera.

area. As discussed in Chapter 2, this may suggest an establishment of mixed husbandry in the animal economy by this time. Among domestic livestock, sheep/goat is the most numerous group according to NISP, reflecting their importance at least in absolute number. In addition, a small number of horses were kept, likely introduced from Central Asia. As is evidenced at sites of Qijia culture in Gansu and desert-edge cemeteries between 2000 to 1600 BP, horses, trumpet-shaped earrings, cast bronze ring-pommel single-edged knives and axes in steppe styles have appeared in Western China during this time period, exhibiting exchanging of innovations with the west (Flad et al. 2007; Li 2002; Levine et al. 2003; Mei 2003; Yuan and Flad 2006). Deer, probably hunted, accounted for only a small proportion of the general animal economy, indicating that hunting had become less important compared with the earlier periods.

8.7 Conclusion

This chapter has analysed the principal features of the animal economies of the five different archaeological sites, incorporating the results of the taxonomic identifications of the previous chapters. Although the fauna from the five sites studied could not represent a complete continuous archaeofaunal sequence at a single site and are individually small samples, they are derived from a limited geographic area, and the variation in natural faunal composition in the environments is restricted due to the geographic difference. In the final chapter, I review these findings to discuss the possible timing and nature of the transition from hunting to husbandry in the study area.

9. Conclusion

9.1 Introduction

The dissertation started with the introduction of the research question in chapter 1: is it possible to distinguish the morphologically very similar Caprinae in the study area, how were the wild Caprinae exploited and how did that relate to the exploitation of domestic sheep and goats, and whence were the domestic caprine brought in if so, and whence was the Tibetan breed domestic sheep developed and did it relate to the local wild *Ovis ammon*? Chapter 2 overviewed the concepts and the current approaches in the study of animal domestication in the world, and summarized the current research status of sheep and goats domestication in China. The review of current zooarchaeological and genetic research on sheep and goats domestication in China showed that the research in this field is suffering from problems such as faunal data collection, interpretation, presentation, and incorrect identification of different species of Caprinae. The review also identified the key research area and time period --- Qinghai and Gansu Province from Epipalaeolithic to Bronze Age.

After the review of the natural environment and archaeological culture settings of the research area in Chapter 3, Chapter 4 reviewed the taxonomy, ecological and geographical distribution of the animal species in the Subfamily Caprinae in this region. All the possible Caprinae species that are likely to be confused with sheep and goats in zooarchaeological work were recognised, and their habitats described. It was decided in Chapter 5 that the main approach in this project would be to focus on a comparative osteoscopic and osteometric study of the speculative Caprinae and *Gazella* species in Western China and *Ovis* in Eurasia based on the modern skeletons and apply the criteria developed to archaeological materials. The faunal remains from five archaeological sites in Gansu and Qinghai Province ranging from 10,000 BP to 3500 BP were selected for examination.

The study of the osteoscopic characters and osteometry of the Caprinae and *Gazella* based on modern specimens in Chapter 6 showed that there are specific differences as well as overlaps on a series of osteoscopic and osteometric features between the taxa studied,

and some could probably be related to the ecological habitats of the animals. In Chapter 7, the criteria were applied to separate the various Caprinae and gazelles in archaeological materials. Different Caprinae were identified, such as *Pseudois*, *Ovis*, and *Nemorhaedus*, and gazelle. It was found that the methods work better on the assemblages that were preserved well and of a large amount, such as Jinchankou, while it is difficult to diagnose the very fragmented and small amount of assemblage at earlier sites. In Chapter 8, the animal economies at the five studied sites were analysed with the identification results of the different Caprinae and *Gazella* in the general taxonomy frequency.

9.2 The Beginnings of Sheep Husbandry in the Studied Area

The analysis of the faunal remains of the five archaeological sites showed some changes in the animal economy of this area from the early to later periods. It changed from hunting based in the late Paleolithic to domestication of c.3500 BP. There is a shift in the role of Caprinae --- from the focus of hunting to sheep being the most important domesticated animal.

Jiangxigou 2(c. 10,000-7000 BP) very probably represents a mainly hunting-gathering based economy. Although there was likely to be an orientation towards agriculture at about 6000 BP, as evidenced by the increasing proportion of ceramics and the appearance of grinding stones, the faunal remains didn't show any clue of domestication. The only securely identified taxa are wild Caprinae, *Gazella*, and deer, which do not support the suggestion that there was sheep domestication and earliest pastoralist occupation at this site (Rhode et al. 2007). However, the faunal materials analysed from this site are very limited, and all the identifiable ones are from 10,000-7000 BP layers. Thus, it might be appropriate to assume that at least during 10,000-7000 BP, people mainly relied on the hunting of wild animals for animal protein.

At Andaqiha (c. 5000 BP), deer were the most numerous group, and Caprinae is the second. Both domestic pigs and dogs were present. Among the Caprinae remains, *Pseudois* is predominant, and a small number of *Nemorhaedus* and *Gazella* also exist.

Based on the current evidence, it is likely that *Ovis* also present, although further evidence is needed to figure out whether they were wild and/or domestic sheep; the former based on current evidence appears more likely. Deer still seems to be the major animal protein resource for Andaqiha people.

It should be mentioned that Andaqiah is just within the natural distribution of *Pseudois* and *Ovis*, while the range *Nemorhaedus* today covers only Shannashuzha and its border is close to Andaqiha. This may explain why *Pseudois* and *Ovis* accounted for a larger portion of the faunal remains at Andaqiha. As shown in the ethnographic fieldwork in Chapter 4, currently both blue sheep and Argali still exist in Qinghai, with blue sheep being more numerous and more frequently captured than wild Argali. It is possible that these two species were also obtained from the local environment in the past. Unlike Andaqiha, the other site of the similar time period, Shannashuzha, lies just outside the current natural range of *Ovis* and is just on the border of the range of *Pseudois*. Amongst the faunal assemblage of Shannashuzha, there is almost no *Ovis* and only a small number of *Pseudois*, while *Nemorhaeuds* was the most numerous Caprinae group. The difference in the species composition of Caprinae between Andaqiha and Shannashuzha corresponds to the situation of the natural animal spectrum of the local environments.

Jinchankou (c. 4000 BP) marked a change in the development of Caprinae domestication compared with the earlier sites. At Jinchankou, Cervidae is also the most numerous group based on the figure of NISP, although Caprinae might have been also quite important. In contrast to Andaqiha, *Ovis* remains were the vast majority in the Caprinae assemblage and are securely identified as domestic sheep. *Pseudois*, *Nemorhaedus*, and *Capricornis* were also identified but are minorities, likely to be wild fauna occasionally exploited. In addition, domestic dogs were also identified and probably were the partners of people. In sum, at Jinchankou, it has been confirmed that domestic sheep were present and that sheep husbandry was probably of similar importance as the hunting of deer in the animal economy.

The latest site, Sanbadognzi, dated to about 3500 BP, showed a predominately

domestic animal spectrum. Among this, sheep were the largest group, accounting for about 40 percent of the total fauna, followed by pigs and then cattle, and the horse was also identified. The only hunted taxa, deer, decreased in proportion compared to the earlier sites. As a site located in the middle of the Hexi Corridor which is traditionally an important route of the population and cultural exchange with Central Asia, it is likely that horses were imported from the west (Flad et al. 2007; Levine 2003; Li 2002; Mei 2003).

As discussed, it has long been assumed that domestic sheep and goat in China were spread from the West and was accepted firstly in Northwestern China. This research found that within the natural distribution of several Caprinae and gazelle, the different animals were exploited by people, including *Pseudois*, *Nemorhaedus*, *Gazelle*, and quite likely also *Ovis* in prehistory. The appearance of domestic sheep in 4000 BP has been confirmed. Considering that the majority of the domestic sheep today are genetically associated with *Ovis orientalis* of Western Asia, it is likely that the sheep present at Jinchankou have spread from the west a result of cultural exchanges or population movements.

As also assumed before, local Argali sheep were possibly used to develop the breeds suitable for people's needs and the local environment, especially at places such as Qinghai-Tibet Plateau where the natural environment is different from the one that 'normal' domestic sheep adapt to. Considering that wild *Ovis ammon* were likely exploited by people in prehistory and also today, gene flow between the Argali and domestic sheep in prehistory cannot be entirely excluded. However, currently, the evidence in this research is still not robust enough to validate or invalidate this assumption. Further research and more evidence are needed in this aspect.

In sum, the analysis of the Caprinae specimens and general fauna from the five sites showed a shift in the ways of Caprinae exploitation over time. It changed from the hunting of local wild Caprinae to the management of domestic sheep, while *Nemorhaedus*, *Capricornis*, *Pseudois*, and *Gazelle* were always hunted. It is likely that *Ovis* were present by 5,000 BP at Andaqiha, although it is not certain whether they were wild and/or domestic. The confirmed domestic sheep at 4000 BP probably represent a result of cultural

communication from the west. In general, this project supports the “short” instead of the “long” chronology of sheep husbandry in prehistoric China.

9.3 Project Assessment

In this dissertation, the taxonomy, ecological and geographical distributions of the Caprinae and *Gazella* in Western China and *Ovis* in Eurasia, and osteoscopic and osteometric differences between them, have been systematically reviewed and explored. Criteria and methods to separate them were identified and applied to archaeological materials. The general animal economies of five sites from late Palaeolithic to Bronze Age were analysed. The study has helped to reveal a general picture in the shift of Caprinae exploitation and husbandry in prehistoric Western China.

Some archaeological Caprinae materials were found more clearly separated than others, especially when the assemblage is large. Nevertheless, the diagnostic criteria were based on the modern samples, with many overlaps in between the different taxa. They could not help to identify every single archaeological specimen, especially when the preservation condition was not perfect and assemblage was small.

The limitation of the osteomorphological work also includes that not all skeletal elements were studied with enough modern specimens. Apart from humeri and metapodials, of which the osteometric data generally contain 20 specimens or above, all the other skeletal elements were studied with fewer than 20 specimens. Also, due to the original weakness in the design of the working method, not all the specimens were scored and photographed when analysed in the museum collections, hence the number of specimens checked for many osteoscopic characters is hardly sufficient for a rigorous study of this kind. Also, although the differences in the mean values of metric ratios for the different groups seem clear, there are variations within a taxon and lots of overlaps in data/features in between. This is especially true for the closely related taxa, such as *Ovis* vs *Pseudois* vs *Capra*.

9.4 Conclusion

In sum, osteomorphological differences have been discovered between the different Caprinae and *Gazella* species studied, with the cline of osteoscopic and osteometric data found related to the ecological adaptations of the animals. However, there are variations in the osteoscopic and osteometric data of a taxon and lots of overlaps between the different taxa. In addition, the criteria developed in this project are based on limited numbers of modern specimens and could not necessarily be used to identify every single archaeological specimen with one hundred percent certainty. Furthermore, the analysis of the shape does not exclude the influence of allometry. Therefore, more work is needed to corroborate the methods to identify the different Caprinae and gazelle.

The methods were applied to the archaeofauna materials from five sites in Qinghai and Gansu province of 10,000-3500 BP. It was found that the different Caprinae from the local environment were exploited as hunted animals from 10,000 BP. At about 4000 BP, definite domestic sheep (*Ovis aries*) appeared and were the most numerous species amongst Caprinae, suggesting that domestic sheep were an important part of the animal economy. By c. 3500 BP, the fauna was mostly composed of domestic animals, and sheep were the most numerous group in the total animal species spectrum. It is likely that domestic sheep were adopted by people through cultural exchange, although more evidence is needed to find out the route, timing, and mechanism of the spread if it did occur.

In conclusion, this research has provided insights into the details of human-animal interactions at five sites of different time periods at Western China in the past, and has revealed a more complex pattern in the nature of animal domestication involving interactions between the different animal species and human populations in this region of Northwestern China which is transitional both ecologically and culturally. The diagnostic features developed in the comparative osteomorphological study of the Caprinae and *Gazella* species will be useful for future zooarchaeological work in China. The variability among the different *Ovis* species discovered in relation to their geo-ecological distribution

and adaptation may also be useful for zooarchaeological work in other regions of the world in tracing the domestication and migration processes of this taxon.

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