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ANIMAL DOMESTICATION AND OSCILLATING CLIMATES

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ABSTRACT.—Two case studies, one set in western Iran, the other in northern Chile, are described in an effort to reintroduce climate as a factor in the prehistoric adoption of goat and llama herding. This paper focuses on the likelihood of short-term variability in precipitation in these arid regions dramatically affecting game availability in a non-density dependent fashion. The effect is the adoption of domestic stock, a technology of risk reduction, in a context of re-orientation of social values from those associated with hunters to those associated with pastoralists.

INTRODUCTION

This paper presents an argument that irregular short oscillations in climate can be isolated as key variables in two widely separated episodes in the record of animal domestication—one in the Zagros Mountains of western Iran, and the other on the western slopes of the Andes in northern Chile. While climate has often been suggested as an agent in the origins of pastoralism and agriculture, the causative links binding environment and human behavior have been insufficiently specified (Harris 1977:184). Either the link is too diffused, that is, able to predict the onset of herding/farming within a broad regional frame, but incapable of dealing with specific sequences at specific sites, or too straight forward, emphasizing the technological and economic aspects of change at the expense of the social and ideological contexts in which it is imbedded. The existence of these flaws has deflected interest from climate as a primary causative element and in the direction of population pressure models (Cohen 1977). Alternatively, the differences between domesticating and non-domesticating societies have been downplayed (Higgs and Jarman 1972), recasting the Neolithic revolution more as a step than a threshold in human history.

This discussion is aimed at revitalizing climate as an element in the origins of animal domestication. Climate is viewed as a sort of boundary mechanism, a frame that describes the limits within which social and technological options are played. The key to the linkage between climate and domestication is oscillation—the occurrence of erratic short-term environmental variability. I try to show how changes in the distribution and availability of game, that can be hypothesized given our knowledge of the climatic history of each region, discouraged the social and technical institutions associated with hunting and encouraged those associated with pastoralism.

DOMESTICATION

There are two basic approaches to defining the term domestication as a cultural process. The first views domestication as a temporally elongated sequence of technological innovations in the methods of extracting resources from animals (Bray 1976: 90). Each innovation has effects on the selective factors conditioning animal reproduction with the result that domestic stock gradually diverge morphologically and behaviorally from their wild ancestors. Hunting and herding, in this view, are distinct sets of ecological relations. Domestication, or the process of moving from one to the other, is modelled by schemes that view culture primarily as an adaptive system designed to wrest resources from the environment. Commonly these schemes include resource stress as a motivating variable, since domestication is seen as a response involving extra work to solve an economic problem.

The continuum of development in doemstication is usually broken into segments which are labeled with such terms as 'selective predation', 'husbanding', 'semi-domestication', and 'full domestication' among many others (Higgs and Jarman 1972, Zeuner 1963). Many of the segments are associated with expectations, concerning alterations in animal morphology, or the equipment required to manage animals in a particular way, that can be recognized in the archaeological record. Further, each segment or form of man/animal relationship is arranged along another continuum of productive potential with each historical innovation—taming, secondary products, selective breeding—linked to larger yields of animal products.

However, a case can be made that some of the initial steps in the development of pastoralism did not necessarily produce increased yields of animal products. This perhaps surprising statement is based on the behavior of many modern pastoralists. The management goal of these herdsmen is not to maximize production of such commodities as meat, milk, and wool. It is rather to maximize the size of the herd. Any production directed activity such as slaughter, milking, and castration potentially reduces to one degree or another the herd growth rate. Said another way, pastoralists try to avoid taking products from their herds preferring instead to have the maximum possible unharvested resource on hand.

Texts on animal management emphasize the point that the technological features associated with husbandry, most of which serve to minimize the impact on herds of mortality factors other than man, disturb the system of checks and balances within an environment by reducing its diversity and so its resilience. Herdsmen eliminate competing predators such as the large canids and felids and tend to the health and security of their animals. The result is that the pastoral herd can have a population structure that has even more mature animals than a wild herd. In that case a greater proportion of forage is going toward animal maintenance than growth in the domestic flocks compared to the wild herd. Productive potential is actually reduced. The desire of pastoralists to increase their herd sizes also places regional systems at risk through the destructive effect on pasturage of over grazing. Despite this well recognized risk herders tend to continue to expand their flocks in competition with each other, particularly in societies with fragmented, 'family' based, forms of pastoral production (Bates 1973:143). This tendency is at least part of the reason large areas of the Near East have been deforested through over-grazing. It is therefore more accurate to say that pastoralism is potentially more productive. Whether that potential is realized is a separate issue. The question is largely one of whether pastoralists can be induced to cull their herds in such a way as to maximize the number of young growing animals.

The answer depends on the pastoralists' perception of risk. Another primary benefit of pastoralism is the freedom to schedule the extraction of animal products with a certainty not available to hunters. Meat, for example, is available year-round if the herdsman is willing to slaughter one of his animals. However, that willingness is tempered by the realization that, in contrast to the exploitation of plants, harvesting animals does not lead to resource renewal (Ingold 1980). Therefore, in the absence of an institution capable of transforming animal products into a form of wealth or credit, later redeemable for food or other animals, even in times of stress, herdsmen will continue to enlarge their herds to provide insurance for themselves and their dependents. Allen (1977), following Jacobs (1969), suggests that the institution which can serve this function best is the village, a nexus where a wide range of resources may be exchanged. Under these circumstances the productive potential of animal management can be released.

The economic benefit of herding is thus two-fold. The immediate gain is stability, insurance against times of stress. In those cases where a reliable institution of exchange is available, management can lead to greater productive levels. The process of domestication in economic terms, however, is initially one of risk redirection. The hunter's gamble on the availability of game is replaced with the herdsman's worries over disease, predators and stock loss.

The second approach to defining domestication emphasizes the social component of the association between human and animal populations. For example Ducos (1978:54) offers: "domestication can be said to exist when living animals are integrated as objects into the socio-economic organization of the human group, in the sense that, when living, those animals are objects for ownership, inheritance, exchange, trade, etc., as are the other objects (or persons) with which human groups have something to do." Domestication in these terms is a social process, a transformation of the rules that structure not just animal populations, but human groups as well. For animals the transformation is primarily one of taming (Hediger 1968:108). When more than one animal is included, it also involves the restructuring of the age and sex distributions of their groups with resultant alterations in social behavior. For human groups the social transformation moves along two paths. The first path establishes specific bonds between individual domesticators and individual domesticated animals—a process that encompasses petkeeping, the use of animals for labor, and milk production. Alternatively, the transformation establishes bonds between populations of domestic animals and populations of domesticators with a blurring of the ties that bind any two individuals together. This second path is associated with what Ingold (1980) has called carnivorous pastoralism, or, on a more elaborate scale, ranching. Neither axis necessarily presupposes the other, and the order of appearance is probably due to the migratory habits of the animal involved—the more migratory, the more likely the first will precede the second, the less migratory, the second may precede the first.

Each of the paths is associated with different human emotional relationships to animals. For instance, Bennett (1964) examined the attitudes of farmers and ranchers on the Great Plains who were raising cattle for meat. He observed that "when animals are herded in fairly large numbers . . . utilitarian attitudes toward the animals tend to become dominant" (p. 37) and "attitudes toward cattle contain almost no element of sympathy or compassion, and very little tendency toward the establishment of relationships between single men and single animals" (p. 42). This attitude contrasts strongly with the affectionate or sentimental relationship that describes the bonds of these ranchers with their horses and dogs, or milkers with their dairy animals.

A difference in attitudes along the two paths also exists in the realm of social structure. Domestication that forms individual bonds is associated with the use of animals for cementing social ties. The cattle of African pastoral systems, which are used for milk and blood production, bear the load of establishing complex intersocietal links, where goats, which are raised primarily for meat, do not (Ingold 1980:186).

The social and ideological factors associated with domestication can also be contrasted with those of hunting groups in a broad way. Ingold (1974, 1980) and Paine (1971) have isolated several important contrasts. First, hunting groups tend to have undivided access to the animals they hunt. The hunting territory and the animals it contains, in other words, are viewed as shared resources though buffer zones between hunting groups may be present (Hickerson 1965). Second, hunting groups tend to have complex redistributional rules that extend outside the family and insure the maximum dispersal of food. These rules for game need not extend to gathered resources. Third, for hunters, expertise in the chase is the important source of prestige. Prestige is not generated by possession of the kill, but by the right to distribute it (Paine 1971: 158). The unit of production is corporate.

Herders, on the other hand, divide access to the resources. The production unit and the circle of redistribution is subsocietal. Prestige is generated through the number of animals held. Successful herders are disinclined to gather dependents around them (as hunters often do), since it would ultimately require division of the source of prestige (and insurance against hard times), the flock. Pastoralist groups are, therefore, more rigid as the individual entrepreneurs balance stock levels with staff to maximize their positions. Explaining the origins of domestication on the social level may therefore be

characterized as offering a plausible solution to the problem of why the concept of value is shifted from a focus on a hunter's skill rather than his property, to a focus on a herdsman's property rather than his skill in accumulating it.

Modeling the Process of Animal Domestication

The process of domestication thus operates in two spheres—productive systems and social institutions. A successful model must explain the transformation in each that is brought on by the shift from hunting to pastoralism. Here I will consider one possible pathway.

Climate change can affect the structure of productive systems by altering in a non-density dependent way the availability of various plant and animal resources. As such, climate has been included among the considerations involved in resources stress explanations for the origins of plant and animal domestication (Binford 1968). Resource stress acts to cause the evolution by creating an imbalance between residents and food supply. Climate change is an efficient factor in this regard because it is non density dependent and does not allow productive systems to adjust their demand requirements in response to the stress. Population pressure is less efficient since predator-prey (or hunter-hunted) relationships are density dependent. That is, the rate of the hunter's kill is proportional to the availability of game. Most predator-prey interactions tend toward either equilibrium points of population abundance or stable limit cycles where the population levels of predator and prey traverse a loop of positions. In either case the density dependent nature of the relationship tends to buffer any population pressure unless an intrinsic rate of population increase for the predator can be hypothesized.

Resolution of the stress can take three forms—abandonment of the region, shifting to alternate resources that are unaffected by the climatic change or changing the mode of production to more efficient forms, or, at least, ones resistant to the particular form of stress. Since we are interested here with the third of these options, it is useful to speculate on what conditions would work against selection of either of the first two. The second option, turning to new resources, would be foreclosed in an environment where all the resource options were being restricted by the climate change. This would be particularly likely in arid or semi-arid ecosystems where the number of herbivore game alternatives is much restricted. The first option, abandonment, would be less attractive when the stress factor was of short or intermediate duration: that is, when experience had taught the residents that bad times tend to be brief, and that game levels will rebound in a relatively brief time. This would be true especially when the game species involved have high natural herd growth rates and when their mortality is not primarily conditioned by density-dependent factors like predators. To summarize, under conditions of short range resource stress in a simplified ecosystem, the option of husbandry or pastoralism appears to be an attractive way to buffer food supplies.

The other side of the problem, how resource stress can act on social institutions to bring about the change in values outlined previously, has been discussed by Ingold (1974:527) with respect to Lappish reindeer specialists:

> Traditionally, Lappish reindeer hunting and fishing groups were organized on a territorial *(siida)* basis. The territory, together with its resources, was viewed as the joint property of the group. As long as these resources were perceived to be quite sufficient to maintain the traditional hunting economy, they "should be regarded as capital in an emic and extra-economic context" (Paine 1971:169). Heuristically we may suppose that increasing scarcity of wild deer would assign to the deer a strictly economic value over and above that of the territory itself.

Placed in the context of resource stress, once climatic variation had reduced game levels to point below which even the greatest hunter could not count on success, value and prestige would come to be attached to the possession of game itself. This shift is also a root

of the different perception that hunters and herders have of their resources. Hunting groups share access to the animals they rely on for food, herding groups divide access to them. During periods of stress those hunters who also possessed tame animals would be in a strong position. Reliance on the offspring of these culturally controlled animals during periods of resource stress would establish the pattern of numerous independent pastoral units within the society, since the axis of taming binds individual animals to individual herders rather than populations to populations.

To return to climate, insofar as people would expect that game levels were likely to continue to oscillate due to unpredictable environmental changes, they would be encouraged to establish insurance herds against this certainty. Groups caught in this pattern of resource oscillation would experience conflicts both between alternative views of property and prestige, and between modes of production based, on the one hand, on shared access to the resources, and on the other, divided access. These tensions would be likely to persist until the disruptive effect on uncontrolled pastoral herd growth effectively eliminated wild game as a resource alternative. Because of the tension, transitional occupations are likely to be rare in the archaeological record, and pastoral management systems will seem to emerge suddenly from hunting societies.

The Mahidasht Region (Fig. 1)

The Mahidasht or the valley regions near Kermanshah, Iran (Levine 1976:487) has been the scene of investigations into the origins of domestication and settled village life since the 1950's. It is part of the Zagros mountain system, a northwest-southwest trending band of rugged terrain in Iraq, Iran and Turkey that is crosscut by a complex drainage system. The joint effect of these physiographic factors has been to produce a topography characterized by independent valley systems connected by narrow and precipitous defiles (Oberlander 1965). The valley floor of the Mahidasht is located at an altitude of approximately 1350 m. The region overlaps two important vegetational zones—the oak forest and the almond/pistacio savannah. The area was occupied during the Pleistocene with samples reported from such sites as Warwasi (Turnbull 1975), Bisitun Cave (Coon 1951), and Ghar-i-Khar (Young and Smith 1966). Until recently the only known early Holocene sites were Sarab, Asiab (Braidwood et al. 1961) and Tepe Ganj Dareh (Smith 1978). However, a recent survey by Smith and Mortenson (n.d.) suggests that condition is an

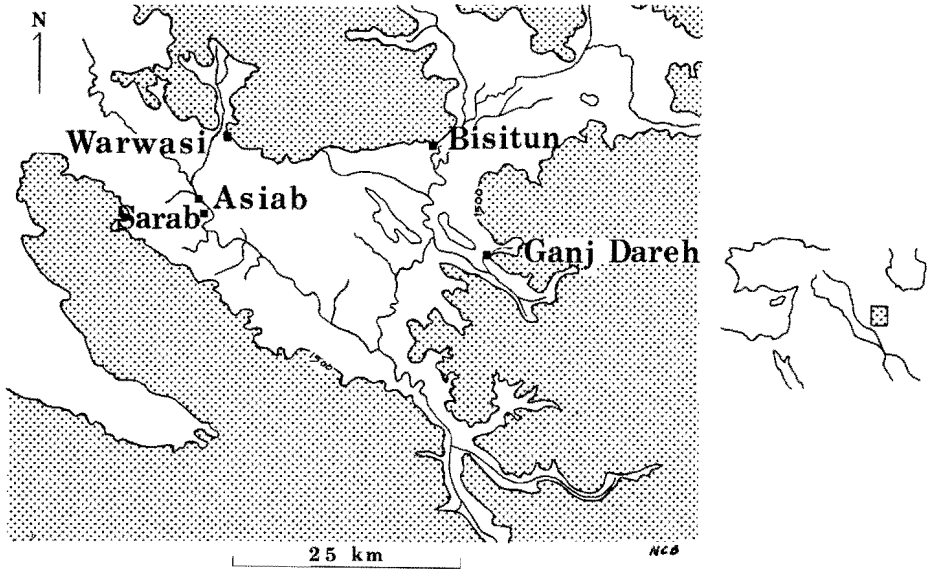

FIG. 1—Location of late paleolithic and early neolithic sites in the Mahidasht region of west-central Iran.

artifact of concentrating the search for sites primarily on the alluvial plain. In their survey, three new sites of early Neolithic character were discovered, all located in narrow "nearly inaccessible valleys" within two or three hours walk of Tepe Ganj Dareh. On the basis of this discovery, they suggest that the initial steps toward sedentary life, pastoralism and agriculture, took place in the small, ecologically diverse valleys surrounding the Kermanshah Valley.

The earliest evidence of animal husbandry comes from the site of Tepe Ganj Dareh, excavated over five seasons by Philip E. L. Smith of the University of Montreal. On the basis of radiocarbon determinations, the site was occupied in the eighth and perhaps ninth millenium B.C. The site contains five superposed occupations. The earliest, labeled Level E, is characterized by a series of basins excavated into culturally sterile soil, no evidence of permanent architecture, and some indication that the site was occupied seasonally, probably in the spring (Hesse 1979). The upper four levels, D - A, contain mud-brick architecture, ceramic storage facilities, and stone mortars and a few fragments of pottery. Evidence for animal husbandry is of two sorts (Hesse 1978). What seem to be goat footprints in some of the bricks from Level D argue that tame animals must have roamed the village. The harvest profiles, estimates of the age and sex of the slaughtered animals, and, therefore, evidence of the system of production, calculated for Levels E and D - A contrast. On the basis of mandibular tooth wear (Payne 1973), the proportion of young sheep and goats (12-24 months) slaughtered during the architectural phases of the occupation increased compared to the earlier material (see Fig. 2). Considering the two species *(Ovis orientalis* and *Capra aegagrus)* separately, on the basis of the relative frequency of fused long bone epiphyses, it appears that only the harvest pattern for the goats changed. Using the fact that goat sexual dimorphism is reflected in the dimensions of many of the bones of the skeleton, it was possible to create individual harvest profiles for both bucks and does (Hesse 1982a, following the suggestions of Higham 1968). The harvest profile for Level E compares favorably with the age and sex proportions found in a wild goat nursery herd—an almost total absence of mature males in a sample dominated by male and female kids and mature females. Tepe Ganj Dareh Level E is roughly contemporaneous with Asiab (Bökönyi 1978) where mature males dominate the samples. When compared, the samples produce a picture of seasonal hunters exploiting sub-populations of goats, taking those age and sex categories that would be expected to be nearby each of the sites based on the seasonal topographic preferences of the species. Tepe Ganj Dareh Level D, on the other hand, has a harvest profile for goats that agrees with the slaughtering patterns of pastoralists—a reduction in infant mortality and elimination of does which fail to kid (Bates 1973:147).

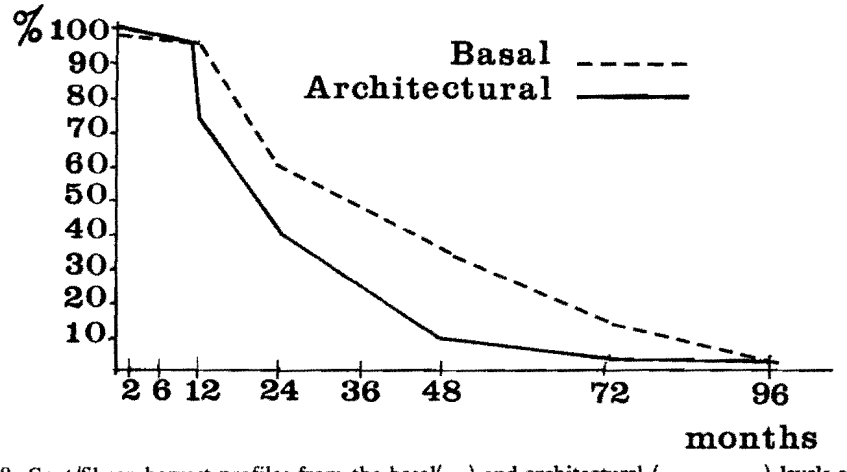

FIG. 2—Goat/Sheep harvest profiles from the basal(—) and architectural (————) levels at Tepe Ganj Dareh. The curves represent estimated percentage survivorship at the ages indicated and are based on tooth wear (Payne 1973).

To draw climate into the discussion about this episode of animal domestication, two observations about the early Holocene environment of the Mahidasht need to be made. First, the evidence suggests that the diversity of the herbivore fauna was reduced from Pleistocene conditions. The faunal samples from Warwasi and Bisitun indicate that Pleistocene subsistence was based on a mix of equids, red deer, gazelle, sheep and goats. In the Holocene, however, equids are absent from Tepe Ganj Dareh, as well as the three new sites discovered by Smith and Mortensen, and present in only very small quantities at Asiab (Bökönyi 1978:6). It is not unlikely that the growth of an oak/pistacio forest on the western slopes of the Zagrow may have been partially responsible for this. Onagers, gazelles, sheep and goats are not well adapted to wooded conditions. Some forms of sheep and goats, in fact, show a marked reluctance to enter forested regions (Geist 1971). In fact, the development of this vegetational pattern may have been an important determinant in creating the distribution of sheep phenotypes in modern Iran (Valdez et al. 1978). However, sheep and goats are vertical rather than horizontal migrators (Formozov 1969). As such they can adapt to seasonable variations in climate by utilizing steep gradients in relatively small areas, rather than moving across extensive tracts of open country. Equids are not so adapted. They tend to migrate significant distances in regions where rainfall is seasonal (Klingel 1974:130). Male equids maintain large territories which they dominate through their visual presence (Ibid.:127). Of all the equid species the least known is the Asiatic wild ass or onager likely to be represented in the Mahidasht samples. However, Clabby (1976:34) notes, "all races of the Asiatic Wild ass prefer the unrestricted views and wide expanses of the open country where their alertness and speed give them maximum protection."

Equids, of course, did not disappear from southwest Asia. What I suggest is that by interfering with migratory routes, the vegetational changes that accompanied the early Holocene caused a rearrangement of faunal communities. The new faunal distributions were zoned, with the foothills on either side of the Zagros mountains supporting the open country herbivores (equids and probably the gazelles), while the mountainous regions were occupied by sheep and goats, species that could successfully exploit islands of rugged terrain in a growing forest. This trend would have forced the occupants of the Mahidasht to specialize more and more on caprines as modern climatic conditions emerged.

Our knowledge of post-Pleistocene climate suggests factors that could induce variations in the remaining game biomass. Biomass is linked to variations in annual precipitation. If the regression equation published by Coe et al. (1976:348) based on twelve African ecosystems is taken as an estimate of the trend of change (not an estimate of actual biomass) expectable in the dry conditions of the Zagros, the modern range of annual rainfall for the Mahidasht (378-490 mm) translates into a 25-30% variation in biomass.

Van Zeist (1969) indicates that early Holocene rainfall was greater than Pleistocene levels, but was concentrated more seasonally, while mean temperature was lower in the period than today. A study of the alluvial deposits in the Mahidasht suggests that the precipitation that did occur in the early Holocene would have been stormier than today (Vita-Finzi 1969). Bobek's (1963) study of Zagros snowlines reports that they oscillated several times during the Holocene. From these observations I tentatively conclude that Holocene conditions in the Mahidasht were characterized by irregular and violent weather. The cooler temperatures implies that much of the precipitation fell as snow.

The serious effects that snowfall can have on sheep or goat populations has been discussed by Formozov (1969). Both snow depth and *nast*—a hard icy layer formed by conditions of repeated melting and refreezing—prevent animals from getting at forage. The most disastrous effects occur when the heavy snowfalls come late in winter. Then it compounds the problems of already exhausted animals and is particularly devastating to the new born. The picture is clear in the following passage, which describes conditions in a region to the north of the Mahidasht.

> In the previous hard winters, many of these animals perished from lack of food, and those remaining alive were greatly exhausted by hunger, and they became the prey of wolves. Radde (1862-1863) showed that the snowy winter of 1831 destroyed the remaining Trans-Baikal mountain sheep . . . which had previously suffered persecution by man. "The destruction of such large and strong animals as argali by this winter proves that nowadays, because of various conditions in which man is completely innocent, even species of large animals can become extinct at least locally." (Formozov 1969:63).

The fact that snowfall can seriously affect sheep populations was emphasized by Murie (1944:65-67, 87-88). Murphy and Whitten (1976) have been able to plot the relationship between snowfall and population levels for the Mt. McKinley Dall Sheep. They conclude that every major population decline is associated with an episode of heavy snow. The ability of these animals to revive from near extermination lies in their high natural herd growth rates, and their relative invulnerability to predators. In fact, the sheep populations studied by Murphy and Whitten experienced several cycles of population growth and decline in the fifty years their data covers. Local oscillations in density are unlikely to be overcome by migrations since sheep and goats are vertical migrants, exploiting botanical successions in precipitous habitats. They show a considerable attachment to home ranges and population exchange between habitats is slow. While these reports have dealt specifically with sheep, it is reasonable to assume that similar patterns would characterize the Near Eastern wild goat, since it seems to be a behavioral analog of New World sheep. Also, the descriptions for Alpine Ibex (Nievergelt 1966) and Bezoars (Schaller 1977) suggest broad similarity between the species.

While the evidence is circumstantial, I believe that it is a reasonable conclusion that the Holocene occupants exploiting the goat habitats fringing the Mahidasht experienced recurrent oscillations in game availability. These oscillations probably took place within the lifetimes of single individuals. This led to two related changes—a need to adapt the mode of production to include the provision of an insurance herd, and a shift in the way resources, prestige, property and the social unit of production were defined.

What could have been the origin of the insurance herd? One explanation (Bökönyi 1973) is that hunters would have simply captured herds, tamed them, then herded and husbanded them. The difficulty with this sort of model is that it is hard to see how the captured herd could be divided among the households of the community as individual properties to form the basis of competing rather than cooperating productive units. In Ingold's (1980) discussion of the origins of pastoralism, the argument is presented that the insurance herd is not bred directly from hunted animals, but are the offspring of tame animals already incorporated into the households. As the property of households, when the insurance herd was used as food during periods of resource stress, it would fall under different redistributive rules than hunted animals in which all members of the band had a stake. In the case of reindeer pastoralism, which is the subject of Ingold's treatment, the source of the tame household animals was the need for transport stock to move the camp along the nomadic round.

Whether a parallel existence of tame household goats in preneolithic Zagros communities can be demonstrated is problematic though some morphologically domestic goats are present at Asiab (Bökönyi 1973). However, the bulk of the slaughtered animals do not seem to have been herded (Hesse 1982a). Three speculations might be offered. First, the footprints found in the Level D bricks suggest that some adult Caprini were highly socialized in the Tepe Ganj Dareh community during the development of pastoralism. Two tentative functional explanations for their presence can be offered—as ritual animals as suggested by the use of horn cores *(Ovis orientalis)* as decorative devices, or as producers of dung for fuel, the nature of their droppings being such that it can only be effectively collected when the animals are penned together. Either, admittedly unsupported, suggestion would place an insurance herd in the Tepe Ganj Dareh community under different conditions than hunted animals.

Rapid increase in the insurance herd, and goats can increase at a rate of 33% per year (Dahl and Hjort 1976:231), would lead to ecological destabilization, reorientation of social priorities, and the establishment of the pastoral way of life.

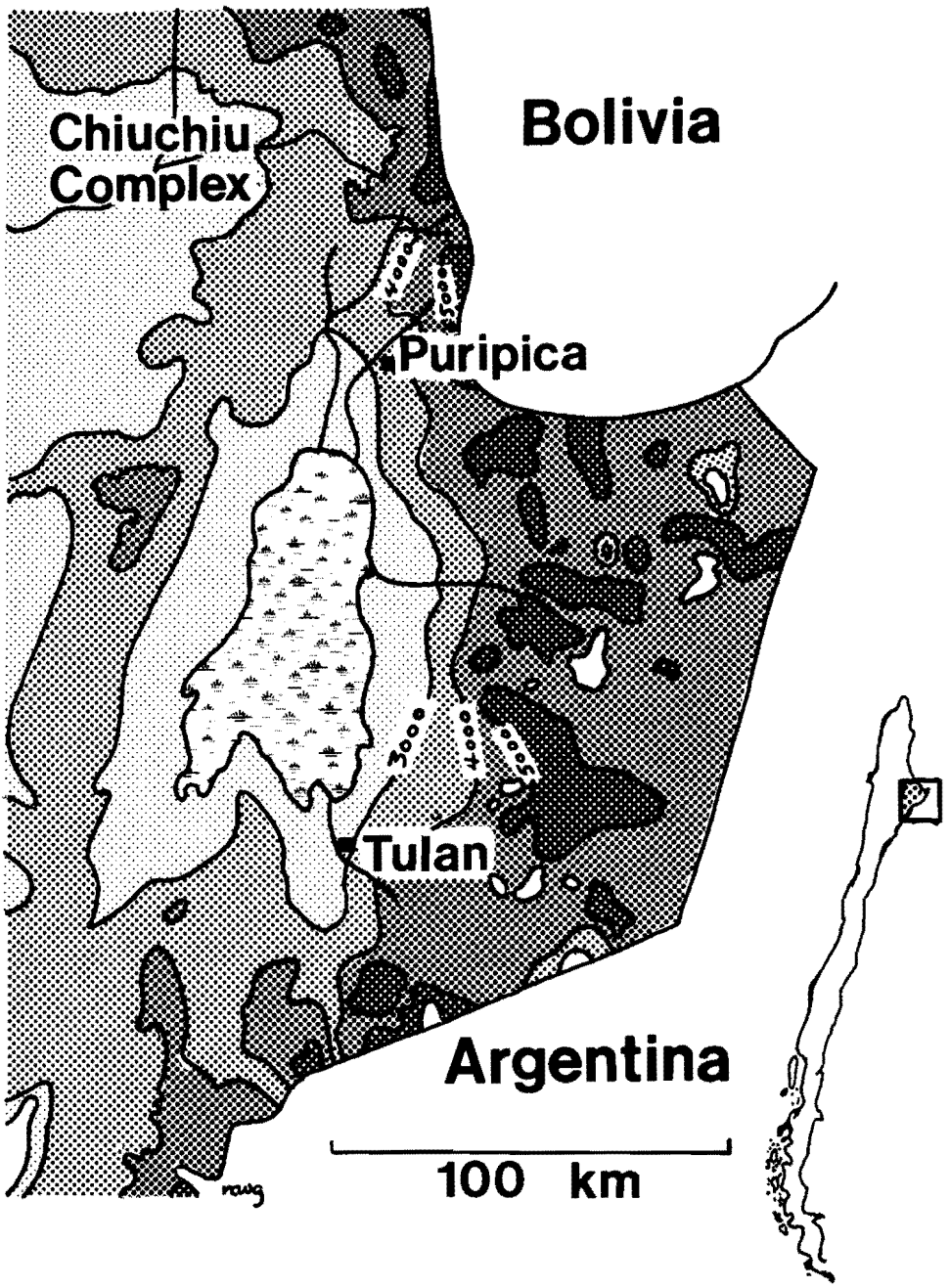

FIG. 3—Location of third millenium B.C. sites in the Salar de Atacama region of northern Chile.

The Salar de Atacama Region

The second case study concerns the arid mountainous regions bordering the Salar de Atacama in northern Chile. The study region, which is centered around the town of San Pedro de Atacama contains three broadly defined habitats. The first of these is the Salar, a basin with a floor located at an elevation of approximately 2500 m. Above 4000 m is the Puna de Atacama, a rugged area dotted with lakes that are the habitat of several varieties of flamingo. According the Núñez and Dillehay (1979:39-40), this region should not be considered similar to puna regions to the north in Peru. They emphasize the harsher nature of the more southerly climate, the more dissected nature of the terrain, which is dotted with volcanoes, though both areas share general climatic instability (Winterhalder and Thomas 1978). Between the puna and the salar is a sloping region cut by a series of small canyons through which water flows year round. Between these canyons the slopes are extremely desertic at the lower elevations, though they do contain important resources including raw material for stone tools.

The earliest occupation of the region that is known from excavations is represented by the sites of Tuina, located to the north and west of the Salar, and San Lorenzo, located to the east, both of which have radiocarbon determinations indicating habitation in the eighth and ninth millenium B.C. Following the occupation of these sites there is a hiatus, possibly brought on by volcanic activity (L. Núñez, personal communication), until approximately 3000 B.C.

The herbivore resources of the Atacama region are more restricted than what is found in the more watered regions to the north. None of the fourteen sites in the region which I have studied have any deer remains. Only one fragmentary metopodial is known from the Chiúchiú complex located just to the north (M. Druss, personal communication). Meat supplies were procured through the exploitation of camelids with supplements obtained from rodents like the viscacha, chinchilla, and tuco-tuco, and birds including the flamingo, the Andean goose and the tinamou. The relative frequency distribution of the remains of these species in the various quebrada and salar sites indicate clearly that the hunting techniques of their occupants were finely tuned to the biological subtleties of the region.

The study of the origins of pastoralism in the Andes has been stymied to some degree by the difficulty of separating the archaeological remains of the various species of camelid. The two basic wild forms (ignoring for the moment, the complexities of that paleontological issue), apparently diverge somewhat in habitat preference, diet, and social behavior (Koford 1957; Raedeke 1977; Rick 1980). The vicuña tends to higher altitudes, has a more rigidly defined territorial system, and prefers grasses, whereas the guanaco is a browser with a looser social structure that occupies somewhat lower elevations. In terms of the Atacama region, vicuña would be common in the puna, guanaco in the quebradas. Because of these behavioral divergences, it is reasonable to assume that hunters would employ somewhat different strategies in killing them. The unfortunate result of this line of reasoning is that unsegregated archaeological samples will tend to mix the evidence of different human behaviors. Wing (1972, 1977), however, has shown that the size difference between the two species can be used to separate archaeological remains. In the samples from the Atacama considered here, that fact was utilized to interpret the bimodal tendency in the distributions of measurements of foot bones (Hesse 1982b). With the faunal collections separated in this way it was possible to detect a contrast in harvest profiles that indicates pastoralism involving only the larger form (Fig. 4).

The sites of interest are Tulan-52, one of a cluster of Archaic sites located just below 3000 m along a quebrada leading to the south and east of of the salar, and Puripica-1, located at about 3200 m above a canyon that leads to the north and east (Núñez 1981).

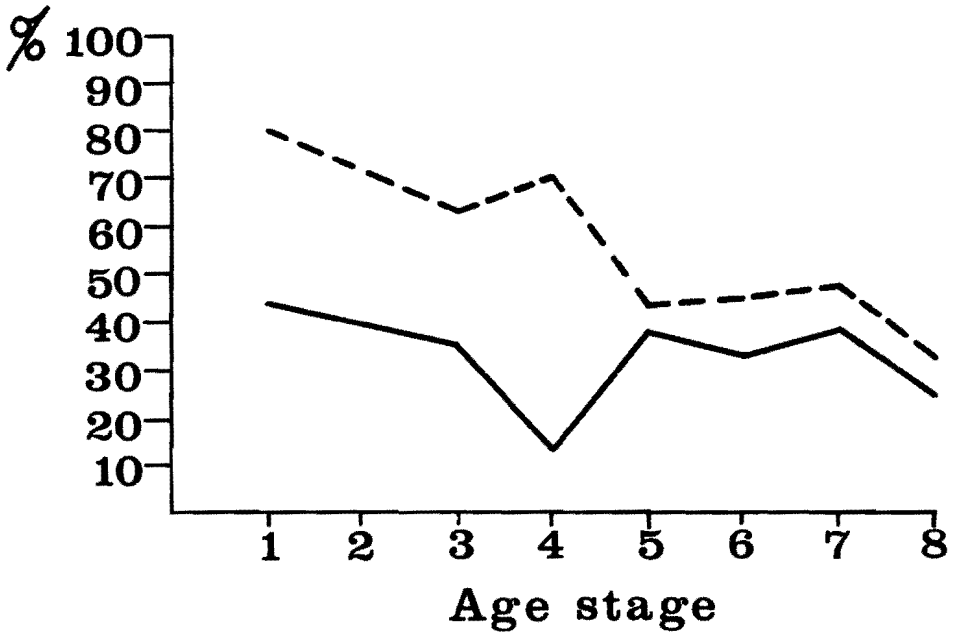

FIG. 4—Camelid harvest profiles from Tulan-52 (---) and Puripica-1 (————). The percentage survivorship is plotted against a series of relative age stages following the suggestions of Wing (1972).

Radiocarbon dates for each site suggest occupation during the mid to late third millenium B.C. The assemblages from both sides include simple stone shelters and mortars. In the case of Tulan-52, it is estimated that there were about 30 semi-subterranean dwellings; in the case of Puripica-1, 40-50. The lithic assemblage from Tulan-52, however, has a higher proportion of projectile points. The excavations at Puripica-1 produced a series of petroglyphs depicting camelids. Both sites contained a mixture of large and small camelids (presumably guanacos and vicuñas). The vicuñas, however, were represented almost exclusively by toe bones. I would suggest that this represents butchering of these small camelids at some distance from the sites, probably reflective of the facts that vicuña territory would have been located at some distance above the sites and only the skins were being imported. A similar interpretation has been drawn by Rick (1980:273) and Simons (1980) for samples that probably contain a mixture of large and small camelids. The majority of these animals were mature at death, at least based on the percentage of fused phalanges, a harvest profile in keeping with wild herd demographics (Hesse 1982b). The harvest profiles for the guanacos, on the other hand, contrast between the two sites, with a much greater proportion of the Puripica guanacos being taken young. More specifically, the shift to this emphasis on young large camelids occurs between levels III and II in the occupation. If young kill is accepted as evidence for domestication (Wing 1972, 1977), I suggest that this shift implies the transformation to pastoralism. It cannot be determined with the evidence at hand whether this adoption represents indigenous taming and domestication of Atacama camelids or import of stock from regions to the north where pastoralism is much earlier documented. Nothing in the archaeological record for the site, however, argues for extensive extra-regional contact.

How is climate involved in this? Two factors stand out. Snowfall on the puna has been identified as a significant cause of camelid mortality. Koford (1957:164) alludes to the effects of snow and hail which is particularly frequent during the birth season on the puna. Alternatively (Jane Wheeler, personal communication), oscillating periods of extreme drought which are recorded in the puna of southern Peru have been identified as primary causes of camelid mortality. Browman (1974:191) notes the effects of both conditions on puna herds of domestic camelids:

> Loss by freezes and snows and through drought and consequent pasture failure also runs high in some years. Several of Diez de San Miguel's 16th century informants reported losses of animals killed by freezes and heavy snows; the Lurinsaya of Acora claim the loss of the entire communal herd of 1,000 in a freeze in 1565. Even though the wet season is the summer season, at the high elevations (4000 m and above) the rain turns to snow, which prevents the flocks from finding forage and causes high losses among the weaker newborn animals.

Further, in the classic ethnography of Andean pastoralism, Flores-Ochoa (1979:95) emphasizes the danger of droughts which are characterized as a main hazard for the llama and alpaca herders he describes.

Bowman (1924:30) reports the history of 19th century precipitation for the Atacama region. Heavy downpours of snowfalls occurred in 1819, 1823, 1952, 1859, 1878, 1885, 1903, and 1911 (from Druss 1978:116). Such precipitation would have created short-lived explosions in the desert vegetation at elevations below the puna, but would have had a devastating effect on the high altitude camelids. If Núñez and Dillehay (1979) are right in their assessment of the inhospitable nature of the Puna de Atacama for year-round habitation, then we can expect that the hunters moving up and down the quebradas to the east of the salar would experience irregular periods of lack of game during their visits to the highlands. The best evidence that the occupants of the Atacama region were experiencing oscillations in moisture availability has been published by Druss (1977, 1978). His study of the Chiúchiú complex produced correlations linking settlement type, location and duration with climatic regimes inferred from artifactual and ecofactual remains (1977:Table 4). He concluded that third and second millenium B.C. settlement patterns were controlled by oscillations in moisture.

Again, while the case is circumstantial in that direct evidence of resource stress cannot be archaeologically documented, I believe that it is a reasonable conclusion that the ancient inhabitants of the Atacama region experienced serious fluctuations in game availability brought on by expectable but not predictable climatic variation. In the case of Puripica this economic uncertainty was buffered at some point midway in the occupation through the incorporation of domestic stock into the way of life. In the case of the Tulan region the adoption of pastoralism seems to have occurred at approximately 1700 B.C. based on evidence from a site adjacent to Tulan-52 (Núñez 1981). The source of the insurance herd, following Ingold's model, would likely have been pack animals, necessary if part of the reason for habitation in the region was the exploitation of the locally abundant mineral resources and trade in vicuña skins.

CONCLUSION

The two case studies just presented have a number of features in common. Both episodes of pastoral development took place in arid or semi-arid ecosystems where the large herbivore population was dominated by a minimum number of species, one basically a browser, the other a grazer. The sites which contain the evidence for pastoralism are located in complex topographies adjacent to larger open spaces. Each environment was probably afflicted by irregular climatic conditions capable of catastrophically affecting game availability.

Domestication has both a technological aspect, the methods of taming and breeding, and a social/ideological one, the intersection of animals with a web of values and interpersonal organization. The explanation of its onset must account in some manner for both of these aspects. Oscillating game availability can be linked to cultural systems both in terms of an effect on productive technologies and on social institutions. The potential result of these effects is carnivorous pastoralism, a predatory adaptation capable of insuring its success by destroying the potential for other systems.

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