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Paleopathology and Health of Native and Introduced Animals on Southern Peruvian and Bolivian Spanish Colonial Sites

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ABSTRACT Spanish colonial sites in southern Peru and Bolivia contain remains of native camelids and introduced bovids with examples of degenerative paleopathologies that are interpreted as reflecting changes in herd management, animal use and animal health following the Spanish conquest. The archaeological contexts include three Spanish colonial wineries from Moquegua in southern Peru and the nearby colonial village of Torata Alta where indigenous people were forced to resettle under Spanish control. Also from Peru is faunal material from the 14th to 16th century rural agropastoral village of Pillistay located near Camana. Animal remains with bone abnormalities are also present in residential, commercial and industrial sites associated with Spanish silver mining near Potosí, Bolivia at Tarapaya and Cruz Pampa. Eighteen pathological specimens are described including examples of degenerative changes to phalanges, vertebrae, tarsals, limb elements and ribs. Paleopathologies present include exostoses, osteophytes, porosity, grooving and eburnation. Examples of phalangeal exostoses on bovid phalanges indicate the use of these introduced animals as draught cattle. Exostoses on camelid first phalanges suggests their use as cargo animals as do thoracic vertebrae with severe cases of degenerative pathology. Introduced caprines contain few pathologies indicating their primary use as food animals. The bone abnormalities from colonial sites are more severe than those reported for prehispanic faunal assemblages. These data provide insights into the health and work behaviour of indigenous Andean camelids and introduced Eurasian animals following the Spanish conquest. Copyright © 2009 John Wiley & Sons, Ltd.

Key words: paleopathology; zooarchaeology; Peru; Bolivia; Spanish colonial period; degenerative abnormalities; exostoses

Introduction

Spanish colonisation of the Americas and the introduction of Eurasian animals changed local systems of economic organisation and production in many regions. Beyond the use of animals for food and food products, animals were employed in work-related tasks, particularly transport and traction. In most areas of the Americas, there were no domesticated mammals that served for work except in the Andean region of South America where llamas and alpacas were the foundation of a well-established pastoral economy. Neither of these animals was used for traction nor ridden for transport; however, the larger sized sure-footed llama was used as a beast of burden in the mountainous terrain to move products from one elevation to another. Also, in the prehispanic past

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both llamas and alpacas were reared for fibre, a valuable secondary product (Wheeler *et al.*, 1995). When Spaniards colonised the Central Andes in the 16th century they introduced a variety of Eurasian domesticates of which cattle and equids (horses, burros or mules) performed the greatest amount of work. Camelid herds also experienced catastrophic declines in numbers following the Spanish conquest (Wheeler *et al.*, 1995). The effects of Spanish economic changes are reflected in the skeletal health of some animal remains from colonial sites.

In this paper, I describe pathologies present on various skeletal elements of bovid, camelid and caprine remains from colonial sites located in and near Moquegua and Camana in far southern Peru and sites outside of Potosí, Bolivia where Spanish silver mining was an economic focus (Figure 1). Wine and brandy produced in Moquegua were traded to Upper Peru (modern Bolivia) where the mining industry was centred. The colonial economy included significant contributions of work by both introduced and native animals. Much pathology present on phalanges and vertebrae of introduced cattle and native camelids from colonial sites suggests that these bone abnormalities are degenerative pathologies associated with work activities. Other pathologies may have resulted from multiple causal factors. Comparisons with skeletal pathologies reported on faunal remains from prehispanic sites from southern Peru and elsewhere in the Andean region indicate that prior to Spanish colonisation skeletal pathologies were less frequent and less severe, but included numerous congenital abnormalities. More systematic analysis and reporting of skeletal pathologies in other geographic regions would contribute to our understanding of the consequences of Spanish colonisation on local economic systems and animal use.

Figure 1. Location map of study regions in Peru and Bolivia.

The archaeological contexts

Moquegua Peru: Spanish colonial wineries and Torata Alta

Locumbilla, Chincha and Yahauy wineries

Spanish colonisation throughout the Americas included the transformation of rural infrastructure to provide familiar foodstuffs and meat products for colonists. Plants and animals of old world origin were introduced throughout the colonies; however, the successful propagation of crops and the rearing of Eurasian animals were dependent on local geographic and environmental conditions. The arid, low elevation (less than 1500 m) coastal valleys of the Central Andes were conducive to the production of many old world crops and animals. Grape stock for the production of wine was one of the crops that thrived in the Andean region. During the mid-16th century Spaniards established a productive wine industry in many of the coastal river valleys of Peru and Chile (Cushner, 1980; Keith, 1976). Wine was an essential element of Iberian cuisine and for Catholic sacraments. The process of distillation, also a Spanish introduction, was used widely to produce brandy with a higher alcohol content. Wine production was carried out in large landed-estates (*bodegas*) where grape processing, fermentation and storage for transport took place. In addition to areas for producing wine and brandy, these estates commonly had animal corrals and 'staging areas' for packing products for transport as well as residential areas where landlords or overseers lived (Rice & Smith, 1989; Smith, 1991).

The Moquegua Bodegas project was a multi-year programme of archaeological survey, exca-

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vation and analysis of wineries in the Moquegua valley of far southern Peru. In the short, steep, 28 km long, Moquegua drainage, Spaniards established 130 wineries or bodegas (Rice & Ruhl, 1989). A team of researchers completed excavation of archaeological deposits at four of the wineries where historical research and preliminary archaeological testing indicated 16th century deposits (Rice & Smith, 1989; Smith, 1991). Pathological specimens of bovid ($n = 4$) and camelid ($n = 4$) remains are present at three of the wineries: Locumbilla (central valley), Chincha (south end of valley) and Yahauy (north end of valley) (Figure 2).

Torata Alta

The site of Torata Alta is located approximately 16 km north of Moquegua in the agriculturally rich Torata Valley at an elevation of 2700 masl (see Figure 2). Torata Alta was a rural village of domestic and public space. Surviving architecture includes 24 rectangular room blocks separated by narrow streets (Van Buren *et al.*, 1993, p. 137). The majority of the structures are residential; however, also present is communal architecture including a plaza, church and other public buildings. Gridded community layouts were a characteristic of Late Horizon, Inca-period communities as well as early Spanish settlements, particularly *reducciones*, where indigenous peoples were resettled under Spanish control to aid in the religious conversion of the population and the extraction of goods and services. It has not been possible to use architecture and site deposits to determine if Torata Alta was constructed during the Late Horizon or exclusively during the colonial period (Van Buren *et al.*, 1993). However, the shallow deposits and material culture present indicate that the site was not occupied for very long and that the majority of the deposits date to the 16th century and early 17th century. Present at the site are Spanish colonial material goods and remains of introduced Eurasian animals. Archaeological evidence (e.g. weaving paraphernalia such as spindle whorls) from the 16th century supports the contention that the site functioned as a colonial *reducción* where the population was resettled and required to provide Spanish overlords with textiles and other marketable goods (Van Buren, 1993).

Excavations consisted of exploratory trenches through midden deposits as well as the excavation of complete structures. Temporal placement of the Torata Alta deposits is based on the presence of a thick lens of ash from the February 1600 eruption of the Huaynaputina volcano. The pathological camelid specimens ($n = 4$) from Torata Alta are from the 16th century deposits (i.e. below the ash-fall) in two of the exploratory trenches.

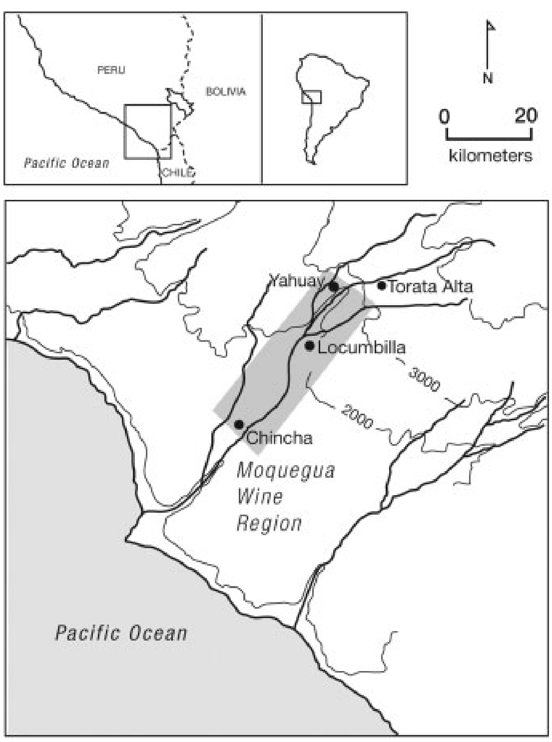

Figure 2. Location of the Moquegua wine region, Chincha, Locumbilla and Yahuay bodegas and Torata Alta in southern Peru.

Potosi, Bolivia: Tarapaya and Cruz Pampa

The community of Tarapaya

Beginning in the 16th century the city of Potosí and its environs were the focus of Spanish silver mining. Surrounding the city were outlying mines and support communities for the urban centre. The community of Tarapaya is located approximately 15 km (9 miles) northwest of Potosí at an elevation of 3300 m (10,800 ft) (Figure 3). Just

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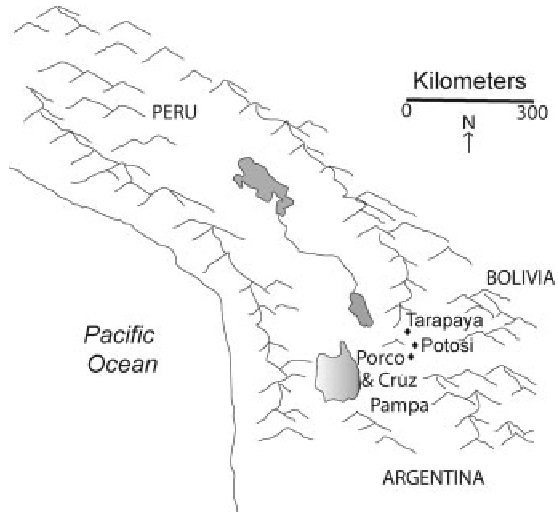

Figure 3. Location of Potosí and Porco, Bolivia and sites of Tarapaya and Cruz Pampa.

north of the village are a set of warm springs and a circular lake that were used therapeutically in Inca and colonial times. During the colonial period Tarapaya was the location of a private inn and residence of a wealthy Spaniard and local administrator (Arzáns de Orsúa y Vela, 1965 [Volume II Book IX]).

Van Buren (1999, pp. 112–115) completed archaeological mapping, testing and excavations at Tarapaya. Faunal remains are from units associated with the inn adjacent to the large circular lake and from the residential area located near the smaller springs. The material culture and historical record suggest that the deposits date primarily to the first half of the 17th century, although the time range of occupation may have been greater (Van Buren, 1999, p. 114). Animal use at Tarapaya primarily served the dietary needs of affluent individuals housed in the inn and the residential buildings. In contrast to other geographic regions of Spanish colonial settlement, the use of animals at Tarapaya was highly Iberian in character with abundant use of introduced caprines and chickens (deFrance, 2003). Two caprine specimens with minimal pathology are present.

Cruz Pampa

The colonial centre of Porco located approximately 50 km (31 miles) southwest of Potosí at an elevation of 4100 m (13 400 ft) was a productive colonial silver mining community. Spanish claims to the rights of the mines of Porco were among the earliest in the region. During the initial years of silver exploitation Spanish-owned silver deposits were processed by native residents using indigenous Andean technology (Van Buren & Mills, 2005). Numerous 16th and 17th century sites are located in and near Porco. Excavation and analysis of various colonial sites in the region is ongoing by Mary Van Buren (2004, Proyecto Arqueológico Porco-Potosí; http://lamar.colostate.edu/~mvanbure/index.htm; Van Buren & Mills, 2005).

Thus far, the best-preserved faunal material is from the site of Cruz Pampa located 300 m southeast of Porco. Excavations over multiple field seasons indicate that the deposits from Cruz Pampa are midden material from domestic structures. One structure contained an indigenous style hearth or *k'oncha* in the floor suggesting that an indigenous female resided at the site. The site deposits also contained a men's leather shoe in European style, a pipe and some jewellery suggesting that the male resident was either a relatively high status indigenous, possibly a *yanacona* (Indian servant), or a lower status Spanish male. According to Van Buren (Van Buren, 2004), this household occupied managerial or supervisory positions in mining production. The deposits dates from approximately 1600 to 1650 and are therefore contemporaneous with the faunal material from Tarapaya and the winery deposits. The Cruz Pampa deposits contain two pathological cattle phalanges.

Camaná, Peru: Pillistay

Pillistay is a rural agropastoral site located in the coastal valley of Camaná in the department of Arequipa north of Moquegua (see Figure 1). Pillistay consists of the ruins of a series of stone-walled buildings with courtyards as well as less elaborate buildings made of organic materials (Owen, 2007; Tantaleán & Owen, 2007). Storage areas are present in the patio, possibly for agricultural products. The site appears to have been constructed in the 14th century, with occupation continuing after the Spanish port town of Camaná

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was founded in 1539, until the volcanic eruption of Huanaputina in AD 1600. The site may have been inhabited by 2–3 dozen families, possibly extended families (Owen, 2007). Ash fall from the eruption of the Huaynaputina volcano covers rich organic site refuse. After the ash fall, the site was abandoned and never reoccupied.

Archaeological investigations completed in 2006 consist of site mapping and a series of test excavations (Owen, 2007; Tantaleán & Owen, 2007). Owen and his crew recovered a few glazed colonial pottery sherds from the surface, but no other European materials. My analysis of the faunal remains indicates that no remains of Eurasian animals are present at Pillistay; however, I identified five caprine specimens representing one individual from the site of Soto, another 16th century site in the region. Although Pillistay was occupied from the 14th to the 16th centuries and was located only about 30 km from the Spanish town of Camaná, the extent to which the residents were involved in the colonial economy is unclear because so few remains of European origin were recovered from the site. Pathological faunal remains from Pillistay include two camelid first phalanges from two different individuals that exhibit degenerative abnormalities on the bone shafts. The two phalanges are from an artefact-rich midden fill excavated between two prepared floor surfaces; therefore, these two camelids are contemporaneous.

Description of skeletal pathologies

The paleopathology of zooarchaeological remains are less systematically reported in the archaeological literature than those occurring on human remains (Baker & Brothwell, 1980; Thomas and Mainland, 2005; Siegel, 1976; Vann & Thomas, 2006). While some standards for reporting animal skeletal pathologies, particularly for draught cattle (Bartosiewicz *et al.*, 1997; Johannsen, 2005) are available, standards for other animals are less uniform than descriptions of skeletal pathologies common in human remains (such as Buikstra & Ubelaker, 1994), particularly for faunal assemblages from sites in the Americas. In this section, I describe the pathologies present. The severity of all camelid and caprine elements is described as mild, medium or severe. I use the stage scoring system of pathology developed by Bartosiewicz *et al.* (1997) to provide an additional estimate of pathological severity for the *Bos taurus* phalanges. After describing the pathologies present, the skeletal elements affected, and the taxa exhibiting pathologies I present a discussion in which I assess the varied roles that both indigenous and introduced animals of Eurasian origin played in Spanish colonies in Peru and Bolivia. Although paleopathologies can result from different aetiologies, these colonial examples demonstrate some patterns in the types of abnormalities present that are interpreted as work related while others are attributed to unknown causes.

Eighteen specimens from seven colonial sites exhibit pathologies (Table 1). For the majority of these sites, the pathological specimens constitute less than 1% of the total assemblage by taxa and time period. Skeletal pathologies are present on remains of Caprines (sheep or goats, $n = 2$), *Bos taurus* (cattle, $n = 6$) and Camelidae (*Lama/Vicugna* sp., *Lama cf. glama* probable domesticated llama or alpaca, $n = 10$) (Figures 4–6). Pathologies are most common and most severe on phalanges ($n = 10$) followed by vertebrae ($n = 4$) (Table 2). Other pathological elements are the rib, tarsal (entocuneiform), radius and humerus. The abnormalities present include lipping (osteophytes), exostoses (the growth of additional bone), porosity (pitting of bone surfaces), grooving and eburnation (degeneration of articular cartilage and resulting change to bone density often manifest as polished bone, especially of articulating surfaces). The most common abnormalities are lipping (osteophytes) on vertebral centra and exostoses on phalanges. Thoracic vertebrae exhibit the greatest degree of pathology; although one cervical vertebra has minimal osteophytes. One camelid rib exhibits lipping on the proximal articular facet. Limb bones are relatively free of pathology. The two caprine specimens with pathology are both forelimb elements: a radius with osteophytes on the proximal surface and a distal humerus fragment with light exostoses.

Phalangeal exostoses involving the first and second phalanges of horses are known as ringbone regardless of the size, extent or location of the bony growth (Lacroix, 1916, p. 118). Baker

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Table 1. Summary of pathologies present on specimens from colonial sites in Peru and Bolivia

Site	Context	Time period	Taxon	Element	Pathology	Site		
						Pathological severity[a]	Taxon NISP for time period	% with pathology
Locumbilla winery	984N/1032.5E	AD 1600–1775	Camelidae	Thoracic vertebrae	Osteophytes on centrum	Medium	122	1.6
Locumbilla winery	Unit 10	AD 1600–1775	Camelidae	Phalanx-1st	Lateral exostosis, hypertrophic shaft	Medium		
Locumbilla winery	Unit 10	AD 1600–1775	*Bos taurus*	Entocuneiform	Osteophytes	Mild	341	0.6
Locumbilla winery	Kiln context	AD 1600–1775	*Bos taurus*	Phalanx-1st	Exostosis on proximal and distal surfaces	Medium, stage 3		
Chincha winery	1017N/1009E	AD 1600–1775	*Bos taurus*	Phalanx-3rd	Exostosis on proximal articular surface	Mild, stage 2	758	0.1
Chincha winery	1034.5/1004E	Post-AD 1775	Camelidae	Rib	Osteophytes on proximal articular surface	Mild	1	100.0
Chincha winery	1087N/1048E	Post-AD 1775	*Lama* sp.	Cervical vertebrae	Osteophytes on centrum	Medium	1	100.0
Yahuay winery	990N/958.5E	Post-AD 1775	*Bos taurus*	Phalanx-3rd	Exostosis on proximal articular surface	Mild, stage 2	216	0.5
Torata Alta	Trench M	Pre-AD 1600	*Lama* sp.	Phalanx-1st	Lateral exostosis	Severe	863	0.5
Torata Alta	Trench M	Pre-AD 1600	Camelidae	Phalanx-3rd	Exostosis on proximal articular surface	Medium	863	
Torata Alta	Trench G	Pre-AD 1600	Camelidae	Thoracic vertebrae	Osteophytes on centrum, eburnation, porosity	Severe	863	
Torata Alta	Trench G	Pre-AD 1600	Camelidae	Thoracic vertebrae	Osteophytes on centrum, porosity, grooving	Severe	863	
Tarapaya	Unit 1	AD 1600–1650	Caprinae	Radius and ulna	Radius-proximal with osteophytes	Mild	1356	0.1
Tarapaya	Unit 9	AD 1600–1650	Caprinae	Humerus	Osteophytes, distal articular surface	Mild	1356	
Cruz Pampa	Unit 10	AD 1600–1650	*Bos taurus*	Phalanx-2nd	Exostosis on proximal articular surface	Mild, stage 2	44	4.6
Cruz Pampa	Structure 3	AD 1600–1650	*Bos taurus*	Phalanx-3rd	Exostosis on proximal articular surface	Mild, stage 2	44	
Pillistay, Camana	Unit 002	Pre-1600	Camelidae	Phalanx-1st	Lateral exostosis	Mild	n/a[b]	
Pillistay, Camana	Unit 002	Pre-1600	Camelidae	Phalanx-1st	Lateral exostosis	Medium	n/a[b]	

[a] Stages of pathology for *Bos taurus* phalanges follows Bartosiewicz *et al.* (1997).
[b] I completed an inventory of the taxa present in the Pillistay test excavations to determine if Eurasian animals were present and any distinctive features of the assemblage. The faunal remains were not quantified by taxon.

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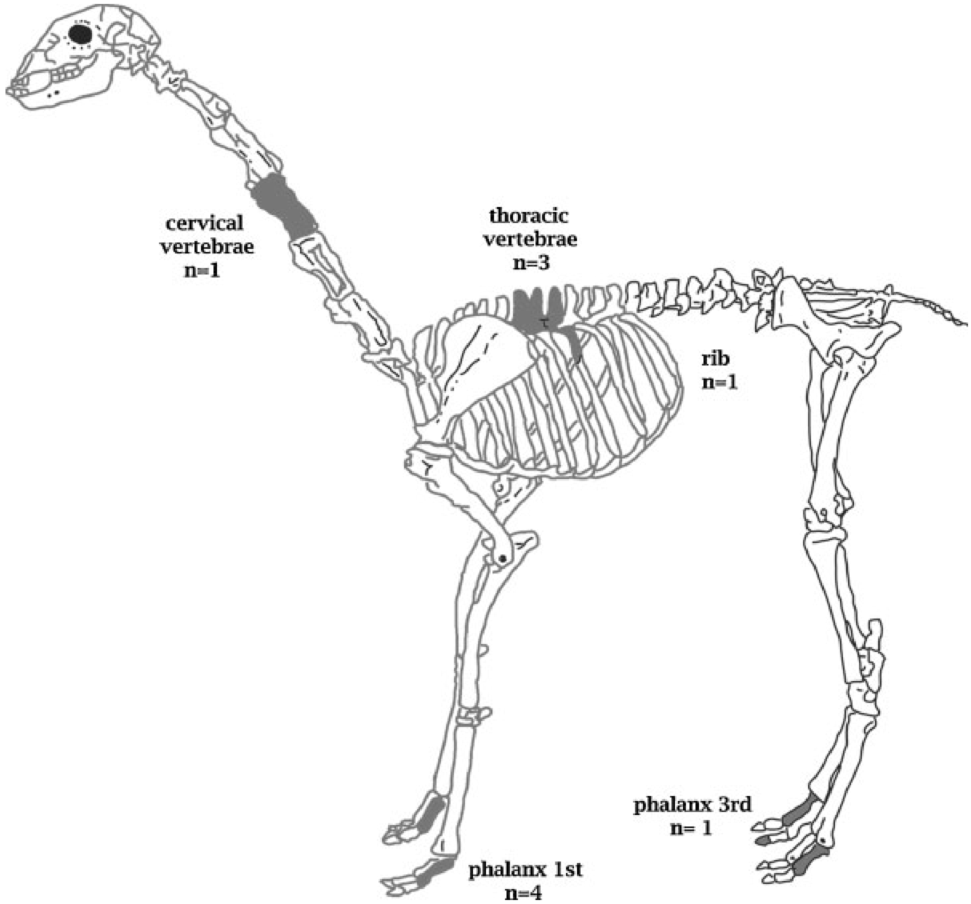

Figure 4. Camelid skeleton showing pathological elements from all sites.

and Brothwell (1980) describe ringbone as occurring on the articulating surfaces of phalanges wherein high ringbone affects the first interphalangeal joint; low ringbone affects the second joint. Exostosis on the shaft of the first phalanx is known as false ringbone. Although the joint is not immediately impacted, the lesions can spread along the shaft and result in varying degrees of ankylosis (Baker and Brothwell, 1980, p. 120). The varieties of ringbone result primarily from some aspect of concussion of the foot particularly when walking on uneven surfaces along with the inability of the limbs to absorb the shock; however, the entrance of foreign matter from a lacerate wound can also cause the reaction (Lacroix, 1916). All varieties of this pathology can result in lameness. Although ringbone is a term generally used to describe bony growth on horse phalanges, the aetiology of the condition is the result of damage to the periosteum and the abnormal growth of bone on the phalanx; therefore, the term ringbone can be applied to other large mammals with this condition. Phalangeal exostoses (i.e. ringbone) are present on bovid and camelid specimens.

One *Bos taurus* first phalanx from the Locumbilla bodega exhibits exostoses on both the proximal and distal articulating surfaces indicating that both high and low ringbone was present (Figure 7). The majority of pathology is on the proximal and anterior surface, although the lateral/medial surface is also affected to some degree. There is no indication of eburnation on either surface, particularly on the proximal surface that articulates with the distal metapodial; therefore, it does not appear that the animals

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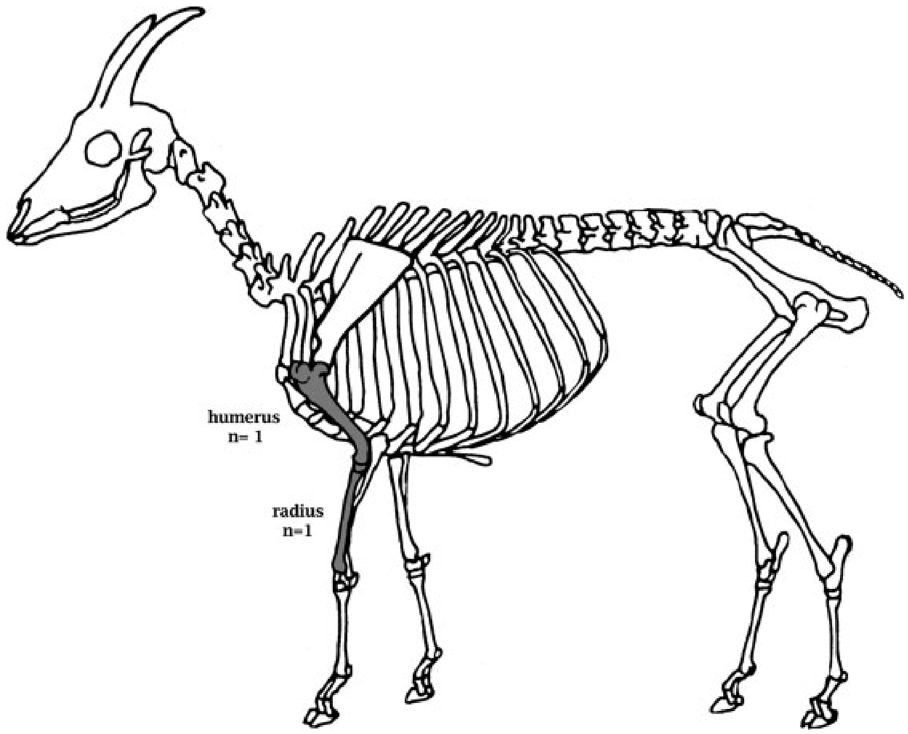

Figure 5. Caprine skeleton showing pathological elements from Tarapaya near Potosí, Bolivia.

suffered considerable lameness. Using the scoring scale developed by Bartosiewicz *et al.* (1997) for draught cattle this specimen is stage 3 of pathology. Four other *Bos taurus* phalanges exhibit stage 2 pathology. At the site of Cruz Pampa outside of Potosí, *Bos taurus* second and third phalanges have minimal exostoses on the articulating surface. At the Chincha and Yahuay wineries *Bos* third phalanges also exhibit minimal exostoses.

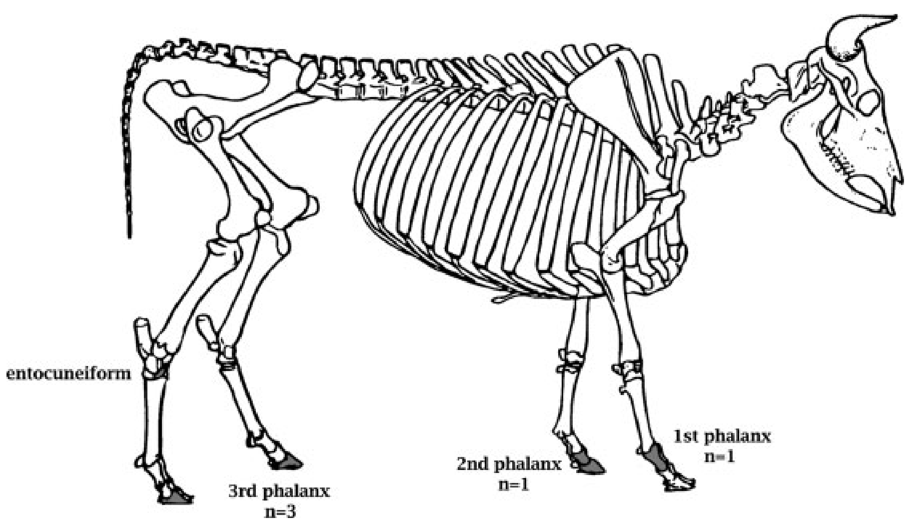

Figure 6. *Bos* skeleton showing pathological elements from all sites.

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Table 2. Skeletal pathologies by taxon, element and type of pathology for colonial sites

Skeletal Pathology by Taxon		
Taxon		#
Caprinae		2
Bos taurus		6
All Camelidae		10
Skeletal pathology by element and taxon		
Skeletal element	Taxon	#
Radius, ulna	Caprinae	1
Humerus	Caprinae	1
Rib	Camelidae	1
Vertebrae-cervical	*Lama* sp.	1
Vertebrae-thoracic	*Lama* sp.	3
Entocuneiform	*Bos taurus*	1
Phalanx-1st	*Lama* sp.	4
Phalanx-1st	*Bos taurus*	1
Phalanx-2nd	*Bos taurus*	1
Phalanx-3rd	*Bos taurus*	3
Phalanx-3rd	*Lama* sp.	1
		18
Types of Pathology		#
Osteophytes		6
Osteophytes, Porosity, Eburnation		1
Osteophytes, Porosity		1
Exostosis proximal/distal articular surfaces phalanges		6
Exostosis lateral/medial shaft 1st phalanx		3
Exostosis and hypertrophic bone		1
		18

The most dramatic examples of pathology are four cases of exostosis (false ringbone) on the first phalanges of camelids. One specimen from the 16th century deposits at Torata Alta in the Moquegua valley has severe pathology with extensive lateral bone growth on the shaft indicating the tendon was partially encased in bone (Figures 8 and 9). The pathology would have resulted in significant pain. The second specimen from the Locumbilla winery exhibits less severe bony growth; however, the diaphysis shaft is hypertrophic, indicating probable additional pathological reaction of the bone (Figures 10 and 11). Two specimens from Pillistay located near Camana, Peru also exhibit phalangeal exostoses; although both are less pathological than the examples from Torata Alta. One specimen has a rounded trough on the lateral surface indicating possible involvement of the tendon (Figure 12). The second specimen contains a very mild exostosis on the lateral surface (Figure 13).

The taxa of the pathological camelid specimens may represent the two domesticated species of South American camelids, llama and alpaca. Dimensional measurements of the lateral-medial breadth of the proximal surface are used to identify the taxa represented (Table 3). The specimen from Torata Alta is in the size-range of llamas. The Torata Alta specimen measuring 21.4 mm is slightly larger than the Locumbilla specimen which measures 20.1 mm. The size range of the proximal lateral-medial breadth of the first phalanx of modern llamas is 20.8–21.9 mm. ($n = 22$) (Miller, 2003, p. 31). Although the Locumbilla specimen is somewhat smaller than the modern comparative llama assemblage, it is slightly larger than the size range reported for alpacas (16.3–19.8). Of the two specimens from Pillistay one is in the size range of a large alpaca (*Vicugna pacos*) (see Table 3). The second specimen is larger than the comparative alpaca specimens and may represent a small llama; however, species identification is inconclusive.

Four camelid vertebrae exhibit pathologies. Two camelid thoracic vertebrae from Torata Alta exhibit severe osteophytes along with porosity and eburnation of the centrum (Figure 14). The pathology of the illustrated specimen extends to the posterior articular surfaces and to the dorsal process. The second thoracic vertebra has

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Figure 7. *Bos taurus* first phalanx from Locumbilla with exostosis on proximal and distal articular surfaces (photo by author). This figure is available in colour online at www.interscience.wiley.com/journal/oa.

osteophytes along with extensive grooving on the posterior surface of the centrum body (Figure 15) A third camelid thoracic vertebra from the Locumbilla bodega has mild osteophytes on the ventral surface of the centrum (Figure 16). One camelid cervical vertebra from the Chincha winery also has osteophytes on the centrum.

Other skeletal elements with mild pathology include one *Bos taurus* entocuneiform (Locumbilla winery), the proximal rib of a camelid (Chincha winery) and the proximal radius and distal humerus of Caprinae specimens from Tarapaya, Bolivia.

Discussion

The range of specimens and taxa with pathologies are used to examine if Spanish colonial changes in animal use had an effect on the skeletal health of either indigenous mammals or introduced ones. Although the pathologies might arise from a variety of aetiologies, the frequency of degenerative foot and vertebral abnormalities suggest that several of the osteological changes resulted from work-related causes and from working older animals. A few specimens exhibit bone changes that may have derived from one or more factors; however, none of the colonial specimens exhibit congenital pathology, fractures, metabolic disease, neoplasmas, nor dental pathology (as described by Siegel, 1976, pp. 352–353).

Degenerative joint disease is evident in *Bos taurus* phalanges. First, second and third phalanges from four sites (three wineries: Locumbilla, Chincha and Yahuay as well as the silver

Figure 8. Camelid first phalanx from Torata Alta with severe exostosis, lateral view (photo by Pat Payne). This figure is available in colour online at www.interscience.wiley.com/journal/oa.

Figure 9. Camelid first phalanx from Torata Alta with severe exostosis in comparison to modern normal first phalanx, anterior view (photo by Pat Payne). This figure is available in colour online at www.interscience.wiley.com/journal/oa.

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Figure 10. Camelid first phalanx from Locumbilla with intermediate degree of exostosis and hypertrophic shaft (photo by Pat Payne). This figure is available in colour online at www.interscience.wiley.com/journal/oa.

Figure 12. Camelid first phalanx from Pillistary with intermediate degree of exostosis (photo by Bruce Owen). This figure is available in colour online at www.interscience.wiley.com/journal/oa.

production site and residential area of Cruz Pampa) exhibit varying degrees of exostoses. All of these pathologies appear to be related to the use of introduced cattle as draught animals (see Baker & Brothwell, 1980; Bartosiewicz *et al.*, 1997; de Cupere *et al.*, 2000). The Cruz Pampa pathological cattle phalanges indicate that whole animals were processed near the site and also suggest that work animals were consumed possibly after their utility had declined.

Figure 11. Camelid first phalanx from Locumbilla with inflammation of bone shaft, lateral and anterior views (photo by author). This figure is available in colour online at www.interscience.wiley.com/journal/oa.

Figure 13. Camelid first phalanx from Pillistary with mild degree of exostosis (photo by Bruce Owen). This figure is available in colour online at www.interscience.wiley.com/journal/oa.

Table 3. Dimensional measurement of first phalanx (lateral-medial breadth) of Torata Alta and Pillistay specimens with phalangeal exostoses

	Sample *n*	Range (mm)
Alpaca, comparative	54	16.3–19.8
Llama, comparative	22	20.8–21.9
Torata Alta	1	21.4
Locumbilla	1	20.1
Pillistay	1	18.7
Pillistay	1	19.9

Comparative measurements of modern llama and alpaca are from Miller (2003, p. 31).

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Figure 14. Camelid thoracic vertebrae from Torata Alta with severe pathology, posterior view of thoracic vertebrae with osteophytes, eburnation and porosity (photo by Pat Payne). This figure is available in colour online at www.interscience.wiley.com/journal/oa.

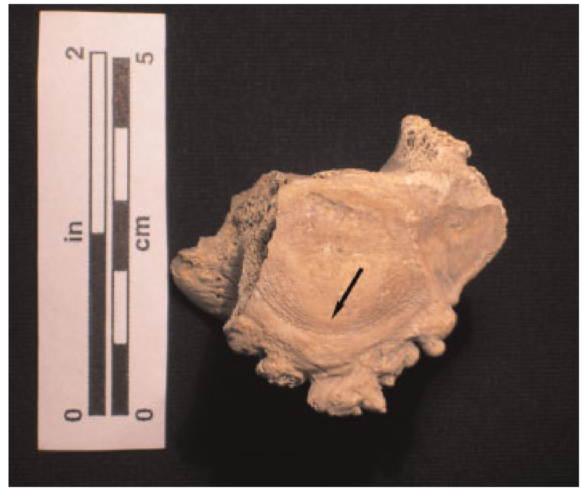

Figure 15. Camelid thoracic vertebrae from Torata Alta with degenerative pathology, posterior view of centrum with osteophytes and arrow indicating grooving on centrum body above osteophytes (photo by author). This figure is available in colour online at www.interscience.wiley.com/journal/oa.

In the Moquegua wine industry corrals and open staging areas where animals were housed are a common feature of many of the wineries (Rice, 1996a). People may have used cattle to prepare lands for planting grape stock, but there was little agricultural production other than viticulture in the valley. Animal-powered machinery was not common. At those wineries that distilled brandy the huge quantities of firewood needed for the distillation process may have been transported with carts pulled by cattle; although mules and burros may have served for this purpose as well. In addition, cattle or oxen would have been used to pull carts and probably to transport wine in ceramic vessels or *botijas* over short distances. Cattle may also have been used to transport the large ceramic tinajas or fermentation and storage jars that held approximately 1400 L and were 1.5–2 m high (Rice, 1994, 1996b). Historical sources indicate that wine products were transported primarily via mule trains or camelid caravans (Cushner, 1980); therefore, cattle were not involved in long-distance transport of wine and brandy. At Cruz Pampa, cattle were probably not used in agricultural activities due to the restricted

Figure 16. Camelid thoracic vertebrae from Locumbilla with degenerative pathology, ventral surface of centrum with exostosis (photo by author). This figure is available in colour online at www.interscience.wiley.com/journal/oa.

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range of crops produced in the high elevation setting, but cattle could have been used in a variety of work-related tasks in the silver mining industry. Animal-powered machinery was also not a common feature of the 16th and 17th century silver industry.

The only other bovid element to contain pathology was an entocuneiform from the Locumbilla winery. This abnormality may indicate that the animal suffered from spavin, a disease of the tarsus (Baker & Brothwell, 1980, pp. 117–118). Exostosis of the small tarsal bones, including the entocuneiform, can affect locomotion. Spavin can result from both hereditary factors and work-related factors, such as severe concussion that results from heavy work or working on hard surfaces. The small tarsal bones are stimulated to form new bone growth when the ligaments are pulled and the membrane covering the bone (periosteum) is lifted away from the bone. Interestingly, no bovid vertebrae or other elements contain pathologies. Bovid pathologies are not reported for Spanish colonial assemblages elsewhere in the Americas including sites where large quantities of cattle remains are present such as Puerto Real on Hispaniola (Ewen, 1991; Reitz and McEwan, 1995; Reitz, 1986), Spanish missions in Texas (deFrance, 1999) and elsewhere in North America (Pavao-Zuckerman & Reitz, 2006).

The pathologies present on caprines appear to be the least work related; although their cause is difficult to determine. At the site of Tarapaya caprines are the most abundant taxon in the faunal assemblage. These deposits are associated with an inn and the residence of a wealthy Spaniard (Van Buren, 1999). The remains representing two caprine individuals are interpreted as food refuse (deFrance, 2003). These two individuals are the only specimens that exhibit abnormal limb elements. The ages of the animals are also of limited utility in identifying the cause of these pathologies because both the proximal radius and distal humerus fuse early in life. According to fusion data, these individuals were at least 10 months of age (Silver, 1969); however, their age at death is unknown. There is no indication that caprines were used for work or kept until old age for secondary products.

Considering the long history of research on camelid domestication and husbandry in the Andean region, relatively few examples of camelid pathology are noted in either the archaeological or ethnoarchaeological literature. Moore (2008) presents examples of pathology including degenerative, congenital, dental, traumatic or infectious lesions and healed breaks for the Formative period highland Bolivian site of Chiripa in the Lake Titicaca basin. In recent excavations at Chiripa Moore (2008) found 22 cases of degenerative pathology including exostoses and bone growth, osteoarthritis, eburnation and grooving. Pathological specimens account for 2.7% ($n = 809$) of the camelid remains from an assemblage that contained predominantly domesticated camelids, but also, remains of both wild guanacos and vicuña. Due to fragmentation Moore (2008) was able to assign class sizes to only 13 of the pathological specimens. Medium and large-sized camelids (probable llamas) ($n = 10$) exhibited greater pathology than the smaller, alpaca-sized and possible vicuña-sized animals ($n = 3$). Affected skeletal portions include axial elements, fore and hindlimbs, especially the proximal femur, and the foot. Thoracic vertebrae centrae demonstrate considerable lipping indicating their probable use as cargo animals (Moore, 2008).

Also present on some highland sites are specimens with polydactylism. Moore (2006, 2008) documents three metapodials ($n = 42$, 7%) with polydactylism. Webster (1993, p. 257) also reports the presence of two metapodials with polydactyly at more recent sites dating to the Middle Horizon (Tiwanaku culture) from the Titicaca basin. Moore (2008) summarises other prehispanic occurrences of multiple-toed camelids elsewhere in the Andean region. Interestingly, none of the colonial specimens exhibit this congenital abnormality.

In addition to inherited deformities, Webster (1993, p. 25) documents 26 examples of pathological bone including exostoses and osteoarthritis present on phalanges, podials, metapodials, rib, vertebrae, scapula and the maxilla. The pathological specimens are from remains representing at least 132 individuals; neither sample NISP nor size data for the pathological specimens are presented by Webster (1993) for the Titicaca Basin samples. Additionally, illustrations of these specimens are not provided; therefore, it is not possible to determine the severity of the

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conditions. Park (2001) also reports degenerative abnormalities on camelid phalanges and other elements from the Tiwanaku site of Iwawi also located in the Titicaca basin. Although the pathological specimens are not identified to species, the majority of the camelids are interpreted as llamas based on both morphometric and other criteria (Park, 2001). Of the 70 pathological camelid specimens identified (total sample $n = 2810$), 45 elements exhibit evidence of stress or joint disease pathology. The first phalanx ($n = 11$) and second phalanx ($n = 14$) exhibit the greatest degenerative pathology followed by rib ($n = 6$), humerus ($n = 6$), astragalus ($n = 2$), innominate ($n = 2$), scapula ($n = 1$), lumbar vertebra ($n = 1$), calcaneus ($n = 1$) and third phalanx ($n = 1$). Stress and joint disease pathology are viewed as evidence of weight bearing activities of llamas used to transport cargo. The remainder of the pathological specimens ($n = 25$) exhibit infectious lesions, dental disease, trauma or auditory exostosis. An illustrated pathological first phalanx from Iwawi is intermediate in comparison to those for the Moquegua specimens.

Formative period sites in Argentina contain evidence of pathological camelid remains. Izeta and Cortés (2006) provide information on two diseased (osteoarthritic) second phalanges of two large-sized camelids (probably a llama and a guanaco) from the site of Loma Alta located in northern Argentina. The pathologies of the Argentina samples are very mild in comparison to the majority of the colonial examples.

At the Middle Horizon site of Cerro Baul (Wari culture) in the Moquegua valley mild versions of phalangeal exostosis are present on second and third camelid phalanges ($n = 2$) and first phalanges ($n = 2$). In addition, one camelid rib has mild osteophytes on the articulating surface or 'rib head' (deFrance unpublished data).

Camelid pathologies in colonial samples are most common on elements of the foot and vertebrae. In comparison to prehispanic pathologies previously reported and summarized here (Izeta & Cortés, 2006; Moore, 2008; Park, 2001; Webster, 1993) the colonial specimens contain more severe examples of bone deformities than those present in preconquest contexts. One first phalanx with extensive exostosis and two arthritic thoracic vertebrae are severely abnormal. These extreme examples suggest that some animals developed degenerative pathology as a result of prolonged improper physiological stress during the colonial period that was unlike that experienced by animals prior to the Spanish conquest. The data presented here suggest that Spanish herd management policies and the probable use of animals in work-related tasks during the colonial period was demanding and affected the skeletal health of some individuals.

The three most severe skeletal specimens are from the 16th century contexts at the site of Torata Alta. Although Torata Alta was incorporated in the colonial economy and a centre of textile production (Van Buren, 1993), interpretations of secondary historical documents suggest that both the wine and silver industry sites were associated more strongly with the movement of commodities, and thus, the probable greater use of indigenous camelids for transport than was Torata Alta. These osteological data suggest that Torata Alta probably had a significant role in the colonial economy and that camelids were the preferred beast of burden. Although feet elements and vertebrae may be affected independently, the occurrence of severe pathology on both portions of the skeleton supports the view that these animals were used in heavy weight-bearing tasks. In addition to the camelid remains, the pathology present on bovid remains also supports the interpretation that cattle were used as draught animals and possibly in other work-related tasks during the colonial period. Interesting, remains of burros and mules are uncommon on these Andean Hispanic archaeological sites, but none found thus far contain pathologies (deFrance, 1993, 1996, 2003); therefore, equids apparently did not replace camelids as the most widely used cargo animal.

The relationship of pathology to camelid breed is difficult to interpret. The size of the camelids from Pillistay is somewhat anomalous. The Pillistay specimens are at the large end of the alpaca range and may represent small-sized llamas or hybrids (see Table 3). The antiquity and diversity of camelid hybrids are not well understood (Miller, 2003; Moore, 2006; Miller and Gill, 1990; Wheeler *et al.*, 1995). Alpacas are not used for transporting goods; therefore, they are usually not travelling long distances and would be

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unlikely to develop foot pathologies related to repeated impact of the foot on hard surfaces. If phalangeal exostoses develop through other aetilogy, such as a product of age-related stress or genetic factors, the presence of pathologies on these smaller-sized camelids may indicate that they were older animals reared for secondary products, such as fibre. Alternatively, the animals may have been moved seasonally from the coastal valley to graze in other habitat; therefore, the pathology resulted from some form of migratory lifestyle. The Locumbilla first phalanx is also smaller than the size range of modern llamas. However, the industrial nature of Locumbilla along with the presence of probable draught cattle with pathologies supports the interpretation that this individual is a smaller-sized llama, possibly a hybrid that developed foot pathology from use as a cargo animal.

The most severely pathological phalanx from Torata Alta is within the size range of the llama. Overall, the Torata Alta camelid assemblage has a very diverse age and size range including large as well as smaller-sized individuals (deFrance, 1993). The presence of other elements (e.g. thoracic vertebrae) with degenerative pathology from larger sized individuals suggests these pathologies resulted from utilitarian activities.

This analysis suggests that during the Spanish colonial period beginning in the 16th century the Central Andean region implemented some changes in how people used animals, but that people continued to use native animals for transporting goods. Both indigenous and recently introduced mammals were used for work-related tasks and possibly late into life. Camelid pathology appears to be more severe in the colonial era than in preceding periods thus reflecting a probable decline in herd health in some regions. Only with more systematic reporting of camelid pathology in both prehispanic and other colonial contexts will we be able to understanding diachronic changes in camelid use and health. Additional faunal remains from colonial sites, especially non-residential sites, will also provide more information on animal health and their possible economic uses. Other than the data presented here, there are reports of pathologies on skeletal remains of introduced Eurasian animals from colonial or more recent sites in the Central Andes.

Conclusions

This research presents the results of an analysis of paleopathologies present on animal remains from seven archaeological sites in Peru and Bolivia dating to the Spanish colonial period. The sites include industrial, commercial, residential and rural locales with occupation from the 16th to the 19th centuries. The sites vary in elevation from low coastal valleys to highland silver mining communities. Eighteen specimens exhibit varying degrees of pathology including exostoses, osteophytes, eburnation, porosity and grooving. In most cases, the pathological remains are a small percentage of the total assemblage. Phalanges of introduced bovids contain degenerative abnormalities that suggest work-related stress from serving as draught cattle. Caprine remains have the least pathology indicating their principal use as food. Native camelids (probably domesticated llamas) remains have the greatest diversity and severity of pathology, particularly on phalanges and vertebrae. Although feet and spines of animals can be affected independently, the bone abnormalities suggest that these animals were employed as cargo animals in the colonial economy. The degree of pathology present on the camelids is greater than described for prehispanic assemblages from the region. These data suggest that for native and introduced animals experienced greater physiological stress under Spanish rule as new economic systems and commercial enterprises were established. The Andean region was the only New World region with a well-established pastoral economy reliant on large domesticated mammals. Spanish colonisation took advantage of existing systems of animal use and also introduced Eurasian animals that served both for work and food.

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