TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCE

Vol. 107, no. 1/2
p. 25-31 (2004)

Osteoarthropathy in a moose (*Alces alces*) from Utah

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Moose (*Alces alces*) are known to suffer from a wide range of diseases including osteoarthropathies. An *Alces* specimen collected in 1989 from Summit County, Utah shows four separate occurrences of osteoarthropathy: 1) extensive remodeling of the fifth and sixth cervical vertebrae and lesser changes in the other cervical vertebrae; 2) massive bony overgrowth on the right calcaneus, whereas the left calcaneus appears free of disease; 3) osteoarthritis in the weight-bearing joints of the pelvis; and 4) a fracture in the right femur. The osteoarthritis in the weight-bearing joints is not atypical for an individual of its age, estimated at 6.0 to 7.5 years. However, infection is a more likely cause for the changes to the bones in the neck and hock. Trauma in the hind limb would be necessary to have caused the fracture in the femur. This individual lived with its ailments long enough for the architecture of its bones to be dramatically affected. Present-day northern Utah is an ecosystem with a paucity of large carnivores, and this individual lived for some time in a weakened and diseased state. In an ecosystem with a balance of carnivores and herbivores it is unlikely that this individual would have lived and suffered as long as it apparently did.

Key words: Alces, moose, Utah, osteoarthropathy, arthritis.

INTRODUCTION

Moose (*Alces alces*) are known to suffer a wide range of diseases including "moose disease," blindness, Bang's disease, tuberculosis, dental and periodontal disease, skin warts and tumors, internal and external parasites, and arthritis (Lankester and Samuel 1997; Peterson 1955). Other reports of osteoarthropathy in the Cervidae include a case in the fossil genus *Praemegaceros* from England (Wells and Lawrance 1978), and modern *Odocoileus* and *Alces* from North America (Peterson 1955; Wobeser and Runge 1975; Peterson 1977; Peterson et al. 1982). While the literature on the effects of disease on bony tissue in humans, and domesticated and other animals, is growing, it is still quite limited. This report adds to our understanding of the range of pathologies that can manifest themselves in bony tissue in modern animals.

The language relating to and describing bone disease is complex. The causes of bone disease are many and diverse. One must understand that some terms form a clinical description of a disease process (terms that describe the signs and symptoms of the disease), and some terms provide a diagnosis of the actual disease-causing process (terms that provide a causal agent as part of the definition). In this paper, the term "osteoarthropathy" describes a general condition of a disease or disease process involving bones without regard to a causal agent.

MATERIAL

In 1989, an *Alces* specimen, (Sternberg Museum of Natural History, Museum of the High Plains Mammalogy #31515), was salvaged from Summit County, Utah (lat. 40°53'56"N, long. 111°10'39"W). Several hind limb elements were discovered in the South Branch of Chalk Creek. These specimens were exposed in the bed of the ankle-deep stream. A trail of bones was traced approximately 10 m upstream to their source, and the specimen was found lying on its left side entirely buried in mud at the margin of the stream. A total of about 85% of the skeleton was recovered. The carcass decayed, leaving an organic-rich mud. Estimates of time elapsed since the individual's death and when it was found can only be speculative. Aside from the organic-rich mud, no trace of soft tissue remained, although the bones still had a considerable amount of grease in them. Depending on the rate of decay, the individual may have died just a few months prior to its being discovered. In addition, numerous insect larval cases were associated with the skeleton in the surrounding mud and cranial sinuses.

The specimen is female and its age is estimated to be about 6.0-7.5 years old (class V-VI) based on the mandibular tooth-wear pattern (following Passmore et al. 1955) and incisor thin section (following Sergeant and Pimlott 1959). Upon cleaning mud from the skeleton, several abnormalities were discovered. Particularly, the fifth and sixth cervical vertebrae (Fig. 1) show massive erosion of the centra and remodeling of the

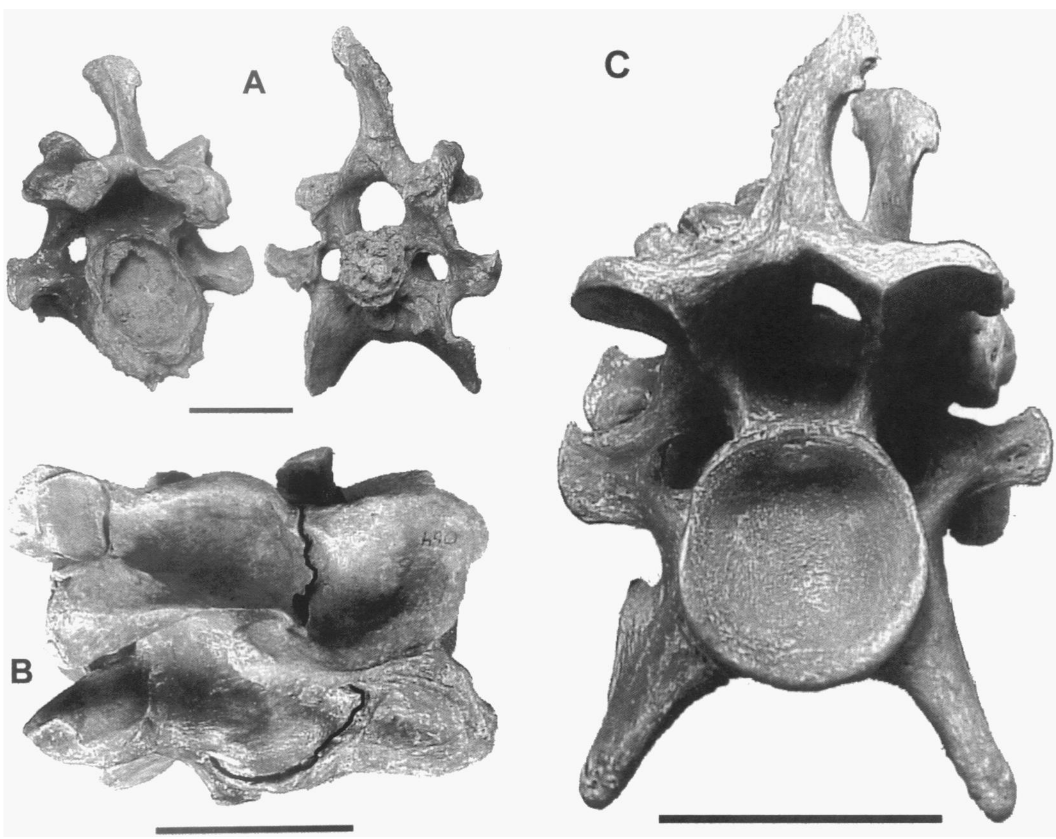

Figure 1. Cervical vertebrae from a moose (*Alces alces*) from Utah. Bar scales are 5 cm. A: Caudal view of the fifth cervical vertebra (left) and cranial view of the sixth cervical vertebra (right) showing extreme erosion of the centra and zygapophyses (vertebral articulations), and the contortions of the neural spines. B: Dorsal view of the fifth (left) and sixth (right) cervical vertebrae in articulation. Line demarcates the abnormal articulation between the pre- and post-zygaphophyses. Cranial to the left. C: Caudal view of the articulated fifth and sixth cervical vertebrae showing the twisted neural spines.

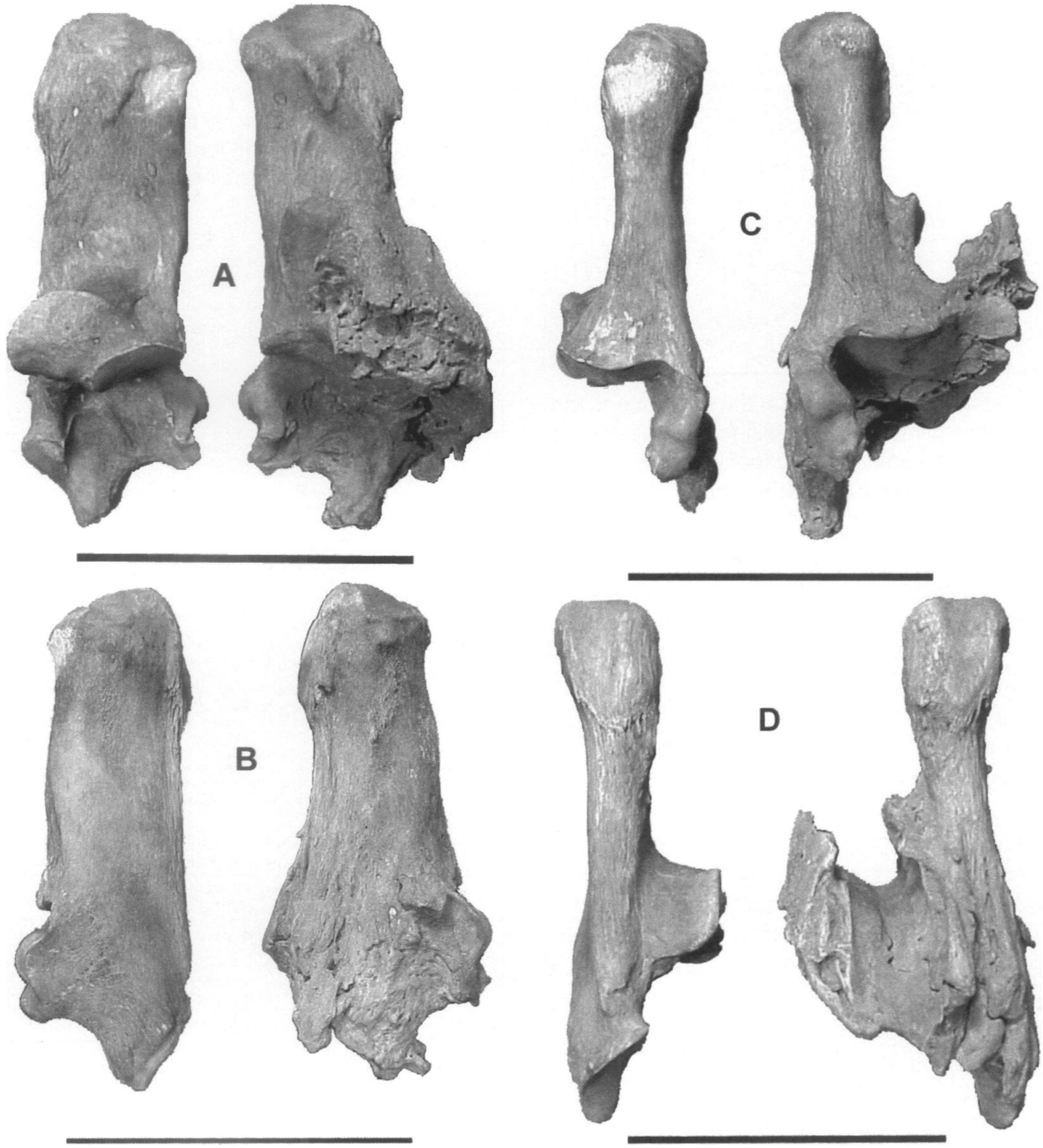

Figure 2. Different views of the left (on left) and right (on right) calcanea. Bar scales are 10 cm. A: Medial view. B: Lateral view. C: Cranial view. D: Caudal view.

zygapophyses (cranial and caudal vertebral articulations). The third, fourth, and seventh cervical vertebrae show deformation of the neural spines. The right calcaneus shows massive abnormal bone growth (Fig. 2), and the right femur suffered a fracture (Fig. 3). Skeletal abnormalities also occur in the sacrum (Fig. 4), right innominate (*os coxae*),

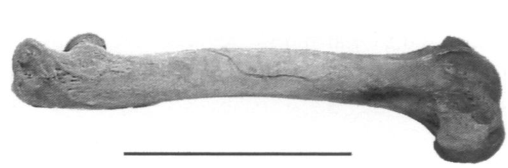

Figure 3. Lateral view of right femur. Note prominent fracture spiraling around bone diaphysis. Bar scale is 20 cm.

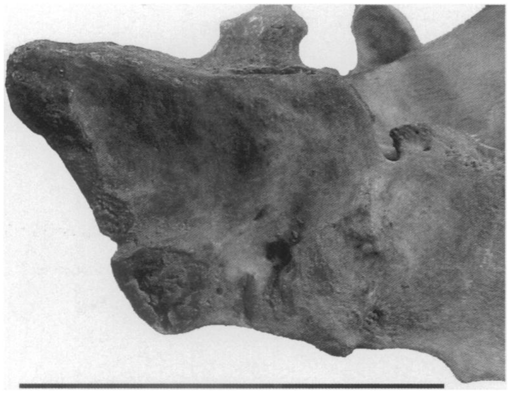

Figure 4. Left lateral view of the sacrum and the sacroiliac joint. Note the pitting and uneven nature on the joint surface that indicates mild osteoarthritis. Bar scale is 10 cm.

and the left metatarsal (cannon bone). A detailed review of all the skeletal elements recovered for this individual was undertaken and potential or real abnormalities were noted in Tables 1 and 2.

Discussion

Osteorarthritis in *Alces*

Peterson (1977) characterized most osteoarthropathy in *Alces* from Isle Royale as osteoarthritis. Following the definition by Sokoloff and Hough (1985), osteoarthritis is defined as a "noninflammatory disorder of movable joints characterized by deterioration and abrasion of articular cartilage, as well as by formation of new bone at the joint surfaces" (p. 1377), and is characterized by osteophytes (spiny bone projections). Peterson (1977) stated that osteoarthritis is common in the weight-bearing joints, particularly the hips, of *Alces*. In addition, he stated that osteoarthritis was not evident before individual moose reached 7 years of age, with predominately older individuals demonstrating this disease.

The Utah specimen does show a degree of osteoarthritis in the weight-bearing joints of the sacrum, innominate, and metatarsal. The age of this individual is consistent with the point at which Peterson (1977) saw development of the disease in other moose. However, osteoarthritis alone cannot account for the changes in the vertebrae, femur, and calcaneus; therefore, other agents must be sought for the additional abnormalities.

Table 1. Gross morphologic description of the axial skeleton of *Alces* specimen (FHSM Mammalogy #31515). Unusual modifications are noted, although some may be ontogenetic changes and not necessarily disease-related. Only the bones recovered for the specimen are listed. "None" means pathology/changes not evident.

Bone element	Evidence of pathology
Cranium	none
Mandible	none
Sternum	none
Cervical vertebrae	
1	none
2	Neural spine and vertebral canal bent to left; pit on left cranial surface
3	Pit on cranial side of centrum; neural spine bent to left; left transverse process bent caudally
4	Neural spine bent to the left; a few osteophytes on spine; pitting on both cranial and on left caudal zygapophyses (vertebral articulations); development of secondary articulations on zygapophyses
5	Neural spine bent to left; whole bone enlarged on left side; secondary articulation on cranial zygapophysis; extensive erosion in caudal side of centrum; remodeling of both zygapophyses; osteophytes on caudal side of centrum
6	Neural spine bent to right; extensive erosion of cranial side of centrum; complete loss of right cranial zygapophysis; remodeling and pitting of left cranial zygapophysis; pitting on left ventral centrum; osteophytes on neural spine; posterior centrum appears normal
7	Two pits on cranial side of centrum; neural spine bent right; secondary articulation on caudal side of centrum
Thoracic vertebrae	
1-3	Only neural spines preserved, appear normal
4	Slight enlargement of the neural spine on the extreme dorsal end
5	Kinks to left near the top of spine; pitting in both cranial and caudal aspects of spine
7	Pitting of right side of neural spine near base resulting in a "network-like" pattern
8-12	none
Lumbar vertebrae	
2-6	none
Sacrum	Remodeling on sacroiliac joint
Ribs	2 out of twenty two recovered show osteophytes on the head

Table 2. Gross morphologic description of the appendicular skeleton of *Alces* specimen (FHSM Mammalogy #31515). Unusual modifications are noted, although some may be ontogenetic changes and not necessarily disease related. Only the bones recovered for the specimen are listed. "None" means pathology/changes not evident. "Missing" means element not recovered.

Bone	**Left**	**Right**
Innominate (*os coxarum*)	missing	Remodeling of sacral articulation
Femur	Development of a "pseudoseptum" in the trochanteric fossa, maybe related to muscle attachment?	Fracture beginning on the cranial surface under the major trochanter and progressing about 7 cm down the anterior face, then twisting around the shaft laterally and proceeding down the lateral surface to 3 cm above the supracondyloid fossa
Tibia	none	missing
Calcaneus	none	Massive bone development on the medial side; articular surface uneven
Astragalus	none	missing
Metatarsal (Cannon)	Osteophytes on the proximal articular perimeter	missing
Scapula	none	missing
Humerus	none	missing
Radioulna	none	missing

Femoral fracture

A visually prominent fracture is present on the right femur beginning on the anterior surface under the major trochanter and progressing about 7 cm down the anterior face, then twisting around the shaft laterally and proceeding down the lateral surface to 3 cm above the supracondyloid fossa. The fracture becomes more visually prominent as it progresses distally. The fracture does not show evidence of healing and presumably occurred shortly before the death of the individual. It is also not impossible that this fracture occurred postmortem.

Cervical vertebrae and calcaneal osteoarthropathy

Figures 1 and 2 show that the cervical vertebrae and the right calcaneus have undergone considerable change. The centra of the vertebrae are deeply pitted. The zygapophyses are highly modified from the normal condition, even to the extent of showing development of secondary articulations. The neural spines are contorted from the normal vertical orientation. When articulated, the cervical vertebrae show a clear bending of the neck and a limited range of motion when the animal was alive.

Additional bone tissue was deposited on the right calcaneus, particularly on the medial side. The disease process, and the bones' response to the stresses they were subjected to, must have taken place for more than a brief amount of time in order to account for these changes in the bone tissue during the life of the individual.

The highly localized nature of the osteoarthropathy of the neck and hock, and the fact that it is not bilaterally symmetrical in the hock, suggest that the origin may be septic rather than systemic or autoimmune. Septic arthritis is caused by a local bacterial, viral, or fungal infection (Mitchell et al.

1988). Such an infection can be caused when pathogens are introduced near a joint, as after an animal bite (Mitchell et al. 1988) or in footrot, a common problem in domestic cattle.

However, the introduction of pathogens can also be, and often is, distant from the subsequently infected joint. Pathogens can migrate through the blood (Schmid 1985a) when the host's systemic immune defense mechanisms fail (Schmid 1985b). For example, infection in bone has been reported after pathogens were released from the lower urinary tract (Henson and Coventry 1956). Once at the joint, the vascular network surrounding the articular margin offers a pathway for pathogen movement from the adjacent soft tissue to the synovium (Schmid 1985a; Mitchell et al. 1988).

Conclusion

This individual shows four distinct osteoarthropathies: 1) extensive remodeling of the fifth and sixth cervical vertebrae and lesser changes in the other cervical vertebrae; 2) massive bone overgrowth on the right calcaneus, although the left calcaneus appears free of disease; 3) arthritic changes to the weight-bearing joints of the pelvis; and 4) a fracture in the right femur. Although the exact causal agents of the bone pathologies cannot be known for certain in the *Alces* specimen reported here, it is clear that the individual suffered from chronic osteoarthropathy. The fracture in the femur would no doubt have been the result of trauma, pre- or postmortem. The osteoarthritis in the pelvis is a common and frequently observed occurrence in moose of this individual's age. This leaves the interesting question of what caused the changes in the neck and hock.

The bending or twisting of the neck might be described generically as scoliosis. It is not possible in this specimen to distinguish between congenital scoliosis and infection resulting from injury or other causes. Although a congenital scoliosis might account for changes in the vertebrae, it does not account for the changes in the calcaneus.

Regarding the cause(s) of this individual's pathologies, a number of alternative hypotheses suggest themselves. At one extreme, each of the four pathological situations seen in this specimen can be explained individually, but it requires many disease causing agents or processes. On the other hand, it is possible that the disease-causing mechanism in both the hock and neck was a systemic infection with multiple points of manifestation. Unfortunately, no crucial test suggests itself that would distinguish one hypothesis as superior.

It is interesting to speculate how this individual lived, apparently for a considerable time, in a state of distress. Lankester and Samuel (1997) noted that moose possess a remarkable ability to recover from both infection and broken bones. In the modern ecosystem of northern Utah, with its lack of large carnivores (due to their extirpation), this diseased and weakened animal must have lived unmolested for quite a while. Finally, environmental pressures led to death. It is reasonable to speculate that in a balanced ecological setting with a population of large carnivores this individual would have been preyed upon before the disease process(es) had time to so dramatically change the bony architecture.

Acknowledgements

I thank Mike Nelson, University of Wisconsin, La Crosse, for providing me the field experience that led to the discovery of this specimen. I benefited greatly from discussions with Mary Morgan, Fort Hays State University Department of Nursing, and Bruce Rothschild, Arthritis Center of Northeast Ohio. Michael Madden and Michael Miller, Fort Hays State University

Department of Medical Diagnostic Imaging; Kathy Hoh, Center for Orthopaedic Care, Cincinnati; and Robert F. Bowerman, Lisa Dinkel, and Stan Unruh, Hays Medical Center, all assisted with radiographs and helpful discussions. H. Robins Richards, Fort Hays State University, assisted me in making thin sections of the incisors. I thank Cameron Liggett, Sternberg Museum, and three anonymous reviewers for their comments in critically reviewing this paper. As always, any mistakes in interpretations are mine alone.

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