Paleohistological Study of Pleistocene Mammoth (*Mammuthus*) Bone

Margaret Streeter, Sean Prall, and Christopher Hill

Paleohistological analysis has been applied to nonhuman bone to provide information on the biological age of animals as well as processes of diagenesis or fossilization (Cook et al. 1962; Sander and Andrassy 2006; Enlow and Brown 1956). Here we report on the histological analysis of two specimens of Pleistocene proboscideans from the western interior of North America. These specimens retain elements of the bone microstructure and are from distinct depositional and taphonomic contexts. The comparison of osteon size and density provides information on the biological age at death of these individuals and has the potential to address questions regarding the rate of growth and development of Pleistocene megafauna. This research illustrates the utility of even small fragments of ancient bone for estimating the lifespan and physiological characteristics of Pleistocene fauna as well as for evaluating post-depositional processes (Hedges 2002; Jans et al. 2002).

The materials analyzed are fragments of cortical bone from two proboscideans. The geologically oldest sample is a fragment of rib recovered from a gravel pit at Miles City, Montana (Hill 2006). It is likely a fragment of *Mammuthus columbi*. However, the presence of mastodon (*Mammut americanum*) in the deposit means that the identification of the specimen as either mammoth or mastodon has not been determined with absolute certainty. The geologic context indicates this specimen is pre-Wisconsin (Illinoian?) in age (younger than the Lava Creek B tephra dated to around 600,000 years ago and possibly older than calcretes dated to at least 124,000 years ago). The geologically younger sample is part of a limb bone from a single, nearly complete *Mammuthus columbi* collected from upland silts in the Deer Creek drainage in eastern Montana. The specimen was found in eolian silts underlying a buried soil and has a collagen (XAD-gelatin) age of about 12,330 RCYBP (Hill 2006). A femur from this mammoth has been reported to contain fibrous collagen but no visible osteocytes or vessels (Schweitzer et al. 2007).

A set of microscopic slides was prepared for each specimen using standard histological procedures (Stout and Paine 1992). Laboratory methods consisted of embedding undecalcified fragments of bone in epoxy resin, cutting the specimen to 100 μm, and hand-grinding the thin section to a thickness of approximately 80 μm (Frost 1958). The slides were examined on a microscope using transmitted and polarized light at 40X, 100X, and 200X magnifications as needed. Measurement of osteon size was accomplished using the point count method at 200X.

The results of these studies provide information on the age, growth and

Margaret Streeter, Sean Prall, and Christopher Hill, Department of Anthropology, Boise State University, Boise, ID 83725-1950; e-mails: margaretstreeter@boisestate.edu seanprall@yahoo.com chill2@boisestate.edu

development and the post-depositional factors that affected the Proboscidean bone. The thin sections show the preservation of the osteon structure, including concentric lamellae that surround the Haversian canals, which extend longitudinally through the bone and provide a passage for small blood vessels. Cortical surfaces were strongly dominated by closely packed osteons (Haversian systems), and osteocytic lacunae were observed. The cortex comprised several generations of secondary osteons (evidence of bone remodeling), whose accumulation has been shown to correlate strongly with age in some mammals (cf. Kerley and Ubelaker 1978). The density of Haversian systems, the fact that no primary lamellar, plexiform bone, or interstitial lamellae were visible indicates that these individuals were mature adults. Mean osteon size and osteon density, which can also be used to evaluate the relative age of individuals, are compared here with a previous study on an adult mastodon (Wu et al. 1970) (Table 1).

Table 1. Histological parameters of Proboscidean bone.

Sample	Mean Osteon Area (mm^2)	Osteon Number ($/mm^2$)
Deer Creek	.090	5.2
Miles City	.064	7.7
Mastodon (Wu et al. 1970)		9.6[1]

[1] Includes osteon fragments.

The thin sections also provide information on the effects of diagenetic alteration (Schultz 2001, Turner-Walker and Jans 2008). The bone of the pre-Wisconsin (Miles City) proboscidean, recovered from terrace gravels, has an amber color reflecting incipient mineralization, most likely related to Fe-enrichment from groundwater. In contrast, the late-Pleistocene (Deer Creek) mammoth bone, recovered from upland eolian silts, is more friable and has very little color, indicating essentially no mineral enrichment. This supports the interpretation that different hydrologic conditions have affected the bones. No evidence of calcite or silica crystal formation or evidence of fungal, algal, or bacterial invasion was observed in either bone.

These data can be compared with other histological studies of fossil bone. Like specimens of *Mammuthus* from Alaska (Eschscholtz Bay) and California (Irvington and Rancho la Brea) (Cook et al. 1962), and from late-Pleistocene northern Europe (Sander and Andrassy 2006), the Montana samples exhibit the persistence of the Haversian systems (secondary bone formation). All the specimens have features that are similar to those found in present-day elephant bone (Cook et al. 1962). Thus, histological studies appear to provide a way to compare the physiology and growth patterns of extinct and extant proboscideans.

References Cited

Cook, S. F., S. T. Brooks, and H. E. Ezra-Cohn 1962 Histological Studies on Fossil Bone. *Journal of Paleontology* 36(3):483–94.

Enlow, D.H., S. O. Brown 1956 A Comparative Histological Study of Fossil and Recent Bone Tissues Part 1. *Texas Journal of Science* 8:405–43.

Frost, H. M. 1958 Preparation of Thin Undecalcified Bone Sections by Rapid Manual Method. *Stain Technology* 33:271–76.

Hedges, R. E. M. 2002 Bone Diagenesis: An Overview of Processes. *Archaeometry* 44(3):319–28.

Hill, C. L. 2006 Stratigraphic and Geochronologic Contexts of Mammoth (*Mammuthus*) and Other Pleistocene Fauna, Upper Missouri Basin (Northern Great Plains and Rocky Mountains), U.S.A. *Quaternary International* 142-143:87–106.

Jans, M. M. E., H. Kars, C. M. Nielsen-Marsh, C. I. Smith, A. G. Nord, P. Arthur, and N. Earl 2002 *In Situ* Preservation of Archaeological Bone: A Histological Study within a Multidisciplinary Approach. *Archaeometry* 44(3):343–52.

Kerley, E. R., and D. H. Ubelaker 1978 Revisions in the Microscopic Method of Estimating Age at Death in Human Cortical Bone. *American Journal of Physical Anthropology* 49:545–46.

Sander, P. M., and P. Andrassy 2006 Lines of Arrested Growth and Bone Histology in Pleistocene Large Mammals from Germany: What Do They Tell Us About Dinosaur Physiology? *Palaeontographica Abt. A.* 277:143–59.

Schultz, M. 2001 Paleohistopathology of Bone: A New Approach to the Study of Ancient Diseases. *Yearbook of Physical Anthropology* 44:106–07.

Schweitzer, M.H. 2007 Soft Tissue and Cellular Preservation in Vertebrate Skeletal Elements from the Cretaceous to the Present. *Proceedings of the Royal Society B.* 274:183–97.

Stout, S. D., R. R. Paine 1992 Brief Communication: Histological Age Estimation Using Rib and Clavicle. *American Journal of Physical Anthropology* 87:111–15.

Turner-Walker, G., M. Jans 2008 Reconstructing Taphonomic Histories Using Histological Analysis. *Palaeogeography, Palaeoclimatology, Palaeoecology* 266:227–35.

Wu, K., K. E. Schubeck, H. M. Frost, and A. Villanueva 1970 Haversian Bone Formation Rates Determined by a New Method in a Mastodon, and in Human Diabetes Mellitus and Osteoporosis. *Calcified Tissue Research* 6:204–19.