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Taphonomy of the Inglewood mammoth (*Mammuthus columbi*) (Maryland, USA): Green-bone fracturing of fossil bones

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ABSTRACT

An adolescent *Mammuthus columbi* at the 24 ka Inglewood site in the eastern USA had not been killed or scavenged by carnivores, and its bones had not been trampled or weathered before burial. The bones were well preserved in an anaerobic and impermeable matrix which was disturbed in the 20th century by earthmoving equipment. The weight of the mechanized equipment broke skeletal elements into fragments with the morphology of "green-bone" fractures. The occurrence of a recently created green-bone type of breakage may be relevant for understanding other fossil proboscidean assemblages.

1. Introduction

This paper describes a site in eastern North America where *Mammuthus columbi* bones in an anaerobic matrix were fractured as if fresh (or "green") while still buried. The bones are directly dated to ~24 ka, as discussed below. A possibility exists that one limb element had been traumatically fractured before the animal died, but if so, the still-buried bone was broken again during construction activity at the site. The fracture morphology of some fragmented pieces is identical to the results of breakage done when bones are fresh. The paper concludes by briefly considering other fossil proboscidean sites with bones possibly fractured by similar processes.

The term "green-bone" fracturing usually refers to deliberate human breakage of defleshed but still fresh and unweathered bones, which is done either to obtain the internal oils/grease or to break off large cortical fragments for shaping into implements. The degree of freshness in green bones may vary from a condition immediately following defleshing of an animal that has been dead less than an hour, to the beginning of drying that starts within 24 h but does not visibly affect bone surfaces, to a later state in which cortical cracks appear. Defleshed bones in warm and sunny tropical environs may develop microcracks within one to three days. In temperate or subarctic environs, the cracking may take weeks or longer to develop on unburied bones, but the bones will be slowly drying and undergoing microbial breakdown of moisture and collagen. Defleshed bones that have dried for days to weeks on ground surfaces but that are not yet in weathering stage 1 (Behrensmeyer, 1978) may break with mixed curvilinear and linear fracture fronts, partly similar to green-bone fracturing.

In this paper, the term "green-bone" fracturing is used to refer only to a morphology which is widely assumed to result from the breaking of fresh bones before burial, fossilization, or mineralization. In this usage, it may or may not be cultural in origin. The widely accepted definition of "green-bone" fracturing includes the presence of (1) helical (a.k.a. spiral or curvilinear) fracture outlines, either exclusively or more often than straight fracture front outlines, (2) "smooth" fracture surfaces (although this is not always literally accurate for proboscidean limb bones, as discussed below in Section 7), and (3) acute angles between fracture surfaces and cortical surfaces (which is also not always correct, as discussed below in Section 7).

The Inglewood mammoth site was mentioned in Haynes (1991: 235–236), and summarized in two technical reports (Haynes, 2015a, b) posted on the Web as free downloadable pdf files. The present paper presents information for a larger audience, with a goal of bringing attention to the site's potential relevance to studies of proboscidean assemblages. Inglewood provides a valuable cautionary lesson for taphonomists who interpret fossil bones.

2. The bones and their context

The site is situated in the coastal plain physiographic province of the state of Maryland, eastern USA, near Washington, D.C (Fig. 1). In 1981, mechanical construction equipment digging a drainage ditch

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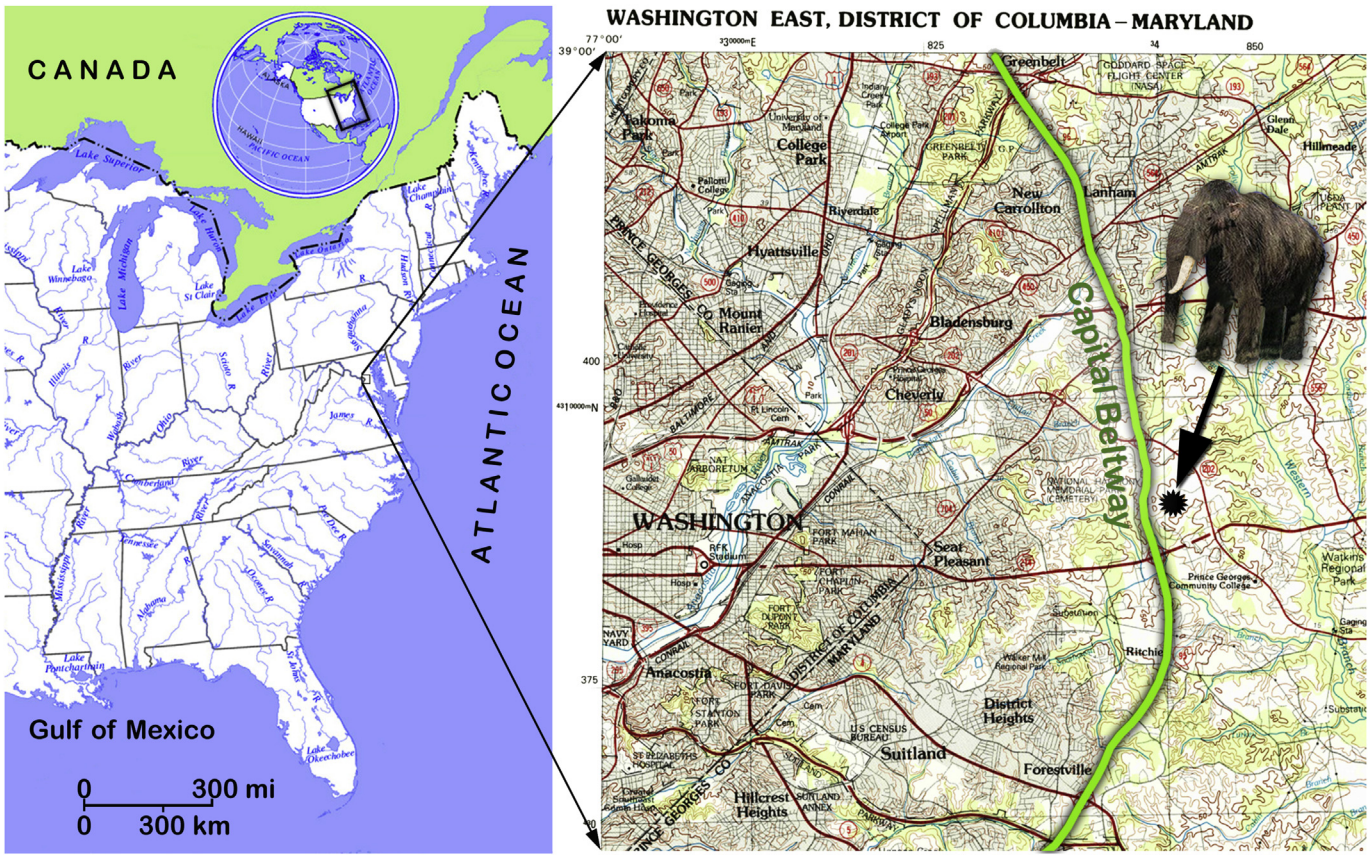

Fig. 1. Location of the Inglewood mammoth site. Maps have been edited from public domain files downloaded from http://nationalatlas.gov.

(Fig. 2) and leveling the open ground for a planned commercial park partly exposed the upper part of a deposit containing the mammoth bones. The excavating machinery leveled the bed of the ditch to ~3–4.5 m below the surface of the gently sloping surrounding field, and possibly ~1.2–1.8 m below the level of an existing natural drainage way, and smoothed the sloping banks. The constructed ditch drained towards an unnamed stream flowing to a tributary of the Patuxent River several miles southeast of the site.

About eight months after the ditch was constructed, a geology student who was hunting Cretaceous fossils in the ditch used a trenching tool to dig out mammoth ribs, tusk fragments, and other elements. He reported the site to the Smithsonian Institution. Controlled salvage excavations were immediately begun, and within four days the remaining bone assemblage was recovered.

The recovered elements that could be identified are listed in Table 1. Missing from the list are the maxilla and most of the upper teeth, one tusk, one scapula, seven larger limb bones, and foot bones.

The bones were mapped and recorded in three dimensions in the field. Fig. 3 is a map of the excavated materials. Deepest bones were at almost the same level in all excavated soundings. The bonebed thickness in the main area was 0.26 m–0.32 m. The main bone concentration was about 2.5 × 2 m in extent, with eight scattered fragments laterally separated by up to 3 m. The sediments originally burying the bones may have been ~1.27 m thick, but most had been removed during the construction of the drainage ditch.

The missing elements may have been collected before the Smithsonian excavations, or removed by the mechanical equipment, and therefore could not be recorded.

Most vertebrae were recovered as unfused segments such as centra and spinous processes. All but three of 21 recovered ribs were unbroken. Other elements had been fragmented, including the cranium (recovered as only a few small pieces), one or possibly two incomplete limb elements, one innominate, one scapula, a few plates of upper teeth, and the mandible.

Mandibular teeth dp4 and M1 were recovered. These teeth are also known as M3 and M4 by field biologists. Measurements were taken by Frank Whitmore, a paleontologist with the U.S. Geological Survey, who determined the taxon to be *M. columbi*. The whereabouts of the teeth are unknown as of the time of this writing, so precise details cannot be presented. Two photographs taken in 1982 (Fig. 4, and Haynes, 1991:7, fig. 1.3) show two very worn third teeth (dp4) and two complete fourth teeth (M1) in early wear in the mandible. Estimated maximum width of the left M1 is ~70 mm, and estimated maximum length ~160 mm. Fifteen enamel loops can be counted on each M1, including one at the rear of each that is only starting to show occlusal wear. The number of plates per 100 mm on the two M1 teeth is just over 10, similar to an average for the lower M1 teeth of both *M. columbi* and *M. primigenius*. The enamel thickness roughly measurable on the photographs of the left M1 averages ~2.5 mm, which is in the known range for *M. columbi* but thicker than for *M. primigenius* (Maglio, 1973; Kurtén and Anderson, 1980). The stage of tooth wear and assigned ontogenetic age are reported below in Section 3.

The sedimentary matrix originally enclosing the bones had been distorted by heavy equipment, but the bones had not been exposed to air when the site was first discovered. The elements remained buried with muddy drainage water continuing to flow over the enclosing sediments in the locus. During the salvage excavations,