Miocene Proboscidean Tooth Found in Evaporite Karst Sinkhole near Gate, Oklahoma

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Abstract: Fragments of a proboscidean tooth were found in Neogene sediments of the Ogallala Formation within an evaporate karst sinkhole formed in Permian redbeds outside Gate, Oklahoma. The pieces were reconstructed and identified by comparison with museum specimens and literature. The tooth was determined to belong to the family Gomphotheriidae, and the species complex *Gomphotherium "productum."* The species is known by other records in the Late Miocene of Oklahoma and surrounding areas. Although a number of collapse sinkholes with fillings of Ogallala Formation sediments are known in Oklahoma, very few of them have been found to contain identifiable fossils such as this one.

Introduction and Methods

Gomphotheres were elephant-like proboscideans that were globally distributed from the Miocene epoch to the Pleistocene. Gomphotheres (Family Gomphotheriidae) were a diverse and paraphyletic group, but were distinguished by their two upper and two lower tusks. In the Miocene, gomphotheres were distributed all across the North American continent, especially the Great Plains. Specifically in Oklahoma, their fossil record spans from about 11 - 6 Ma (million years ago), where it includes the genera *Amebelodon, Gomphotherium, Rhynchotherium,* cf. *Serbelodon*, and *Stegomastodon* (Lambert and Shoshani 1998; Schultz 2002; Czaplewski and Smith 2003; Czaplewski 2008).

In this paper we describe a proboscidean tooth fragment found in an evaporite karst sinkhole in Beaver County, Oklahoma. Evaporite karst is common in western Oklahoma; Permian redbeds in this region include layers of gypsum and other evaporate rocks that are occasionally prone to subsurface dissolution, forming sinkholes and caves of various types (Meyers 1962; Johnson 1989, 1996; Johnson and Neal 2003; Gutiérrez et al. 2007). These sinkholes are occasionally filled with buff to yellow to brown Neogene sands and silts of the Ogallala Formation, and they sometimes preserve vertebrate fossils in the region (e.g., at the Rowe-Lewis Ranch quarries in Texas with late Miocene horse bones and leaf fossils; Schultz 2002). At times, these local structural collapses can be larger and develop sizable fillings of Ogallala Formation sediments with abundant vertebrate fossils. In the Miocene they may have held small lakes and ponds with fish, turtles, and alligators, as well as horses and other terrestrial animals on the surrounding uplands, as evidenced by fossils of the Beaver local fauna, Oklahoma (Schultz 2002).

The sinkhole in which the fossil tooth occurred was located along an approximately 4 m-high bluff that runs horizontally for about 45 m and was possibly exposed by local faulting

as well as subsurface collapse; in this bluff, the strata are dipping to the east, possibly indicating a larger-scale collapse outside the boundaries of the small, vertical-walled sinkhole in the central portion of the exposed bluff. The small vertical-walled sinkhole is well exposed in cross-section within the bluff (Figure 1), and has a semicircular surface expression (seen in plan view in Google Earth imagery) truncated by the exposure of the bluff face. In cross-section the Permian beds dip from both vertical walls of the sink toward the center of the sink (Fig. 1; partly obscured by modern trees). In this part of Beaver County, widespread Permian rocks are overlain by Neogene rocks of the Ogallala Formation. According to Oklahoma Geological Survey surface geology maps, the Ogallala Formation unconformably overlies the Permian Rush Springs Formation in the immediate vicinity of the sinkhole (Stanley et al. 2002). Most beds of the Ogallala Formation in Oklahoma preserve fossils of Miocene age. On the land surface on top of the collapse we observed a thin veneer of pale buff-colored deposits of the Ogallala Formation only 30 m away from the sinkhole, and there is detritus of Ogallala within the sinkhole. The tooth fragment is clearly of Miocene age, and it could have weathered out of the overlying Ogallala Formation deposits and fallen into this sinkhole more recently. Alternatively, Ogallala Formation deposits containing the fossil tooth might have once filled part of the sinkhole in the Miocene, but mostly weathered away since.

The sinkhole is partially filled with Permian breakdown and paler Miocene sediments. Cheek tooth fragments of a mastodont proboscidean were found in this sinkhole by Albert Laverty while surface prospecting for fossils in 2014. The fossil site is designated as Oklahoma Museum of Natural History (OMNH) locality V1748, and is about 9.5 km southwest of the town of

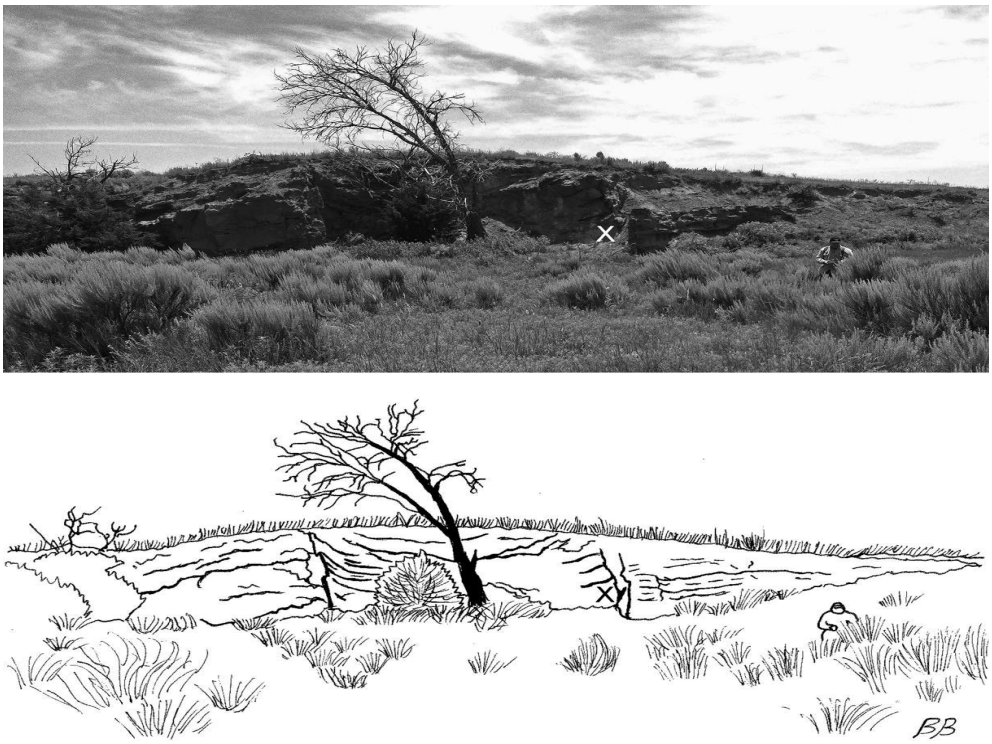

Figure 1. Photograph and interpretive sketch of the fossil locality and collapse sink (with trees growing at the center of the base) in which the partial gomphothere tooth (Oklahoma Museum of Natural History 79124) occurred, Beaver County, Oklahoma. X indicates the spot where the tooth was found. View is toward the south.

Gate, Beaver County, Oklahoma. The site was visited by an OMNH crew in 2015, when we used picks and shovels to dig through more of the sinkhole fill sediments. In the process, a few more fragments of the tooth and a small chip of bone were recovered. The fragments were transported to the Vertebrate Paleontology Lab of the OMNH where they were reconstructed into a partial tooth, now cataloged as OMNH 79124. The tooth was measured with a dial caliper to the nearest 0.01 mm.

Results and Discussion

The tooth is part of a lower left molar, either m2 or m3 (Figure 2). Our initial uncertainty about whether it is an m2 or m3 stems from the fact that at least half of the tooth is missing. Its size matches better that of m3s and is larger than m2s of other gomphothere teeth in the OMNH vertebrate paleontology collection. In addition, it shows a wear facet on one end caused by interdental contact with an adjacent molar. We interpret that end as the anterior end of an m3, because the m3 is the last tooth to appear in adult gomphotheres and the posterior end could not have been in contact with another tooth. The m3 is at a relatively light stage of wear, and has very thick enamel with a simple enamel pattern composed of single trefoils. Due to the incompleteness of the molar, we were only able to make one meaningful measurement; the width of the first lophid is 76.6 mm.

We adopted the dental terminology proposed by Tassy (2014:fig. 2; translated to English). Using a model describing the degrees of zygodonty developed by Wang et al. (2016), we determined that the sinkhole tooth displayed level 0 zygodonty, indicating a relatively primitive level of complexity compared to other gomphotheres and mastodons. Specifically, the m3 shows the following characteristics: blunt pretrite main cuspid, singular non-crestlike pretrite mesoconelet, weak non-crestlike pretrite central conules, blunt non-crestlike postrite main cusp that is anteroposteriorly compressed, large and blunt non-crestlike postrite mesoconelet that is not subdivided, weak postrite central conules, and anteroposteriorly narrow interlophids.

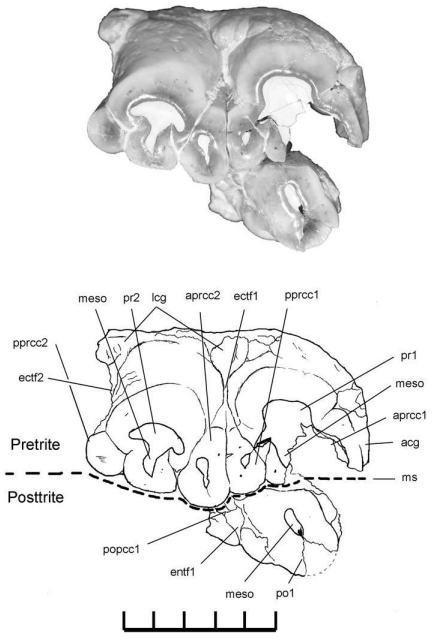

Figure 2. Dental nomenclature for the lower left molar of a gomphothere adapted from Tassy (2014: fig. 2b) and applied to Oklahoma specimen (OMNH 79124). Heavy dashed line indicates the median sulcus, which separates the pretrite and posttrite aspects of the tooth. Abbreviations: acg, anterior cingulum; aprcc1, anterior pretrite central conule of 1st lophid (paraconid); aprcc2, anterior pretrite central conule of 2nd lophid; ectf1, ectoflexus of 1st interlophid; ectf2, ectoflexus of 2nd interlophid; entf1, entoflexus of 1st interlophid; lcg, lingual cingulum; meso, mesoconelet of each half-lophid on either side (pretrite or posttrite) of the median sulcus; ms, median sulcus; po1, posttrite main cusp of 1st lophid (metaconid); popcc1, posterior posttrite central conules of 1st lophid; pprcc1, posterior pretrite central conule of 1st lophid (protoconulid); pprcc2, posterior pretrite central conule of 2nd lophid; pr1, pretrite main cuspid of 1st lophid (protoconid); pr2, pretrite main cuspid of 2nd lophid. Scale bar = 5 cm.

These morphological characteristics demonstrate that the tooth belongs to the genus *Gomphotherium*, which has a fossil record in North America, Eurasia, and Africa. The only species of *Gomphotherium* currently recognized in North America is *Gomphotherium*

"productum." We also compared the sinkhole tooth with other proboscidean teeth identified as *G. "productum"* from the Arnett locality (OMNH locality V54, early Hemphillian). *Gomphotherium "productum"* molars from Arnett that are at a similar stage of wear also very closely match the morphological characteristics of our sinkhole tooth.

The species *G. "productum"* was recognized by Wang et al. (2017) as a species-complex that needs further study, because the taxon might include undiagnosed additional species. For this reason, we place quotation marks around the name "*productum*." The species spans geologic time from 16 million to 4 million years ago (Wang et. al 2017), and accordingly, confirms a Miocene age for the molar from the sinkhole deposit. Mammalian fossils found elsewhere in western Oklahoma in sediments of the Ogallala Formation indicate that the formation there reflects the Late Miocene, and the fossils represent both the Clarendonian and Hemphillian North American Land Mammal Ages (NALMA; Schultz 2002). Typical fossils of the Ogallala Formation in western Oklahoma represent megafauna or large vertebrates (few microvertebrates) including giant tortoises, alligators, scimitar-toothed cats, nimravids (false cats), bone-cracking dogs, shovel-tusked gomphotheres, diverse camelids (up to four genera during the Clarendonian), other extinct artiodactyl families, diverse horses (up to 10 genera during the Clarendonian), and rhinoceroses (Schultz 2002). Relatively few small collapse sinkholes filled with Ogallala sediments are recognizable in western Oklahoma, and fewer still yield vertebrate fossils (Czaplewski 2008; personal observation). This find is a rare and distinctive occurrence of a single identifiable Neogene fossil from a small collapse sink in Oklahoma. Because these sinkholes sometimes form a part of the surface drainage (draining into the subsurface voids) and have been present since at least the Miocene, they probably provided waterholes during the Neogene at which animals like gomphotheres could drink, possibly become trapped, or into which their remains could have been washed. It is not possible to assign this occurrence of *G. "productum"* to one of the two of the Late Miocene NALMAs, because no other faunal remains or taxa were recovered in the collapse sinkhole that could help narrow the age range. Nevertheless, a Late Miocene age is consistent with other Miocene localities and faunas in western Oklahoma (Schultz, 2002).

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