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Youngest radiocarbon age for Jefferson's ground sloth, *Megalonyx jeffersonii* (Xenarthra, Megalonychidae)

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ABSTRACT

A partial skeleton of the extinct ground sloth, *Megalonyx jeffersonii*, recovered from a farm near Millersburg, Ohio in 1890, was radiocarbon dated for the first time. The ungual dated is part of a skeleton mounted for exhibit at the Orton Geological Museum at Ohio State University and was the first mounted skeleton of this animal. From its initial discovery the bones were treated with multiple organic compounds that had the potential to compromise the radiocarbon age and the specimen required special treatments in order to obtain a valid radiocarbon age. The ^{14}C measurement on the ungual from this skeleton (11,235 ± 40 ^{14}C yr BP = 13,180–13,034 cal yr BP) is the youngest ^{14}C age presently determined for *M. jeffersonii*.

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Introduction

The partial skeleton of the *Megalonyx* was discovered in December 1890 by Abraham Drushell while excavating a ditch to drain a bog on his farm in Berlin Township, near Millersburg, Holmes County, Ohio, N 40°34.98′, W 81°48.82′. The elevation of the site is approximately 329 m (1080 ft). The bones were preserved in a foot-thick layer of shell–marl overlain by a peat and were recovered at a depth of about 2 m (6 ft) below ground level (Claypole, 1891; Orton, 1891).

As reported by Claypole (1891), the recovered parts of the skeleton included three teeth, one hyoid, one broken cervical, three lumbar, one caudal, three complete ribs, five partial ribs, one clavicle, one radius, two femora, one tibia, two fibulae, two patellae, and two calcanea. Claypole (1891) also reported that 22 carpals and tarsals, five metacarpals and metatarsals, nine phalanges, and eleven unguals were recovered. We have subsequently identified the following in the mounted skeleton: left manus: lunar, ungual digit I, second metacarpal and three phalanges, fourth metacarpal and proximal phalanx, fifth metacarpal; right manus: first metacarpal and proximal phalanx, all phalanges second digit, fourth metacarpal and all phalanges, fifth metacarpal; right pes: navicular, entocuneiform, mesocuneiform, second metatarsal with proximal and second phalanges, fourth metatarsal with all phalanges; left pes navicular, second metatarsal with proximal phalanx, third metatarsal and the ungual of digit four. The digit assignment for the phalanges is based on where they are currently placed in the articulated skeleton. Given the general similarity of the phalanges from different digits to each other, it is possible that some have been placed on the incorrect digit of either the manus or pes. In 1891, Mrs. Drushell used a hot glue to preserve the bones prior to their donation to Ohio State University (Murphy, 1979). These bones (OSU 15758) were subsequently mounted for display at the Orton Geological Museum, Ohio State University, Columbus, Ohio (Fig. 1). Despite *Megalonyx* being the first reported ground sloth in North America and first described by Thomas Jefferson in 1799 (Jefferson, 1799), only two other partial skeletons, one from Henderson, Kentucky and the other from Natchez, Mississippi had been found prior to the Millersburg specimen and both were represented by smaller portions of the skeleton (Leidy, 1855). All other previous records of *Megalonyx* consisted of isolated bones and teeth. The Millersburg specimen is the first *Megalonyx* found in Ohio (Orton, 1891). Since its discovery two additional partial skeletons have been found in the state, from Huron (Hay, 1923; Redmond et al., 2012) and Darke County (Mills, 1975).

The Millersburg specimen has the distinction of being the first skeleton of *Megalonyx* mounted for a museum exhibit (Fig. 1) and was installed in 1896, on Thomas Jefferson's birthday, April 13th. The skeleton was mounted by Ward's Natural Science Establishment of Rochester, New York, with missing parts of the skeleton either being entirely fabricated, e.g., the pelvis or provided by plaster casts of other *Megalonyx* specimens. For example, the skull is a cast of the Owen

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Figure 1. Photo of mounted skeleton of *Megalonyx jeffersonii*, OSU 15758, in Orton Geological Museum, Ohio State University.

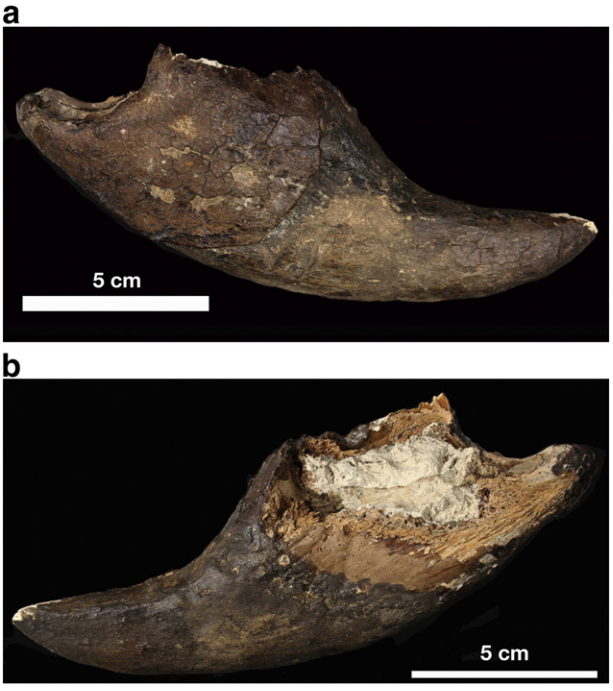

Figure 2. Lateral (a) and Medial (b) views of the *Megalonyx jeffersonii* ungual phalanx used for AMS ^{14}C dating. Infilling plaster, and exterior shellac and black paint are evident.

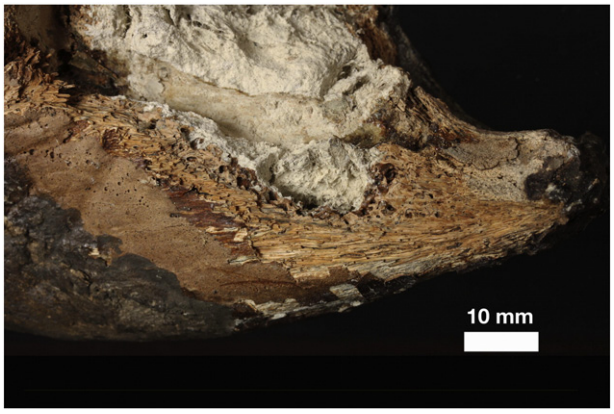

Figure 3. Close-up view of the ungual phalanx and the infilling plaster, and exterior black paint overlying reddish brown shellac on the bone's exterior surface.

specimen from Canoe Creek, near Henderson, Kentucky (Leidy, 1855, Plates I–III). Following mounting, the entire skeleton was painted black, thereby making it difficult to distinguish original bone from either the casts or fabricated parts. When the skeleton was remounted in 1979, the bones were cleaned and shellac was added as a preservative (Murphy, 1979).

New dating details

A portion of the ungual from the second digit ("index finger") of the right manus was sampled for ^{14}C dating. Because the skeleton had experienced significant contamination during earlier preservation attempts, dating the bones required more than routine chemical purification. The bones had first been coated with an animal-based glue in 1891, paint in 1896 and finally shellac in 1979. Our approach combined physical

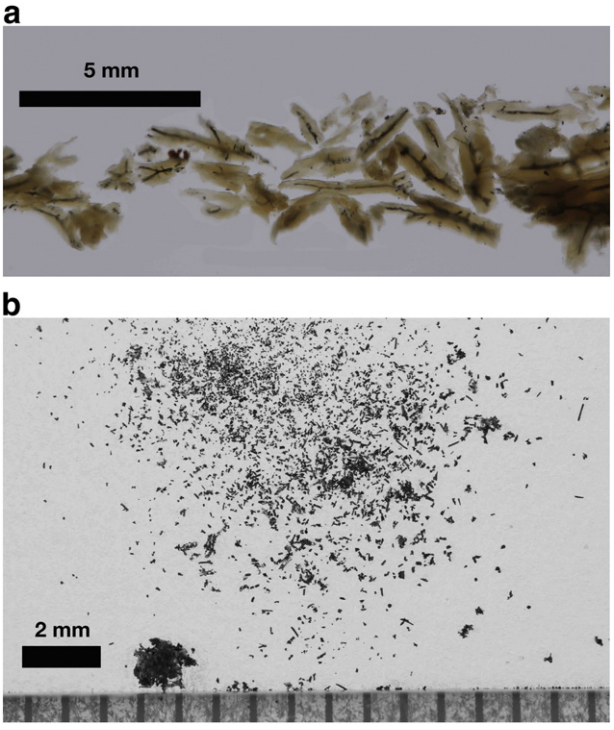

Figure 4. Collagen fibrils (a) remaining after decalcification and KOH extraction. The collagen separates from glues and preservatives that have different physical behaviors than the collagen and leaves individual fibrils. After KOH extraction that removes humates, collagen is gelatinized, which dissolves collagen but not hot water-insoluble detritus such as clays and silts, shellac, paint and iron oxides filling Haversian canals (3b).

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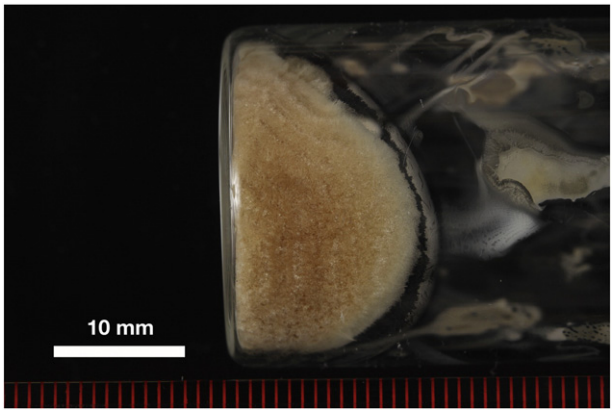

Figure 5. Freeze dried gelatin obtained by dissolving alkali-treated decalcified collagen in 90 °C, pH 2 water and filtering the solution through a 0.45 μm membrane.

dissection to avoid obvious contaminants with dating of different chemical fractions to identify contamination at specific stages of the purification process.

Figures 2b and 3 illustrate how the paint and shellac are restricted to the specimen's exterior and do not penetrate into the cortical bone. These preservatives were physically avoided by removing bone as far from the reddish brown shellacked bone as possible and closest to the medullary cavity (Fig. 3). While shellac and black paint were easily identified visually; the first preservative, animal-based glue applied in 1891, was not readily evident. Animal-based glues are collagen dissolved from hides and bones. Because their composition is identical to fossil collagen being isolated for ^{14}C dating, there is potential for the glues to contaminate the bone collagen. Consequently, the ungual was treated to remove the modern (1891 AD) glue as well as the paint and shellac. Two different chemical fractions (Gelatin and XAD-collagen) were dated to assess the removal of the three preservatives. During decalcification, fragments of the glues and preservatives separated from the fossil bone and its collagen, and were decanted and removed. As decalcification and subsequent KOH extraction proceeded, individual collagen fibrils became visible and it was evident that glues separated from the fibrils and left the intact, fossil collagen (Fig. 4a). Heating the fossil collagen in 90°C, pH 2 water for 15 min dissolved the collagen, but left silts, clays, iron oxides and preservatives as insoluble residues (Fig. 4b) that were separated from the gelatin solution during filtration through a 0.45 μm Millex Durapore membrane. The freeze-dried gelatin (Fig. 5) was hydrolyzed in 6 N HCl at 110°C and passed through an XAD resin column to remove fulvic acids. Both the gelatin and XAD chemical fractions were AMS ^{14}C dated to test if their ages differed. The gelatin fraction measured 11,205 ± 35 ^{14}C yr BP (UCIAMS-116384) and the XAD-purified fraction dated 11,235 ± 40 ^{14}C yr BP (UCIAMS-116401). Radiocarbon ages were calibrated to 'calendar' ages using OxCal Version 4.2, IntCal 13 curve; Copyright C. Bronk Ramsey 2014, Updated May 9, 2014. The overlap of the two measurements at one standard deviation is evidence that preservatives, especially the 1891 AD animal-based glue, had been removed and did not affect the $^{14}C/^{12}C$ composition of the fossil collagen. A less likely, but possible explanation, is that both the gelatin and XAD fractions retained the same amount of 1891 AD contamination and that the specimen dates older than its measured age of 11,235 ± 40 ^{14}C yr BP.

Additional data regarding the quality of the collagen's chemical preservation are from the collagen's stable isotope analyses. The $\delta^{13}C$ value was −20.2‰ (VPDB) and the δ ^{15}N value was 5.0‰ (AIR). The C/N ratio (atomic percent) was 3.28 and the collagen measured 40.5% C and 14.4% nitrogen, all values within accepted limits for collagen (DeNiro, 1985).

The more highly purified chemical fraction is the XAD-purified hydrolyzate, therefore only the ^{14}C age on the XAD fraction is used as the age for the ungual. This value is 11,235 ± 40 ^{14}C yr BP (13,180–13,034 cal yr BP) (UCIAMS-116401).

The −20.2‰ $\delta^{13}C$ value for this specimen indicates a diet of only C_3 plants, which is consistent with other specimens of *Megalonyx*. These

Table 1
Radiocarbon ages for *Megalonyx jeffersonii*. Calendar ages are calculated using IntCal 13, OxCal 4.2. Ages measured on lower quality chemical fractions, e.g., KOH-Collagen, are not calibrated nor are ages with greater-than values. Radiocarbon ages converted to calendar ages using OxCal Version 4.2, IntCal 13 curve; Copyright C. Bronk Ramsey 2014, Updated May 9, 2014.

	Locality	Specimen element	^{14}C age ^{14}C yr BP ± SD	Fraction dated	Lab no.	Cal yr BP 2 σ	Reference
Direct ages							
1.	Millersburg, Holmes Co. Ohio	OSU-15758 Ungual phalanx	11,235 ± 40	XAD–gelatin hydrolyzate	UCIAMS-116401	13,180–13,034	This paper
	Millersburg, Holmes Co. Ohio	OSU-15758 Ungual phalanx	11,205 ± 35	KOH–gelatin	UCIAMS-116384	–	This paper
2.	Lang Farm, Bureau Co. Illinois	SR-1463 Cortical bone from mandible	11,430 ± 60	XAD–gelatin hydrolyzate	CAMS-33974	13,413–13,135	Schubert et al. (2004)
	Lang Farm, Bureau Co. Illinois	ISM-492815 Cortical bone from mandible	11,485 ± 40	XAD–gelatin hydrolyzate	CAMS-82933	13,437–13,253	Schubert et al. (2004)
3.	Niver Farm, North Fairfield, Huron Co. Ohio	IL-2007-01 Femur	11,740 ± 35	XAD–gelatin hydrolyzate	UCIAMS-38250	13,714–13,454	Redmond et al. (2012)
4.	Haven Site, Emmons Co. North Dakota	ND 00-10.1 Ungual phalanx	11,915 ± 40	XAD–gelatin hydrolyzate	CAMS-87696	13,831–13,565	Hoganson and McDonald (2007)
5.	Bishop Ranch, Grant Co. Washington	Cortical bone from skull	12,130 ± 50	XAD–gelatin hydrolyzate	CAMS-63089	14,151–13,811	Chatters et al. (2004)
6.	Big Bone Cave, Van Buren Co. Tennessee	ANSP-15193 Caudal vertebra	>43,100 >50,800	Cartilage XAD–gelatin hydrolyzate	CAMS-87691 UCIAMS-11681	– –	Stafford and McDonald (unpublished)
Associated ages							
7.	SeaTac Airport, King Co. Washington	Peat within pelvis	12,300 ± 200	ABA–macroflora	(UW-8)	15,093–13,770	McDonald (1998) Dorn et al. (1962)
8.	Ansonia (Carter Bog), Darke Co. Ohio	Wood	12,190 ± 215	ABA–Wood	(UGa-666)	15,010–13,590	Mills (1975)
9.	Livingston Dam, Polk Co. Texas	Wood	21,590 ± 570	ABA–Wood	Radiocarbon Dating Lab Shell Research Center	27,194–24,615	Lundelius and Slaughter (1976)

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include the 400 ka, middle Irvingtonian (Interglacial) Camelot fauna in South Carolina (Kohn et al., 2005) and *Megalonyx jeffersonii* specimens from the late Pleistocene faunas from Saltville, Virginia (France et al., 2007) and Edmonton, Alberta (Bocherens et al., 1994). The $\delta^{15}N$ value of 5.0‰ is similar to previous values on this species and indicates that the animal's diet was that of a typical herbivore. The habitat of this animal was one containing only C_3 plants and was most likely a forest, although pure C_3 grasslands and wooded C_3 grasslands would yield a similar C_3-dominated, $\delta\ ^{13}C$ value of approximately −20‰.

Discussion and review of previous radiocarbon ages for Megalonyx

This is only the sixth radiocarbon age based directly on a specimen of *Megalonyx* (Table 1). Other radiocarbon ages in the literature for *M. jeffersonii* are associated with organic matter that does not accurately date the specimen (Table 1). Given the uncertainty of dating macroflora physically associated with vertebrate fossils, these ^{14}C analyses provide only an age estimate, not an absolute date suitable for extinction or climate change chronologies. The age differences between a vertebrate specimen and associated wood or other organic matter, particularly in bog environments, can range from a few tens of years to, more commonly, 400–1000 yr or more (Joyce, 2006; Waters et al., 2011).

As the youngest date for *Megalonyx*, the age of 11,235 ± 40 ^{14}C yr BP (13,180–13,034 cal yr BP) overlaps by 28 yr with the earliest age estimate for the Clovis Culture, the Lange Ferguson Site (11,080 ± 40 ^{14}C yr BP; 13,062–12,816 cal yr BP) (Waters and Stafford, 2007). Unlike the North Fairfield, Ohio *Megalonyx* with cut marks (Redmond et al., 2012), the Millersburg specimen has no indications of having been killed or processed by humans. While informative, this new youngest record for this taxon cannot by itself be used to support any argument for its extinction along with other members of the late Pleistocene North American megafauna whether due to humans, climatic/environmental change or any of the other causes that have been proposed. Coupled with the geographically close North Fairfield specimen 11,740 ± 35 ^{14}C yr BP (13,714–13,454 cal yr BP) the two sites suggest 500–700 cal yr of overlap between humans and Jefferson's sloth. However, the increasing evidence for even older pre-Clovis sites in North America, e.g., Manis Washington, Paisley Caves Oregon, and Buttermilk

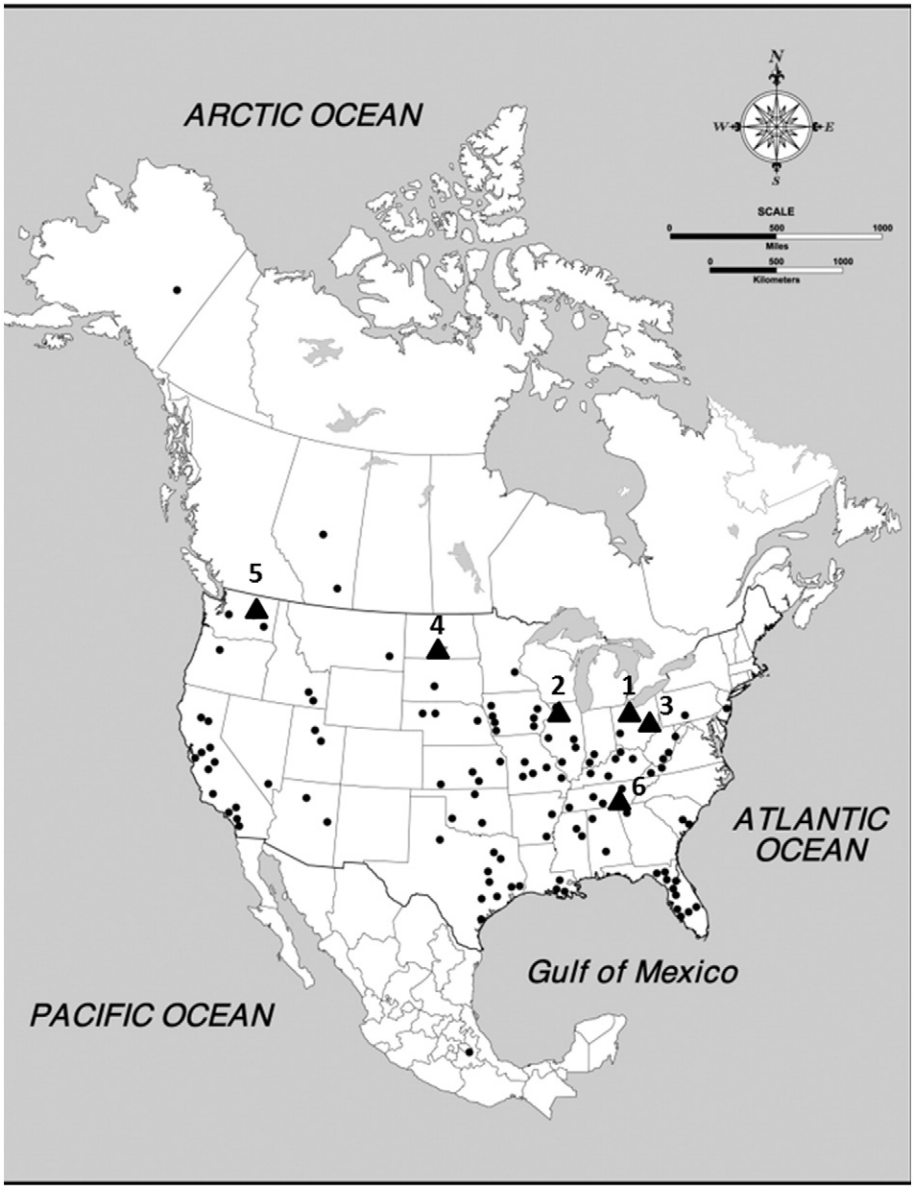

Figure 6. Map showing distribution of sites with *Megalonyx jeffersonii*. Numbers on the map correspond to the sites with radiocarbon ages listed in Table 1. Base map after Hoganson and McDonald (2007).

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Creek Texas, among others (for specific references on each site see Waters and Stafford, 2014) indicate that the overlap between humans and the Jefferson's Sloth could be at least 2000 cal yr. The Millersburg *Megalonyx* predates the start of the Younger Dryas at 12,900 cal BP (11,021 ^{14}C yr BP = 12,890 cal yr BP) (Stuiver et al., 1995; Kinzie et al., 2014) by at least 70 yr.

To assess the possible causes for the extinction of the Jefferson sloths, a sample of only six high-accuracy radiocarbon ages is too small. To fully determine why the Jefferson's ground sloth went extinct and the geographic pattern of its extinction, significantly more radiocarbon ages are needed for the entire geographic range of the species. Compared to the 25 radiocarbon ages available for the Shasta ground sloth, *Nothrotheriops shastensis* (see Steadman et al., 2005 for list), the number available for *Megalonyx* is minimal. However, the ages available for *Nothrotheriops* represent only seven of the 50 localities within the range of radiocarbon dating (McDonald and Jefferson, 2008), and of the 25 ages listed, ten are from a single locality, Rampart Cave, Arizona. The distribution of *N. shastensis* was substantially smaller than that of *Megalonyx* in the latest Pleistocene (Hoganson and McDonald, 2007) and most of the finds with radiocarbon ages are from the arid southwestern United States (McDonald and Jefferson, 2008). In comparison, the five direct, finite ages on *Megalonyx* are a very small subset of the 104 known Rancholabrean localities for the species (Fig. 6) (Hoganson and McDonald, 2007) that are <50,000 yr old, but while they cover a wider geographic area there are still substantial parts of the taxon's range for which no radiocarbon ages exist. So, while informative, the new age is not definitive, with regard to explaining the extinction of the Jefferson's sloth given the overall small sample size of quality radiocarbon ages. The number of direct, high-accuracy radiometric ages is even smaller or nonexistent for many of the other North American Pleistocene taxa, therefore determining the ultimate cause and patterns of their extinction at this time is impossible and cannot be resolved until there is a larger database of high quality radiocarbon ages obtained directly from morphologically identifiable specimens.

Acknowledgments

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References

Bocherens, H., Fizet, M., Marioitti, A., Gangloff, R.A., Burns, J.A., 1994. Contribution of isotopic biogeochemistry (^{13}N, ^{15}N, ^{18}O) to the paleoecology of mammoths (Mammuthus primigenius). Historical Biology 7, 187–202.

Chatters, J.C., Hackenberger, S., McDonald, H.G., 2004. A Jefferson's ground sloth from the terminal Pleistocene of Central Washington. Current Research in the Pleistocene 21, 93–94.

Claypole, E.W., 1891. Megalonyx in Holmes County, Ohio 1890. American Geologist 7 (122-.132 and 149–153).

DeNiro, M.J., 1985. Post-mortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction. Nature 317, 806–809.

Dorn, T.F., Fairhall, A.W., Schell, W.R., Takashimas, Y., 1962. Radiocarbon dating at the University of Washington I. Radiocarbon 4, 1–12.

France, C.A.M., Zelanko, P.M., Kaufman, A.J., Holtz, T.R., 2007. Carbon and nitrogen isotopic analysis of Pleistocene mammals from the Saltville Quarry (Virginia, USA): implications for trophic relationships. Palaeogeography Palaeoclimatology Palaeoecology 249, 271–282.

Hay, O.P., 1923. The Pleistocene of North America and its vertebrate animals from the states East of the Mississippi River and from the Canadian Provinces East of Longitude 95°. Carnegie Institution of Washington Publication 322, 1–499.

Hoganson, J.W., McDonald, H.G., 2007. The first report of the occurrence of Jefferson's ground sloth (*Megalonyx jeffersonii*) in North Dakota and its paleobiogeographical and paleoecological significance. Journal of Mammalogy 88, 73–80.

Jefferson, T., 1799. A memoir on the discovery of certain bones of a quadruped of the clawed kind in the western parts of Virginia. Transactions of the American Philosophical Society 4, 246–250.

Joyce, D.J., 2006. Chronology and new research on the Schaefer mammoth (?*Mammuthus primigenius*) site, Kenosha County, Wisconsin, USA. Quaternary International 142–143, 44–57.

Kinzie, C.R., Que Hee, S.S., Stich, A., Tague, K.A., Mercer, C., Razink, J.J., Kennett, D.J., DeCarli, P.S., Bunch, T.E., Wittke, J.H., Israde-Alcántara, I., Bischoff, J.L., Goodyear, A.C., Tankersley, K.B., Kimbel, D.R., Culleton, B., Erlandson, J.M., Stafford Jr., T.W., Kloosterman, J.B., Moore, A.M.T., Firestone, R.B., Auro Tortosa, J.E., Jordá Pardo, J.F., West, A., Kennett, J., Wolbach, W.S., 2014. Nanodiamond-rich layer across three continents consistent with major cosmic impact at 12,800 Cal BP. Journal of Geology 122, 475–506.

Kohn, M.J., McKay, M.P., Knight, J.L., 2005. Dining in the Pleistocene — who's on the menu? Geology 33, 649–652.

Leidy, J., 1855. A memoir of the extinct sloth tribe of North America. Smithsonian Contributions to Knowledge 7, 1–68.

Lundelius Jr., E.L., Slaughter, B.H., 1976. Notes on American Pleistocene tapirs. In: C.S., Churcher. (Ed.), Athlon: Essays on Paleontology in Honour of Loris Shano Russell. Royal Ontario Museum, Life Sciences, Miscellaneous Publications, pp. 226–243.

McDonald, H.G., 1998. The sloth, the president, and the airport. Washington Geology 26, 40–42.

McDonald, H.G., Jefferson, G.T., 2008. Distribution and habitat of *Nothrotheriops* (Xenarthra, Nothrotheridae) in the Pleistocene of North America. In: Wang, X., Barnes, L.G. (Eds.), Geology and Vertebrate Paleontology of Western and Southern North America, Contributions in Honor of David P. Whistler. Natural History Museum of Los Angeles County Science Series 41, pp. 313–331.

Mills, R., 1975. A ground sloth, *Megalonyx*, from a Pleistocene site in Darke County, Ohio. Ohio Journal of Science 75, 147–155.

Murphy, J.L., 1979. Millersburg Ground Sloth. Ohio Historical Society (Echos 18, 1, 3).

Orton, E., 1891. On the occurrence of *Megalonyx jeffersonii* in central Ohio. Bulletin of the Geological Society of America 2, 235.

Redmond, B.G., McDonald, H.G., Greenfield, H.J., Burt, M.L., 2012. New evidence for Late Pleistocene human exploitation of Jefferson's Ground Sloth (*Megalonyx jeffersonii*) from northern Ohio, USA. World Archaeology 44, 75–101.

Schubert, B.W., Graham, R.W., McDonald, H.G., Grimm, E.C., Stafford, T.W. Jr, 2004. Latest Pleistocene paleoecology of *Megalonyx jeffersonii* and *Cervalces scotti*. Quaternary Research 61, 231–240.

Steadman, D.W., Martin, P.S., MacPhee, R.D.E., Jull, A.J.T., McDonald, H.G., Woods, C.A., Iturralde-Vinent, M., Hodgins, G.W.L., 2005. Asynchronous extinction of late Quaternary sloths on continents and islands. Proceedings of the National Academy of Science 102, 11763–11768.

Stuiver, M., Grootes, P.M., Braziunas, T.F., 1995. The GISP2 δ^{18}O climate record of the past 16,500 years and the role of the sun, ocean, and volcanoes. Quaternary Research 44, 341–354.

Waters, M.R., Stafford, T.W. Jr, 2007. Redefining the Age of Clovis: implications for the peopling of the Americas. Science 315, 1122–1126.

Waters, M.R., Stafford Jr., T.W., 2014. The first Americans: a review of the evidence for the late Pleistocene peopling of the Americas. In: Graf, K.E., Ketron, C.V., Waters, M.R. (Eds.), Paleoamerican Odyssey, Texas A&M University Press, College Station, pp. 487–506.

Waters, M.R., Stafford, T.W., McDonald, H.G., Gustafson, C., Rasmussen, M., Cappellini, E., Olsen, J.V., Szklarczyk, D., Jensen, L.J., Gilbert, M.T.P., Willerslev, E., 2011. Pre-Clovis mastodon hunting 13,800 years ago at the Manis site, Washington. Science 334, 351–353.

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