化石研究会会誌　Journal of Fossil Research, Vol. 57(1/2), 50-57(2024)

[Original Article]

A newly discovered woolly mammoth molar from off the Notsuke Peninsula in Hokkaido, Japan

Keiichi Takahashi[1✉], Sanjeeta Sharma Pokharel[2,3], Kodzue Kinoshita[3], Kazuhito Ishiwata[4] and Yuji Soeda[5]

Abstract

In April 2024, a new woolly mammoth molar was discovered off the Notsuke Peninsula in eastern Hokkaido. It was found to be a well-worn right maxillary first molar, and AMS^{14}C of the molar suggested an age range of approximately 42,000 to 41,000 cal BP. The dating results obtained in this study, along with those from three previously discovered specimens within the vicinity of the Notsuke Peninsula, indicate that woolly mammoths inhabited this region roughly from MIS 3 to the onset of MIS 2. The molar was recovered from a slightly deeper seafloor that had been deepened by tidal currents, and the fossil-bearing layer is presumed to be a sand and gravel stratum based on the conditions of occurrence. The δ^{13}C value of the molar is −18.0 ‰, which is higher than that of the common woolly mammoth found in northern Eurasia. This difference in δ^{13}C values may be ascribed to the feeding habits of the woolly mammoths that inhabited this region or coastal area.

Key words: *Mammuthus primigenius*, Woolly mammoth, Hokkaido, AMS^{14}C dating, stable isotope

1. Introduction

A total of fourteen woolly mammoth fossils have been reported from Japan. With the exception of one case discovered in the Sea of Japan off Shimane Prefecture, all the others were discovered in Hokkaido (Takahashi et al., 2006; Takahashi et al., 2013).

In this paper, we name the newly discovered woolly mammoth molar, found on April 26, 2024, off the Notsuke Peninsula in eastern Hokkaido (about 1.2 km from land), as “the Third Notsukesaki Specimen”. We report the circumstances of the discovery, a morphological description of the molar, and present the results of dating and isotope ratio measurements, along with some accompanying discussion.

The fossil molar reported here was retrieved from the seafloor by a fishing boat (Daihachi Kaisei Maru, affiliated with the Notsuke Fishery Cooperative Association) engaged in scallop fishing operations near the discovery site. Subsequently, Mr. Hayato Adachi, a crew member who was sorting salvaged scallops, discovered the molar fossil. On May 8, the molar fossil was delivered to Notsuke Elementary School, where

Received: 30 August, 2024; Accepted: 23 October, 2024

1 Lake Biwa Museum (Director Emeritus) Oroshimo, Kusatu, Shiga 525-0001, Japan
2 The Hakubi Center for Advanced Research, Kyoto University, Yoshida-honmachi, Sakyo-ku, Kyoto 606-8501, Japan
3 Graduate School of Asian and African Area Studies, Kyoto University, Yoshida-honmachi, Sakyo-ku, Kyoto 606-8501, Japan
4 Bekai-cho Local History Museum, 30 Miyamai-cho, Betsukai-cho, Notsuke-gun, Hokkaido 086-0201, Japan
5 Makubetsu-cho Board of Education, Churui General Branch Office, 439-1 Churui Nishiki-cho, Makubetsu-cho, Nakagawa-gun, Hokkaido 089-1707, Japan
✉E-mail: keiichitakahashi0224@gmail.com

Adachi's son attends. The school teacher, Shinji Hasegawa, recognized the significance of the fossil and brought it to the Betsukai Town Local History Museum.

Ishiwatari, deputy director of the Betsukai-cho Local History Museum, contacted Soeda, the senior manager of the Makubetsu-cho Board of Education, who was familiar with fossils in Hokkaido. Takahashi, who had received a request from Soeda, examined the fossil molar and confirmed its classification as a right upper first molar of woolly mammoth, *Mammuthus primigenius*.

Takahashi conducted measurements and provided descriptions of the molar, while AMS^{14}C dating and stable isotope measurements were performed by Paleo Lab Co., Ltd. (Saitama, Japan), commissioned by the Betsukai-cho Historical Museum. The review of the obtained ages and stable isotope measurements was overseen by Pokharel and Kinoshita of Kyoto University, and all the authors contributed to the comprehensive discussion of the results.

This molar represents a significant discovery, as both the discovery site and the age of the habitat are known. It is expected to be one of the most important specimens for the study of Japanese woolly mammoths in the future, considering the valuable dating and isotope ratio information obtained.

2. Description

2.1 Description of molar

Order Proboscidea Illiger, 1811
Family Elephantidae Gray, 1821
Genus *Mammuthus* Burnette, 1830

Mammuthus primigenius (Blumenbach), 1799

Material: Right upper first molar, kept by Betsukai-cho Local History Museum (BLHM, Specimen No. 4)
Locality: Off the Notsuke Peninsula, Notsuke-cho, Notsuke-gun, Hokkaido (43°59′49″N, 145°34′55″E) (Fig. 1)
Horizon: Unknown
Age: AMS^{14}C dating of collagen extracted from the root of the molar indicates 36,650 ± 230 yr BP (Laboratory

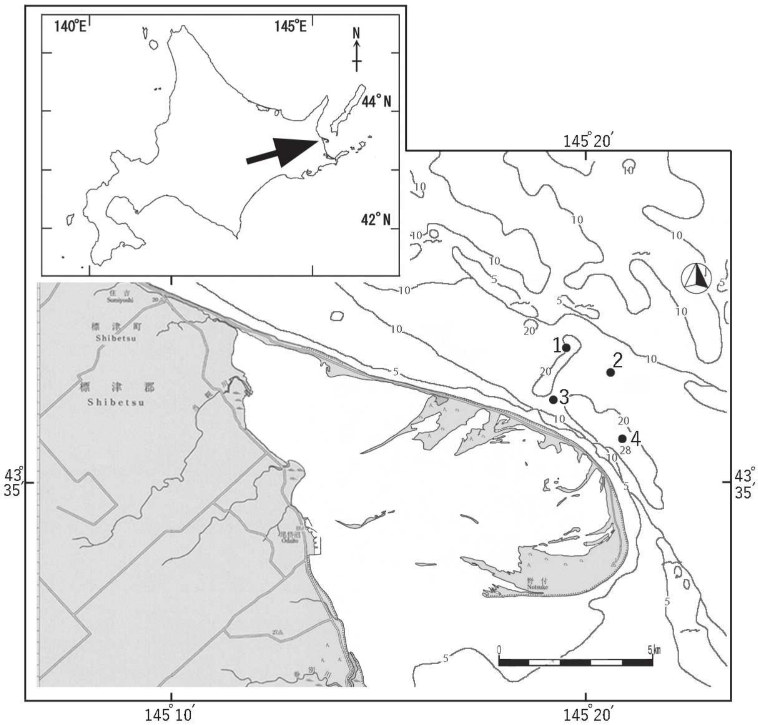

Fig. 1 Localities of the Third Notsukesaki specimen (4) and other woolly mammoth specimens from the same area.
The figure is based on the nautical chart 'Approaches Notsuke Suido (W18)' published by the Japan Coast Guard and issued by the Japan Hydrographic Association (December 2005). 1. First Notsukesaki specimen, 2. Todowara specimen, 3. Second Notsukesaki specimen, 4. Third Notsukesaki specimen. Dark areas indicate land. Depth units are in meters.

No. PLD-52878). Calibrated age 41.960–41,218 cal BP (2σ) was obtained using the program OxCal 4.4 (Ramsey, 2008; Ramsey and Lee, 2013).

Description: The molar consists of eleven well-worn plates. The occlusal surface is oval, with a narrower transverse diameter on the proximal side than on the distal side. The whole enamel loops are narrow in mesial–distal section, and mesial and distal parts of the enamel loops are parallel to each other. Lamella frequency is 8. Enamel is thin (1.9-2.2 mm), with fine enamel folds. The lingual and buccal views are triangular. The distal plane is strongly tilted proximally toward the root tip (Fig. 2).

The measurement method for the specimens followed Takahashi (1991). Measurements of the specimen are given in Table 1.

2.2 Dating and isotope ratio measurements

The dating and ^{13}C and ^{15}N stable isotope measurements were performed at Paleo Lab Co., Ltd. The following description is based on the report of Paleo Lab Co., Ltd.

Methods

Before collagen was extracted, the sample was

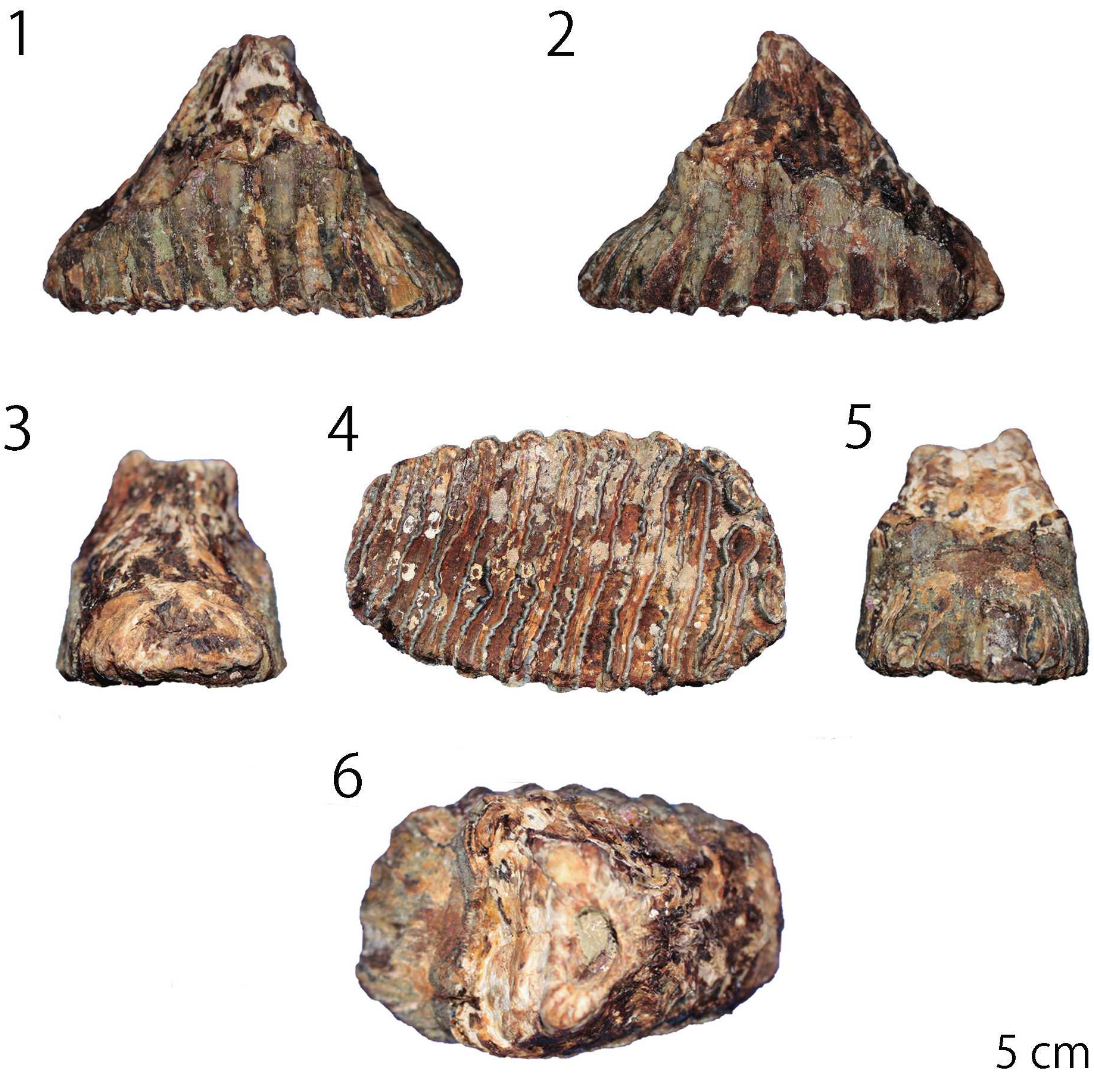

Fig. 2 The Third Notsukesaki specimen, *Mammuthus primigenius* (right upper M1)
1. lingual view, 2. buccal view, 3. mesial view, 4. occlusal view, 5. distal view, 6. root view

Table 1. Measurements of the Third Notsukesaki specimen (Right upper M1)

Plate number	+11
Using plate number	11
Length of crown	119.8 mm
Maximum length of crown	ditto
Occlusal surface length	ditto
Height of crown	50.1 mm (8th lamella) ＊82.4 mm to the tip of the root.
Maximum height of crown	ditto
Width of crown	72.6 mm (8th lamella)
Masticatory face width	ditto
Enamel thickness	1.9–2.2 mm
Lamellar frequency	8 (buccal side), 8 (lingual side) ＊Values measured over a length of 5 cm and multiplied by two.
Eruption angle	50°
Occlusal angle	85° –90°

washed by ultrasonic and acetone washing to remove stains, adhesive oils, and fats on the surface. The Flash EA1112 (Thermo Fisher Scientific Inc., Tokyo, Japan) gasification pre-treatment analyser (EA) was used to determine the carbon and nitrogen content, with acetonitrile (Kishida Chemical Co., Ltd.,Osaka, Japan) used as the standard sample.

The carbon stable isotope ratio ($\delta^{13}C_{PDB}$) and nitrogen stable isotope ratio ($\delta^{15}N_{AIR}$) were measured using a DELTAplus Advantage mass spectrometer (Thermo Fisher Scientific Inc.), with IAEA Sucrose (ANU) used as the standard for carbon stable isotope ratios and IAEA N1 for nitrogen stable isotope ratios.

For carbon and nitrogen stable isotope ratio measurements, samples were sealed in tin containers and dropped into a combustion furnace in the EA with ultra-pure oxygen, where they were combusted and gasified at high temperatures using the oxidation heat of tin, and completely oxidized with an oxidation catalyst. Next, nitrogen oxides were reduced in a reduction column, water was trapped with magnesium perchlorate, and CO_2 and N_2 were separated in a separation column for detection and quantification by TCD, respectively. The furnace and separation column temperatures were 1000°C, 680°C, and 35° C, respectively. The separated CO_2 and N_2 were directly introduced into the mass spectrometer through the interface with a helium carrier gas, and the stable isotope ratios were measured. The C/N ratio (molar ratio) was calculated based on the obtained carbon and nitrogen contents.

For radiocarbon dating, the extracted collagen was sealed in quartz tubes and burnt to gasify the CO_2. The CO_2 gas was then purified and graphitised. The resulting graphite was measured using an accelerator mass spectrometer (Paleo Labs, compact AMS: NEC-1.5 SDH). The obtained ^{14}C concentrations were corrected for isotope fractionation effects, and ^{14}C age and calibration age were calculated. Calibrated age ranges of ^{14}C ages were obtained by OxCal4.4. The correction function supplied with OxCal was also used to examine marine reservoir effects.

Table 2. Results of carbon and nitrogen stable isotope ratio measurements

Pre-treatment weight	170.38 mg
Collagen recovery volume	11.29 mg
Collagen recovery rate	6.6 %
Carbon content	36.9 %
Nitrogen content	13.2 %
C/N ratio (molar ratio)	3.26
Carbon stable isotope ratio ($\delta^{13}C_{PDB}$)	–18.0 ‰
Nitrogen stable isotope ratio ($\delta^{15}N_{AIR}$)	7.2 ‰

Table 3. Results of radiocarbon dating and Calibrated ^{14}C age range.

$\delta^{13}C$	–17.73 ± 0.16
^{14}C age	36,650 ± 230 yr BP
Conventional ^{14}C age	36,647 ± 227 yr BP
Calibrated ^{14}C age range (1σ)	41.795–41,382 cal BP
Calibrated ^{14}C age range (2σ)	41.960–41,218 cal BP

Table 4. List of specimens discovered off Notsuke Peninsula

Loc. no	Specimen name	Portion	Date of collection	^{14}C age (Lab. no.)	Conventional ^{14}C age (yr BP ± 1σ)	Calibrated ^{14}C age (cal BP, 2σ)	$\delta^{13}C$ (‰)	References	Depository
1	First Notsukesaki specimen	Right upper M3	Middle of May, 1981	20,243 ± 243	–	24,996 – 23,816 BP	–	Kamei (1987) Akiyama et al. (1989)	BLHM
				20,700 ± 120 (Beta-184269)	20,770 ± 120	25,321 – 24,632	-20.6	Takahashi et al. (2006)	
2	Todowara specimen	Right lower P4 or M1	May 11, 1986	Radiocarbon dating attempted, but not possible (Beta-184268)	–	–	–	Kamei (1987) Takahashi et al.(2006)	BLHM
3	Second Notsukesaki specimen	Left lower M1	Middle of May, 2003	>42,980 (Beta-184935)	–	–	-17.7	Takahashi et al. (2006)	BLHM
4	Third Notsukesaki specimen	Right upper M1	April 26, 2024	36,650 ± 230 (PLD-52878)	36647 ± 227	41,960 – 41,218	-18.0	This report	BLHM

Measurement results

The results of carbon and nitrogen stable isotope ratio measurements are shown in Table 2, and the radiocarbon dating results are shown in Table 3.

3. Discussion

3.1 Woolly mammoths discovered off the Notsuke Peninsula

Including the present specimen, four woolly mammoth fossils have been recovered from the Notsuke Peninsula (Fig. 1, Table 4). These fossils were found in the area used for scallop farming, where young scallops are 'ground-spread' on the seabed to grow.

To haul up the grown scallops, a net affixed with an iron claw at the entrance, referred to as 'Keta-ami', is deployed and dragged along the seabed. In this process, the woolly mammoth fossils lying on the seabed are coincidentally ensnared to the net.

The locations of mammoth elephant fossils found off Notsukezaki are marked on the nautical chart, indicating that they are taken from areas of slightly deeper water than the surrounding area (Fig. 1). Owing to the nature of the scallop fishery, consisting of several repetitions of deploying and dragging a net for several tens of minutes within a defined fishing area, determining the exact collection site is challenging. However, it is evident that the woolly mammoth fossil was recovered during the operations on a specific day.

The hollows in the seabed from which these woolly mammoth fossils were recovered are thought to be landforms that formed during the glacial low sea level period (Suga et al., 2007).

Evidence indicates that vertebrate fossils have been found in geologically analogous landforms in the Seto Inland Sea and surrounding Awaji Island in the west of Japan (Kurashiki Museum of Natural History, 1988; Watanabe, 2004; Nakao, 2004, etc.), but these hollows were created by tidal currents digging into the seabed.

Based on the fishermen's information, the discoverers of the Second Notsukesaki specimen and the present specimen reported the substantial presence of gravel on the seabed in the area where fossils were found. This is also confirmed by Suga et al. (2007). It can be inferred that the woolly mammoth fossils found off Notsuke Peninsula are contained in the sand and gravel layer below the seabed, and they are likely to be exposed during scallop fishing operations in areas where ocean currents have eroded the strata, causing them to dislodge and surface out of the strata.

3.2 Age of inhabitation

The chronology of the occurrence of woolly mammoths in Hokkaido has been summarized by Takahashi et al. (2013). According to Takahashi et al. (2013), the ages of woolly mammoths range from 45,110 ± 480 to 16,320 ± 90 yr BP without calibration of calendar age. The present third Notsukesaki specimen has an age of 36,650 ± 230 yr BP (41.960 - 41,218 car BP (2σ)), which falls within the previously reported ages of woolly mammoths in Hokkaido.

The findings from the Notsuke Peninsula indicate that the specimens are at least 20,000s years old, possibly exceeding 40,000 years in calendar age. This suggests a continuous presence of woolly mammoths in this area from MIS 3 to the beginning of MIS 2 (Table 4). As discussed below, if these woolly mammoths had been foraging on seaweed and sea grass found and washed up along the shoreline, it is also essential to address the marine reservoir effect on radiocarbon dating.

The marine reservoir effect, depending on the proportion of marine products ingested, can influence the ^{14}C age, necessitating an estimation of the marine product dependency rate and subsequent correction. Based on Yoneda (2005), the marine product dependency ratio was assumed to be 35.1%. Calibration for the marine reservoir effect was performed using the provided function in OxCal, resulting in the regional correction factor (ΔR) of 230 ± 139 yr, which is an average of the values surrounding Kunashiri Island (Kuzmin et al., 2001).

The calibrated calendar year value (2σ) reflects a range of 41,712–40,810 cal BP (obtained from the Paleo Lab report). The analysis indicates that considering or not considering the marine reservoir effect did not significantly change the results.

3.3 Carbon and nitrogen stable isotope ratios

In the present study, the stable isotope ratios of carbon and nitrogen (δ^{13}C and δ^{15}N) were measured using collagen samples extracted from the root dentine of the molar (Table 2). The δ^{13}C and δ^{15}N values measured from animal collagen reflect and correspond to the isotopic composition of the plants consumed by the animal, the soil in which the plants grew, and are influenced by climatic and environmental parameters (Kohn, 1999; Lee-Thorp, 2008).

Rey-Iglesia et al. (2024) discussed circular structures in woolly mammoth bones found at the Kostenki 11 site in south-west Russia. They presented the δ^{13}C and δ^{15}N values for 378 published woolly mammoth data from North America, Russia and Europe, and 38 data from the Kostenki 11 site, dating from >55,500–13,871 cal yr BP. The δ^{13}C values ranged roughly from –23 to –19.5 ‰, and the δ^{15}N values ranged from 2 to 15 ‰.

In contrast, the δ^{13}C and δ^{15}N values of the newly discovered woolly mammoth molar from off the Notsuke Peninsula were found to be –18.0 ‰ and 7.2 ‰, respectively. This δ^{13}C value is remarkably higher than those from northern Eurasia and northern North America.

The present analysis reported a collagen recovery rate above 1% and a C/N ratio of 3.26, within the normal range of 2.9–3.6 (DeNiro, 1985), indicating no significant collagen alteration or carbon contamination from external sources, including the effects of marine diagenesis.

Nevertheless, δ^{13}C values are slightly higher than those of the common woolly mammoth and also higher than those of common herbivores (–23.3 to –18.9 ‰; van der Plicht and Kuitems, 2022). Similar value was also reported in the Second Notsukesaki specimen. With the probable effects of marine diagenesis and alteration being lower, these high δ^{13}C values are likely attributable to the feeding habits and dietary preferences of C4 plants, CAM (Crassulacean Acid Metabolism) plants, seaweed and sea grasses, which have reportedly high δ^{13}C values (as observed (δ^{13}C value of -18.4 (bone) ‰) in the extant Namib desert elephants feeding on CAM plants, Vogel et al., 1990). We plan to further investigate this aspect after examining the data from other woolly mammoth fossils from Hokkaido in the future.

Acknowledgments

We thank Hayato Adachi, the discoverer of this specimen, for donating the specimen to the Betsukai-cho Local History Museum. Tomohiro Mitani of Paleo Labs, Co. Ltd., performed the dating and isotope analysis of the specimen, and provided detailed instructions on the interpretation of the results. Gentaro Kawakami of the Geological Survey of Hokkaido, Hokkaido Research Organization provided useful literature on the bottom sediments off Notsuke Peninsula. We are also grateful to reviewers Hideo Nakaya and Yoichi Kondo who made constructive suggestions for improvement of the manuscript.

References

Akiyama M, Kamei T, Nakai, N. (1989) ^{14}C age of elephant fossils from sea bottom. Journal of Fossil Research 22, 22-23 (in Japanese)

DeNiro MJ (1985) Postmortem preservation and alteration of in vivo bone collagen isotope ratios in relation to paleodietary reconstruction. Nature 317, 806-809

Japan Hydrographic Association (2005) Nautical chart 'Approaches Notsuke Suido (W18)'.

Kamei T (1987) New finds of the wooly mammoths teeth from the sea bed of the Nemuro Strait, Hokkaido, Japan. Matsui Masaru kyouju kinen ronbunsyu [Professor Masaru Matsui Memorial Volume], 1-12 Sapporo (in Japanese with English title)

Kurashiki Museum of Natural History (1988) Vertebrate fossils from the sea bottom of Bisan-seto, West Japan -Report of researches on the Yamamoto collection I-. Kurashiki Museum of Natural History, 109p, pls.1-3 (in Japanese with English title)

Kohn MJ (1999) You are what you eat. Science 283, 335-336

Kuzmin Y V, Burr GS, Jull AJT (2001) Radiocarbon reservoir correction ages in the Peter the Great Gulf, Sea of Japan, and eastern coast of the Kunashir, Southern Kuriles (northwestern Pacific). Radiocarbon 43, 477-481

Lee-Thorp J A (2008) On isotopes and old bones. Archaeometry 50, 925-950

Nakao K (1994) Molar teeth of Naumann's elephant from the Naruto Straits kept in the Tokushima Prefectural Museum. Bulletin of the Tokushima Prefectural Museum 4, 1-47 (in Japanese with English abstract)

Ramsey CB (2008) Deposition models for chronological records. Quaternary Science Reviews 27, 42-60.

Ramsey CB, Lee S (2013) Recent and Planned Developments of the Program OxCal. Radiocarbon 55, 720-730.

Rey-Iglesia A, Pryor AJE, Wilson T, Teeter MA, Margaryan A, Khaskhanov R, Meillour LL, de Jager D, Troché G, Welker F, Szpak P, Dudin AE, Lorenzen ED (2024) Ancient biomolecular analysis of 39 mammoth individuals from Kostenki 11-Ia elucidates Upper Palaeolithic human resource use. bioRxiv, 2024.06.14.598638;
doi: https://doi.org/10.1101/2024.06.14.598638

Suga K, Sagayama T, Nishina K, Murayama Y, Uchida Y (2007) Environment of submarine geology in the coastal area of Hokkaido -4- Sea of Okhotsk and Strait of Nemuro. Special Report, Geological Survey of Hokkaido, 34, 46p

Takahashi K (1991) 2. Kyushi [Molar]. In Kamei T (ed.) Nihon no choubirui kaseki [Japanese proboscidean fossils], 122-130, Tsukiji shokan publishing Co. Ltd., Tokyo (in Japanese)

Takahashi K, Soeda Y, Izuho M, Yamada G, Akamatsu M, Chang C (2006) The chronological record of the woolly mammoth (*Mammuthus primigenius*) in Japan, and its temporary replacement by *Palaeoloxodon naumanni* during MIS 3 in Hokkaido (northern Japan). Palaeogeography Palaeoclimatology Palaeoecology 233, 1-10

Takahashi K, Soeda Y, Izuho M, Oda H Oishi T (2013) A review of studies of proboscidean fossils from Hokkaido. Journal of fossil research, 45, 44-54 (in Japanese with English abstract)

van der Plicht J, Kuitems M (2022) Fossil bones from the North Sea: Radiocarbon and stable isotope ($^{13}C/^{15}N$) data. Radiocarbon 64, 633-668

Vogel JC, Talma AS, Hall-Martin AJ, Viljoen P (1990) Carbon and nitrogen isotopes in elephants. South African Journal of Science 86, 147.

Watanabe K (2004) The deposited fossils of Naumann's elephant from the Kitan Strait, Seto Inland Sea, Japan. Bulletin of the Natural History Museum, Kishiwada City 1, 39-46 (in Japanese with English abstract)

Yoneda M (2005) Isotope analysis on human remains from the Usu Moshiri site. In: Dodo Y (ed.) Phylogenetical and Bioarchaeological Studies of the Epi-Jomon Inhabitants in Hokkaido, Japan, with Special Reference to the Human Skeletal Remains Unearthed at the Usu-Moshiri site. 2002-2004 Fiscal Year Research Report of Grant in Aid for Scientific Research (B), 273-288 (in Japanese)

A newly discovered woolly mammoth molar from off the Notsuke Peninsula in Hokkaido, Japan

Keiichi Takahashi, Sanjeeta Sharma Pokharel, Kodzue Kinoshita, Kazuhito Ishiwata and Yuji Soeda

北海道野付半島沖から新たに発見されたマンモスゾウ臼歯化石

高橋啓一[1]・Sanjeeta Sharma Pokharel[2, 3]・木下こづえ[3]・石渡一人[4]・添田雄二[5]

[1] 滋賀県立琵琶湖博物館（名誉館長）〒525-0001　滋賀県草津市下物町1091
[2] 京都大学白眉センター　〒606-8501　京都市左京区吉田本町
[3] 京都大学大学院アジア・アフリカ地域研究研究科　〒606-8501 京都市左京区吉田本町
[4] 別海町郷土資料館　〒086-0201　北海道野付郡別海町別海宮舞町30
[5] 幕別町教育委員会　〒089-0604　北海道中川郡幕別町忠類錦町98

要旨

2024年4月26日に北海道東部に位置する野付半島の沖から新たなマンモスゾウの臼歯化石が発見された．化石はよく咬耗した右上顎第１大臼歯であり，その年代は暦年補正した年代でおよそ4万2000～4万1000年前であった．これまで発見されている野付半島沖の３点の標本も含めて考察すると，この地域には少なくとも MIS 3～MIS 2の始まりにかけてマンモスゾウが生息していたことがわかる．化石の包含層は砂礫層であり，潮流で包含層にまで海底が掘り下げられた水深のやや深い場所で，転石の状態で存在している可能性があることなどが推定される．また，今回の化石の $\delta^{13}C$ の値は－18.0 ‰であり，この値はこれまで世界各地から知られている一般的なマンモスゾウの値に比較して高い値を示しているが，その原因としてはこの地域あるいは海岸地域に生息していたマンモスゾウの食性が関係している可能性が考えられる．