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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)

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Abstract

The chronological record of the woolly mammoth (*Mammuthus primigenius*) in Japan is reevaluated on the basis of new and previously published radiocarbon dates obtained from 9 of the 11 known specimens. The dates range from 45,110 ± 480 to 16,320 ± 90 years BP. However, the exact provenance of the youngest specimen, from Yubari, is unknown. Excluding this specimen, woolly mammoths appear to have been present in Japan from around 45 ka to 20 ka, although perhaps not continuously. Remains of Naumann's elephant *Palaeoloxodon naumanni*, from Yubetsu, eastern Hokkaido, gave a radiocarbon date of 30,520 ± 220 years BP. Since this species was adapted to temperate forests, and previous pollen analysis indicated there was a slight climate amelioration from about 34 ka to 26 ka (correlated with MIS 3), it is probable that *P. naumanni* temporarily displaced *M. primigenius* during this period in Hokkaido.

Keywords: Woolly mammoth; *Mammuthus primigenius*; *Palaeoloxodon naumanni*; Hokkaido; Radiocarbon dates; Climate change; Late Pleistocene

1. Introduction

Fossil remains of *Mammuthus primigenius* are very scarce in Japan; only 11 specimens have been recovered. Ten were found on land in Hokkaido or the Nemuro Strait, and one was recovered from the Sea of Japan off Shimane Prefecture, western Japan (Fig. 1). Some ^{14}C dates of these specimens have been reported (Akiyama et al., 1989; Nakai et al., 1991; Yamada et al., 1996) and the period during which *M. primigenius* existed in Japan has been discussed (Minato, 1955, 1966, 1967; Kamei, 1987; Yamada et al., 1996), but the dates of the horizons and the radiocarbon data were too imprecise to provided a basis for any conclusions.

This paper presents radiocarbon dates of nine specimens based on the existing data (Akiyama et al., 1989;

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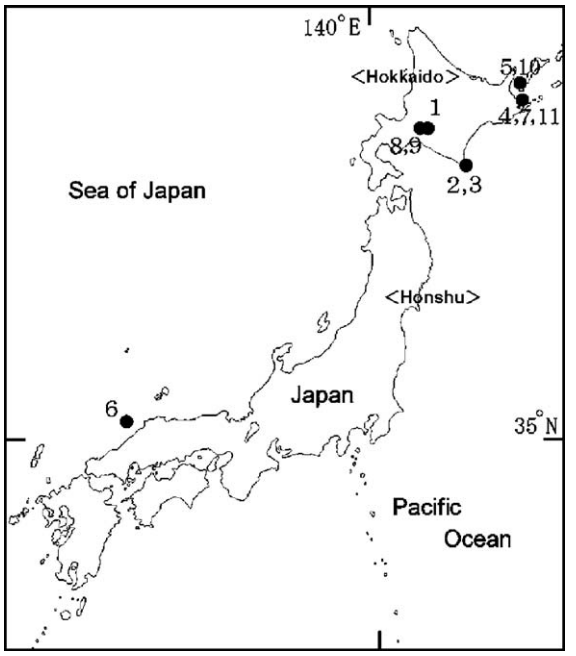

Fig. 1. Locality map of *Mammuthus primigenius* in Japan. **1**. Yubari specimen (? Yubari, Hokkaido); **2**. first Ogoshi specimen (Ogoshi, Erimo, Horoizumi, Hokkaido); **3**. second Ogoshi specimen (Ogoshi, Erimo, Horoizumi, Hokkaido); **4**. first Notsukesaki specimen (Nemuro Channel, Hokkaido); **5**. first Rausu specimen (Nemuro Channel, Hokkaido); **6**. Sawada specimen (off Onsentsu, Shimane Pref.); **7**. Todowara specimen (Nemuro Channel, Hokkaido); **8**. first Yuni specimen (Yuni, Yuubari, Hokkaido); **9**. second Yuni specimen (Yuni, Yuubari, Hokkaido); **10**. second Rausu specimen (Nemuro Channel, Hokkaido); **11**. second Notsukesaki specimen (Nemuro Channel, Hokkaido).

Nakai et al., 1991; Yamada et al., 1996; Kamei, 1990) and new analyses. Using these dates, we have been able to reconstruct the general features of mammoth population dynamics at the extreme southeast limit of the range of *M. primigenius* during the last 50,000 years.

2. Materials, methods and ^{14}C results

This study is based on 11 specimens of *M. primigenius* from Japan (Table 1). One other specimen has been reported by Minato (1955, 1967), a part of a tusk and some post-cranial bones found 2 km outside of Wakamatsu village in Hokkaido (now part of Setana town). This find is excluded from our study because it is hard to confirm the specific identification based only on the figure of an incomplete tusk shown in the paper, and the location of the material is unknown.

Radiocarbon dating of 8 of the 11 available specimens conducted for this study. All samples for the dating were directly obtained from the woolly mammoth materials. In a pre-treatment, a series of alkali treatments followed by ultra-filtration, produced a highly purified gelatinous fraction for dating. In particular the molars would were dematerialized in 0.1 N cold HCl until all mineral matter was removed and the collagen extracted. The collagenous proteins were then rinsed to neutralized them and subjected to a series of alkali soakings to remove humics (depending on the degree of preservation of the collagen the alkali concentrations were between 0.5% and 2% wt/wt). The collagen was then rinsed to neutralize it, again acid leached with 0.1 N HCL examined under a microscope to picking for any roots or other foreign matter, centrifuged repeatedly, filtered and finally dried ready for combustion. After the extensive pre-cleaning and careful extraction, the dating was measured by the AMS methods. However, collagen could not be extracted from the Todowara specimen owing to its poor state of preservation.

It was possible to compare our new dates with two specimens, the first Notsukesaki and first Rausu specimens, which had been similarly analyzed before. The five remaining specimen, the Yubari, second Ogoshi, and second Notsukesaki specimens, as well as the first and second Yuni specimens, were dated by us for the first time. Nine specimens in total, including two other specimens that had been dated earlier, the second Rausu and the second Notsukesaki specimens, constitute the materials for the present discussion.

2.1. Yubari specimen

This specimen was reported by Makiyama (1938) as a right upper M3 found in Yubari, Hokkaido. He wrote, “The present Japonic material was got in exchange for money from a trader without a note on geology in detail, but it was seemingly in the terrace deposit.” However the exact source locality of the specimen is not known. (Minato, 1955; Shikama, 1943; Kamei, 1987). A ^{14}C date for this specimen was obtained for the first time by us, and is 16,32 0 ± 90 years BP. This is the youngest date obtained so far for woolly mammoth remains in Japan.

2.2. First and second Ogoshi specimens

These specimens were reported by Minato (1955). Both are molars (right upper M2 and right lower M3) found near the Cape Erimo. The right upper M2 was lost in a fire in 1964. Minato (1967) reported that these specimens occurred in the Ogoshi Formation, which is covered by the Shikotsu pumice fall deposit 1 (Spfa 1). The ^{14}C age of Spfa 1 was estimated to be 40–45 ka by

Machida and Arai (2003). However, the specimens were found at the base of the outcrop, not embedded in the sediment. A geological and paleoenvironmental reinvestigation of the site was conducted to decide the horizon of origin of these two molars (Matsuzawa and Kosaka, 1987; Hoshino and Matsuzawa, 1987). As the result, both of the Ogoshi specimens are presumed to have come from the upper part of the Erimo Formation, which is characterized by gravel beds containing interbedded peaty clay and clay beds. The peaty silt bed, in which the first Ogoshi specimen supposedly originally lay, was dated to be 22,230 ± 1440 years BP (Matsuzawa and Kosaka, 1987).

A ^{14}C date of 19,580 ± 80 years BP for the second Ogoshi specimen was obtained for the first time by us. This confirms that the horizon of occurrence was the upper part of the Erimo Formation, as was estimated by Matsuzawa and Kosaka (1987).

2.3. First Notsukesaki specimen

This specimen was reported by Kamei (1987) and it was called "the Notsukesaki specimen". As described later, however, a new specimen was recovered from the sea bottom in the Nemuro Strait off Notsukesaki, so we rename this specimen as "the first Notsukesaki specimen". It was restored for research although it suffered some breakage while being left to stand for a long time after being found on the sea bottom. The specimen was first identified as the distal part of a right upper M3 by Kamei (1987). However the inclination of the dental cervical line and the curvature of the dental lamellae in side view indicate that this specimen must be a lower molar. We identify it as a right lower M3.

Akiyama et al. (1989) reported the ^{14}C age of this specimen to be 20,243 ± 670 years BP. A very similar value (20,770 ± 120 years BP) was obtained by our re-dating.

2.4. Rausu specimen

Kamei (1987) reported that this specimen was an almost complete lower right M3 except that the first median lamella had been lost. On the contrary, we consider that the specimen has been worn out as far as the distal end of the molar, and the medial portion of the original molar has been lost to attrition. The ^{14}C date of this specimen as reported by Nakai et al. (1991) was 23,816 ± 884 years BP. Nakai et al. (1991) reported this specimen from "off Shiretoko (from the sea bottom)". Judging by the date, and the fact that the only specimen known from the sea bottom off Shiretoko was the Rausu specimen reported by Kamei (1987), it is certain that the specimen reported from off Shiretoko by Nakai et al. (1991) is the same as the Rausu specimen reported by Kamei (1987). We dated the specimen again at 25,010 ± 120 years BP.

2.5. Todowara specimen

This specimen was reported by Kamei (1987). It had suffered a heavy damage, so it is difficult to identify which molar it is. Although Kamei (1987) identified it as a left lower M1, the possibility that is a right M1 or P4 cannot be denied. We tried to date this specimen, but collagen for dating could not be extracted from it.

2.6. First and second Yuni specimens

These two specimens were both recovered from Yuni town, Hokkaido, and were reported by Ono (1991). Nakaya et al. (1992) described the situation of discovery of both molars, the upper right M1 having been found from the bottom of a gravel quarry buried 7 m deep in 1990. According to the relevant people, the specimen seems actually to have been recovered from a depth of 10 m. By questioning the discoverer, its estimated that the original horizon was gravel bed called the Uryu terrace deposit by the Uma-oi Collaborative Research Group (1983, 1987). The fossil horizon is overlain by Shikotsu pumice fall deposits (Spfa-7 and 10) that were estimated >40 ka (now-estimated >60 ka). Radiocarbon dating of a wood fragment from the underlying of the fossil horizon yielded a date of 58,450 ± 1610 years BP (Ono, 1991). From these results it was assumed that the age of the first Yuni specimen is around 50 ka (Nakaya et al., 1992). Afterwards, in 1991 a molar assumed to be an upper left M1 or M2 was recovered from the same area. Accurate horizon of the second molar was not known because it was found among gravel after a gravel-sorting machine had passed; however the second molar also came from the same horizon.

Our analyses give ages of 45,110 ± 480 years BP and 37,400 ± 250 years BP, respectively. These are much younger than Nakaya et al. (1992) estimated and indicate that the estimation of the fossil horizons was inaccurate. The ^{14}C dates indicate that these molars come form sediments above the pumice fall deposits.

2.7. Second Rausu specimen

This is an upper left M2 that was reported by Yamada et al. (1996). This specimen was recovered

Table 1
Specimen list of *Mammuthus primigenius* in Japan

Loc. no.	Specimen name	Portion	Date of collection	Locality	Horizon	Conventional ^{14}C age (years BP)	σ^{13}C (‰)	Lab. no.	Depository
1	Yubari specimen	Right upper M3	Unknown	? Yubari, Hokkaido	Unknown	16,320 ± 90	−20.8	Beta-187606	Kyoto University (Kyoto)
2	First Ogoshi specimen	Right upper M2	Around 1941	Ogoshi, Erimo, Horoizumi, Hokkaido	Ogoshi Formation (Minato, 1967) or Upper part of the Erimo Formation (Matsuzawa and Kosaka, 1987)	–	–	–	Destroyed by fire in 1964
3	Second Ogoshi specimen	Right lower M3	May 30 of 1954	Ogoshi, Erimo, Horoizumi, Hokkaido	Ditto	19,580 ± 80	−21.7	Beta-188519	The National Science Museum (Tokyo)
4	First Notsukesaki specimen	Right lower M3	Middle of May of 1981	North of Notsu-kesaki in the Nemuro Channel, Hokkaido	Unknown (17–20 m in the depth of water)	20,770 ± 120	−20.6	Beta-184269	Betsukai-cho Local Material Hall (Hokkaido)
						20,243 ± 670		Akiyama et al. (1989) No description about the lab. number	
5	First Rausu specimen	Right lower M3	February of 1982	6 miles point from the Rausu Port toward the Kunashiri Island, Hokkaido	Unknown (120–130 m in the depth of water)	25,010 ± 120	−24.1	Beta-185830	The Preparative Office of Nemuro Municipal Museum (Hokkaido)
						23,816 ± 884		Nakai et al. (1991)	
6	Sawada specimen	Left lower M3	Middle of November of 1984	30 km off Onsentsu, Shimane Pref.	Unknown (about 200 m in the depth of water)	23,680 ± 880		Akiyama et al. (1989) No description about the lab. number	Tottori Prefectural Museum (Tottori)
7	Todowara specimen	Right lower M1 or P4	May 11 of 1986	2–3 km off Todowara of the Notsukesaki, Hokkaido	Unknown	Radiocarbon dating attempted, but not possible		Beta-184268	Betsukai-cho Local Material Hall (Hokkaido)
8	First Yuni specimen	Right upper M1	June of 1990	Higasi-mikawa, Yuni, Yuubari, Hokkaido	Uryu terrace deposit Higashi-Chitose Formation)	45,110 ± 480	−25.1	IAAA-32222	Yuni Yumekku Hall (Hokkaido)
9	Second Yuni specimen	Left upper M2	October of 1991	Ditto	Ditto	37,400 ± 250	−25.6	IAAA-32223	Ditto
10	Second Rausu specimen	Left lower M3	January 17 of 1992	16 km southeast off the Rausu Port, Hokkaido	Unknown (70–80 m in the depth of water)	38,920 ± 760		Yamada et al. (1996) Beta-85090	Atsukeshi-cho Board of Educaton (Hokkaido)
11	Second Notsukesaki specimen	Left lower M1	Middle of May of 2003	1 km off the Notsukesaki, Hokkaido	Unknown	>43,100	−17.7	Beta-184935	Betsukai-cho Local Material Hall (Hokkaido)

by a fishing boat from the sea floor 16 km southeast of Rausu Port in 1992. Yamada et al. (1996) reported the ^{14}C age of this specimen to be 38,920 ± 760 years BP.

2.8. Second Notsukesaki specimen

This specimen has not been reported before. It was recovered by a scallop boat 1 km off Notsukesaki in the middle of May, 2003. Our investigation showed this specimen to be the distal part of a well-worn left lower M1. The ^{14}C age of the root of the molar was dated to be >43,100 years BP.

2.9. Sawada specimen

This left lower M3 was recovered from 200 m below the surface of the sea by a Danish trawler off Shimane Prefecture, western Japan in 1984, and it is the only mammoth specimen discovered in Japan outside Hokkaido. Nishio (1985) described this specimen as *Palaeoloxodon naumanni* at first. Thereafter, Dr. Yoshikazu Hasegawa, who was a professor at Yokohama National University at that time, re-identified it as *M. primigenius*, and then Kamei (1990) and Takahashi (1990) concurred with this. Kamei (1990) reported the ^{14}C age of the specimen to be 23,630 ± 880 years BP.

This discovery site is located a long way south from other Japanese sites. Kamei (1990) proposed a hypothesis that the remains of a woolly mammoth drifted from mainland China. In the meantime Jin et al. (1998) reported that woolly mammoths migrated from N44° to about N35° in the east margin of mainland China during 23 ka–12 ka which supports Kamei's hypothesis (Fig. 2, Plates I–II).

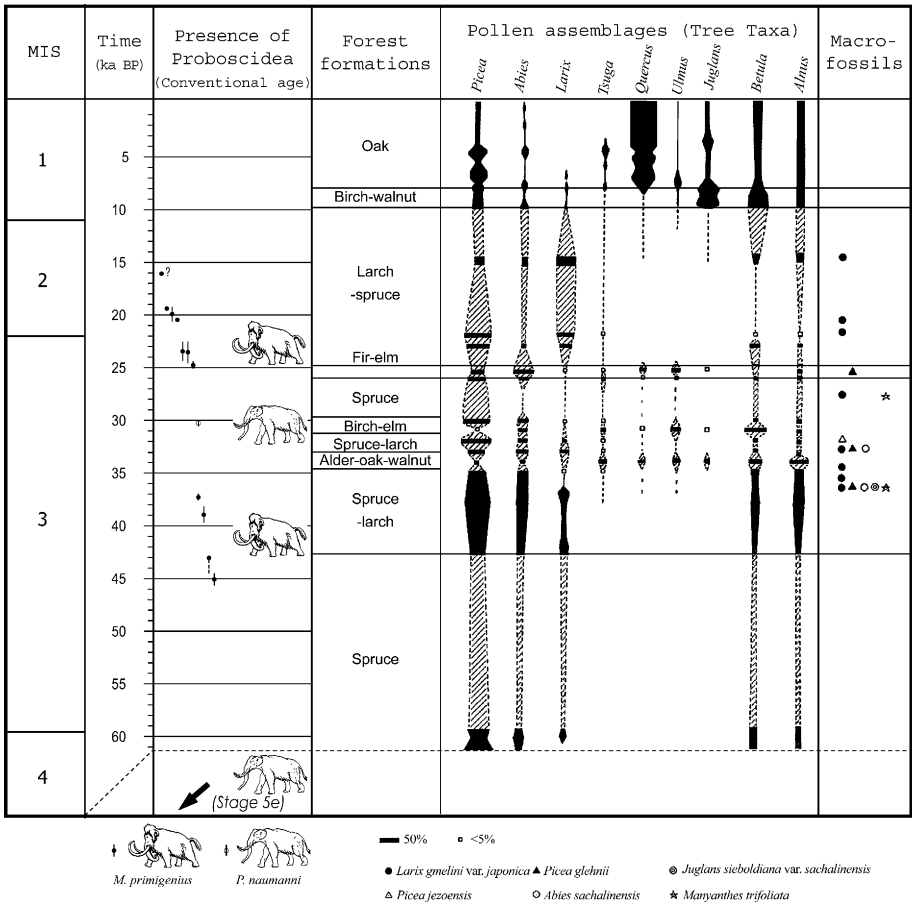

Fig. 2. Relationship between vegetation and proboscidean fossils in the southwestern part of Hokkaido after 60 ka. Note that only tree taxa are shown in this figure. Herb taxa were important throughout much of the period (see text). Modified from fossil pollen assemblage and macrofossils from the Ishikari Lowland by Igarashi (1993).

3. Discussion

The range of the ^{14}C dates from published records and our new analyses is from 45,110 ± 480 years BP to 16,320 ± 90 years BP. The exact provenance of the youngest record specimen, the Yubari specimen is not known, as mentioned above. It is, therefore, proper to exclude it from consideration in appraising the range of radiocarbon dates of woolly mammoths in Japan. Accordingly, we judge this range to have been from around 45 ka to 20 ka.

The Sawada specimen form the Sea of Japan off Shimane Prefecture was found at a point distance from other Japanese woolly mammoths specimens. Kamei (1990) proposed a hypothesis that the woolly mammoth remains drifted from mainland China. Sixteen *Palaeoloxodon* remains are reported from the Sea of Japan, besides the Sawada specimen. Although most specimens were discovered off the coast of Shimane and Tottori Prefectures, west Japan, molars were also discovered off the coasts of the Noto Peninsula, central Japan and northeast of the Yamato ridge that is almost the center of the Sea of Japan. It is unlikely that the Yamato ridge was land during the Pleistocene. Moreover, there exists no evidence that the vegetation of the area sound with the Sawada specimen was suitable for woolly mammoths habitat. Considering in the light of these data, we concur with Kamei (1990) that the Sawada specimen probably drifted from mainland China.

In Hokkaido, during 60–35 ka and 25–10 ka the vegetation included open forest of taiga composed mainly of *Larix gmelinii*, *Picea pumila*, and *Picea jezoensis* with grassy plains (Igarashi et al., 1989, 1990; Igarashi, 1993). Pollen analysis results of the Kenbuchi Basin in northern Hokkaido showed that a huge variety of grass plants such as Ranunculaceae, Compositae, *Polenonium*, Umbelliferae, Rosaceae, Leguminosae, *Sanguisorba*, Thalictrum, Labiatae, Cyperaceae and Gramineae developed under cold/dry climatic conditions during 2.5–1.6 ka (Igarashi et al., 1993). Such climate conditions and vegetation are similar to those of northernmost Sakhalin at present, provided an environment for woolly mammoths.

It is well known, though, that from around 34 ka to 26 ka there was a slight climate amelioration, referred to as MIS 3. During this period, the vegetation of the Ishikari Lowland in western Hokkaido was dominated by deciduous broadleaf trees such as *Betula*, *Alnus*, *Ulmus*, and *Quercus*, together with *Tsuga* and boreal conifers (Igarashi and Kumano, 1981). It appears that the temperature of this period was warmer than that of the preceding and following periods. The fact that *P. naumanni* has been found at Yubetsu, eastern Hokkaido, with a ^{14}C date of 30,520 ± 220 years BP (Takahashi et al., 2004) has supported the results from vegetation analysis. *P. naumanni* has been recovered from over 150 sites of Honshu area dating from about 300 ka to 20 ka. During this period, the vegetation of the area was cool-temperate to warm-temperate forests. We may infer that *P. naumanni* was adapted to temperate forests, and it migrated from Honshu to Hokkaido with a northward expansion of temperate forests, as suggested by Takahashi et al. (2004). Therefore, it is presumed that woolly mammoths migrated north from Hokkaido. A similar scenario of range shifts is known for *Palaeoloxodon antiquus* and *M. primigenius* in Europe. *P. antiquus* was a species of temperate and Mediterranean woodland, like *P. naumanni*, whereas *M. primigenius* was a cold-adapted species, and climatic caused vegetational changes evidently drove these range shifts (Stuart, 2005).

Recently radiocarbon dates of woolly mammoth remains in northern Asia (Zenin et al., 2000, Kuzmin et al., 2000, Orlova et al., 2000, MacPhee et al., 2002;

Plate I. *Mammuthus primigenius* in Japan. (see page 7).

1. Yubari specimen (right upper M3), 1a) buccal view, 1b) lingual view, 1c) occlusal view;
2. Second Ogoshi specimen (right lower M3), 2a) occlusal view, 2b) lingual view, 2c) buccal view;
3. First Notsukesaki specimen (right lower M3), 3a) occlusal view, 3b) lingual view, 3c) buccal view;
4. First Rausu specimen (right lower M3), 4a) occlusal view, 4b) lingual view, 4c) buccal view.

Plate II. *Mammuthus primigenius* in Japan (continued from Plate I). (see page 8).

1. Todowara specimen (right lower M1 or P4), 1a) occlusal view, 1b) buccal view, 1c) lingual view;
2. First Yuni specimen (right upper M1), 2a) buccal view, 2b) lingual view, 2c) occlusal view;
3. Second Yuni specimen (left upper M2), 3a) lingual view, 3b) buccal view, 3c) occlusal view;
4. Second Rausu specimen (left lower M3), 4a) lingual view, 4b) buccal view, 4c) occlusal view;
5. Second Notsukesaki specimen (left lower M1), 5a) occlusal view, 5b) buccal view, 5c) lingual view;
6. Sawada specimen (left lower M3), 6a) lingual view, 6b) buccal view, 6c) occlusal view.

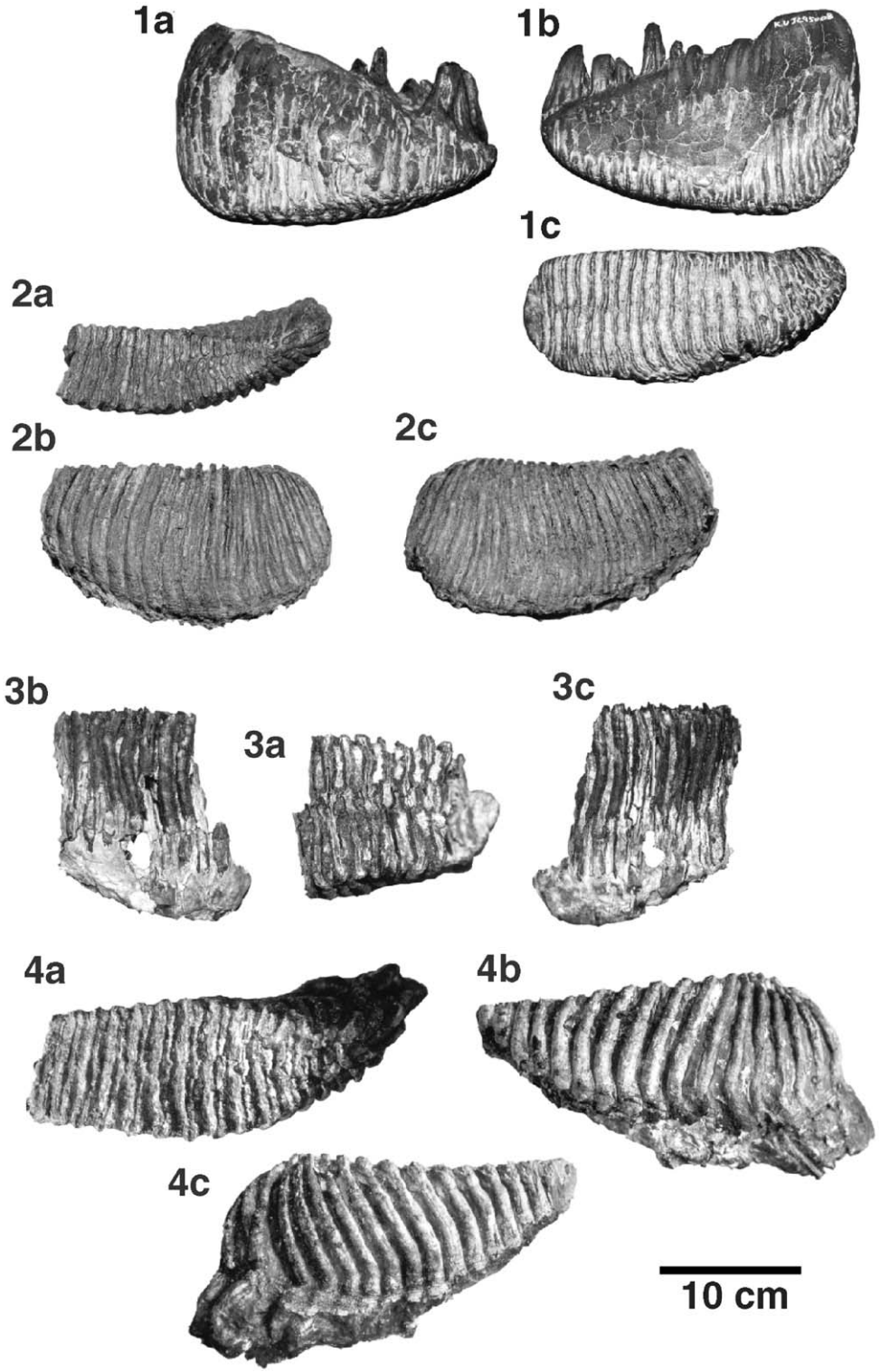

Plate I. (*caption on page 6*).

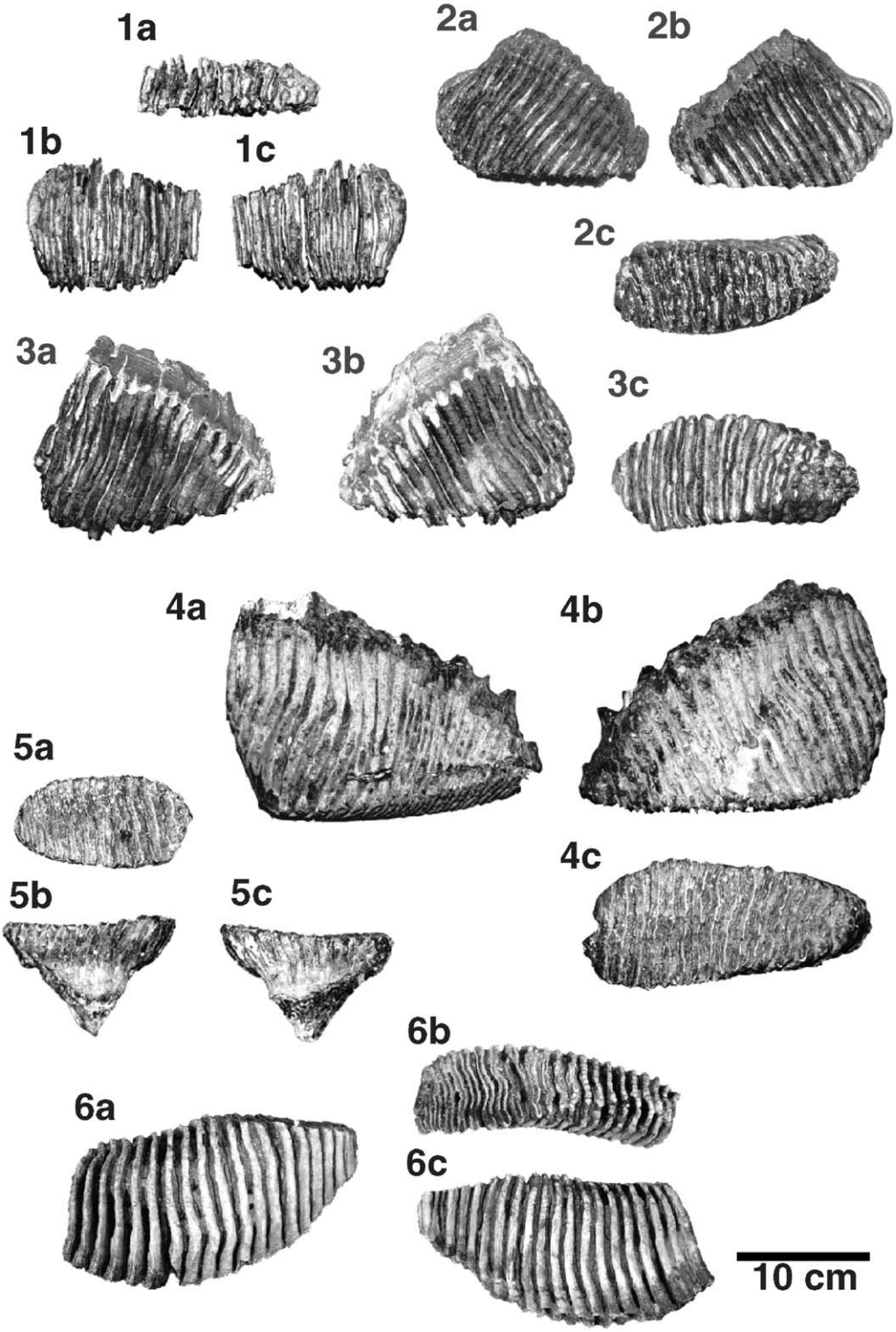

Plate II. (*caption on page 6*).

Stuart et al., 2002, Kuzmin et al., 2003) indicate that woolly mammoths existed throughout northern Asia until around 12 ka, when a rapid contraction of their habitat began being associated with global climate changes. However the studies of the radiocarbon dating and the vegetation in Hokkaido suggest the possibility of woolly mammoths migrating south or north with global climate change around 45 ka to 20 ka. The evidence of woolly mammoths migrating in Hokkaido has yet to be sufficiently clarified. This topic will be discussed in more detail in the future, when additional evidence will have been accumulated in Hokkaido and other areas.

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