Taxonomic Invalidity of Busk's Elephant (Elephas maximus buski Matsumoto, 1927) demonstrated by AMS 14C dating

Authors: Takahashi, Keiichi, and Yasui, Kensuke

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Taxonomic invalidity of Busk's elephant (*Elephas maximus buski* Matsumoto, 1927) demonstrated by AMS ^{14}C dating

KEIICHI TAKAHASHI[1] AND KENSUKE YASUI[2]

[1]*Lake Biwa Museum, 1091 Oroshimo, Kusatsu, Shiga 525-0001, Japan (e-mail: takahasi@lbm.go.jp)*
[2]*Toyohashi Museum of Natural History, 1-238 Oana, Oiwa, Toyohashi, Aichi 441-3147, Japan*

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Abstract. The ages of the holotype and a referred molar of *Elephas maximus buski* described by Matsumoto in 1927, and a molar supposedly of the same subspecies described by Makiyama in 1938 from Higashi Betsuin temple in Nagoya, were investigated by AMS (Accelerator Mass Spectrometry) dating. The holotype (IGPS 7266) may date from any of four periods between 1676 and 1941 cal AD, with 1732–1777 cal AD being the most probable (40.7% likelihood). The referred specimen (IGPS 5845) most likely dates from 1784–1796 cal AD (39.4% probability), and the specimen from Higashi Betsuin from 1454–1494 cal AD (52.9% probability). The present specimens, including the holotype are, therefore, not fossils. Historical records show that Asian elephants did not inhabit Japan at these times. These molars must have been imported into Japan in some fashion during historical times and do not represent a subspecies distinct from extant Asian elephants, *E. maximus*. Although the nominal subspecies *E. maximus buski* is clearly invalid, it is not clear which of the three extant subspecies of Asian elephant is its senior synonym in this research.

Key words: AMS ^{14}C dating, Asian elephant, *Elephas maximus buski*, taxonomy

Introduction

About ten species of fossil elephant have been reported from Japan. Remains of molars of the Asian elephant *Elephas maximus* Linnaeus, 1758 have also been reported several times (Table 1). The first such report, by Adams (1868), concerned a tooth uncovered more than 40 miles (i.e., more than 64 km) from the seacoast between Kanagawa and Edo (present-day Tokyo). While expressing doubt as to whether this specimen was indeed a fossil, Adams ended up reporting it as one. His paper included a supplemental remark by G. Busk, who indicated that this molar was identified as that of an Asian elephant, but also that it was slightly bigger than an average-sized molar of extant conspecifics.

Matsumoto (1927) later established *Elephas indicus buski* as a subspecies of Asian elephant, based on a molar found in Ninohe, Iwate Prefecture. Under Article 73.1 of the International Code of Zoological Nomenclature (International Commission on Zoological Nomenclature, 1999), the "type-specimen" so-called by Matsumoto (1927) is the holotype fixed by original designation. He also assigned to this subspecies 1) a left lower third molar bought in Tokyo, 2) the molar reported by Adams (1868), and 3) some molars that he had earlier reported (Matsumoto, 1924) from ?Sapporo in Hokkaido and from Gifu and Wakayama Prefectures. The left lower third molar that he called a "referred specimen" and the other specimens included in this subspecies by Matsumoto (1927) are all paratypes under Article 72.4.5 of the Code, but to avoid ambiguity, we call the former "the referred specimen" herein. Because there was no evident taphonomic modification or "fossilization" of these specimens, Matsumoto (1927) attributed them to the post-Monastirian period, i.e., after the last glacial epoch.

Shikama (1937) and Naora (1944) accepted Matsumoto's (1927) taxonomy, but Takai (1938) excluded *E. maximus buski* from his Japanese Neogene mammalian list because of the possibility that the specimens had been imported from India in historical times.

Although Makiyama (1938) reported a molar from Higashi Betsuin temple in Nagoya, Aichi Prefecture and another specimen from the riverside of the Yasu River in Shiga Prefecture as *E. maximus*, he thought that the holotype and other referred specimens of *E. m. buski* reported by Matsumoto (1927), as well as the specimen reported from Edobashi in Tokyo by Naumann (1881), were actually *Palaeoloxodon naumanni* (Makiyama, 1924). Sub-

Table 1. List of Asian elephants reported from Japan. Five specimens that were reported by Matsumoto (1924) and Shikama (1937) without locality data are omitted. Otsuka (1976), which was cited by in Hasegawa (1977) could not be confirmed.

	Original identification	Locality	Horizon	Tooth class	Date of collection	Depository	Original reference	Remarks
1	*Elephas indicus*	?Sapporo, Hokkaido	Unknown	Molar	Unknown	Geological Survey of Japan (burned in Great Kanto Earthquake of 1923)	Matsumoto (1924)	Matsumoto (1927) treated it as *E. i. buski*.
2	*Elephas indicus*	Ninohe District, Iwate Prefecture	Unknown	Left upper first molar	Unknown	The Tohoku University Museum (IGPS7266)	Matsumoto (1924)	Matsumoto (1927) treated it as *E. i. buski* (Holotype of *E. i. buski*). Makiyama (1938) treated it as *P. naumanni*.
3	*Elephas maximus*	"Edobashi", Chuou ward, Tokyo	Unknown	Lower molar	Unknown	The University Museum, The University of Tokyo (CV 13810)	Naumann (1881)	Matsumoto (1927) treated it as *E. i. buski*. Makiyama (1938) treated it as PM4 of *P. naumanni*.
4	*Elephas maximus*	> 40 miles (> 64 km) from coast between Kanagawa and Edo (now Tokyo)	Unknown	Right upper second molar	1859	Natural History Museum, London	Adams (1868)	Matsumoto (1924) treated it as *E. indicus*. Okazaki (1982a) suggested it may be *E. m. buski*.
5	*Elephas indicus*	Gifu Prefecture	Unknown	Unknown	Unknown	Geological Survey of Japan (burned in Great Kanto Earthquake of 1923)	Matsumoto (1924)	Matsumoto (1927) treated it as *E. i. buski*.
6	*Euelephas trogontherii*	Hishiike-cho, Nishio, Aichi Prefecture	Unknown	?Right upper second molar	Unknown	Geological Survey of Japan (burned in Great Kanto Earthquake of 1923)	Matsumoto (1924)	Makiyama (1938) treated it as *P. naumanni*. Okazaki (1982a,b) suggested it may be *E. m. buski*.
7	*Elephas maximus*	Higashi Betsuin temple, Tachibana, Naka ward, Nagoya, Aichi Prefecture	?Upper Atsuta Formation	Right lower third molar	1852	Aichi High School	Makiyama (1938)	Okazaki (1981, 1982a) suggested it may be *E. m. buski*.
8	*Elephas trogontherii*	Reported as bed of Yasu River; actually bed of Seri River, Taga town, Inugami county, Shiga Prefecture	Unknown	Left lower first molar	Ca. 1916	Taga Town Museum	Makiyama (1924)	Hasegawa (1977) treated it as *E. maximus*.
9	*Elephas maximus*	Fukae-higashi, Higashinari ward, Osaka, Osaka Prefecture	Soil 2 m below ground level	Left upper third molar	Ca. 1907	Osaka Museum of Natural History (OMNH M4003F)	Ikebe and Chiji (1959)	
10	*Elephas indicus*	Wakayama Prefecture	Unknown	Right lower third molar	Unknown	Unknown	Matsumoto (1924)	Matsumoto (1927) treated it as *E. i. buski*.
11	*Elephas namadicus naumanni*	Bed of Naka River, Roji, Minami ward, Fukuoka, Fukuoka Prefecture	Hasegawa (1972): "?Nissa gravel bed"; Karakida *et al.* (1994): "the Suzaki bed"	Right upper forth milk molar	1951	Kyusyu University Museum	Matsuo and Yoshimura (1953)	Okazaki (1982a,b) suggested it may be *E. m. buski*.
12	*Elephas maximus*	Upper reaches of Sendai River, Tsuruda town, Satsuma county, Kagoshima Prefecture	Unknown	Mandible	Unknown	Unkown	Otsuka (1976)	Quotation of Hasegawa (1977)
13	*Elephas indicus buski*	Unknown (purchased in Tokyo)	Unknown	Left lower third molar	Unknown	The Tohoku University Museum (IGPS 5845)	Matsumoto (1927)	Makiyama (1938) treated as *P. naumanni*.

sequently, Ikebe and Chiji (1959) reported a molar of *E. maximus* from Fukae-higashi, Higashinari ward, Osaka, and "Otsuka (1976)" reported a mandible of the same species collected from Sendai River in Tsuruda, Satsuma County, Kagoshima Prefecture. "Otsuka (1976)" was cited by Hasegawa (1977), but its existence could not be confirmed. In his paper listing the specimens of *E. maximus* from Japan, Hasegawa (1977) noted, concern-

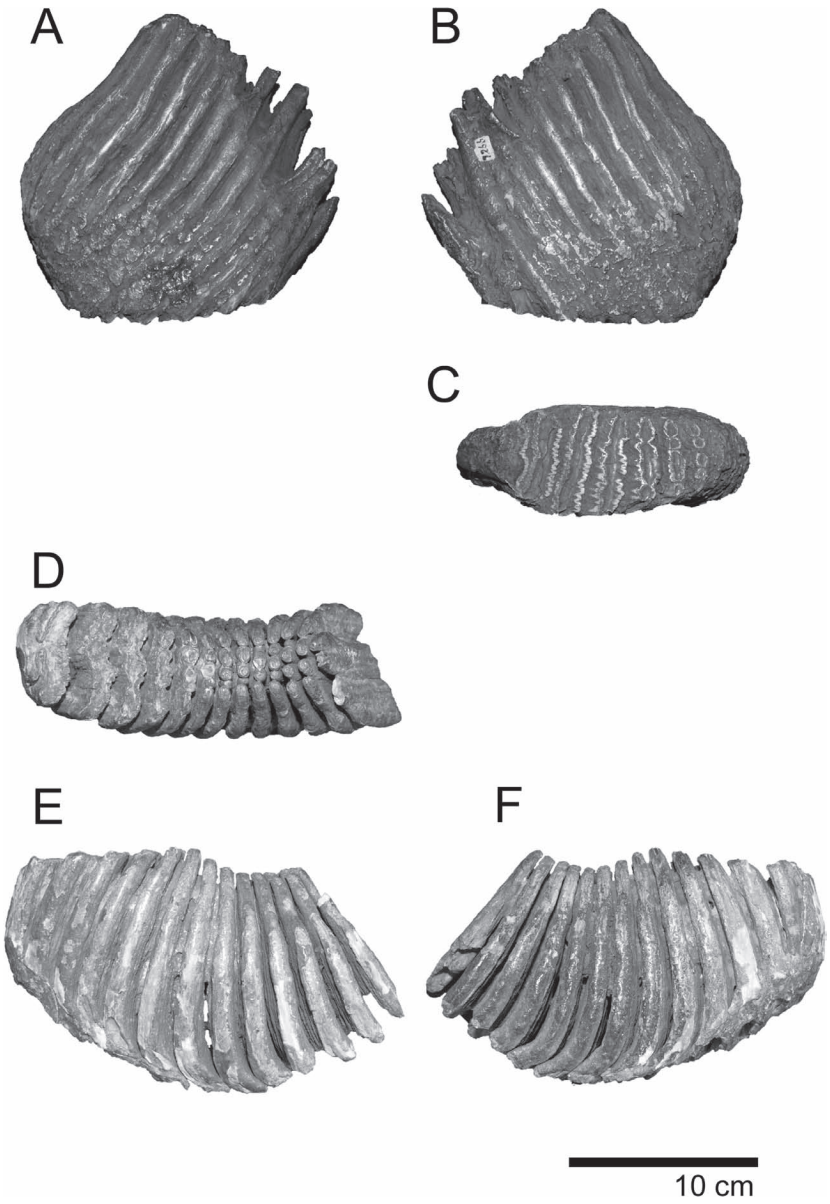

Figure 1. Photographs of Asian elephant molars from Japan subjected to redescription and AMS ^{14}C dating in the present study (1). **A–C,** holotype of *Elephas maximus buski* (Tohoku University Museum Reg. No. IGPS 7266), left upper first molar; A, lingual side; B, buccal side; C, occlusal side; **D–F,** specimen from Higashi Honganji Betsuin temple in Nagoya (kept by Aichi High School, unregistered), right lower third molar; D, occlusal side; E, lingual side; F, buccal side.

ing those reports, that "most people are negative in recognizing those specimens as fossils", but he also remarked, "It is strange that there are no record of the transported specimens though such rare things are discovered from the various localities of Japan."

Okazaki (1982b) suggested that a molar from Hishiike-cho, Nishio City, Aichi Prefecture, which had been identified as *Euelaphas trogontherii* (Pohlig, 1885) by Matsumoto (1924) and as *Paraelephas trogontherii* (Pohlig, 1885) by Takai (1938), was really *E. m. buski*. In addition, Okazaki (1982b, 1984) renamed Hasegawa's (1977) specimen that had earlier been reported from the Yasu River (actually collected from the Seri River; Okazaki, 1982b) in Shiga Prefecture as *Parelephas* sp. Kamei (1991) believed that all specimens identified as *E. m. buski* should be classified as either the extant *E. maximus* or extinct *P. naumanni*.

The general view now seems to be that some of the

Table 2. Measurements of specimens. Measurements were carried out following Takahashi (1991). The symbol "+" represents more plates at the mesial or distal part of the molar, now lost.

	Holotype of *E. m. buski* (IGPS 7266)	Referred specimen of *E. m. buski* (IGPS 5845)	Specimen from Higashi Betsuin temple (No registration number)
Tooth class	Left upper first molar	Left lower third molar	Right lower third molar
Plate number	+12+	15+	1/2 13+
Using palate number	7	4	5
Length of crown	153 mm	180 mm	155 mm
Maximum length of crown	153 mm	222 mm	213 mm
Occlusal surface length	116 mm	76 mm	89 mm
Height of crown	162 mm (8th)	145 mm (4th)	120 mm (6th)
Maximum height of crown	162 mm	147 mm	119 mm
Width of crown	60 mm (4th plate)	75 mm (3th plate)	64+ mm (3th plate)
Masticatory face width	58+ mm (3th plate)	72 mm (5th plate)	62 mm (6th plate)
Enamel thickness	2.3–2.7 mm	2.7–3.2 mm	2.6–2.7 mm
Lamella frequency	8 (buccal) 8 (lingual)	6 (buccal) 5.5 (lingual)	7 (buccal) 6.5 (lingual)
Eruption angle	70°	–	–
Occlusal angle	54°	–	–

Asian elephant specimens reported from Japan are not *E. maximus* at all, while other specimens are indeed from Asian elephants but in some way represent recent artificial transport from foreign lands. However, scientific evidence based on modern techniques has been lacking to confirm this latter hypothesis. In an effort to correct this, we determined the age of the type specimen of *E. m. buski*, the other specimen from the same locality that was referred to this subspecies by Matsumoto (1927), and also Makiyama's (1938) specimen from Nagoya, by AMS (Accelerator Mass Spectrometry) dating.

Material

Holotype of *Elephas maximus buski* Matsumoto, 1927

Tooth class.—Left upper first molar (Figure 1A–C).

Depository.—Tohoku University Museum (Reg. no. IGPS 7266).

Locality.—Ninohe, Iwate Prefecture.

Horizon.—Unknown.

Reference.—Matsumoto (1927).

Description.—Complete molar with abrasion of roughly mesial half of occlusal surface. Surface color dark brown, but part of enamel exposed on occlusal surface white. Coronal cement not complete, but much remaining in situ. Enamel rings of occlusal surface oval and small; crowded enamel folding also seen. Lateral fissure not visible. Five enamel tubercles on each lamella in distal region. Measurements shown in Table 2.

Referred specimen (paratype) of *Elephas maximus buski* Matsumoto, 1927

Tooth class.—Left lower third molar (Figure 2A–D).

Depository.—Tohoku University Museum (Reg. no. IGPS 5845).

Locality.—Unknown (purchased in Tokyo).

Horizon.—Unknown.

Reference.—Matsumoto (1927).

Description.— Complete molar with abrasion of mesial part, cut artificially at midpoint of mesio-distal length. Surface color dark brown. Coronal cement almost complete. Dentin and cementum milky-white, and enamel white, as seen in section, indistinguishable from those of extant elephant molars. In lateral view, lamellae appearing somewhat compressed in mesial-distal direction. Facet for anterior molar present on mesial side. Folding relatively strong in enamel rings of occlusal surface. In section, enamel rings oval with strong folding. Measurements shown in Table 2.

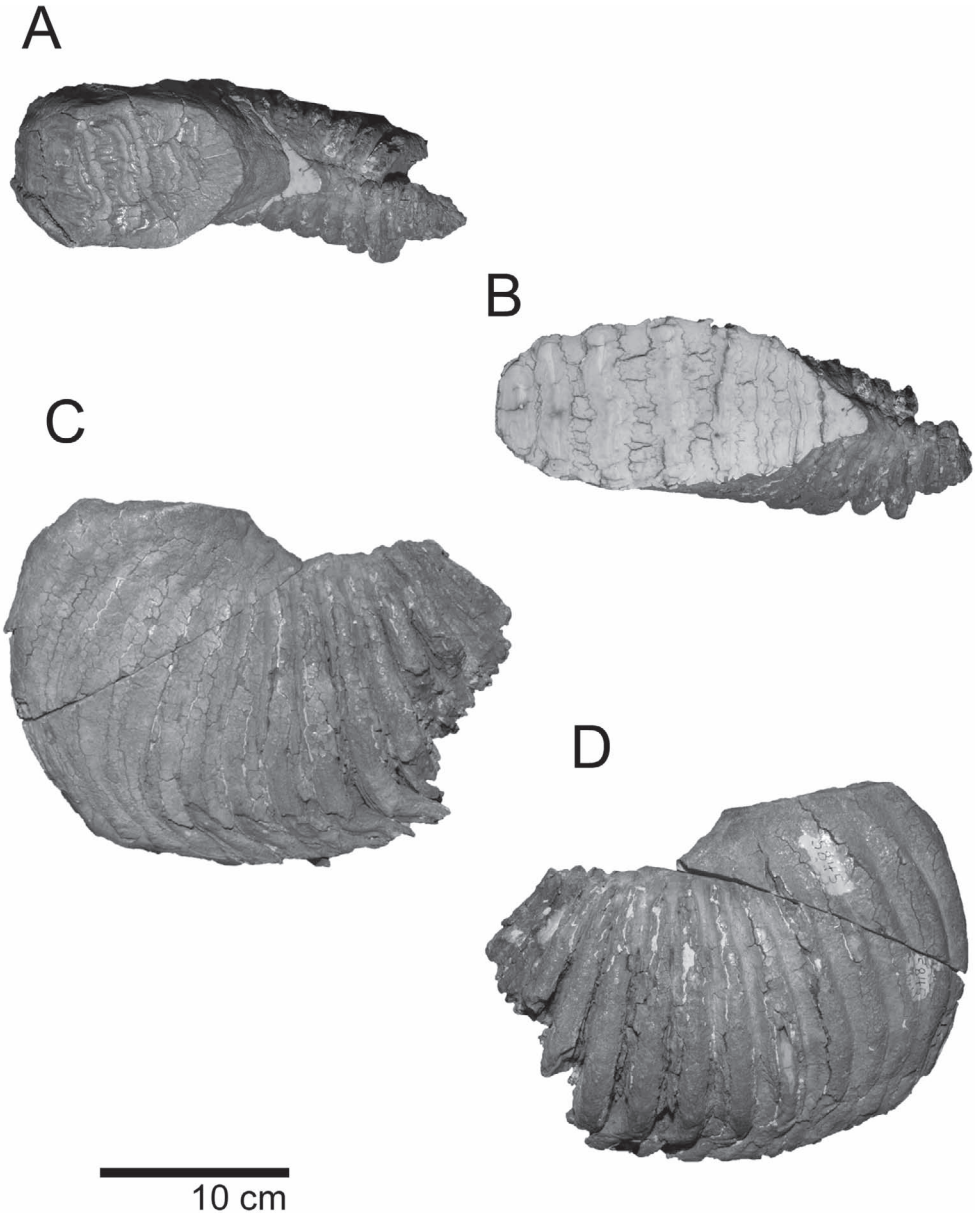

Figure 2. Photographs of Asian elephant molars from Japan subjected to the redescription and AMS ^{14}C dating in the present study (2). **A–D,** referred specimen (paratype) of *Elephas maximus buski*, left lower third molar (Tohoku University Museum Reg. No. IGPS 5845); A, occlusal side; B, cutting plane; C, buccal side; D, lingual side.

Specimen from Higashi Betsuin temple in Nagoya

Tooth class.—Right lower third molar (Figure 1D–F).

Depository.—Aichi High School (no registration number).

Locality.—Shinshu Otani-ha Nagoya Betsuin (also known as Higashi Betsuin) temple, Tachibana, Naka ward, Nagoya, Aichi Prefecture.

Horizon.—Unknown (2 m below ground).

Reference.—Makiyama (1938).

Description.—Complete, rather narrow molar with abrasion of mesial part. Surface color dark brown, but dentin and enamel seen in a broken lamella surface white and milky-white, respectively, indistinguishable from those of extant Asian elephant molars. Coronal cement absent. Enamel rings on occlusal surface oval in most mesial part of tooth, where abrasion most advanced, but divided into three equal sections by constrictions in third

Table 3. Results of AMS ^{14}C dating of three molars attributed to *Elephas maximus buski* by Matsumoto (1927) or to *E. maximus* by Makiyama (1938). PLD is an analysis number of Paleo Lab Co., Ltd. The measured radiocarbon ages are unadjusted values before correction by the extent of isotopic fractionation on the $^{13}C/^{12}C$ ratio. Calendar-calibrated dates are provided along with the conventional ^{14}C ages.

Specimen	Analysis number	$\delta^{13}C$ (‰)	Conventional ^{14}C age (yrBP ± 1σ)	Measured ^{14}C age (yrBP ± 1σ)	calendar-calibrated date (cal AD)	C/N ratio
Holotype of *E. m. buski* (IGPS 7266)	PLD-26055	−20.03±0.25	158±17	160±15	1676–1685 (7.6%) 1928–1941 (7.6%) 1799–1808 (7.6%) 1732–1777 (40.7%)	3.29
Referred specimen of *E. m. buski* (IGPS 5845)	PLD-26055	−11.74±0.15	222±18	220±20	1657–1666 (28.8%) 1784–1796 (39.4%)	3.25
Specimen from Higashi betsuin temple (No registration number)	PLD-23486	−24.47±0.24	378±18	380±20	1454–1494 (52.9%) 1602–1614 (15.3%)	3.53

lamella, where abrasion less advanced. Loxodont sinus absent from all enamel rings. Several enamel tubercles present on distal parts of non-abraded lamellae. Measurements shown in Table 2.

Methods and results of AMS 14C dating

In order to take samples for dating, we visited the specimen depositories and ground the molars using a rotary micromotor for dental laboratories. The pretreatment and AMS ^{14}C dating were performed by Paleo Lab Co., Ltd., as follows: To remove contamination of organic matter from the sample, surfaces were cleaned using an ultrasonic cleaning device. The washed samples were leached in 0.2 M NaOH at 4°C for 12 h. After neutralization and drying the reacted samples were pulverized using a mortar and pestle. The sample powders were decalcified in 1.2 M HCl at 4°C for 12 h in a cellulose tube, and were subsequently gelatinized in distilled water acidified to pH 3.0 at 90°C for 12 h. The gelatinized samples were cleaned using a glass filter, and the dissolved gelatin was recovered by freeze-drying. To measure the atomic ratios of carbon and nitrogen and $\delta^{13}C$ and $\delta^{15}N$ values, extracted collagen was analyzed using an elemental analyzer coupled to an isotope ratio mass spectrometer. The isotope ratios were calculated based on the difference from reference materials of carbon and nitrogen in per mille units. To synthesize graphite for radiocarbon dating, CO_2 gas from the gelatin was purified, then reduced to graphite with hydrogen over iron powder in a vacuum line (Minagawa *et al*., 1984; Kitagawa *et al*., 1993). The ^{14}C content in the synthesized graphite was measured by AMS using a compact accelerator mass spectrometer (NEC 1.5SDH). The calender age is obtained in OxCal 4.2 with IntCal 13 (Ramsey, 2009; Reimer *et al*., 2013). A further measurement of the C/N profile of each sample was also done, with values falling within the range (2.9–3.6) typically exhibited by bone collagen (*cf.* DeNiro, 1985) (Table 2). This indicates a low probability of exogenous contamination. The holotype of *E. m. buski* (IGPS 7266) may date from any of four periods between 1676 and 1941 cal AD, with 1732–1777 cal AD having the highest probability (40.7%). The referred specimen (IGPS 5845) similarly had a most probable date range of 1784–1796 cal AD (39.4% likelihood), and that of the molar from Higashi Betsuin temple in Nagoya was 1454–1494 cal AD (52.9% likelihood) (Table 3).

Discussion

The three examined specimens of *Elephas maximus buski* that are stored at the Tohoku University Museum and at Aichi High School are indistinguishable from the extant Asian elephant, *E. maximus*, in size and morphological characters such as the extent of enamel folding. In addition, while the surface coloration of these specimens is dark brown, inside the enamel is white and the dentine and cementum are milky white as mentioned above, just as in extant Asian elephants. These observations indicate at least that the three examined molars are not fossils; instead, they may belong to or be very closely related to the extant Asian elephant.

AMS ^{14}C dating of these three specimens indicates various ranges of possible age, but the holotype most likely dates from 1732–1777 cal AD, the referred specimen most likely from 1454–1494 cal AD, and the specimen from Nagoya most likely from 1454–1494 cal AD. Such dates indicate that the elephants lived in historical times, specifically from the Muromachi to the middle of the Edo Periods of the Japanese history (the beginning the

14th century to the middle of the 17th century). However, there is no mention of wild Asian elephants inhabiting Japan in any historical document: These three specimens, either as living elephants or as isolated teeth, must have been imported artificially into Japan from foreign lands. According to Isono (2007), there are six records of living Asian elephants brought into Japan from overseas before the Meiji Period, i.e., before 1868. The many discoveries of Asian elephant molars listed in Table 1 suggest that unrecorded Asian elephant molars were imported as well, perhaps as medicinal goods or gifts.

Yamada (1966) reported that the Asian elephant molar was discovered underground in the foundation of Higashi Betsuin temple in Nagoya by digging near a wall that had collapsed in the Great Ansei Earthquake in 1854. However, that temple, officially known as Shinshu Otaniha Nagoya Betsuin, was established in 1690, considerably later than the AMS ^{14}C date of the molar there. Earlier, a castle belonging to Nobuhide Oda (father of the powerful 16th century samurai warlord Nobunaga Oda) stood at the same site. This castle is thought to have been built in 1534, so the molar evidently predates it, too.

The origin of molars assigned to *Elephas maximus buski* has been unclear. The results of this study show that the "type" and referred specimen that Matsumoto (1927) considered to be a new fossil subspecies of elephant actually belonged to Asian elephants that lived in the 18th century. The nominal subspecies *E. m. buski* is not based on fossils after all, but on artificially transported specimens of extant Asian elephant. This subspecies is, therefore, invalid. Three extant subspecies are known in *E. maximus*. As the specimens studied in this research are all isolated teeth, it is difficult to identity to which subspecies the specimens belong. As previously pointed out, AMS dating also supports the inference that Asian elephant fossils from Japan may be artificial transports from foreign lands.

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