1 Geology and Quaternary environments of the Tategahana Paleolithic site in
2 Nojiri-ko (Lake Nojiri), Nagano, central Japan

3
4 Y.Kondo ^a, Y.Takeshita ^b, T.Watanabe ^a, M.Seki ^a and Nojiri-ko Excavation
5 Reserch Group ^c

6
7 a Nojiriko Museum
8 287-5Nojiri, Shinano-machi Kamiminochi-gun, Nagano 389-1303 Japan
9 e-mail kondo@avis.ne.jp

10
11 b Yoshihiro Takeshita
12 Institute of Education,Shinsyu University
13 6-ro Nishinagano, Nagano city, Nagano 380-8544 Japan
14 e-mail takey@shinshu-u.ac.jp

15
16 a Tetsuya Watanabe
17 Nojiriko Museum

18
19 a Megumi Seki
20 Nojiriko Museum

21
22
23 c Nojiri-ko Excavation Reserch Group
24 Nojiriko Museum
25 e-mail nojiriko@avis.ne.jp

Abstract

Excavation of the Tategahana Paleolithic site at Nojiri-ko (Lake Nojiri), central Japan, began in 1962, and the 21st excavation was performed in 2014. The Upper Pleistocene to Holocene fluvio-lacustrine Nojiri-ko Formation is distributed in and around Nojiri-ko. Fossils such as those of Naumann's elephant (*Palaeoloxodon naumanni*) and Yabe's giant deer (*Sinomegaceros yabe*), representing the ice age in Japan, have been excavated there in large quantities; at least 46 Naumann's elephants have been found. The fossils have been excavated in strata dating to 37.9–60.4 ka, comparable to MIS 3. Analysis of fossil pollen assemblages indicates that the vegetation at the time was a mixture of coniferous and broad-leaved trees. Bone instruments and spiral flakes made from elephant and deer bones, and stone tools created from stone, not found in the peripheral region, have been excavated from the Nojiri-ko Formation, and concentrated clusters of different types of fossilized elephant bones have been found.

The top horizon containing elephant remains is 37.9 ka old, and thus older than MIS 2 (the Last Glacial Maximum), making it unlikely that Naumann's elephant disappeared from Nojiri-ko only because of climatic cooling. Findings strongly suggest that the occurrence of these large mammal fossils is the result of human activity. The Tategahana Paleolithic site provides important insights into the transitional phase from Asian Paleanthropine to *Homo sapiens* in Japan.

1. Introduction

Nojiri-ko (Lake Nojiri) is located in the northern part of the Fossa Magna region of central Japan (36°49'N, 138°13'E). The water level of Nojiri-ko is at an altitude of 657 m above sea level, with the deepest point at 38.5 m, and it covers an area of 4.5 km². Nojiri-ko is the second-largest lake in the Nagano Prefecture. The Myoko, Kurohime, and Iizuna volcanoes are situated to the west and the Madarao volcano to the east of Nojiri-ko.

In 1948, the owner of a lakeside inn found a fossil molar of a Naumann's elephant (*Palaeoloxodon naumanni*) on the western shore of Nojiri-ko. At that time, the stratigraphic horizon of the fossil was unclear. The first Nojiri-ko excavation was performed in March 1962 at the site where the molar was found in order to fix the stratigraphic horizon of the fossil. Lacustrine sediments are distributed on the bottom and around the lake, grading

1 laterally into terrestrial sediments consisting chiefly of volcanic ash.
2 Subsequent excavations and geological surveys revealed that the lacustrine
3 sediments of Nojiri-ko and its surrounding area bear fossils and belong to a
4 late Pleistocene series, now named the Nojiri-ko Formation. More than 20
5 fossils were collected during the first excavation, including the femur of a
6 Naumann's elephant and the upper jaw of a Yabe's giant deer (*Sinomegaceros*
7 *yabei*).

8 In the third excavation, conducted in 1964, two stone flakes were found,
9 which drew the researchers' attention toward the relationship between
10 Paleolithic humans, the Naumann's elephant and the giant deer. The fifth
11 excavation was conducted in March 1973, involving 1100 participants from
12 across Japan. A research body was organized under the name of the Nojiri-ko
13 Excavation Research Group, composed of both specialists and non-specialists
14 and including members of the public such as primary school children,
15 university students, teachers, and housewives. This excavation yielded
16 artifacts such as retouched bone flakes and tools, together with many fossils.
17 Bones of Naumann's elephant and giant deer were often found *en masse*
18 (Nojiriko Excavation Research Group, 1975). From the sixth excavation
19 (1975) to the ninth excavation (1984), a large number of elephant fossils were
20 found on the lake floor 30 m from the current shoreline. During this time,
21 advances made in the study of pollen, plant, and diatom fossils and
22 entomolites enabled researchers to visualize in high resolution the transition
23 of the paleo-environment of the site.

24 Currently the Nojiri-ko Excavation Research Group biannually carries out
25 excavations at the western shore of Nojiri-ko, called the Tategahana
26 Paleolithic site, with the aim of investigating the relationship between the
27 paleo-environment and Paleolithic humans (Nojiriko Excavation Research
28 Group, 1997; 2011). Since 1997, a major aim has been to unearth evidence of
29 a possible kill-butcher site. In the 20th excavation, conducted in 2014,
30 which involved about 200 people, more than 750 pieces of fossils and
31 archeological remains were discovered and sediment samples for microfossil
32 study were collected.

34 2. Geology

35 2.1. Lake Nojiri-ko and surrounding areas

36 The area around Nojiri-ko is underlain chiefly by Miocene to Lower

1 Pleistocene sediments such as marine and fluvial deposits, volcanic rocks, and
2 intrusive rocks; Quaternary volcanic products from the Madarao, Iizuna,
3 Kurohime, and Myoko volcanoes; and Lower Pleistocene to Holocene
4 sediments such as alluvial fan deposits, debris flow deposits, and lake and
5 fluvial deposits (Fig. 1).

6 The Tategahana excavation site (Fig. 2) and surrounding areas such as the
7 central part of Nojiri-ko, including the NJ88 Drilling Site, Ikejirigawa
8 Lowland, and Nakamachi Hill, are in ascending order underlain by basement
9 layers (debris flow deposits and volcanic rocks of the Middle to Late
10 Pleistocene), the Biwajima-oki Formation (massive peaty silt belonging to the
11 Late Pleistocene), the Ikejirigawa debris avalanche deposit (Late Pleistocene),
12 and the Nojiri-ko Formation (lacustrine deposits belonging to the Late
13 Pleistocene to Holocene) (Fig. 2). Many tephra beds are intercalated with the
14 Biwajima-oki and Nojiri-ko formations and have been employed as a key to
15 determine detailed stratigraphies (Geology Research Group for Nojiri-ko
16 Excavation, 1980; 1984a; 1984b; 1990). Many tephra beds in these formations
17 are derived from the Kurohime and Myoko volcanoes (Geology Research
18 Group for Nojiri-ko Excavation, 1984b) (Fig. 1).

19 The Kamiyama and Nojiri Loam formations (an eolian deposit and
20 heterotopic facies respectively contemporaneous with the Biwajima-oki and
21 Nojiri-ko formations) are distributed on the tops and slopes of the hills around
22 Nojiri-ko (Fig. 2).

23 24 2.2 Lithostratigraphy and age of the Nojiri-ko Formation

25 The Nojiri-ko Formation, which at the Tategahana excavation site consists of
26 lacustrine deposits, is in ascending order divided on the basis of its lithofacies
27 into the Kannoki Silt Member, the Umibata Sand and Silt Member, the
28 Tategahana Sand Member, and the Fuyoko Sand and Silt Member (Geology
29 Research Group for Nojiri-ko Excavation, 2004) (Fig. 2). Each member is
30 subdivided into two to seven units on the basis of its lithofacies. The Kannoki
31 Silt Member is divided into K1 and K2, the Umibata Sand and Silt Member
32 into U1 to U3, the Tategahana Sand Member into T1 to T7, and the Fuyoko
33 Sand and Silt Member into F1 to F4. Units U2 to T7 in the Nojiri-ko
34 Formation bear many fossils, including those of Naumann's elephant and
35 Yabe's giant deer (Kondo et al., 2007).

36 The depositional age of each of the members of the Nojiri-ko Formation has

1 been estimated by using seven time-marker tephra beds (Kuronuka: K-Ah;
2 Nuka I: AT; BW1466: TKN0301; Kigoma: DKP; Kibiokoshi: Tt-E; Togenuka:
3 Aso-4; and Kotsubu-bio: On-Pm-1) and the rate of sedimentation found from
4 the NJ88 drilling core, as follows: Kannoki Silt Member: 68.2–61.1 ka;
5 Umibata Sand and Silt Member: 61.1–48.6 ka; Tategahana Sand Member:
6 48.6–37.9 ka; Fuyoko Sand and Silt Member: 37.9 ka to present, in ascending
7 order (Nagahashi and Ishiyama, 2009) (Fig. 3).

8 9 2.3. Birth and transition of Nojiri-ko

10 The “Kawara” (dark gray fine volcanic ash), which is one of the marker tephra
11 beds in the Upper Kamiyama Loam Formation, occurs just above the
12 boundary of the Biwajima-oki and Kannoki formations in the NJ88 drilling
13 core (Fig. 2). The Ikejirigawa debris avalanche deposit, which was formed by
14 the collapse of the Kurohime volcano, is also overlain by the Kawara on the
15 southern part of the Nakamachi Hill (Ishii and Geology Research Group for
16 Nojiri-ko Excavation, 1997). From the sedimentation rate in the NJ88 drilling
17 core, the age of the Kawara has been estimated at 68.2 ka (Nagahashi and
18 Ishiyama, 2009). Consequently, after the collapse of the volcano, the
19 Ikejirigawa debris avalanche deposit dammed up old valleys and formed
20 Nojiri-ko at approximately 68 ka.

21 The depositional centers of the lower and the upper parts of the Nojiri-ko
22 Formation are respectively situated in the western and eastern (currently the
23 deepest) parts of the lake (Fig. 3). The Nojiri-ko Formation overlies the
24 basement rocks such as Madarao volcanic rocks on most parts of the lake’s
25 margin, except on the western margin. In the western part of the lake the
26 thickness of the Nojiri-ko Formation decreases westward, and the
27 Tategahana Sand Member and the Fuyoko Sand and Silt Member show offlap.
28 These phenomena indicate that the western coastal region and the
29 Nakamachi Hill have been rising gradually, which is the major cause of the
30 damming-up of Nojiri-ko.

31 32 3 Vertebrate fossils

33 3.1. Vertebrate taxa

34 The mammalian and avian fossils obtained from the Nojiri-ko Formation
35 consist of the following species: *P. naumanni*, *S. yabei*, *Alces alces*, *Cervus* sp.
36 cf. *nippon*, *Ursus arctos*, *Lepus* sp., *Microtus* sp., *Anser fabalis*, *Phalacrocorax*

sp. cf. *carbo*, and *Phasianus soemmerringii* (Fig. 4). The greater part of the vertebrate fossil assemblage is made up of two species: *P. naumanni* account for 92% of the total number of identified specimens and *S. yabei* account for 7.7% (Fig. 5).

Fossils of *P. naumanni* have been obtained over an area ranging from the U2 unit of the Umibata Sand and Silt Member to the uppermost T7 unit of the Tategahana Sand Member. *S. yabei* fossils have been obtained over an area ranging from the U2 unit of the Umibata Sand and Silt Member to the T7 unit of the Tategahana Sand Member. A fossil of the moose *A. alces* was first discovered in the T3 unit of the Tategahana Sand Member; it was a fragmentary left dentary with almost complete M3. Most fossils of rare species have been found in the T4 to T6 units of the Tategahana Sand Member. Of the identified fossils, 61.4% were excavated from the T1 to T3 units, 13.8% from T4 to T6 units, and 9.2% from the T7 unit. The age of the Nojiri-ko Formation from which Naumann's elephant fossils have been excavated is 38 to 60 ka. (Paleo-vertebrate group of Nojiri-ko Excavation Research Group, 1975; Fossil Mammal Research Group for Nojiri-ko Excavation, 1980; 1984; 1987; 1990; 1993; 1996; 2000; 2003; 2006; 2008; 2010a; 2010b; 2012; 2014; 2016; Kondo et al., 2001) (Table 1).

3.2. Number of fossils per unit time and unit volume in each horizon

The times and volumes of deposition in each unit differ. When comparing the number of fossils in each horizon, the number of fossils deposited per unit time and volume of horizon has to be considered. The deposition period and the volumes excavated so far are as follows: U2 unit of the Umibata Sand and Silt Member: 6100 years and 77.8 m³; U3 unit of the Umibata Sand and Silt Member: 5700 years and 477 m³; T1 to T3 units of the Tategahana Sand Member: 4800 years and 2285.3 m³; T4 to T6 units of the Tategahana Sand Member: 1200 years and 1505.6 m³; T7 unit of the Tategahana Sand Member: 4700 years and 859.9 m³.

The greatest number of fossils per unit time was deposited in the T4 to T6 units, at 0.87 pieces/1000 years/m³. Assuming that natural crushing conditions were constant, many fossils were deposited over a short period in these units. The number of fossil is 0.623 pieces/1000 years/m³ in the T1 to T3 units, and 0.346 pieces/1000 years/m³ in the T7 unit. Thus, although there are many fossils in the latter two horizons, they are not as abundant as in

others in terms of per unit volume and per unit time.

3.3 Mode of occurrence of the T4 unit of the Tategahana Sand Member

Three clusters or concentrations of bones of *P. naumanni* associated with artifacts are recognized in the excavated area of the T4 unit of the Tategahana Sand Member. Items in the skull cluster include an incomplete skull, fragments of skull, an upper M3, a radius, a remnant of wood, and a boulder. Items in the rib cluster include 23 ribs (from the same individual), vertebrae, a stylohyoid, a bone cleaver, some refitted bone flakes, and a bone flake core. Those in the forelimb cluster include a scapula, an ulna, carpals, and metacarpals (from the same individual). These fossil assemblages of skull, ribs, and forelimbs collected within an area of 40 m² probably belong to the same individual. The arrangement of fossil assemblages is almost parallel to the present shoreline (NE-SW), and we presume that the shoreline of that age coincided with the recent shoreline. The mammalian bones and fragments were likely scattered to some extent by hydrodynamic transport (Fossil Mammal Research Group for Nojiri-ko Excavation, 1984) (Fig. 6).

3.4 Age profile of *P. naumanni*

The age determination method proposed by Laws (1966) was applied to a total of 66 molars (31 upper, 35 lower). Estimated ages are presented in African elephant years (AEY) after the method of Haynes (1991). The results were as follows: 0 to 12 AEY, 4.5%; 13–24 AEY, 17%; 25–36 AEY, 39%; 37–48 AEY, 10.5%; and 49–60 AEY, 29%. Prime-age adults are the most predominant, followed by senile animals. Calves and juveniles are conspicuously rare, a result of time-averaged selective mortality (Mazima and Fossil Mammal Research Group for Nojiri-ko Excavation, 1997).

3.5 Morphological features of *P. naumanni* in Nojiri-ko

The cranium of *P. naumanni* has a moderately raised parieto-frontal crest and considerably inclined incisive alveoli, which are characteristic of the genus *Palaeoloxodon* (Inuzuka, 1977). The stylohyoid bone has a distinct and stout process at the dorsal border of the base of the posterior ramus (Inuzuka et al., 1975). This is unique to *P. naumanni*. The tusks are strongly curved and twisted in males, not straight as in *P. antiquus*. The longest specimen of tusk was 2.4 m long.

1 The skull of *P. naumanni* from Nojiri-ko has a characteristic bulge in the
2 forehead bone above the nostrils, caused by a moderately raised parieto-
3 frontal crest.

4 The molars of Nojiri-ko specimens are generally larger than those of
5 specimens from other localities such as the Seto Inland Sea. The loxodont
6 sinus is well developed in the lower molars compared with that in the upper
7 molars. The shoulder height of *P. naumanni* from Nojiri-ko, as estimated from
8 the femur length, is 2.7–2.8 m, while the shoulder height of specimens from
9 other localities in Japan is 2.4–2.8 m (males) and 1.9 m (females). The limbs
10 are thick and the forelimbs are better developed and longer than the hind
11 limbs (Mazima, 1997).

12 13 3.6 Minimum number of individuals

14 The total minimum number of individuals (MNI) of *P. naumanni* from
15 excavations in the Nojiri-ko Formation from 1995 to 2014 has been estimated
16 at about 46 animals. The MNI and age range in each unit are as follows: U2
17 unit of the Umibata Sand and Silt Member: 1 animal and 54.3–60.4 ka; U3
18 unit: 7 animals and 48.6–54.3 ka; T1 to T3 units of the Tategahana Sand
19 Member: 19 animals and 43.8–48.6 ka; T4 unit: 2 animals and 42.9–43.8 ka;
20 T5 unit: 7 animals and 42.8–42.9 ka; T6 unit: 1 animal and 42.6–42.8 ka; T7
21 unit: 9 animals and 37.9–42.6 ka (Fig. 7).

22 23 4 Archaeological materials

24 Three horizons have yielded bone flake tools: the U3 unit of the Umibata Sand
25 and Silt Member and the T1 to T3 and T4 units of the Tategahana Sand
26 Member. Typical spiral flakes from the T7 unit of the Tategahana Sand
27 Member were detached from the long bones of *S. yabei*. These spiral flakes
28 show a higher probability of being the by-product of bone marrow
29 procurement by humans, because a percussion point is evident on the surface
30 of each flake (Ono and Nojiri-ko Excavation Research Group, 1986) (Fig. 8).

31 The stone artifacts obtained from the Tategahana excavation site include
32 edge-damaged flakes, a retouched flake, intact flakes, and cores and scrapers.
33 Three concentrations of large bones, such as the skulls and shoulder blades
34 of *P. naumanni*, associated with spear-shaped wooden tools and large pebbles
35 have been recognized. This circumstantial evidence emphasizes the likelihood
36 that the site was not a settlement but a butchering or “kill” site. (Ono, 2001;

1 Ono et al., 2002; Ono, 2004).

2 The artifact assemblages obtained from the U3 unit of the Umibata Sand and
3 Silt Member to the T7 unit of the Tategahana Sand Member are distinguished
4 by bone tools and coarse, small, lithic flake tools (Anthropology and
5 Archaeology Research Group for Nojiri-ko Excavation, 2006).

6
7
8 5 Climatic and paleovegetation history during the Last Glacial Maximum
9 in and around Nojiri-ko

10 The Biwajima-oki Formation is characterized by an abundance of
11 *Cryptomeria*, *Alnus*, and herbal pollens representing the Cyperaceae and
12 Gramineae (Palynological Research Group for the Nojoro-ko Excavation,
13 1993).

14 The Kannoki Silt Member is occupied by subarctic conifers such as *Abies*,
15 *Picea*, *Tsuga*, and *Pinus* (subgenus *Haploxylon*). Cool-temperate broad-leaved
16 deciduous trees such as *Fagus*, *Quercus* (subgenus *Lepidobalanus*), *Ulmus*,
17 *Zelkova*, *Juglans*–*Pterocarya*, and *Acer* are very rare. *Larix* and *Betula* are
18 characteristically common from the Kannoki Silt Member to the U2 unit of
19 the Umibata Sand and Silt Member.

20 The horizon ranging from the U3 unit of the Umibata Sand and Silt Member
21 to the T7 unit of the Tategahana Sand Member is characterized by rather
22 high percentage of cool-temperate broad-leaved deciduous elements and
23 Pinaceae other than *Abies*. Broad-leaved deciduous trees and conifers
24 infrequently but repeatedly show alternate increases and decreases. The
25 abundances of pioneer plants such as *Betula*, *Corylus*, *Artemisia*, *Thalictrum*,
26 and Gramineae show abrupt increase in some horizons immediately above
27 the tephra layers and then gradually decrease.

28 The F2 unit of the Fuyoko Sand and Silt Member is occupied by subarctic
29 conifers such as *Picea*, *Abies*, *Tsuga*, and *Pinus* (subgenus *Haploxylon*).
30 *Betula* also accounts for a high percentage, especially in the two horizons
31 immediately below and above the conifer-rich horizon. The ratio of AP/NAP
32 (Σ arboreal pollen/ Σ non-arboreal pollen) is very high.

33 Cool-temperate broad-leaved deciduous trees rapidly reach a high percentage
34 again in the F2 and F3 units of the Fuyoko Sand and Silt Member.

35 The fossil pollen assemblages of the above-mentioned upper Pleistocene and
36 Holocene sediments are divided into nine assemblage zones, which are

further divided into many subzones (Nasu et al., 1997).

6 Discussion

The question of whether humans lived in the Japanese Islands 40,000 years ago has so far been answered in the negative, based on the results of DNA analyses and anthropological studies using archeological materials. Izuhio and Kaihu (2015) suggest that the UP suddenly emerged in different regions of Japan around 38 ka ago, signaling the arrival of *Homo sapiens* in this part of eastern Asia. This time corresponds to the upper age limit of archaeological materials and fossils from the Nojiri-ko Formation. Mitochondrial DNA analyses of the Japanese people have established the existence of various local population groups in the Japanese Islands no more than 40 ka ago (Shinoda, 2015). However, a mammoth kill site discovered in West Siberia was estimated to have an age of 45 ka (Pitulko et al., 2016). This important discovery shows that humans had reached Siberia by that time, and necessitates a DNA-analysis-based review of the age of human diffusion. The discovery of moose fossils in the Nojiri-ko Formation indicates that moose moved from Siberia to Honshu Island. The possibility that humans crossed from Siberia to Honshu Island earlier than 45 ka ago is undeniable.

Tsutsumi (2011) notes that it is difficult to judge whether the archaeological materials from the Nojiri-ko Formation are indicative of human activity.

Bone material with a spiral fracture was recently found in the Nojiri-ko excavation and examined by Ono (2001), and the number of spiral flakes found has increased over time (Anthropology and Archaeological Research Group for Nojiri-ko Excavation, 2003).

Norton et al. (2009) examined the cut marks on fossils from the Nojiri-ko Formation and determined that hunting had occurred around Nojiri-ko about 40 ka ago. However, Iwase et al. (2015) stated that these conclusions were not based on an accurate examination of other factors that were probably associated with the megafaunal demise. Nevertheless, the Nojiri-ko excavation did reveal that large mammals such as Naumann's elephant moved to Nojiri-ko between the two periods of coldest climate [Marine Isotope Stage (MIS) 4 and MIS 2], and human remains dated to the same time have been excavated from the formation. It is therefore reasonable to hypothesize that large mammals and humans moved to Nojiri-ko when the climate was relatively warm (i.e., in MIS 3). Considering the climate and environment 40

ka ago, it is certainly possible that humans coexisted with large mammals around Nojiri-ko.

7. Conclusions

Here, we reviewed studies covering the period until the 20th excavation in 2014 at Nojiri-ko, central Japan, by the Nojiri-ko Excavation Research Group. The results of recent excavations have provided a detailed image of the site's geologic stratigraphy and age.

The sedimentary environment, fossils, and archeological material may be put into a relative context (Fig. 9). The Nojiri-ko Formation and its megafaunal components have been lithologically divided into ten units in ascending order, based on calibrated ^{14}C data and sedimentation rates derived from NJ88 drilling cores ranging from 37.9 to 60.4 ka. Fossils of large animals such as Naumann's elephant and human remains from the Tategahana excavation site have been excavated over a narrow area and a limited age range. The MNI of Naumann's elephant differs among unit levels, peaking in the T1 to T3 units, with 19 animals having an age of 42.8–48.6 ka.

The Nojiri-ko Formation is divided by fossil pollen assemblage stratigraphy into nine pollen assemblage zones. Extremely cold climatic conditions are recognized in two horizons. The lower horizon—the U1 and U2 units of the Umibata Sand Silt Member—is indicated by the Pinaceae zone, corresponding to MIS 4. The upper horizon—the F2 unit of the Fuyoko Sand Silt Member—is indicated by the *Picea–Abies* subzone, corresponding to the Last Glacial Maximum, MIS 2. The upper age limit for *P. naumanni* is 37.9 ka, which is older than MIS 2. Therefore, change of climatic conditions cannot be the sole reason for the absence of *P. naumanni* in strata younger than 38 ka in Nojiri-ko. The archaeological context suggests that the place functioned as a kill or butchering site.

These results provide a chronological and paleo-environmental framework for human settlement in Japan during the Pre-upper and Upper Paleolithic periods, which is considered the transitional phase from Asian Paleanthropine to *Homo sapiens*.

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5 6 References

7 Anthropology and Archaeology Research Group for Nojiri-ko Excavation,
8 2003. Results of Archaeological Investigation of the 14th Nojiri-ko
9 Excavation. Bulletin of the Nojiri-ko Museum 11, 37-50 (in Japanese
10 with English abstract).

11 Anthropology and Archaeology Research Group for Nojiri-ko Excavation,
12 2006. Result of the Archaeological Investigation of the 15th Nojiri-ko
13 Excavation and a Reexamination of the Stone Artifacts from the
14 Tategahana Site. Bulletin of the Nojiri-ko Museum 14, 31-53 (in
15 Japanese with English abstract).

16 Aoki, K., Irio, T., Oba, T., 2008. Late Pleistocene tephrostratigraphy of the
17 sediment core MD01-2421 collected off the Kashima coast, Japan.
18 The Quaternary Research (Daiyonki-kenkyu) 47, 391-407 (in
19 Japanese with English abstract).

20 Fossil Mammal Research Group for Nojiri-ko Excavation, 1980. Fossil
21 Remains of the Naumann Elephant from the Nojiri-ko Formation.
22 The memories of the Geological Society of Japan 19, 167-192 (in
23 Japanese with English abstract).

24 Fossil Mammal Research Group for Nojiri-ko Excavation, 1984. Fossil skull
25 of the Naumann elephant from the Nojiri-ko Formation in the 8th
26 Nojiri-ko Excavation. Monograph the association for the Geological
27 Collaboration in Japan 27, 157-164 (in Japanese with English
28 abstract).

29 Fossil Mammal Research Group for Nojiri-ko Excavation, 1987. Vertebrate
30 Fossils from the Nojiri-ko Formation in the Lake Nojiri Excavation
31 (1984-1986). Monograph the association for the Geological
32 collaboration in Japan 32, 137-158 (in Japanese with English
33 abstract).

34 Fossil Mammal Research Group for Nojiri-ko Excavation, 1990. Vertebrate
35 Fossils from the Nojiri-ko Formation in the Lake Nojiri Excavation
36 (1987-1989). Monograph the association for the Geological

1 Collaboration in Japan 37, 111-134 (in Japanese with English
2 abstract).

3 Fossil Mammal Research Group for Nojiri-ko Excavation, 1993. Vertebrate
4 Fossils from the Nojiri-ko Formation in the Lake Nojiri Excavation
5 (1990-1992). Bulletin of the Nojiri-ko Museum 1, 29-52 (in Japanese
6 with English abstract).

7 Fossil Mammal Research Group for Nojiri-ko Excavation, 1996. Vertebrate
8 Fossils from the Nojiri-ko Formation in the Lake Nojiri Excavation
9 (1993-1995). Bulletin of the Nojiri-ko Museum 4, 41-64 (in Japanese
10 with English abstract).

11 Fossil Mammal Research Group for Nojiri-ko Excavation, 2000. Vertebrate
12 Fossils from the Nojiri-ko Formation in the Lake Nojiri Excavation
13 (1996-1999). Bulletin of the Nojiri-ko Museum 8, 29-44 (in Japanese
14 with English abstract).

15 Fossil Mammal Research Group for Nojiri-ko Excavation, 2003. Vertebrate
16 Fossils from the Nojiri-ko Formation in the Lake Nojiri Excavation
17 (2000-2002). Bulletin of the Nojiri-ko Museum 11, 57-77 (in Japanese
18 with English abstract).

19 Fossil Mammal Research Group for Nojiri-ko Excavation, 2006. Vertebrate
20 Fossils from the Nojiri-ko Formation in the Lake Nojiri Excavation
21 (2003-2005). Bulletin of the Nojiri-ko Museum 14, 55-69 (in Japanese
22 with English abstract).

23 Fossil Mammal Research Group for Nojiri-ko Excavation, 2008. Vertebrate
24 Fossils from the Nojiri-ko Formation in the 16th Nojiri Excavation.
25 Bulletin of the Nojiri-ko Museum 16, 23-32 (in Japanese with English
26 abstract).

27 Fossil Mammal Research Group for Nojiri-ko Excavation, 2010a. Vertebrate
28 Fossils from the Nojiri-ko Formation in the 17th Nojiri Excavation.
29 Bulletin of the Nojiri-ko Museum 18, 33-50 (in Japanese with English
30 abstract).

31 Fossil Mammal Research Group for Nojiri-ko Excavation, 2010b. The first
32 occurrence of fossil *Alces alces* (Cervidae, Alceini) from the Upper
33 Pleistocene Nojiri-ko Formation, Shinano Town, Nagano prefecture,
34 Japan. Earth Science (Chikyu Kagaku) 64, 219-233 (in Japanese with
35 English abstract).

- 1 Fossil Mammal Research Group for Nojiri-ko Excavation, 2012. Vertebrate
2 Fossils from the Nojiri-ko Formation in the 18th Nojiri Excavation.
3 Bulletin of the Nojiri-ko Museum 20, 35-47 (in Japanese with English
4 abstract).
- 5 Fossil Mammal Research Group for Nojiri-ko Excavation, 2014. Vertebrate
6 Fossils from the Nojiri-ko Formation in the 19th Nojiri Excavation.
7 Bulletin of the Nojiri-ko Museum 22, 51-64. (in Japanese with English
8 abstract).
- 9 Fossil Mammal Research Group for Nojiri-ko Excavation, 2016. Vertebrate
10 Fossils from the Nojiri-ko Formation in the 20th Nojiri Excavation.
11 Bulletin of the Nojiri-ko Museum 24, 47-65 (in Japanese with
12 English abstract).
- 13 Fukusawa H., 1995. Non-Glacial Varved Lake Sediment as a Natural
14 Timekeeper and Detector on Environmental Changes. The
15 Quaternary Research (Daiyonki-kenkyu) 34, 135-149 (in Japanese
16 with English abstract).
- 17 Geology Research Group for Nojiri-ko Excavation, 1980. Geology of the
18 Excavation Site at Lake Nojiri and Its Surrounding Areas (1976
19 1978). Memoirs of the Geological Society of Japan **19**, 1-31 (in
20 Japanese with English abstract).
- 21 Geology Research Group for Nojiri-ko Excavation, 1984a. Stratigraphy of
22 the Nojiriko Formation - Geology of the excavation site at Lake
23 Nojiri and its surrounding area, Ser. 3 (1981-1983). Monograph,
24 Association for the Geological Collaboration in Japan **27**, 1-21 (in
25 Japanese with English abstract).
- 26 Geology Research Group for Nojiri-ko Excavation, 1984b. Stratigraphy of
27 the Kamiyama Loam Formation and the Nojiri Loam Formation
28 Geology of the excavation site at Lake Nojiri and its surroundings
29 areas, Ser. 4 (1979 1983). Monograph, Association for the Geological
30 Collaboration in Japan **27**, 23-44 (in Japanese with English
31 abstract).
- 32 Geology Research for Nojiri-ko Excavation, 1987, Geology of the Excavation
33 Site at Lake Nojiri and Its Surrounding Areas, Ser.5 (1984-1985).
34 Monograph, Association for the Geological Collaboration in Japan,
35 32, 1-21 (in Japanese with English abstract).

- 1 Geology Research Group for Nojiri-ko Excavation, 1990. Geology of the
2 Excavation Site at Lake Nojiri and Its Surrounding Areas, Ser.6
3 (1986-1988). Monograph, Association for the Geological
4 Collaboration in Japan 37, 1-13 (in Japanese with English abstract).
- 5 Geology Research Group for Nojiri-ko Excavation, 2004. Geology of The
6 Excavation Site at Lake Nojiri and Its Surrounding Areas, Northern
7 part of Nagano Prefecture - On the redefinition of the Nojiri-ko
8 Formation -. Bulletin of the Nojiri-ko Museum 12, 1-13 (in Japanese
9 with English abstract).
- 10 Haynes, G., 1991. Mammoths, mastodonts, and elephants: biology, behavior,
11 and the fossil record. Cambridge University Press, Cambridge.
- 12 Inuzuka, N., 1977. On a fossil skull of *Palaeoloxodon naumanni* from
13 Saruyama, Shimosa-machi, Chiba Prefecture, central Japan. The
14 Journal of the Geological Society of Japan 83, 523-536 (In Japanese
15 with English abstracts).
- 16 Inuzuka, N., Hasegawa, Y., Nogariya H., 1975. On the stylohyoid bone of
17 *Palaeoloxodon naumanni*. Earth Science (Chikyu Kagaku) 29, 36-44
18 (In Japanese with English abstracts).
- 19 Izuho, M., Kaifu, Y., 2015. The Appearance and Characteristics of the Early
20 Upper Paleolithic in the Japanese Archipelago. In: Kaifu, Y., Izuho,
21 M., Goebel, T., Sato, H., Ono, A. (eds.) Emergence and Diversity of
22 Modern Human Behavior in Paleolithic Asia. Texas A&M University
23 Press, College Station, pp.289-313.
- 24 Ishii, Y., and Geology Research Group for Nojiri-ko Excavation, 1997.
25 Middle-Upper Pleistocene series around Kann'noki, Shinano-machi,
26 Nagano Prefecture. Bulletin of the Nojiri-ko Museum 5, 9-18 (in
27 Japanese with English abstract).
- 28 Iwase, A., Takahashi, K., Izuho, M., 2015. Further Study on the Late
29 Pleistocene Megafaunal Extinction in the Japanese Archipelago. In:
30 Kaifu, Y., Izuho, M., Goebel, T., Sato, H., Ono, A. (eds.) Emergence and
31 Diversity of Modern Human Behavior in Paleolithic Asia. Texas
32 A&M University Press, College Station, pp 325-344.
- 33 Kondo, Y., Mazima, N., Nojiri-ko Research Group, 2001. *Palaeoloxodon*
34 *naumanni* and its environment at the Paleolithic site of Lake Nojiri,
35 Nagano Prefecture, Central Japan. In: Cavaretta, G., Gioia, P.,
36 Mussi, M., Palombo, M.R. (Eds.), The World of Elephants:

1 Proceedings of the 1st International Congress. Consiglio Nazionale
2 delle Recherche, Rome, pp. 284-288.

3 Kondo, Y., Mazima, N., Fossil Mammal Research Group for Nojiri-ko
4 Excavation, 2007. Vertebrate fossils and Paleoenvironment from the
5 Nojiri-ko Formation. In: Inuzuka, N., Takahashi, K. (Eds.), Jubilee
6 Publication in Commemoration of Prof. Kamei Tadao's 80th
7 Birthday, pp.117-126 (In Japanese with English abstracts).

8 Laws, R., M., 1966. Age criteria for the African elephant *Loxodonta a.*
9 *africana*. East African Wildlife Journal 4, 1-37.

10 Mazima, N., Fossil Mammal Research Group for Nojiri-ko Excavation 1997.
11 Age profile for the Naumann's Elephant from Lake Nojiri. Bulletin of
12 the Nojiri-ko Museum 5, 41-46 (in Japanese with English abstract).

13 Mazima, N., 1997. Some feature of the Naumann's Elephant from Lake
14 Nojiri. Bulletin of the Nojiri-ko Museum 5, 41-46 (in Japanese with
15 English abstract).

16 Nagahashi, Y., Ishiyama, A., 2009. Reconstruction of the chronological
17 records and the major elements composition of glass shards
18 containing in tephra beds from the NJ 88 sediment core sample,
19 Lake Nojiri-ko, Nagano Prefecture. Bulletin of the Nojiri-ko
20 Museum 17, 1-57 (in Japanese with English abstract).

21 Nakamura, Y., Kondo, Y., 2003. In search of the hunter of Naumann's
22 elephant-Display commentary book. Nojiriko Museum (In
23 Japanese).

24 Nasu, T., Matsue, M., Sakamoto K., Watanabe M., Takemoto H. Mizutani
25 A., 1997. Climatic and Paleovegetational History During the Last
26 Glacial Stage and Holocene in and around Lake Nojiri, Central
27 Japan. In: Jablonski N.G. (Ed), The Changing Face of East Asia
28 during the Tertiary and Quaternary. Proceedings of the Fourth
29 Conference on the Evolution of the East Asian Environment, Hong
30 Kong, 413-419.

31
32
33 Nojiri-ko Excavation Research Group, 1975. The Lake Nojiri Excavation
34 1962-1973. Kyoritsu Press, Tokyo (in Japanese with English
35 abstract).

- 1 Nojiri-ko Excavation Research Group (Eds), 1997. Nature and Man of the
2 Last Glacial Maximum. Kyoritsu Press (In Japanese).
- 3 Nojiri-ko Excavation Research Group, 2011. In search of “Nojiri-ko man”.
4 Nojiri-ko Excavation 50th Anniversary magazine. Nojiri-ko Museum
5 special issue (in Japanese).
- 6 Norton, C., J., Kondo, Y., Ono, A., Zhang, Y., Diab, M. C., 2009. The nature of
7 megafaunal extinctions during the MIS3-2 transition in Japan.
8 Quaternary International, 30, 1-10.
- 9 Ono, A. and Nojiri-ko Excavation Research Group, 1986. Bone technology in
10 the Late Palaeolithic of East Asia: A Nojiri-ko Case Study. The
11 Pleistocene Perspective vol.1 The World Archaeological Congress 1-7.
- 12 Ono, A., 2001. Flaked Bone Tools: An alternative perspective on the
13 Paleolithic. University of Tokyo Press, Tokyo (In Japanese with
14 English abstracts).
- 15 Ono, A., Sato, H., Tsutsumi, T., Kudo, Y., 2002. Radiocarbon dates and
16 archaeology of the late Pleistocene in the Japanese islands.
17 Radiocarbon 44, 477-494.
- 18 Palynological Research Group for the Nojoro-ko Excavation, 1993. Fossil
19 pollen assemblages of a drilling core from the bottom of Lake Nojiri
20 with reference to Late Pleistocene environments. In: Nojiri-ko
21 Excavation Research Group (Ed.), Last Glacial Paleoenvironments
22 in Central Japan-Subaqueous Drilling Research In Lake
23 Nojiri-, Monograph of The Association for the Geological
24 Collaboration in Japan, 41, 39-52 (in Japanese with English
25 abstract).
- 26 Pitulko, V., V., Tikhonov, A., N., Pavlova, E., Y., Nikolskiy, P., A., Kuper,
27 K., E., Polozov, R., N., 2016. Early human presence in the Arctic:
28 Evidence from 45,000-year-old mammoth remains .Science, 351, 260-
29 263.
- 30 Sakai, J., Akabane, S., Nasu, T., Taruno, H., Mazima, N., Nakanura, Y., Kondo, Y.,
31 Kumai, H., 1996. Nojiri-ko and Paleoenvironment of Last Glacial
32 Period. Urban Kubota, 35, Oosaka.
- 33 Shinoda, K., 2015. Japanese origin idea to recite in DNA, Iwanami
34 Press, Tokyo (in Japanese).

Tada, R., Irino, T., Koizumi, I., 1999. Land-ocean linkages over orbital and millennial timescale record in late Quaternary sediments of the Japan Sea. *Paleoceanography*, 14, 236-247.

Takahashi, K., Mazima, N., Fossil Mammal Research Group for Nojiri-ko Excavation. 1991. Morphological description and its variation in the molars of the Naumann's elephant (*Palaeoloxodon naumanni* (Makiyama)) from Lake Nojiri, Nagano Prefecture, Central Japan. *Journal of Fossil Research*, 24, 7-32. (In Japanese)

Tsutsumi, T., 2011. Palaeolithic Age in Japanese Islands. Kawadeshoboshinsha, Tokyo (in Japanese).

Volcanic Ash Research Group for Nojiri-ko Excavation. 1993. Volcanic ash layers of a drilling core in Lake Nojiri, Central Japan. In: Nojiri-ko Excavation Research Group (Ed.), Last Glacial Paleoenvironments in Central Japan-Subaqueous Drilling Research In Lake Nojiri-, Monograph of The Association for the Geological Collaboration in Japan, 41, 1-26 (in Japanese with English abstract).

Figure captions

Fig. 1. Geological map of the area surrounding Lake Nojiri-ko. Modified from Sakai et al. (1996).

Fig. 2. Lithostratigraphy of the area surrounding Lake Nojiri-ko. Modified from Nojiri-ko Excavation Research Group (2011).

The correlations of Kuronuma, Nuka I, Kigoma, Kibiokoshi, Togenuka, and Kotsubu bio with K-Ah, AT, DKP, Tt-E, Aso-4, and On-Pm1 follow Volcanic Ash Research Group for Nojiri-ko Excavation (1993) and Nagahashi and Ishiyama (2009). The correlation of BW1466 with TKN0301 follows Nagahashi and Ishiyama (2009). The ages of K-Ah, AT, Aso-4, and On-Pm-1 follow Fukuzawa (1995), Tada et al. (1999), and Aoki et al. (2008), respectively.

Fig. 3. Geological map and geological section of the area surrounding Nojiri-ko. Modified from Geology Research Group for Nojiri-ko Excavation (1987).

Fig. 4 Vertebrate fossils from the Nojiri-ko Formation.

1
2 Fig. 5 Proportions of fossil species from the Tategahana site.

3
4 Fig. 6 Distribution of fossils and artifacts from the T4 unit of Tategahana
5 Sand Member, Nojiri-ko Formation. Modified from Fossil Mammal Research
6 Group for Nojiri-ko Excavation (1987).

7
8 Fig. 7 Minimum number of individuals of *Palaeoloxodon naumanni* from the
9 Nojiri-ko Formation.

10
11 Fig. 8 Artifacts from the Tategahana site. Modified from Nakamura et al.
12 (2003).

13
14 Fig. 9 Summarized results of Nojiri-ko excavation (1962–2011). Modified
15 Nojiri-ko Excavation Research Group (2011).

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17
18 Table 1 Number of vertebrate fossils from the Nojiri-ko Formation.
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- Myoko Volcanic Rocks (Middle Pleistocene to Present)
- Kurohime Volcanic Rocks (Middle to Late Pleistocene)
- Izuna Volcanic Rocks (Middle Pleistocene)
- Madarao Volcanic Rocks (Early to Middle Pleistocene)
- Hakamadake Volcanic Rocks (Early to Middle Pleistocene)
- Pre Quaternary Volcanic Rocks
- Debris flow deposits and Fan deposits Lake and Alluvial deposits (Holocene)
- Debris flow deposits and Fan deposits Lake and Alluvial deposits (Upper Pleistocene)
- The Middle Pleistocene (Samizu Fm.)
- The Middle Pleistocene (Toyono Fm.)
- Marine and fluvial deposits (Pliocene to Lower Pleistocene)
- Volcaniclastic Rocks (Pliocene to Lower Pleistocene)
- Marine and fluvial deposits (Miocene)

Geologic time		Tephrostratigraphy		Litho-stratigraphy		Age (ka)		Volcanic Activity		mammalian fossils																																																																																																																																																																																																																																																																																												
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Quaternary	Late Pleistocene	Nojiri Loam Formation	Upper	Kashiwabara Black ash	Kuronuka (K-Ah)	F4	F3	F2	F1	T7	T6	T5	T4	T3	T2	T1	U3	U2	U1	K2	K1	Ikejiri-gawa lowland	Nakamachi Hill south, north	Tategahana	NJ88 Drilling Core	6.0	14.7	29.0	37.9	42.6	42.8	42.9	43.8	48.6	54.3	60.4	61.1	64.3	68.2	70.0	87.0	98.4	44.0	Myoko Volcano	Birth of Nojiri-ko	Kurohime Volcano	Palaeoloxodon naumanni	Sinomegaceros yabei																																																																																																																																																																																																																																																						
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Age (ka) Stratigraphic unit Tephra

Fauna

- Bone fragment
- ✓ incisor(tusk)
- ▲ tusk fragment
- ▲ molar
- △ Lamella
- ／ Rib
- ◇ Vertebra
- ▽ Scapula
- hip bone
- ▬ Long bone
- short bone
- ★ Skull
- ★ Skull fragment
- └ Mandible
- ∨ Stylohyoid
- ▤ palmate antler
- ▲ Antler fragment
- ★ Skull fragment
- bone fragment
- ◇ Vertebra
- ▬ Long bone
- Short bone
- ▬ Maxilla • Mandible
- Fece fossil
- × Other animal
- ／ Wooden fragment
- Gravel

- ◎ bone tool and flake
- 1 Bone flake
 - 2 Retouched bone flake
 - 3 Refitted bone flake(1+2)
 - 4,5,6 Bone flake
 - 7 Bone core
 - 8 Refitted bone flake(4+5+6+7)
 - 9 Spiral bone flake
 - 10 Bone flake
 - 11 Refitted bone flake(9+10)
 - 12 Spiral bone flake
 - 13 Rib bone
 - 14 Refirtted bone (12+13)

Unit

animal