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## RADIOCARBON DATING EVIDENCE FOR MAMMOTHS ON WRANGEL ISLAND, ARCTIC OCEAN, UNTIL 2000 BC<sup>1</sup>

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**ABSTRACT.** Radiocarbon dating results of mammoth tusks, teeth and bones collected on Wrangel Island between 1989 and 1991 reveal a unique mammoth refugium during the Holocene. We used an improved chemical procedure to obtain and purify collagen from bone. Benzene synthesized from the samples was measured using a liquid scintillation counter. The validity of our data has been confirmed by the results of our measurements on two international control sample series (IAEA and TIRI) and by parallel measurements of Wrangel Island mammoth remains at other laboratories.

### INTRODUCTION

The systematic <sup>14</sup>C dating of woolly mammoth (*Mammuthus primigenius*) remains, carried out in our laboratory for many years, should help determine the cause or causes of the mammoths' extinction. Among the remains found well preserved in permafrost are those of the mammoths known as Shandrin, Terekhtyakh, Magadan, Khatanga and Yuribei (Arslanov *et al.* 1980, 1982). Many scientists assume that the most probable cause of extinction was an abrupt change in climatic conditions during the Pleistocene/Holocene transition, a period corresponding to the <sup>14</sup>C dates of the youngest mammoths of Siberia. Others invoke an anthropogenic agency, or a combination of cultural and paleoclimatic forces. An exhaustive explanation of the cause is not yet possible. In the Late Pleistocene, the range of mammoths shifted northward. In the Crimea and the Caucasus, mammoths became extinct >20–30 ka ago; on the Russian plain they were still present *ca.* 13 ka ago (Arslanov *et al.* 1972; Lavrov and Sulezhytsky 1992). Based on <sup>14</sup>C ages, the latest mammoth remains found in western Europe (northern France, Switzerland and Great Britain) also date to 12–13 ka ago, when their remains become relatively uncommon (see Stuart 1991).

The last refugia of the mammoth were thought to be the Siberian Arctic and the Arctic islands, including Gydan and Taimyr Peninsulas and the Severnaya Zemlya Archipelago. The youngest <sup>14</sup>C date our laboratory obtained for the Yuribei mammoth (Gydan peninsula, Siberia) was 10,000 ± 70 BP, based on stomach contents (plant debris). Similar results were later obtained by L. Sulerzhytsky (Geological Institute of the Russian Academy of Sciences, Moscow) for tusk and tooth remains of mammoths of the Taimyr Peninsula, Siberia (Lavrov and Sulerzhytsky 1992). <sup>14</sup>C data thus indicated that mammoths became extinct, even in the refugia of the continental Siberian Arctic, *ca.* 9.7–10 ka ago. However, in 1990, our first five dates for mammoth remains from Wrangel Island were all of Holocene age, ranging from 7390–4740 BP (Vartanyan *et al.* 1992). This surprisingly young estimate prompted us to continue investigations at that location.

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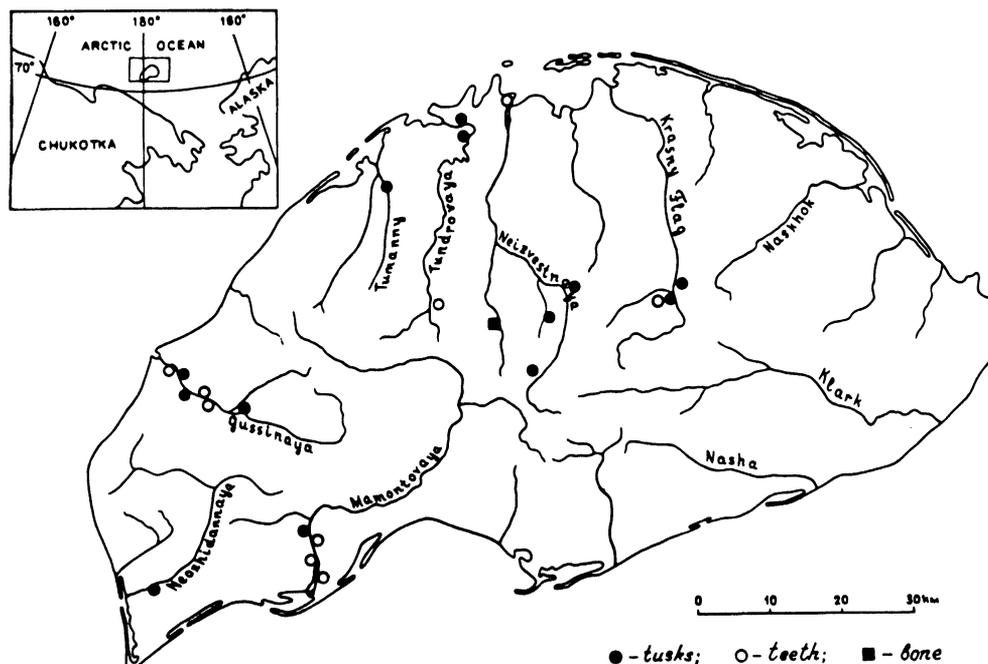


Fig. 1. Location map of Wrangel Island, showing sites of mammoth samples

#### GEOGRAPHY OF THE SITE

Wrangel Island is located on the border of the East-Siberian and Chukchi Seas, between 70° and 72°N, and 177°E and 176°W (Fig. 1). *Ca.* 8000 km<sup>2</sup>, the island is separated from the continent by the Long Strait, with a minimum width of 140 km, and a depth of  $\geq 45$  m. The eastern, western, and central portions of the island have low mountain ranges (up to 1100 m asl) and bisected plateaus; the northern (“Akademia Tundra”) and southern portions are plains.

The Quaternary sediments of Wrangel Island are not very thick; they are primarily aleurite, sand, shingle and peat of Late Pleistocene and Holocene age. The coastal-marine sediments (in the Akademia Tundra) and the alluvium of the high terraces of large rivers, as well as the spare, heavily ice-bearing sand-shingle terraces of the lower hilly terrain, all seem to be of Pleistocene age. Numerous solifluction and other slope sediments of the mountainous part of the island, river-valley alluvium (floodplain and the first terraces of large rivers), and peat and lacustrine thermokarst sediments are widespread on the plains and intermontane depressions, and are of Holocene age.

Bone-rich horizons such as the “Edoma” strata in Siberia have not been found on Wrangel Island. All the bone specimens were collected from riverbed and slope sediments. Only well-preserved tusks (except for one split tusk), teeth and bones were collected. We selected teeth for dating from the collection of S. Vartanyan, made in 1991, which was previously studied by V. E. Garutt of the Zoological Institute of Russian Academy of Sciences.

#### METHODS

Although all samples were well preserved in frozen ground, we used stronger pretreatment than conventional to remove impurities. We extracted and purified bone collagen using a procedure devel-

oped in our laboratory to remove both easily soluble and relatively insoluble organic contaminants (Arslanov and Svezhentsev 1993). We found that the well-known HCl-NaOH and Longin's procedures by themselves did not sufficiently purify collagen.

We obtained carbon from the purified collagen by means of pyrolysis, then lithium carbide according to the reaction  $2C + 2Li \rightarrow Li_2C_2$ . Benzene synthesis was carried out using a high-efficiency vanadium-alumina-silica catalyst ( $V_2O_5 \cdot Al_2O_3 \cdot SiO_2$ ) that enabled us to produce benzene with up to 96% yield. Sample activity was measured with a coincidence scintillation counter using quartz spherical vials (8.46 ml capacity); background and modern standard count rates were 1.9 cpm and 56.8 cpm, respectively. Our techniques for pretreatment and measurement are described in detail elsewhere (Arslanov, Tertychnaya and Chernov 1993).

## RESULTS AND DISCUSSION

We dated 23 samples of *Mammuthus primigenius* remains from Wrangel Island. The youngest and the oldest presently known dates of mammoth remains from the Siberian Arctic and Severnaya Zemlya (Makeev, Arslanov and Garutt 1979; Arslanov *et al.* 1982; Lavrov and Sulerzhitsky 1992) are given in Table 1. Table 2 shows our Wrangel Island dates; 20 out of the 23 samples proved to be of Holocene age, falling within the range  $3730 \pm 40$  to  $7390 \pm 30$  BP. Three dates on teeth from Wrangel Island were Pleistocene in age: LU-2823, -2792 and -2807 at *ca.* 12, 13 and 20 ka, respectively (Table 2), when Wrangel Island was part of Beringia.

TABLE 1. Oldest and Youngest <sup>14</sup>C Dates on Mammoths of Arctic Siberia (excluding Wrangel Island)

Material and location	Lab no.	<sup>14</sup> C age (yr BP)
<i>Continent</i>		
Fragment of mammoth skin, Khatanga River, Taimyr Peninsula	LU-1057	≥53,170
Plant debris from mammoth stomach, Yuribei River, Gydan Peninsula	LU-1153	10,000 ± 70
Mammoth tusk, Nizhnaya Taimyra River	GIN-1823	9670 ± 60
Mammoth tooth, Nizhnaya Taimyra River	GIN-1495	9860 ± 50
<i>Arctic Islands</i>		
Mammoth tusk, October Revolution Island, Severnaya Zemlya Archipelago	LU-610	11,500 ± 60

Geomorphological reconstruction indicates that Wrangel Island formed a part of Beringia (an area that included Chukotka, Alaska, and the huge expanse of the surrounding shelf) during the Late Pleistocene, when the global sea level was *ca.* 100 m below the present level. At the end of the Pleistocene or beginning of the Holocene, Wrangel Island separated from the continent (Hopkins 1975), becoming a refugium for the mammoth population. Our data show that this population survived as long as 6000 yr after all mammoths on the continent were extinct. Morphological studies of mammoth teeth demonstrate that a previously unknown dwarf species of mammoth evolved on Wrangel Island (Vartanyan *et al.* 1993).

Three Wrangel Island mammoth teeth were found to be of Late Pleistocene age, with one sample (LU-2807) (Table 2) deriving from the period of the Late Glacial maximum (~20,000 BP). We obtained similar dates for a mammoth tusk collected on Severnaya Zemlya Archipelago (19,270 ±

TABLE 2.  $^{14}\text{C}$  Dates of Mammoth Remains from Wrangel Island

Lab no.	Material, provenience	$^{14}\text{C}$ age (yr BP)	Calibrated age (cal BC)*
<i>Tusks and Bone</i>			
LU-2741	Tusk (8 cm diameter (d)) from the bed of the lower Neozhydannaya River	3730 $\pm$ 40	2192–2038
LU-2756	Tusk (11 cm d) from the bed of the lower Mamontovaya River	4400 $\pm$ 40	3082–2924
LU-2768	Tusk (9 cm d) from the bed of Tumanny Creek	4410 $\pm$ 50	3090–2924
LU-2556	Tibia bone (0.1–0.2 m) from the floodplain of the upper Lemmingovaya River	4740 $\pm$ 40	3626–3382
LU-2740	Tusk (6 cm d) from the bed of the lower Tundrovaya River	4900 $\pm$ 40	3706–3646
LU-2745	Tusk (9.5 cm d) from the bed of the lower Goosinaya River	5200 $\pm$ 30	4036–3972
LU-2744	Tusk from the bed of the middle Goosinaya River	5250 $\pm$ 40	4216–3990
LU-2742	Tusk from the bed of the lower Goosinaya River	5310 $\pm$ 90	4232–4000
LU-2535	Tusk from left bank of the Red Flag River valley, 2 km upstream from the mouth of the Otrozhnaya River	5480 $\pm$ 50	4440–4252
LU-2558	Tusk from diluvium-solifluction sediments on the western slope of Mount Kit, left side of Neizvestnaya River valley	6610 $\pm$ 50	5567–5450
LU-2736	Tusk from creekbed on the left side of the upper Neizvestnaya River valley	6760 $\pm$ 50	5666–5585
LU-2746	Tusk (7 cm d) from the bed of the lower Tundrovaya River	7040 $\pm$ 60	5954–5816
LU-2559	Tusk from the bed of middle Vetvisty Creek	7360 $\pm$ 50	6214–6062
LU-2444	Tusk from the right side of Red Flag River valley, area of the mouth of the Otrozhnaya River	7390 $\pm$ 30	6216–6176
<i>Teeth</i>			
LU-2798	Last upper molar from the bed of the lower Mamontovaya River (N-MAM-6)	4010 $\pm$ 50	2574–2464
LU-2808	Tooth fragment from the bed of the lower Mamontovaya River (N-MAM-2)	4040 $\pm$ 30	2582–2492
LU-2794	Last lower molar from the bed of the lower Mamontovaya River (N-MAM-5)	5110 $\pm$ 40	3966–3812
LU-2799	Last lower molar from the bed of the lower Goosinaya River (N-GUS-9)	6260 $\pm$ 50	5262–5088
LU-2810	Tooth fragment from the bed of the lower Goosinaya River (N-GUS-9)	6890 $\pm$ 50	5766–5672
LU-2809	Last lower molar from the bed of the upper Tundrovaya River	7250 $\pm$ 60	6158–5988
LU-2823	Last lower molar from the bed of the lower Goosinaya River (N-GUS-8)	12,010 $\pm$ 110	12,200–11,925
LU-2792	Last lower molar from the bed of the middle Red Flag River	12,980 $\pm$ 80	13,580–13,325
LU-2807	Last lower molar found on a beach, 1 km from the mouth of the Neizvestnaya River	20,000 $\pm$ 110	--

\*Calibrated age calculated using CAL15 (van der Plicht 1993)

130 BP) (Makeev, Arslanov and Garutt 1979), and for a front leg-bone found at the mouth of the Lena River, on the Bykovsky Peninsula (21,630 ± 240 BP, LU-1328, Tomirdiaro *et al.* 1984). All of these data support the thesis that during the last glacial maximum, conditions in the East-Siberian Arctic and on the northern islands were adequate for habitation by mammoths.

**ON THE RELIABILITY OF MAMMOTH DATES**

How reliable are these Wrangel Island dates? The question is legitimate: bone is difficult to date, due to its high potential for absorbing external humid acids from groundwater. However, all our mammoth samples were well preserved and were collected from frozen ground. We used a reliable procedure for the chemical treatment of the bone (Arslanov and Svezhentsev 1993), which permitted us to obtain a collagen purified of organic contaminants, whatever their solubility. In addition, the viability of our methods and measurements is supported by our dating of a series of samples for inter-laboratory quality control supplied by the International Agency for Atomic Energy (IAEA) and by Glasgow University, the Third International Radiocarbon Intercomparison (TIRI) (Scott *et al.* 1992). All of our dates (Table 3) were in accordance with the control figures, within the limit of double-measurement uncertainties.

TABLE 3. Measurements of <sup>14</sup>C Activity and Age Determination of TIRI-Control Samples

TIRI code	Material	St. Petersburg measurements	TIRI mean values
A	Grain	117.02 ± 0.57%	116.12%
B	Wood	4580 ± 40 BP	4486 BP
C	Cellulose	129.27 ± 0.58%	129.81%
D	Peat	3730 ± 40 BP	3799 BP
E	Humic acid	10,980 ± 70 BP	11,066 BP
F	Iceland double spar	≥50,000 BP	≥46,076 BP
G	Wood	≥51,560 BP	≥42,962 BP
H	Peat	11,130 ± 40 BP	11,115 ± 116 BP
I	Travertine	11,170 ± 80 BP	11,034 ± 127 BP
J	Wood	1590 ± 40 BP	1593 ± 50 BP
K	Carbonate	18,400 ± 140 BP	18,166 ± 238 BP
L	Whalebone	12,580 ± 60 BP	12,605 ± 127 BP

Later, 2 teeth and 1 tusk from Wrangel Island were dated at The University of Arizona Radiocarbon Laboratory (AA) (Long, Sher and Vartanyan 1994) and by L. Sulerzhitsky in the laboratory of the Geological Institute of the Russian Academy of Sciences (GIN). The data shown in Table 4 are in excellent agreement and, along with data from the Third International Radiocarbon Intercomparison (TIRI), these measurements confirm the reliability of our dates.

TABLE 4. Age determinations of Wrangel Island Mammoth Remains: Results of Three Laboratories

Sample	Age and sample number	
GUS-9, tooth	6260 ± 50, LU-2799	6360 ± 60, AA-11529
PIK-1, tooth	7250 ± 60, LU-2809	7295 ± 95, AA-11530
20-M, tusk	6760 ± 50, LU-2736	6750 ± 30, GIN-6990

## CONCLUSION

During the last glacial maximum (*ca.* 20 ka ago), environmental conditions on Wrangel Island proved capable of sustaining habitation by mammoths. Our data show that woolly mammoths persisted on Wrangel Island in the mid-Holocene, from 7390–3730 yr ago.  $^{14}\text{C}$  dating has shown that mammoths inhabited Wrangel Island for as long as 6000 yr after the estimated extinction of *Mammuthus primigenius* on the Siberian continent.

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