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GEOGRAPHY

# New Data on the Dynamics of the Mammoth *Mammuthus primigenius* Distribution in Europe in the Second Half of the Late Pleistocene–Holocene

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The history of the last glacial period is well elucidated in the scientific literature. Integrated studies have made it possible to establish the natural-climatic conditions of this unique time. Vegetation cover and complexes of mammals for some time intervals of the Valdai (Vistula) Ice Age have been recovered [1–3].

In these works changes in the mammoth distribution between 50 ka and the Late Holocene were analyzed. The wide interval considered was heterogeneous, and it included three basic stages: the Valdai (Vistula) megainterstadial, correlated with the marine isotope 3 stage (MIS 3), the late stage of the Ice Age (MIS 2), and the Holocene (MIS 1). The Middle Valdai megainterstadial was the warmest period during the last glacial period, and it is characterized by numerous climatic fluctuations. The earliest interstadials and stadials of MIS 3 were not under consideration here, so their age datings are not sufficiently good; that is, they are beyond the limits of $^{14}C$ method possibilities. Materials referred to the following stadials were analyzed: the Moershooft interstadials (~46–44 ka), the Hosselo stadials (44–39 ka), the Hengelo stadials (38–36 ka), the Huneborg stadials (36–33 ka), the Denecamp interstadials (the same as those of Bryansk and Dunai), (33 to 25 ka) [1].

During the second stage of the last glacial period, the climatic situation was also heterogeneous. In [1, 3] the mammoth distribution was studied in the last glacial maximum (LGM) during the Valdai (Vistula) glaciation (24–17 ka), in the Late Ice Age (17–12.4 ka), in the warm interstadials Belling, Allered (12.4–10.8 ka), and in the Late Dryas stadial (10.8–10.3 ka).

Some findings of mammoth bones are referred to the Holocene: preboreal–boreal (10.3–8 ka), the Atlantic period (8–4.7 ka), and the subboreal period (4.7–2.6 ka).

## MATERIALS AND METHODS

For all the selected time intervals, maps of findings of mammoth bones dated throughout the territory of Europe were made. The PALEOFAUNA Paleontological Database [4] was used as a source of information.

Recent age datings of the mammoth bones were obtained at Groningen University by Prof. J. van der Plicht as part of the RFBR-NWO project. Dates are not calibrated.

During analysis of the evolution of the range of the mammoth *Mammuthus primigenius* for over 50 000 years, data of 381 localities in Europe (809 $^{14}C$ age datings) were used. Based on the remnants of the Eurasian mammoth, more than 1500 $^{14}C$ age datings for 750 localities were obtained.

### *The Dynamics of Mammoth Distribution*

Figure 1a shows all the localities of bones of the mammoth *Mammuthus primigenius* Blumenbach throughout the territory of Northern Eurasia described in the publications of N.K. Vereshchagin, G.F. Baryshnikov, A.N. Tikhonov, P.A. Kosintseva, A. Lister, A. Stewart, R. Musil, R.-D. Kalke, P. Ukkonen, and many others, summarized in the PALEOFAUNA database. The Late Pleistocene range of the mammoth covered a large part of the continent, but in

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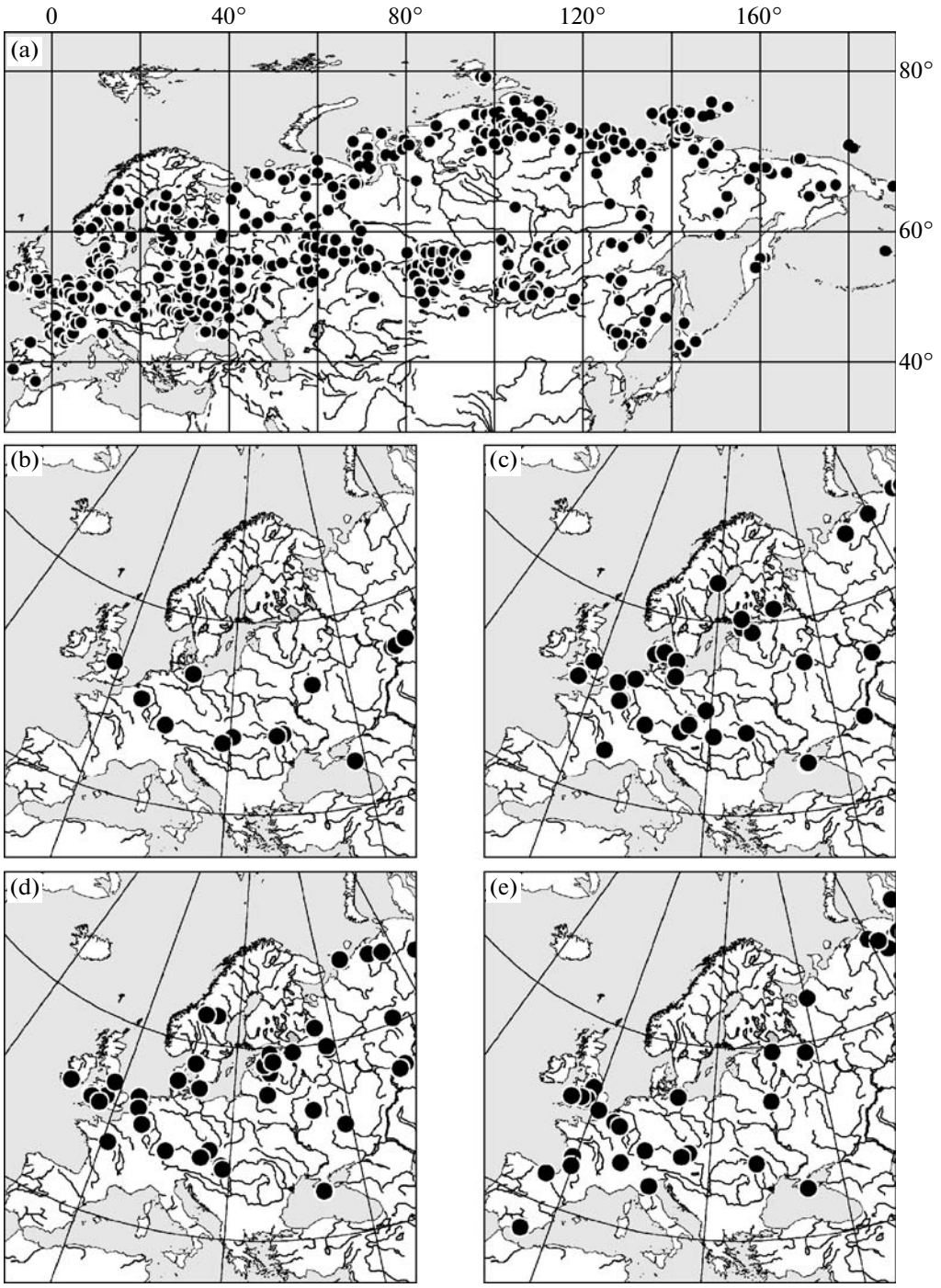


**Fig. 1.** The localities of Late Pleistocene mammoth bones in Northern Eurasia (a). The localities of mammoth bones, synchronous in age to the Moershooft interstadials (b), the Hosselo stadials (c), the Hengelo interstadials (d), and the Huneborg stadials (e).

some different time intervals of the second half of the Late Pleistocene–Holocene, the range changed significantly (Figs. 1, 2).

### *The Megainterstadial of the Last Glacial Period (MIS 3)*

The main findings of mammoth referred to the Moershooft interstadial (~46–44 ka) (Fig. 1b) are concentrated in the central part of Europe. The widest distribution of the mammoth was during the Hosselo stadial cooling (44–39 ka), when the mammoth population migrated far north in Europe and reached the shores of the Arctic Ocean (Fig. 1c). Perhaps the continuous degradation of the forest zone under the influence of cooling made a contribution to this migration to the north. There are numerous localities of the mammoth in the British Isles, where it could have

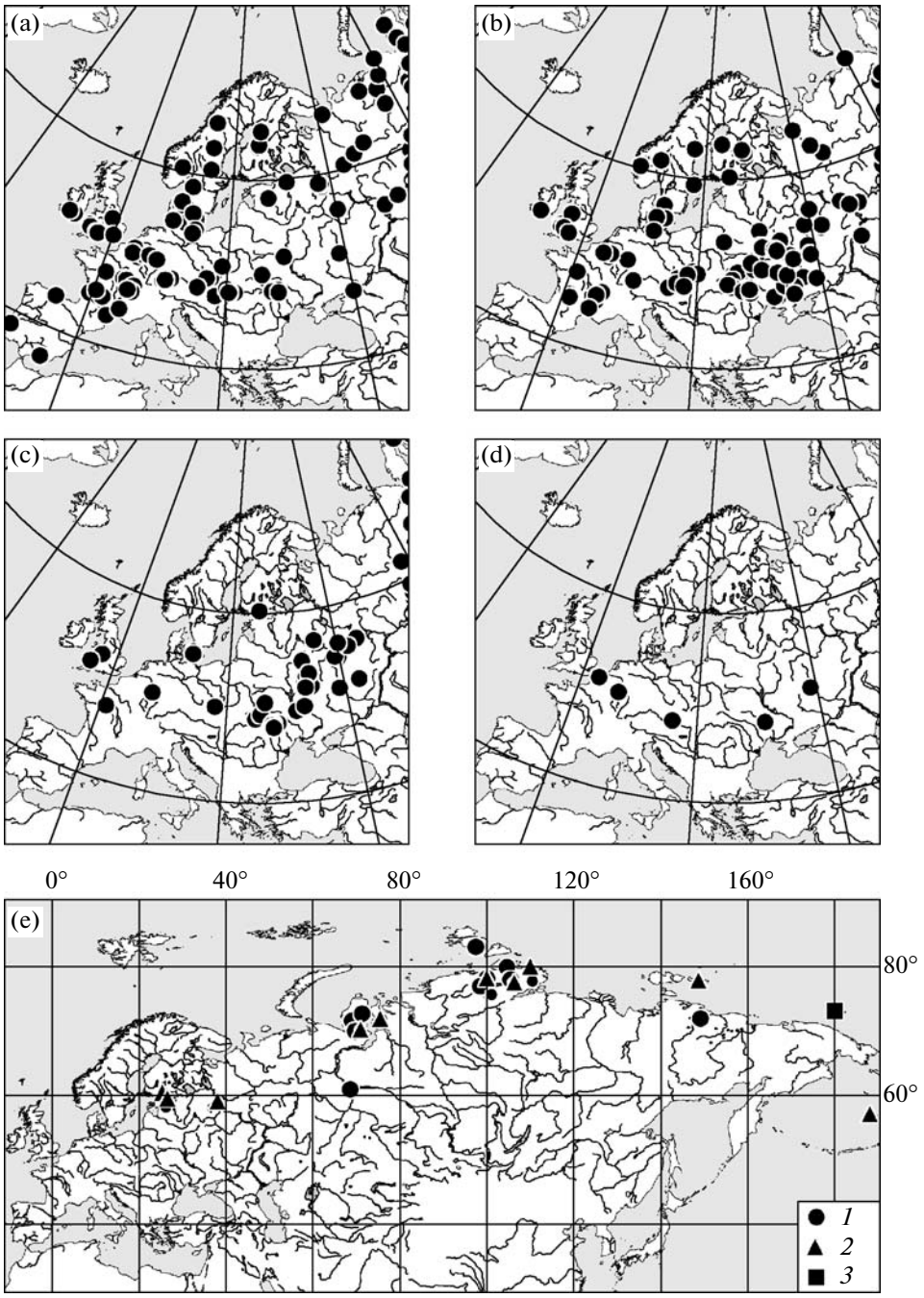


**Fig. 2.** The localities of mammoth bones synchronous in age to the Denecamp interstadial (Bryansk) (a); the last glacial maximum (LGM) (b); the Late Ice Age (c), the warm interstadials (Belling, Allered) (d); and the Late Dryas stadials, the Early Holocene, and the Middle and Late Holocene (e).

gone across the shallow shelf at the beginning of the Ice Age. The late localities of mammoth bones, referred to the Hengelo interstadial (39–36 ka), were found practically all over Europe. The findings of the mammoth in Scandinavia allow us to say that there existed ice-free areas there (Fig. 1d). In the subsequent cool Huneborg period (36–33 ka), the northern boundary of the mammoth range in Western Europe moved to the south (the mammoth disappeared in the territory of Fennoscandia, although continued to dwell in the north of Eastern Europe (Fig. 1e). Indirectly, this indicates an increase in the thickness of the Scandinavian ice sheets. The findings of this species in Southern Spain, where the mammoth probably migrated under the influence of cooling, are unique [5].

At the end of the Middle Valdai (Vistula) late megainterstadial, during the Denecamp interstadial (Bry-

ansk), the mammoth distribution covered virtually all of Europe, including the Iberian Peninsula, the British Isles, and the northern part of Eastern Europe. For this time interval within the NWO-RFBR project, there were obtained the first age datings for Vaigach Island. Numerous findings of *Mammuthus* in Scandinavia testify to the serious degradation of the ice cover and the existence of ice-free areas. The northern boundary of the mammoth range in the British Isles also moved to the north. On the other hand, the mammoth disappeared at that time from the Crimea Peninsula and the Pre-Caucasus, where it was noted in some earlier time intervals (Fig. 2a). In the last glacial maximum (LGM), the mammoth was widely distributed throughout most of Europe except the Iberian Peninsula, the Apennine Peninsula, the Balkan Peninsula, and the Crimea Peninsula. Thus, one can observe the reduction in the mammoth range in the south, which might be connected with the climatic conditions, and the hunting activity of primitive men. It is remarkable that the remnants of mammoth are not found out over a large part of the Scandinavian Peninsula. This may be connected with extension of the ice cover (Fig. 2b). There are only rare findings of the mammoth in the northern part of Eastern Europe, which may be connected with extremely harsh climatic conditions. The area of the mammoth in the Late Ice Age reduced significantly, and the mammoth population disappeared completely from the Scandinavian Peninsula. The southern boundary moved to the north (Fig. 2c), which probably can be connected with start of warming and an increase in the population density in Europe and, consequently, an increase in mammoth hunting. In addition, there is a remarkable difference between the maps of the mammoth localities for the Belling and Allered warm periods. The mammoth remnants referred to this warm period were found in only five localities in Europe, located in the center of the supercontinent (Fig. 2d).

One can suppose that the mammoth lived further north, but there are no factual data for the time being. The total map of mammoth distribution over the period of 12.4–10.8 ka shows clearly the destruction of the mammoth range under influence of significant warming, which caused, accordingly, changes in the vegetation cover.

Figure 2e shows the recent findings of the mammoth in Eurasia referred to the Late Dryas, as well as the Early, Middle, and Late Holocene. Certainly, in a short period of the Late Dryas stadials, the mammoth range was already separated into few "islands." Remnants were found in the lower reaches of the Irtysh River, the Yamal Peninsula, and in the lower reaches of the Indigirka River. Further separation of the mammoth range occurred in the Holocene. In the early Holocene, separate herds of mammoths lived in the territory of the Baltic states, the Yamal Peninsula, the Taimyr Peninsula, the Gydan Peninsula, the Severnaya Zemlya Archipelago (October Revolution Island), in the basin of the Ob River, the New Siberia Islands (New Siberia Island), and Wrangel Island. In the Middle and the Late Holocene, the population of the last mammoth remained only on Wrangel Island and the St. Paul Islands in the Pacific Ocean. The most recent age dating (3685 ka) of the mammoth living in Eurasia is made based on material from Wrangel Island [6].

## CONCLUSIONS

The PALEOFAUNA database, containing the information about more than 5000 $^{14}C$ age datings of the Late Pleistocene–Holocene mammals of Eurasia, developed by authors of [1–3] allowed us to approach the detailed analysis for study of the dynamics of distribution of the most remarkable species of the mammoth fauna, *Mammuthus primigenius*, which lived in the second half of the Late Pleistocene–Holocene. As a result of compiling and obtaining new radiocarbon datings, it was possible to trace the connection of the dynamics of the mammoth distribution with climatic changes over the last 50 ka. Repeated extensions of the mammoth range during the cool stadials in the Late Pleistocene and its reduction during the interstadials were revealed. This work demonstrates the stages of a consistent separation of the mammoth range between the Pleistocene and the Holocene and the time and place of extinction of the mammoth. The progressive warming, started in the Late Pleistocene and the Holocene and the following sharp changes in the environment (formation of the continuous forest belt, disappearance of the open periglacial landscapes rich in grass vegetation (the "mammoth" steppe), an increase in thickness of snow cover, etc.) were crucial for the mammoth population. As a result, the mammoth range was separated into some isolated areas, and then the mammoth became completely extinct. In addition, the hunting activity of ancient man probably also influenced mammoth extinction. A relic isolated population of the mammoth existed until the Late Holocene only on Wrangel Island. Thus, the compilation of all the data available demonstrates the character of the dynamics of mammoth distribution over the last 50 000 years during 11 intervals of the Late Pleistocene and the Holocene.

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