Chronology and environment of woolly mammoth (*Mammuthus primigenius* Blumenbach) extinction in northern Asia

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Over the past decade radiocarbon (^{14}C) dating has allowed us to reconstruct patterns of latest survival of woolly mammoth in Northern Asia (Stuart 1991; Sulerzhitsky 1997; Vasil'chuk *et al.* 1997; Orlova *et al.* 2000). At present, we have about 360 ^{14}C dates from 150 localities, including: Siberia and adjacent territories of the Russian Far East; Kazakhstan; and northeastern China. Although it is possible that additional information may alter the current picture, the substantial body of data that we now have allows us to reconstruct the dynamics of mammoth extinction in Northern Asia with a reasonably high degree of confidence.

The data available at the beginning of 2000, show that prior to *ca.* 12,000 ^{14}C years ago (BP) mammoths were present throughout almost all of Northern Asia. Within the period ca. 15,000-12,000 BP, ^{14}C-dated mammoth remains (40 dates) are known from the eastern Chukotka Peninsula (longitude 170° W) as far as the Irtysh River in Western Siberia (69° E); and from the Taymyr Peninsula and Kotel'nyy Island (latitude 75-76° N) to Volchya Griva in Western Siberia (55° N), Sosnovy Bor in Eastern Siberia (53° N), and Khorol and Xiaonanshan in the Far East (44-47° N).

After *ca.* 12,000 BP, the range of mammoths was significantly reduced (Fig. 1). Until recently, mammoth remains with ^{14}C-dates younger than this (13 dates) were available only for the High Arctic, north of 69° N. However, in 2000, the additional ^{14}C dates were obtained from the Volchya Griva locality (54°30′ N, 80°12 E′) in the Barabinskaya steppe of the southern West Siberian Lowland, 175 km west of Novosibirsk (Fig. 1). These are: 11,090±120 BP (SOAN-4291), from 1.24 m below the surface; 12,520±150 BP (SOAN-4293), 1.30-1.35 m; and 14,280±285 BP (SOAN-4292), 1.44 m. Collagen for dating was extracted using cold HCl solution (Sulerzhitsky, 1997: 185-187; Kuzmin & Orlova, 1998: 3-5). It is clear that the youngest date, SOAN-4291, is likely to be correct as it is in good agreement with the site stratigraphy, suggesting survival of mammoths in southwestern Siberia until *ca.* 11,000 BP. This suggestion needs to be confirmed by additional data. Previous ^{14}C dates for the Volchya Griva range from *ca.* 14,800 BP to *ca*. 13,600 BP (Orlova 1990; Orlova *et al*. 2000).

At the Berelekh River locality, most of the ^{14}C dates are within the period *ca.* 13,700-12,000 BP. However, a later date of *ca.* 10,400 BP was obtained (on a thoracic vertebra) from the 2nd (10-12 m) terrace deposits (Orlova, 1979). In addition, three ^{14}C dates were obtained on the same individual mammoth from the Yuribei River: 9600±300 BP (VSEGINGEO); 9730±100 BP (MGU-763); and 10,000±70 (LU-1153) (Sokolov 1982). In view of the pretreatment procedures used (L. D. Sulerzhitsky, pers. comm. 2001) the LU-1153 value has been accepted as the most reliable-

whereas the VSEGINGEO and MGU-763 values were discarded (Sulerzhitsky, 1997: 197).

A chronology of mammoth extinction in Siberia, based on currently available evidence, is presented in table 1. During *ca.* 14,800-11,100 BP, mammoth survived in southern West Siberia in association with steppe environments on the watersheds, and with birch and spruce forests in the river valleys (Orlova 1990). However, after *ca.* 11,000 BP, they were restricted to the High Arctic, where the latest known ^{14}C dates come from the Taymyr Peninsula (Fig. 1).

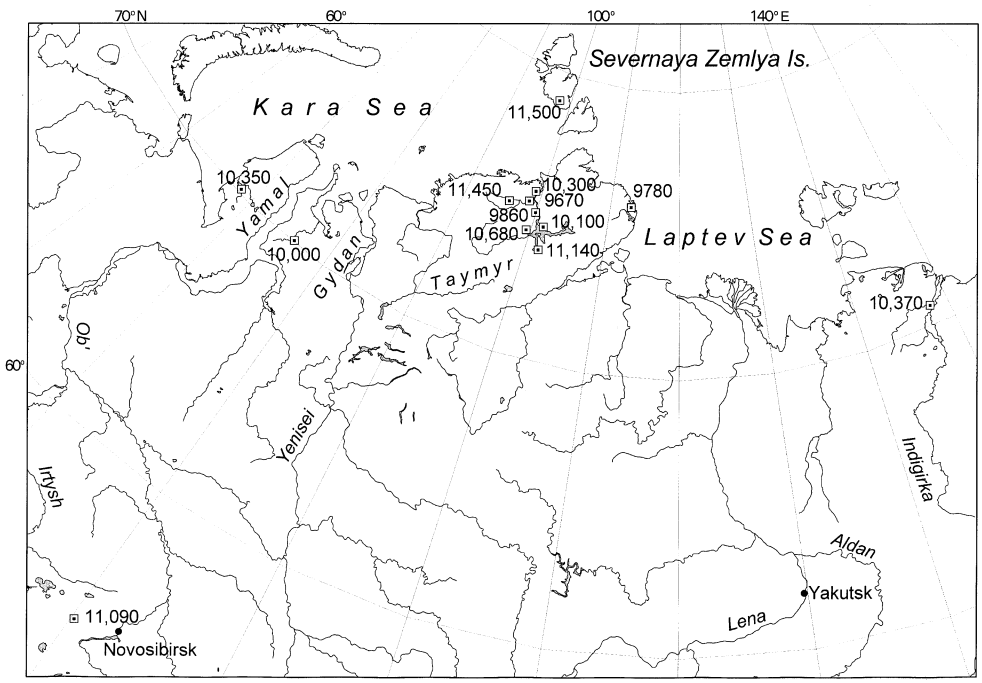

Fig.1 - Latest radiocarbon-dated mammoths in northern Asia (11,500-9,670 BP)

Tab.1 - ^{14}C age of the latest mammoths in Siberia (12,000-9700 BP)

Location	^{14}C age, BP (±1σ)	Lab No.	Calendar age, cal BP (±2σ)
Nizhnaya Taymyra River (Taymyr Pen.)	9670±60	GIN-1828	11,260-10,600
Andrei Polar Station (NE Taymyr Pen.)	9780±40	GIN-8256	11,330-10,890
Nizhnaya Taymyra River	9860±50	GIN-1495	11,630-11,120
Yuribei River (Gydan Pen.)	10,000±70	LU-1153	12,290-11,170
Engel'gardt Lake (Taymyr)	10,100±100	GIN-1489	12,780-11,170
Nizhnaya Taymyra River	10,300±100	GIN-1828k	12,890-11,230
Mutnaya Seyakha River (Yamal Pen.)	10,350±50	GIN-6386	12,830-11,700
Berelekh River (Northeast Siberia)	10,370±70	SOAN-372	12,880-11,580
Nganasanskaya River (Taymyr)	10,680±70	GIN-3768	13,000-12,170
Volchya Griva (West Siberia)	11,090±120	SOAN-4921	13,780-12,640
Baykuraneru Bay, Taymyr Lake	11,140±180	GIN-3067	13,850-12,340
Mamonta River (Taymyr)	11,450±250	T-297	15,300-12,350
Oktyabrs'koy Revolyutsii Is. (Arctic)	11,500±60	LU-610	13,840-13,150
Berelekh River	12,000±130	LU-149	15,410-13,430

Using the CALIB 4.3 calibration program (Stuiver *et al.* 1998), we obtained calendar ages for the youngest ^{14}C mammoth dates (Tab. 1). The latest mammoths in West Siberia date from *ca.* 13,800-12,600 cal BP; *ca.* 12,900-11,600 cal BP in the Berelekh River basin; *ca.* 12,800-11,700 cal BP in the Yamal Peninsula; *ca.* 12,300-11,200 cal BP in the Gydan Peninsula; and *ca.* 11,300-10,600 cal BP in the Taymyr Peninsula

It seems clear that the Taymyr Peninsula was the last mainland refugium for mammoths in Northern Asia. Palaeoenvironmental studies in Taymyr show that in the Younger Dryas, *ca.* 10,900 BP, tundra with shrub birch was the prevailing vegetation (Bardeeva *et al.* 1980; Muratova *et al.* 1993). At the Younger Dryas/Holocene boundary, *ca.* 10,000 BP, and in the Preboreal period, *ca.* 9300-9100 BP, tree cover increased and the main vegetation type became forest-tundra with spruce, pine, larch, and tree birch (Kind 1974; Bardeeva *et al.* 1980). About 10,500 BP, larch (*Larix sibirica*) appeared in the Novaya River basin (72°35′ N) (Ukraintseva 1990), and today this is the most northerly occurrence of trees in the Arctic Ary-Mas forest massif. At the beginning of the Holocene, the northern limit of larch was north of the Novaya River (Ukraintseva 1990).

From evidence of the environmental conditions in most of Siberia during the Late Glacial, *ca.* 15,000-10,000 BP, it appears that mammoths lived in a landscape of tundra and forest-tundra (cf., Lozhkin 1998). The increase of tree species in the vegetation cover, which began at *ca.* 12,500-12,000 BP (e.g., Lozhkin 1993; Sher 1997), corresponds with a marked decrease in mammoth distribution.

Future work on mammoth extinction should include a search for the latest mammoths (i.e., less than *ca.* 13,000 BP) in southern Siberia. From existing ^{14}C data (e.g., Kuzmin & Orlova 1998), we suspect that several Siberian sites might yield post-13,000 BP mammoth remains: Volchya Griva in Western Siberia; and several Upper Paleolithic sites in Eastern Siberia, e.g. Afontova Gora 1 and 3 (Astakhov 1999), Kokorevo 2 (Tseitlin 1979: 111-112), Listvenka (Derevianko *et al.* 1992: 34-48; Drozdov *et al.* 1999: 149), and Bolshaya Slizneva (Derevianko *et al.* 1992: 22-34). Additional work is also needed in the Taymyr Peninsula, primarily in the Taymyr Lake area.

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