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Late Pleistocene to Early Holocene Paleoclimatic Boundaries and Human Settlement of the East Siberian Arctic

This article examines archaeological records relating to the East Siberian Arctic in the Stone Age. It spans approximately 50,000 years, from the early stage of MIS 3 to the Early Holocene. Human settlement of the region can be divided into three main stages: early (~50,000–29,000 BP, MIS 3), middle (~29,000–11,700 BP, MIS 2), and late (11,700–8000 BP). The peopling of Arctic Eurasia and the cultural evolution in that part of the world were driven both by abiotic and biotic factors, as evidenced by the correspondance between archaeologically detectable changes and key paleoclimatic events. Early human settlement of that region is associated with a population marked by West Eurasian genetic ancestry, whose cultural elements are typical for Southern Siberia. The early settlers were replaced by people displaying East Asian ancestry, migrating northwards under the impact of climatic changes. It is concluded that the successful peopling of the Arctic was facilitated by the adoption of critically important innovations such as sewing with eyed bone needles, and manufacture of long shafts and pointed implements made of mammoth tusks. Lithic industries marking various stages are described. That of the early stage is characterized by flake technology; in the middle stage, wedge-shaped core technology appeared; and the principal feature of the late stage is microprismatic technology, indicating total population replacement. The onset of the Holocene coincides with a key innovation—land transportation by dogsled, resulting in much higher mobility.

Keywords: *Stone Age, Upper Paleolithic, human settlement of the Arctic, environment and climate change, complex technologies.*

Introduction

The paleogeographic situation in the part of the Eurasian Holarctic studied was determined in the Late Pleistocene by the absence of large glacial formations parallel to European and North American ice sheets. The dynamics of these ice sheets determined natural, climatic, and also cultural and historical development. In the northern regions of Eastern Siberia, these processes depended on changes in the “sea-land” balance, with an increased area of land in cold periods, aridization of the climate, and emergence of a distinctive habitat (mammoth steppe) as a part of the Eurasian belt of open landscapes in the Late Pleistocene. This regional feature amplified the impact of global climate trends. In Eastern Siberia, the tundra-steppe biome encompassed contemporary lowlands along the Arctic Ocean coast, as well as expansive arctic plains that occupied drained portions of the present-day shelf. A decrease in ocean levels in the Bering Strait area led to a land bridge connecting the Eurasian and North American continents. Known as the paleogeographic phenomenon of Beringia, this land connection exerted a profound influence on the region's natural development, ancient human migration, and cultural and historical processes.

Peopling of the East Siberian Arctic

The available archaeological record of the Stone Age in the East Siberian Arctic covers approximately 50,000 years from the Late Pleistocene (early stage of MIS 3) to the Early Holocene (beginning of MIS 1). Although the data are scarce, three chronological groups can be identified: the early group covers ca 50,000–29,000 BP, MIS 3 (Fig. 1, *G–I*; 2, *A*, *B*); the middle group is from ca 29,000 to ca 11,700 BP, MIS 2 (see Fig. 1, *G–I*; 2, *C*, *D*); and the late group belongs to the Early Holocene, from 11,700 to ca 8000 BP (see Fig. 1, *G–I*; 2, E)*. Our overall knowledge of the East Siberian Arctic for the second half of the Holocene, based on the dated sites, is shown in Fig. 2, *F*. Since the time of the initial peopling, beginning after 50,000 BP, the Arctic region of Eastern Siberia has continuously been inhabited by people, including the least favorable climatic periods, during which the presence of people became fragile (see Fig. 2, *C*).

The overwhelming majority of archaeological evidence is associated with warm periods (see Fig. 1), which suggests a positive demographic trend in human populations. For example, the Yana complex of sites indicates stable prosperity in the local Upper Paleolithic culture, coinciding with the Greenland Interstadial (GI) 5 (see Fig. 1). Earlier sites also indicate a similar trend. The earliest evidence corresponds to the onset of GI 13, which experienced warmer and more humid conditions than the beginning of MIS 3. At that time, an ecosystem of open spaces, with an increasing role of grains favorable for the existence of megafauna, emerged in the western part of Arctic Beringia (see Fig. 1). The alternating patterns of relative warming and cooling within the MIS 3 interstadial, along with the cooling of the extreme continental climate in MIS 2, contributed to the wide spread of tundra-steppe landscapes. These landscapes varied based on their local setting, but maintained similar features over large territories, which played a crucial role in the initial peopling.

The early phase of the MIS 3 interstadial (see Fig. 1) yielded few archaeological materials, spread over ca 3000 km (see Fig. 2, *A*, *B*) and close in age (within 1000–3000 years). Consequently, peopling of the region was very rapid. This could only have been possible if humans appropriated an ecological niche that was free at the time of their arrival, and which had a familiar landscape, not requiring adaptation to a different environment. As a result, the region was rapidly populated with an extremely low demographic density (Sikora et al., 2019).

Radical changes in the material culture of the ancient population of the East Siberian Arctic were associated with natural and climate changes, and with the influx of migrants to the region. Anthropological remains of the Pleistocene are very rare in Siberia and are sporadic in the Arctic (see Fig. 1, *J*). During MIS 3 and 2, the inhabitants of the East Siberian Arctic most likely mainly consisted of Ancient North Siberians, including the inhabitants of the Yana site (Ibid.). The genetic features of the migrants who displaced or assimilated this population are documented by a significant fragment of a *Homo sapiens* skull found on the lower reaches of the Kolyma River, specifically on the Duvanny Yar outcrop. This discovery, dating back approximately 10,000 years, indicates the complete replacement of the previous inhabitants of the region by individuals carrying East Asian genomes (Ibid.).

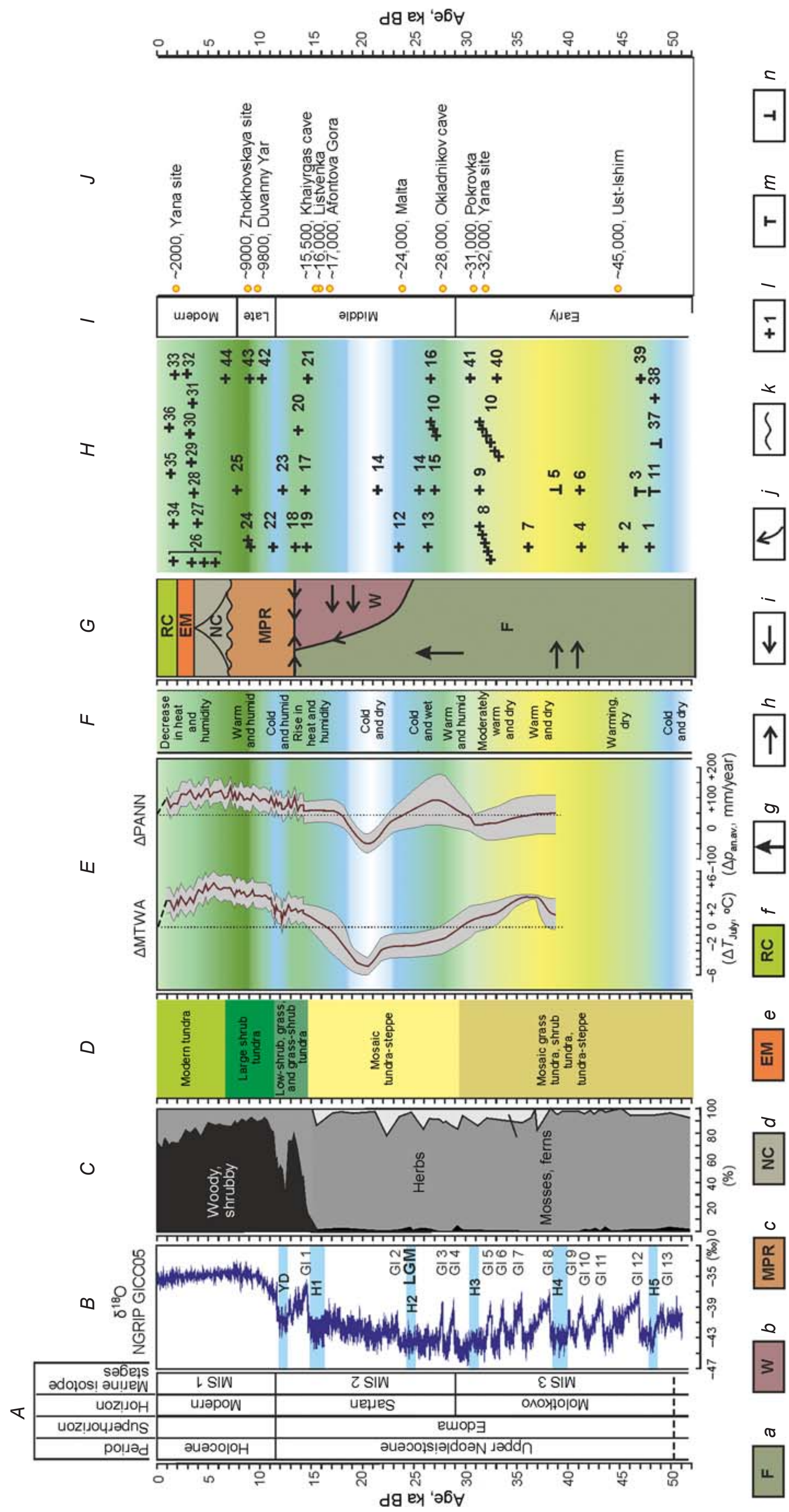
Adaptation of the East Siberian Arctic population in the Stone Age

The difficulties of living in vast open spaces of the mammoth steppe were successfully overcome with a set of well-known Upper Paleolithic innovations. These reflect the technological development of the early human culture (Hoffecker J., Hoffecker I., 2018). The finds at the Yana site serve as ample evidence of such technologies (Pitulko, Pavlova, 2019; Pitulko, Pavlova, Nikolsky, 2015); their signs have also been recorded at other sites. Initially, the most important were three technologies: procuring food by hunting, making clothing, and building dwellings. At all chronological segments, animal procurement supplied raw materials for the manufacture of goods from hides, skins, and bones. The most significant bone items were hunting weapons and sewing tools.

Sewing was one of two technologies that played a vital role in the survival of humans in cold regions of the planet. The advancement of sewing was characterized by the introduction of eyed needles, with the earliest examples discovered in Siberia. Large-scale clothing production in the Upper Paleolithic is confirmed by the evidence from Yana (Pitulko, Pavlova, 2019). Availability of eyed needles made it possible to sew multi-layered clothes, adjust them to size, and create a whole range of sewn products, such as footwear, sleeping bags, soft containers and bags, as well as dwellings. Judging by the evidence from Yana, dwellings were light ground structures with hearths (Pitulko et al., 2013); bones of large animals, including mammoths, were used as fuel in the winter.

One of the most important cultural and economic features of that period were relationships in the "man-

*Hereafter, the calendar age is used.



A
B
C
D
E
F
G
H
I
J
Age, ka BP
Period
Superhorizon
Horizon
Marine isotope stages
Holocene
Upper Neopleistocene
Edoma
Modern
Sartan
Molotkovo
MIS 1
MIS 2
MIS 3
δ18O NGRIP GICC05
YD
GI 1
H1
GI 2
LGM
H2
GI 3
GI 4
H3
GI 5
GI 6
GI 7
GI 8
H4
GI 9
GI 10
GI 11
GI 12
H5
GI 13
Woody, shrubby
Herbs
Mosses, ferns
(%)
Modern tundra
Large shrub tundra
Low-shrub, grass and grass-shrub tundra
Mosaic tundra-steppe
Mosaic grass tundra, shrub tundra, tundra-steppe
ΔMTWA
ΔPANN
Decrease in heat and humidity
Warm and humid
Cold and humid
Rise in heat and humidity
Cold and dry
Cold and wet
Warm and humid
Moderately warm and dry
Warm and dry
Warming, dry
Cold and dry
RC
EM
NC
MPR
W
F
Modern
Late
Middle
Early
~2000, Yana site
~9000, Zhokhovskaya site
~9800, Duvanny Yar
~15,500, Khaiyrgas cave
~16,000, Listvenka
~17,000, Afontova Gora
~24,000, Malta
~28,000, Okladnikov cave
~31,000, Pokrovka
~32,000, Yana site
~45,000, Ust-Ishim
a
b
c
d
e
f
g
h
i
j
k
l
m
n

Fig. 1. Climatic, paleonatural, and archaeological record of the East Siberian Arctic.

A – regional stratigraphic map of the Yana-Kolyma Lowland and bordering mountains (Stratigraficheskiy kodeks, 2019: 58; Sher, 1984; Sher, Kaplina, Ovander, 1987); *B* – NorthGRIP $\delta^{18}O$ scale, and the sequence of Greenland interstadials (GI 1–GI 13) (after (Svensson et al., 2008)); blue bands mark the approximate position of the Young Dryassic cooling (YD) and Heinrich events (H1–H5) (after (Tierney et al., 2008)); *C* – diagram of the general composition of pollen spectra: section of Quaternary deposits Mkh IC (after (Sher et al., 2005)) and sequence of bottom sediments from Lake Dolgoye (after (Pisaric et al., 2001; Klemm et al., 2013)); *D* – biomes; *E* – paleoclimatic reconstructions based on paleoflora analysis: ΔMTWA – deviation of air temperatures of the warmest month from modern values (ΔT_{July}, °C), ΔPANN – deviation of average annual precipitation from modern values ($\Delta p_{average\ year}$, mm/year); *F* – total climate changes; *G* – archaeological chronicle of the East Siberian Arctic; *H* – dated archaeological sites shown according to their calendar age (after (Pavlova, Pitulko, 2020: Tab. 1, fig. 2), with additions after (Dikov, 1993: 36–56; Pavlov, Suzuki, 2020; Khlobystin, 1998: 38–40; Cheprasov, Obade, Grigoriev et al., 2015; Cheprasov, Chlachula, Obade et al., 2018; Chlachula et al., 2021; Gusev, 2002; Kirillova, Shidlovskiy, Titov, 2012; Pitulko, 2001; Pitulko, Pavlova, 2016: 110–125; Pitulko, Pavlova, Nikolskiy, 2017; Pitulko et al., 2016)): *1* – Bunge-Toll-1885 site, *2* – Kyuchus, *3* – Verkhniy locality, Yana complex of sites (YCS); *4* – Novaya Sibir/West, *5* – Novaya Sibir/East, *6* – AL044-2005 site, *7* – Omoloy, *8* – Severny and Yana V localities, Yana mammoth "cemetery"/YMAM (YCS), *9* – Buor-Khaya/Orto-Stan, *10* – Diring-Ayan, *11* – Bolshoy Anyui, *12* – Zyryanka-1, *13* – Lagerny locality (YCS), *14* – Yana A locality (YCS), *15* – Ilin-Syalakh 034; *16* – Wrangel Island, *17* – Ilin-Syalakh bone bed site, *18* – Lake Nikita, *19* – Urez-22, *20* – Berelekh georchaeological complex; *21* – Achchagyi-Allaikha, *22* – Tytylvaam IV; *23* – Cape Kamenny, *24* – Zhokhovskaya site, *25* – Tuguttakh, *26* – Siktyakh I, *27* – Rodinskoye burial, *28* – Chertov Ovrag, *29* – Burulgino, *30* – Rauchuagytgyn I, *31* – Pegtymel, *32* – Aachim-baza, *33* – Aachim-mayak, *34* – Cape Baranov, *35* – Pegtymel Cave, *36* – Shalaurova Izba, *37* – Zyryanka, *38* – Sopochnaya Karga mammoth, *39* – Irelyakh-Siene, *40* – Kastykhtakh mammoth, *41* – Tabayuryakh mammoth, *42* – Nayvan, *43* – Chelkun IV, *44* – Tagenar VI; *I* – stages of peopling; *K* – dated anthropological remains from various regions of Siberia. *G–F, I, K* – after (Pavlova, Pitulko, 2020).

a – flake-based industry; *b* – industry of wedge-shaped cores with microblades; *c* – microblade industries based on prismatic reduction; *d* – Neolithic cultures with degradation of microblade technology after 3000 BP; *e* – emergence of metals: cultures of the Bronze Age; *f* – late prehistoric/protohistoric cultures, including the Eskimos of the Arctic coast and the Bering Strait area; *g–j* – migrations: *g* – from south to north, *h* – from west to east, *i* – from east to west, *j* – to the northwest; *k* – replacement of the edge-faceted wedge-shaped reduction by microprismatic reduction; *l* – dated archaeological sites; *m* – open dating; *n* – possible dating based on the structure of the stratigraphic sequence.

mammoth" system. Many sites of the early and middle stages of the area's settlement (at least 11) are associated with mass accumulations of mammoth bone remains of anthropogenic origin, resulting from human hunting, which led to emergence of "warehouses" (reserves of raw materials).

Mammoth hunting was an important activity aimed at obtaining raw materials for the manufacture of hunting equipment—long points and full-sized spears, which were needed because of the constant shortage of wood (Pitulko, Pavlova, Nikolsky, 2015). This was the second crucial technology of the Upper Paleolithic in the East Siberian Arctic. Mammoth meat was used for food, but did not play a substantial role in the diet of ancient hunters, who hunted bison, horses, and reindeer in large numbers (Pitulko et al., 2013). There is no evidence of large-scale one-time hunting of mammoths.

In terms of the development of the lithic industry, there are obvious fundamental differences between the sites remaining from different stages of the settlement of the region. For example, the early period was characterized by a flake industry of archaic appearance, which was based on splitting pebbles and retained some Middle Paleolithic features or rather the method of simplified splitting. These features are observed in the Yana industry at the final period of the early stage. However, there is no reason to believe that it was preceded by some advanced technology of blade production. Material evidence from the last glacial maximum show only traces of human presence, which was low at that time. The only site with stone items of this period suggests that an industry of small blades, produced using cores with circular reduction, was spreading in the East Siberian Arctic at that time. At the end of the early stage of human settlement in the region, a technology of edge-faceted wedge-shaped reduction appeared, manifested by evidence from rare sites in the west of Chukotka and possibly in the north of the Yana-Indigirka Lowland.

The spread of the microblade blank technology was most likely associated with migration of populations from inland areas, who encountered sharp cooling and aridization of the climate due to the global climate trend in the LGM period, desertification of the region, northward shift of vegetation zones, changes in landscapes, and spatial redistribution of faunal populations serving as a resource base for that population. In fact, the very emergence of the technology of small blade production by splitting wedge-shaped cores most likely resulted from environmental changes that caused the loss of the mammoth from the biome of the southern part of the tundra-steppe belt of Northern Eurasia. Mammoth tusks served as an important raw material for the production of hunting equipment, such as long points and/or full-sized spears. Spatial dynamics of the local population of mammoths (Pitulko, Nikolskiy, 2012) suggests that their

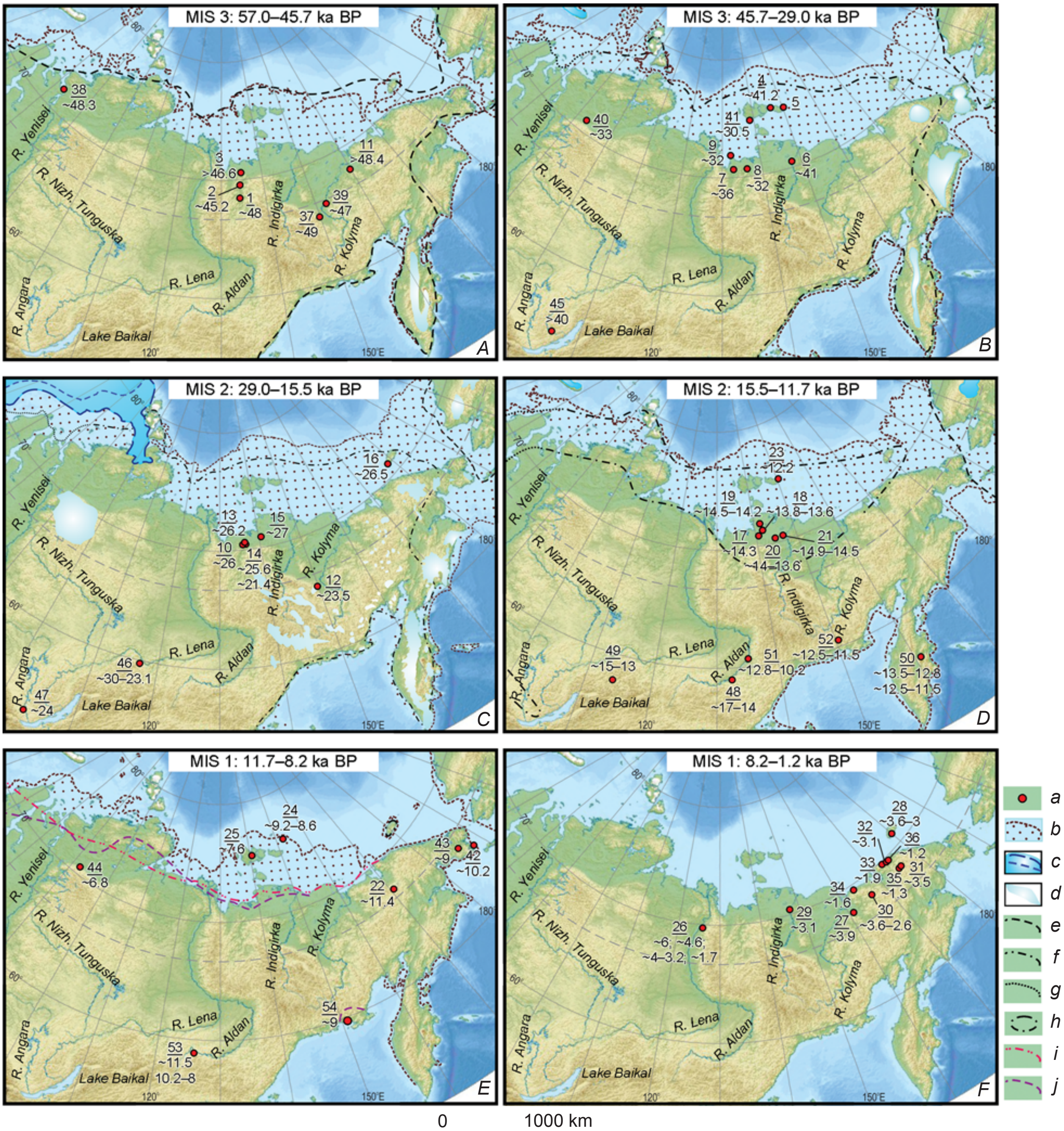


Fig. 2. Archaeological sites of the Late Pleistocene–Early Holocene in Eastern Siberia.

Reconstructions of the drained shelf area and the land-sea boundary made after (Pico, Creveling, Mitrovica, 2017), at a World Ocean level lower than modern levels: *A* – ca 40 ka, BP 40 m; *B* – ca 32–31 ka BP, 90 m; *C* – ca 27 ka BP, 120 m; *D* – ca 14 ka BP, 70 m; *E* – ca 9 ka BP, 30 m; *F* – ca 9 ka BP, 30 m. Numbering scheme used in the maps: the numerator designates the number of the archaeological site, and the denominator represents its age (×1000 years). *1–44* – see Fig. 1; *45* – Makarovo IV; *46* – Khaiyrgas Cave; *47* – Malta; *48* – Dyuktai Cave; *49* – Bolshoy Yakor; *50* – Ushki; *51* – Ezhantsy; *52* – Kheta; *53* – Ust-Timpton; *54* – Uptar I (after (Dikov, 1993: 35–56; Mochanov, 1977: 6–32, 49–58; Slobodin, 1999: 36–57, 59–73; The Paleolithic…, 1998; Kuzmin et al., 2017; Pitulko, Pavlova, 2016)).

a – archaeological sites; *b* – drained shelf area and land-sea boundary; *c* – complex of sheet glaciation (after (Dalton et al., 2020; Hughes et al., 2015)); *d* – mountain glaciation (after (Galanin, 2012; Barr, Clark, 2012; Glushkova, 2011)); *e–h* – areas of woolly mammoths: *e* – in Northeast Asia and Alaska (after (MacDonald et al., 2012)), *f* – in Northeast Asia (after (Pitulko, Nikolskiy, 2012)), *g* – in Western Siberia (after (Kahlke, 2014)), *h* – isolated population of mammoths on Wrangel Island (after (Vartanyan et al., 2008)); *i* – northern boundary of the woody *Betula* area ca 9000 BP, based on its dated macroremains (after (Kremenetski, Sulerzhitsky, Hantemirov, 1998; Binney, Willis, Edwards et al., 2009)); *j* – northern boundary of *Larix* ca 9000 BP, based on its dated macroremains (after (Kremenetski, Sulerzhitsky, Hantemirov, 1998; Binney, Willis, Edwards et al., 2009; Binney, Edwards, Macias-Fauria et al., 2017)).

distribution area steadily declined, moving in a northern direction. Notably, a new stone processing technology based on reduction of wedge-shaped cores spread in the same direction (to the north and east) from the regions of Northern China and Mongolia, adjacent to Western Beringia.

The traditions of flake-based industries remained intact in the region up to the transition to the Holocene. During the late Pleistocene, assemblages containing mainly teardrop-shaped, small incomplete bifaces (known as Chindadn points) emerged. However, with the onset of the Holocene, these artifacts vanished, and reduction techniques underwent another transformation. Across the entire region, spanning from Taimyr to Chukotka and extending from the southern regions to high latitudes, the widespread adoption of micro-prismatic reduction technology occurred rapidly (see Fig. 1, *G*; 2, *E*). This was associated with the arrival in Eastern Siberia of the carriers of the East Asian genetic lines (Sikora et al., 2019). These events might have been accelerated by the availability of land transport (dogsleds) among the Early Holocene population. Their appearance, associated with completion of the dog/wolf domestication process in the Terminal Pleistocene, was the most important innovation at the turn of the Holocene (Pitulko, Pavlova, 2020).

Conclusions

The record of human settlement in the Arctic covers about 50,000 years. This evidence marks the final stage in the global dispersal of anatomically modern humans. The initial peopling of the East Siberian Arctic in the Late Pleistocene was associated with a population whose gene pool was dominated by the West Eurasian lineage.

The initial peopling of Arctic regions and the ability of people to thrive during the Late Pleistocene, despite the changing natural environment, can be attributed to the adoption of significant technological advancements, which consisted of complex technologies. Remarkable shifts in archaeological cultures correspond to the crucial paleoclimatic events that occurred during the Late Pleistocene and Early Holocene periods.

During the Late Pleistocene, the population inhabiting the East Siberian Arctic followed the economic model of continental hunters, using any available resources in the form of local populations of Pleistocene fauna. At the onset of the Holocene, species diversity decreased to a state close to the one we have now; in the Arctic zone, the main source of livelihood for the population became reindeer.

Technologies for the production of hunting equipment (long points and full-sized spears) from mammoth tusk, together with sewing technologies, played a crucial role in the Late Pleistocene adaptations. The most important innovation at the onset of the Holocene was the creation of land transport (dogsleds). This accomplishment ensured the mobility of the population and facilitated the rapid dissemination of cultural knowledge, gene exchange, and the development of large social and cultural systems.

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