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Revising the archaeological record of the Upper Pleistocene Arctic Siberia: Human dispersal and adaptations in MIS 3 and 2

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ABSTRACT

As the main external driver, environmental changes largely predetermine human population distribution, especially in the Arctic, where environmental conditions were often too extreme for human survival. Not that long ago the only evidence of human presence here was the Berelekh site in the lower reaches of the Indighirka River. This landmark dates to 13,000–12,000 years ago but it was widely accepted as documentation of the earliest stage of human dispersal in the Arctic. New research discussed here, shows that humans began colonizing the Siberian Arctic at least by the end of the early stage of MIS 3 at around 45,000 years ago. For now, this earliest known stage of human occupation in the arctic regions is documented by the evidence of human hunting. The archaeological record of continued human occupation is fragmentary; nevertheless, evidence exists for each significant phase including the Last Glacial Maximum (LGM). Siberian Arctic human populations were likely supported by the local mammoth population, which provided humans with food and raw material in the form of mammoth tusks. Processing of mammoth ivory is recognized widely as one of the most important peculiarities of the material culture of ancient humans. In fact, ivory tool manufacturing is one of the most important innovations of the Upper Palaeolithic in northern Eurasia. Technology that allowed manufacturing of long ivory shafts – long points and full-size spears – was critical in the tree-less open landscapes of Eurasian mammoth steppe belt. These technological skills reach their greatest extent and development shortly before the Last Glacial Maximum but are recognizable until the Pleistocene-Holocene boundary across Northern Eurasia in all areas populated by mammoths and humans. Loss of this stable source of raw material due to the late Pleistocene mammoth extinction may have provoked a shift in post-LGM Siberia to the Beringian microblade tradition. This paper reviews the most important archaeological findings made in arctic Siberia over the last twenty years.

1. Introduction

Arctic Siberia can roughly be defined as the vast area north of the Arctic Circle that spans between the Ural Mountains in the west and the Bering Strait in the east. The Upper Pleistocene Arctic Siberia was even larger when shelf areas were exposed during the cold stages of this time period, but shrunk as a result of the post-LGM transgression that started 15,000 years ago. Dramatic environmental changes, which took place in this area in the past 60,000–50,000 years, were likely the most powerful driving factors for cultural changes. Unfortunately, until now, Arctic Siberian prehistory remained largely unexplored. Thus, Arctic West Siberia had not produced any Pleistocene archaeological data while there are finds of Pleistocene animals dated to MIS 3 and 2 (e.g., Astakhov and Nazarov, 2010). Although fragmented, this record suggests environmental conditions suitable for humans, too, at least in certain periods.

Until recently, the Taimyr Peninsula, which constitutes a significant part of the Arctic, was lacking any evidence for human habitation before 6000 years BP except for a few very provisional finds that can be attributed to the terminal Pleistocene (Khlobystin, 2006). Again, there are many radiocarbon-dated remains of the Upper Pleistocene fauna which successfully survived in the area until the Pleistocene/Holocene boundary and even into the

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Holocene (e.g., MacPhee et al., 2002; Mol et al., 2006; Nikolskiy et al., 2011; Sulerzhitsky, 1995). However, clear indication of prehistoric human presence in the western Taimyr Peninsula was recently demonstrated by the discovery of mammoth remains with human-inflicted injuries at Sopochnaya Karga in the Yenisei river mouth (Pitulko et al., 2016a,b). This find expanded the record far beyond the Pleistocene/Holocene boundary down to almost 50 ka. Further east, there is no indication for a Pleistocene occupation before entering the coastal plain commonly known as the Yana-Indighirka-Kolyma lowland. This part of Arctic Siberia lies in the northernmost areas of the Upper Pleistocene Western Beringia (see, e.g. West, 1996).

Relatively recently, the archaeological record of Arctic Western Beringia literally consisted of a single pre-Holocene site, discovered by Vereschagin in the 1970's, while studying the Berelekh "mammoth graveyard" (Vereschagin, 1977; Vereschagin and Mochanov, 1972). This site was considered to be approximately 13,000–12,500 years old (Mochanov, 1977; Mochanov and Fedoseeva, 1996); however, human habitation episodes near the "mammoth graveyard" are actually no older than 12,100–11,800 ^{14}C years BP and thus largely post-date the accumulation of mammoth remains (Pitulko, 2011; Pitulko et al., 2014a).

Archaeological exploration of the arctic and sub-arctic regions of Western Beringia, including those closest to the Bering Land Bridge, resulted only in few discoveries in undateable contexts (Dikov, 1979, 1997). Realistically, only the Kymyneikey site (Laukhin et al., 1989; Laukhin and Drozdov, 1991), similarly to the Berelekh site, could be more or less confidently interpreted as evidence of earliest pre-Holocene human diffusion in the Far East Siberian Arctic. This information allowed Goebel and Slobodin (1999) to estimate the timing of entry into Western Beringia no earlier than 14,000 years ago. Most of the evidence discovered by that point related to the Beringian microblade tradition, defined by West (1981, 1996) based on wedge-shaped core technology. Goebel (2002) interpreted the appearance of this tradition as an adaptation to the MIS 2 cold conditions, firmly connecting most important visible cultural change in the material culture of the Late Pleistocene Beringia inhabitants and the environmental conditions.

Beringian microblade tradition was thought to be replaced by micro-prismatic knapping during the Pleistocene-Holocene transition, in which case it could serve as a chronological marker and as evidence for a cultural response to the major environmental changes. However, is the tradition persisted in different areas of South (Ineshin and Tetenkin, 2010), sub-Arctic (Dikov, 1979), and Arctic Western Beringia (Kiryak et al., 2003) throughout the Holocene.

By the beginning of the 21st century, nothing was known about the Upper Pleistocene Arctic Siberia occupation, save for a few temporary human habitation episodes during the Terminal Pleistocene. The question of LGM and pre-LGM habitation remained unanswered.

The discovery of late MIS 3 Yana RHS (Pitulko et al., 2004) changed this situation, doubling the length of known human habitation in Western Beringia and prompting further investigation of the area. As a result, convincing evidence for earliest human habitation in Arctic Siberia now dates to approximately 50,000–45,000 (Fig. 1). Most of the newly discovered sites except for one of the two oldest localities (Bunge-Toll 1885 site, 68° N), are located north of the 70° N. This includes Sopochnaya Karga site in western Taimyr Peninsula. The Upper Paleolithic archaeological record starts in the late initial MIS 3 and continues to the end of the Pleistocene, including the most unfavorable conditions of MIS 2 (LGM, or Sartan glacial of the Siberian geochronological scheme). The latest sites in the record that pre-date the Holocene are also the most numerous. Human dispersal within the Arctic Siberia and the archaeologically visible changes in the material culture seen as adaptations are clearly driven by the Late Quaternary environmental changes in the area.

Environmental changes in Arctic Siberia through MIS 3 as a driving factor for human populations.

Successive large-scale complex restructuring of the environment in Arctic Siberia within the last 60,000 years, which included the global MIS 4 to MIS 3 transition, the LGM, the post-glacial and the Pleistocene to Holocene transition (Fig. 2), certainly contributed to human dispersal within the Arctic Siberia and affected the cultural development of the region's human population. Living in a changing environment obviously encouraged the development of new skills and changes in subsistence economy needed to maintain survival. Climate, vegetation, and landscape changes were important by themselves, but together they also contributed to changes in abundance and the spatial distribution of prey species.

Based on the Western Beringian paleoenvironmental record (Figs. 2–4), environmental conditions during MIS 3 can be characterized as follows. During the Karginsk Interglacial (MIS 3, 57-24 kya), due to the 55–80 m drop in global sea level, arctic Western Beringia stretched to the very northern islands of the New Siberian archipelago and the Wrangel Island (Fig. 3). During the second part of MIS 3, after 31,000 years ago, global sea level drop reached 100–110 m below relative to modern (Clark et al., 2009). Relatively warm and dry climate characterized the western part of this area; summer temperatures were similar to the modern ones or exceeded them by 4–4.5°C. Annual precipitation was also similar to modern levels and could exceed it by 50–100 mm/year (Fig. 2). In the eastern part of the region, climate varied throughout this interval, with conditions that were sometimes cooler and sometimes warmer than present.

Thus, Andreev et al. (2001) have documented graminoid-rich tundra vegetation covering wide areas of the emergent shelf of East Siberian Sea during MIS 3. Reconstructed summer temperatures then were possibly 2 °C higher than during the 20th century. Further south, at Elikchan 4 Lake in the upper Kolyma drainage, Anderson and Lozhkin (2001) have retrieved a sediment record (bottom core), that contains at least three MIS 3 intervals when summer temperatures and treeline reached late Holocene conditions. At the same time, MIS 3 fossil insect faunas studied in the lower Kolyma are thought to have thrived in summers that were 1–4.5 °C higher than recently (Alfimov et al., 2003). This is also found for the Yana site area as well (Pitulko et al., 2013a,b). It is widely recognized that variable paleoenvironmental conditions were typical of the MIS 3 (Karginsk) period throughout Arctic Russia (Hubberten et al., 2004; Miller et al., 2010).

The warmest widespread MIS 3 interval in Beringia occurred 44-35 ka ago (Anderson and Lozhkin, 2001); it is well represented in proxies from interior sites although there is little or no vegetation response in areas closest to Bering Strait. Although MIS 3 climates of western Beringia achieved modern or near modern conditions during several intervals, climatic conditions in eastern Beringia appear to have been harsher than modern conditions for all of MIS 3. Consistent with this pattern, the transition from MIS 3 to MIS 2 is marked by a shift from warm-moist to cold-dry conditions in western Beringia (Anderson and Lozhkin, 2001). These observations are cited widely by Miller et al. (2010). Anderson and Lozhkin (2001) often stress 'mosaic' character of the vegetation across Western Beringia where different habitats may be presenting at the same time (see also Hubberten et al., 2004). These are basically treeless tundra landscapes where sparce forested areas were generally developed in valleys (gallery forest).

Plant communities were slightly different in the western and eastern parts of Arctic Western Beringia (Figs. 2 and 4). The vast western part was characterized by open tundra-steppe herb-

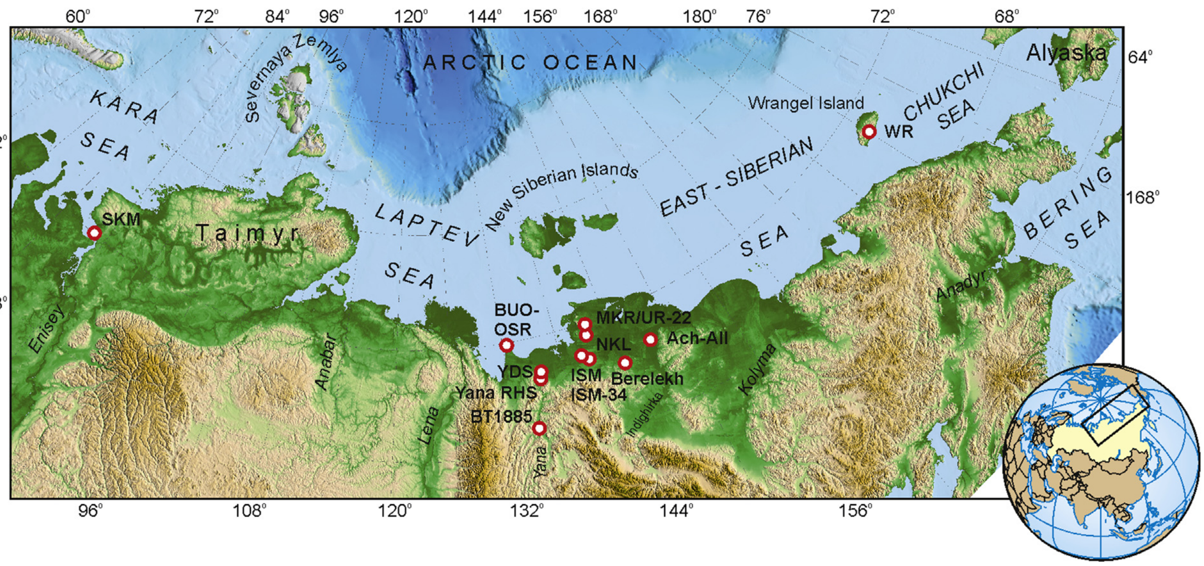

Fig. 1. Upper Pleistocene archaeological sites in Arctic Siberia (west to east): SKM – Sopochnaya Karga mammoth kill-site; BT1885 – Bunge-Toll 1885 site; Yana RHS – Yana site locality including Yana mass accumulation of mammoth and YDS (Yana Downstream site); BUO-OSR – Buor-Khaya – Orto-Stan River accumulation of mammoth; MKR/UR-22 – Urez-22 site in Maksunuokha River; NKL – Nikita Lake site, Maksunuokha River; ISM – Ilin-Syalakh mass accumulation of mammoth; ISM-34 – Ilin-Syalakh site; Berelekh – Berelekh geoarchaeological complex; Ach-All – Achchaghyi-Allaikha accumulation of mammoth.

Stratigraphic units of Western Beringia | Palaeoenveronments

Ages [kyr]	Nomenclature: Siberian	Nomenclature: North American	Marine Isotope Stages (MIS)	Vegetation: West part Laptev Sea region, Yana-Idighirka lowland	Vegetation: East part Chukotka
11.0 - 0 ka BP	Holocene	Holocene	MIS 1	After ca. 10.3 kyr BP- shrub tundra and wetland vegetation; after 5 ^{14}C kyr BP - grass tundra, dwarf birches in protected places	After 10 ^{14}C kyr BP- mosaic of subshrub-graminoid tundra and Betula forest-tundra; after ca. 4.5 ^{14}C kyr BP- herb tundra
24.0 - 11.0 ka BP	Sartan	Late Wisconsinan	MIS 2	Open arctic pioneer and steppe herb-dominated tundra-and steppe-like environments, and after ca. 13 kyr BP - grass-sedge dominated habitats, shrubs in protected places	Herb-dominated tundra, and herbshrub tundra; abundant steppe communities
57.0 - 24.0 ka BP	Karginsk	Middle Wisconsinan	MIS 3	Open hemicryophyte tundra-steppe herb dominated vegetation, shrub willow stands in more protected places and wetland vegetation in riparian sites with a stable high water level	Mix of shrub and herb-shrub tundra that occasionally included tree Betula and Pinus pumila. River valleys supported forest-tundra with Betula, Chosenia, and Larix

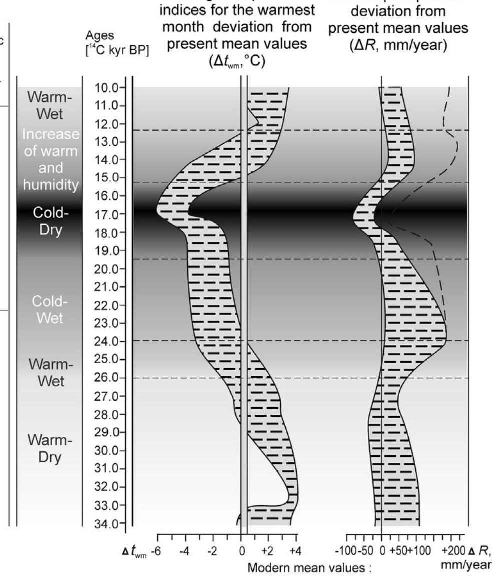

Fig. 2. Stratigraphic units and palaeoenvironments of Arctic Siberia (arctic Western Beringia). Stratigraphic units are based on Kind (1974), Anderson and Lozhkin (2001), Lozhkin (1977), Volkova and Khazina (2009), Borisov (2010), Pitulko and Pavlova (2010). Palaeoenvironments: vegetation (west part) is based on Schirrmeister et al. (2002), Kienast et al. (2005), Pavlova et al. (2010), Pitulko et al. (2007, 2013b), Andreev et al. (2011); vegetation (east part) is based on Anderson and Lozhkin (2001), Lozhkin et al. (2007). Climate conditions and parameters are based on Pitulko et al. (2007, 2013b), Pavlova et al. (2009a,b), Pitulko and Pavlova (2010).

dominated vegetation; shrub willow stands grew in more protected places and wetland vegetation existed in riparian sites with a stable high water level (Andreev et al., 2011; Hubberten et al., 2004; Kienast et al., 2005; Pitulko et al., 2007, 2013b; Schirrmeister et al., 2002; Wetterich et al., 2008, 2009). The vegetation of its eastern part was a mix of shrub and herb-shrub tundra that occasionally included tree Betula and *Pinus pumila*. River valleys supported forest-tundra with Betula, Chosenia, and Larix (Anderson and Lozhkin, 2001; Lozhkin et al., 2007; Lozhkin and Anderson, 2011). Generally uniform, this mosaic forbs-dominated tundra-steppe habitat, or the mammoth steppe (Guthrie, 2001), supported numerous large Pleistocene herbivore species (see, e.g. Lorenzen et al., 2011; MacDonald et al., 2012; Nikolskiy et al., 2011; Shapiro et al., 2004; Willerslev et al., 2014). With some fluctuation in population numbers, they remained successful throughout entire MIS 3.

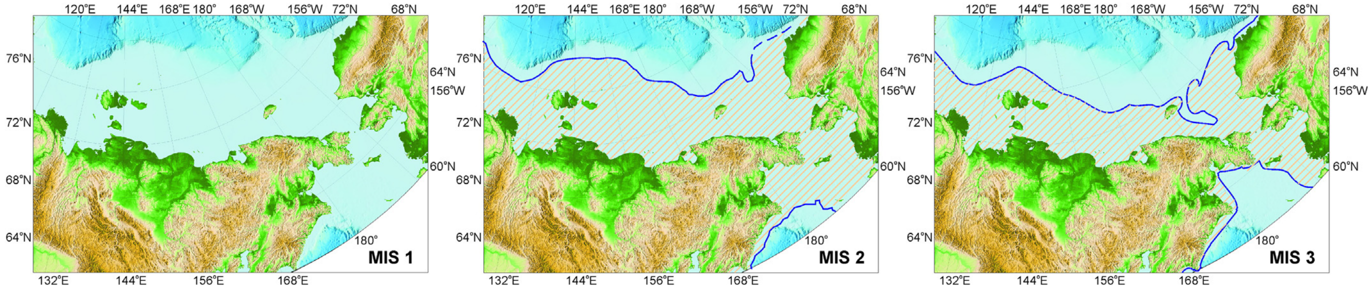

Fig. 3. Shoreline reconstruction for MIS 3, MIS 2 and the modern shoreline. The MIS 3 shore line position is based on Hopkins et al. (1982), Anderson and Lozhkin (2001, 2011); the MIS 2 reconstruction is based on Alekseev (1991), Manley (2002), Brigham-Grette et al. (2004).

The Upper Paleolithic people are often seen as mammoth hunters responsible for the extinction of these animals. Whether people really hunted mammoth or not, this species was demonstrably important to humans, however, not as a food, but rather as a "supplier" of raw materials (bones and tusks for tool making, house building, and decoration; wool for ropes and snare tackle; and, possibly, skins for house constructions). In other words, in proboscideans everything is good (Boschian and Saccà, 2015), including surplus and by-products such as dung which, along with fat and bones, served as fuel in treeless landscapes (Rhode et al., 2003); the animals even provided well-marked path systems (Haynes, 2006). Humans made use of these resources long before the Upper Paleolithic (e.g., Ben-Dor et al., 2011; Barkai and Gopher, 2013). Living side by side with mammoths would be beneficial for humans in many terms, and stress in mammoth population could become a problem which drove archaeologically visible cultural changes (Pitulko and Nikolskiy, 2012).

The appearance of bone and ivory tool production is one of the hallmarks of Early Upper Paleolithic culture in the mammoth-steppe belt of Northern Eurasia. This innovation, according to Anikovich (1992), warrants calling this time "the Bone Age" by analogy with the importance of bronze and iron for later times. The number of ivory/bone tools increases worldwide, irrespective of site taphonomy. Bone tool use survived even the subsequent innovation of metal tools. Importantly, the Upper Paleolithic use of bone and ivory allowed survival in open landscapes and then led to the rapid colonization of the mammoth steppe belt by the Upper Paleolithic humans.

1.1. Early MIS 3 archaeological record in central and eastern Arctic Siberia

In 2012, a partial carcass of a woolly mammoth (*Mammuthus primigenius* Blumenbach, 1799) was excavated from frozen sediments exposed in the coastal bluff on the eastern shore of Yenisei Bay at N 71° 54′ 19.2″ and E 82° 4′ 23.5″ (Fig. 1). Exposure stratigraphy is composed of several clear structural elements which includes a peat deposit sealing the level that produced mammoth remains (Pitulko et al., 2016a,b).

Several radiocarbon dates help anchor the Sopochnaya Karga mammoth, or SK mammoth, in time (Table 1). The peat layer (Bed 3) is dated to 36,000 ± 2500 ^{14}C years BP (LE-9822). A small willow branch fragment from Bed 3 yielded an age of 47,600 + 10,200/-4400 ^{14}C years BP (LE-9821). Bed 4, which marks the beginning of the taberite sediments, produced a date of 18,200 + 2600/-2200 ^{14}C years BP (LE-9823). This sequence is above Bed 1 that holds the mammoth carcass. Considering these dates, the age of the Sopochnaya Karga mammoth (SK mammoth hereafter) can be estimated at about 40 ka. Direct date on a tibia bone, 44,570 + 950/-700 ^{14}C years BP (Table 1), is consistent with the stratigraphy and the surrounding deposit dates. Additional dates independently received on mammoth remains are in agreement with this chronology (Maschenko et al., 2014). Thus, the mammoth carcass is a rare *in situ* specimen from the early phase of MIS 3 when the mammoth population in Taimyr was slowly growing (Nikolskiy et al., 2011; Sulerzhitsky, 1995).

This is an exceptionally complete mammoth skeleton with a small amount of preserved soft tissue, including the remains of the fat hump and the penis. The large amount of fat at the hump indicates that the mammoth was in a good physical condition. This was a young male of around 15 years old according to the tooth eruption model (Maschenko et al., 2014).

The mammoth bones exhibit a number of unusual injuries described in detail in Pitulko et al. (2016a,b). Damage is seen on the left scapula, the left jugal bone, the fifth left rib, and the second right rib. Unequivocal postmortem damage is also recorded on the tip of the right tusk and the mandible, the left coronoid process of which is broken off.

A small rounded hole was discovered on the internal side of the left jugal bone after it was separated from the skull during the excavation. The bone is uniformly patinated and has no evidence of recent damage. To clarify the character of this unusual injury, the bone was studied using X-ray computed tomography. The shape of the injury suggests that the tip of the weapon, which damaged the jugal bone, had a thinned symmetric outline and was relatively sharp. In most cases bone or ivory weapons have a conical tip, symmetric and quite acute (~30–40°) at the end, but they are relatively fragile and often break as they penetrate bones. In this case, the tool resisted breaking and inflicted cranial bones. The blade retained its weapon characteristics and kept enough energy to go through the cheekbone surface, penetrating deeply into the bone. The blow was evidently very strong and was suffered by the animal from the left back and from top down, which is only possible if the animal is lying down on the ground.

This injury itself is probably the result of a missed blow, targeting the base of the trunk. This specific hunting method is still practiced in Africa by elephant hunters who target to the base of the trunk to cut major arteries and cause mortal bleeding (Kulik, 1971). This blow becomes necessary after the animal has been sufficiently injured, and the mammoth bones display numerous injuries in the thoracic area (to ribs and the left scapula).

The most remarkable injury is to the fifth left rib (Fig. 5), caused by a slicing blow, inflicted from the front and somewhat from above downward. The incision is filled in with well-rounded sand particles from the matrix deposits. Although a glancing blow, it was strong enough to go through skin and muscles and damage the bone. A similar but less powerful blow also damaged the second right front rib. Such blows were aimed at internal organs and/or blood vessels. The SK mammoth was also hit in the left scapula at least three times.

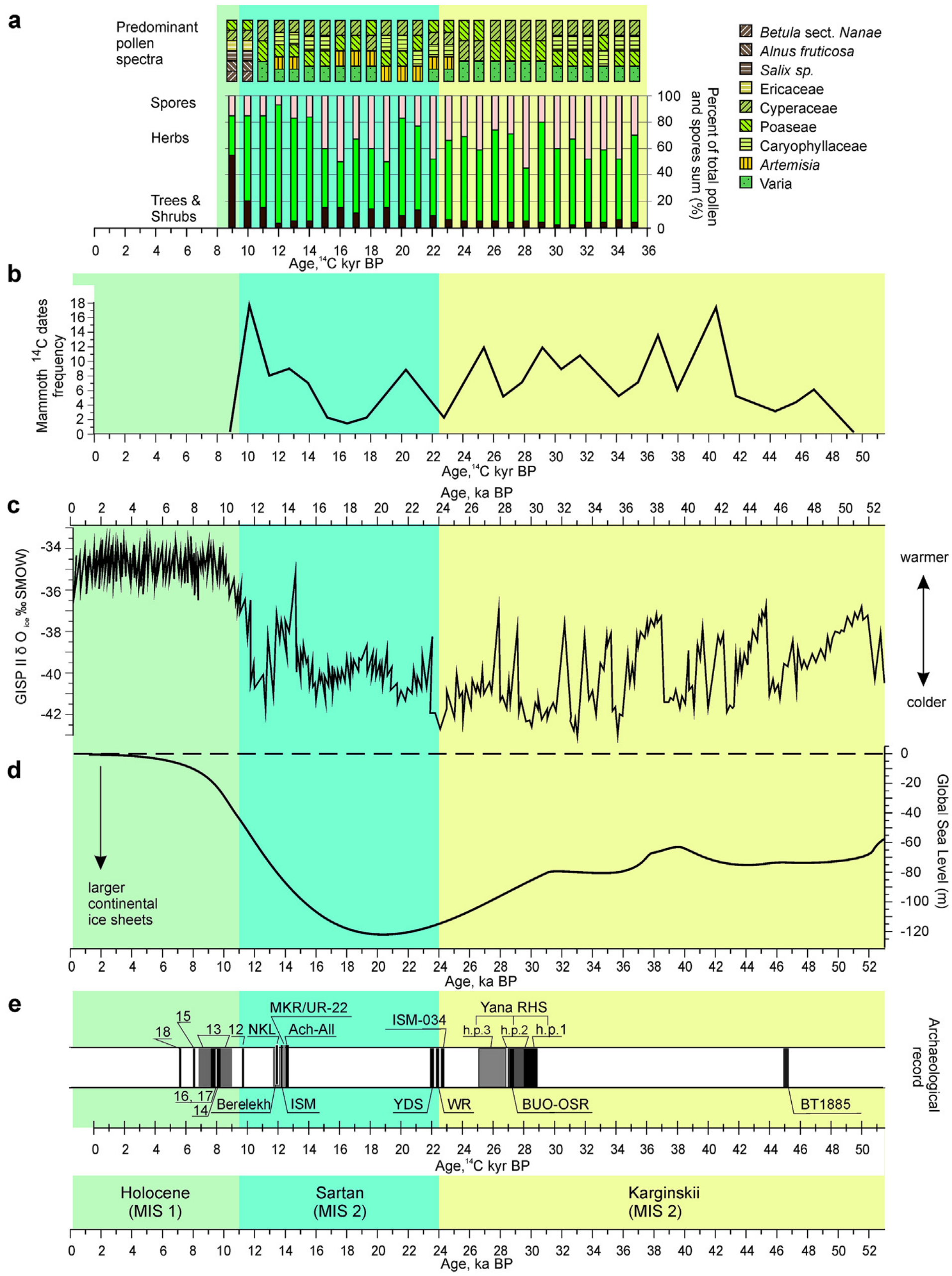

Fig. 4. Environmental changes in Arctic Siberia (MIS 3 through the Pleistocene/Holocene transition) and archaeological record: **a**, changes in plant communities seen through the pollen spectra (after Pavlova et al., 2009a); **b**, relative changes in mammoth population numbers (after Nikolskiy et al., 2011); **c**, GISP II oxygen isotope record ($\delta^{18}O_{ice}$) from the Greenland Ice Sheet ice core (Stuiver and Grootes, 2000); **d**, changes in global sea level over the same time period (Waelbroeck et al., 2002); **e**, archaeological record of the Arctic Siberia, archaeological sites: 1- Bunge-Toll 1885 site (BT-1885); 2 – Yana site complex (Yana RHS); 3 - Buor-Khaya/Orto-Stan site (Buo-OSR); Ilyn-Syalakh 034 (ISM-034); 5 – Wrangel island (WR); 6 – Diring-Aian site (YDS); 7 – Achchaghyi-Allaikha (Ach-All); 8 – Urez-22 (MKR/UR-22); 9 – Ilyn-Syalakh (ISM); 10 – Berelekh site (BEREL); 11 – Nikita lake site (NKL); Early Holocene: 12 – Tytylvaam site complex (T-vaam); 13 – Naivan (NN); 14 – Zhokhov site (Z); 15 – Tuguttakh (T-TAKH); 16 – Chelkun (CLK); 17 – Ananaiveem (A-VEEM); 18 – Koölen (KOL).

Table 1
Radiocarbon dating results for the Sopochnaya Karga mammoth kill site based on Maschenko et al. (2014) and Pitulko et al. (2016a,b).

Sample accession number	Dated material	Radiocarbon age, 14C years BP ± 1	Stratigraphic position, top to bottom
LE-9823	decomposed plant remains	18,200 + 2600/-2200	Bed 4, top contact
LE-9822	decomposed plant remains	36,000 ± 2500	Bed 4, bottom contact
LE-9821	willow branch fragment	47,600 + 10,200/-4400	Bed 3, bottom contact
GAMS-12565	Bone collagen, left ilium bone	37,830 ± 160	Bed 1, top part of it
GAMS-12566	Muscle tissue	43,350 ± 240	Bed 1, top part of it
GAMS-12567	Hair	41,100 ± 190	Bed 1, top part of it
GrA-57723	bone collagen from mammoth tibia bone	44,570 + 950/-700	Bed 1, top part of it

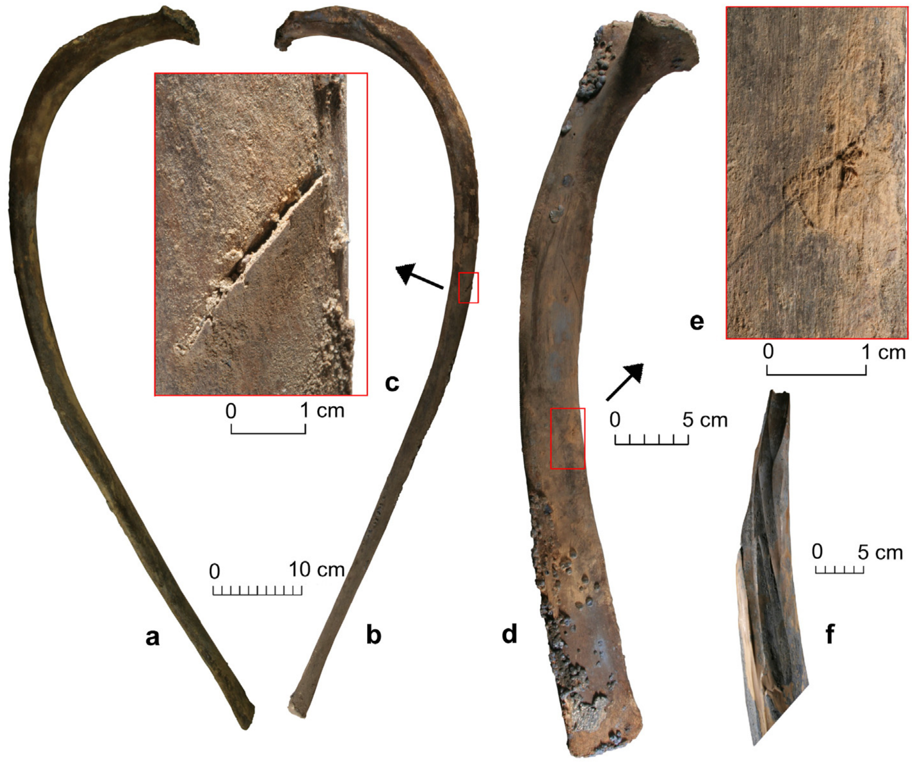

Fig. 5. Human-inflicted lesions on Sopochnaya Karga mammoth bones: **a**, fifth left rib with hunting lesion, posterior view; **b**, fifth left rib with hunting lesion, anterior view; **c**, enlaged view of the area with incision; **d**, the second right rib with incision; **e**, enlarged view of damaged area; **f**, human modified mammoth tusk with multiple lamellar scars on its tip surface, after Pitulko et al. (2016a).

The SK mammoth remains also display postmortem damage, which indicate human activity. Firstly, the ramus of the mandible is broken. These bones are quite strong: even when found isolated in much harsher taphonomic conditions, they often remain complete. However, in anthropogenic contexts, mammoth mandibles are mostly lacking one or both coronoid processes. Such mandible treatment may reflect tongue extraction. The Yana collection showed that mammoth tongue was often consumed by the hunters, perhaps as a ritual food or a delicacy (Nikolskiy and Pitulko, 2013), but in this particular case, the tongue would have been used as a piece of rich meat which is easy to use. Additionally, the only preserved right tusk of the SK mammoth shows traces of human modification. Several relatively thin sub-parallel spalls were removed from the tip of it. The tip of the tusk, normally quite blunt, served as a platform for these removals.

Thus the natural breakage pattern found on mammoth tusks (Vereshchagin and Tikhonov, 1999) and that of the recent elephant (Haynes, 1991) is completely different from those observed on the SK mammoth tusk. At the same time, such technique is quite different from ivory technology known in arctic Siberia in late MIS 3 (Pitulko et al., 2015). However, the same approach might have been used to produce ivory tools with asymmetric working part known in the younger archaeological sites found in Arctic Siberia (Pitulko, 2013).

Thus SK mammoth bone remains provide well-supported evidence for human involvement in its death. These are: (i) a lesion on jugal bone, (ii) a butchery mark on the fifth left rib (the most solid evidence), and (iii) the worked distal end of the right tusk. The same butchery pattern is well-known for mammoth bones from the Yana RHS complex (Pitulko et al., 2015). In particular, it is repeatedly documented for mammoth ribs (Pitulko et al., 2016a,b). The bone lesion found on the rib of SK mammoth fully replicates that pattern. Altogether, these findings leave no doubt that people were present in central Siberian Arctic by 44,570 + 950/-700 ^{14}C years BP (GrA-57723), or 49,150 - 47,100 cal BP. The SK mammoth locality can thus be accepted as mammoth kill site that presents the earliest evidence for human occupation in the arctic regions.

Independently, another locality in the eastern Siberian Arctic (Fig. 1) produced evidence for human habitation that also dates to the early MIS 3 (Pitulko et al., 2014c, 2016a,b). It comes from the Bunge-Toll 1885 site (Pitulko et al., 2014c) which locates at little stream called Unigen which is a left tributary of the Yana River at N 68° 55′, E 134° 28’ (Figs. 1 and 6). This assemblage of Pleistocene faunal remains including mammoth, wooly rhinoceros, and bison, produced a Pleistocene wolf humerus with a human-inflicted injury in its proximal part. X-ray computed tomography investigation indicates that this puncture-cut wound on the wolf's left humerus, caused by a sharp object with high force, could have been inflicted only by a human (Pitulko et al., 2014c, 2016a,b).

The weapon shape reconstruction indicates it was a rather sharp implement with a conical tip, most likely a projectile point made of bone or mammoth ivory. Hence, the Bunge-Toll 1885 site find represents evidence of human presence in Northern Siberia in the early MIS 3 around 45 kya, long before the Yana RHS site (Pitulko et al., 2004, 2013a) was occupied. It is not clear to what extent the other bones from the Bunge-Toll 1885 site are associated with human activity; however, the entire complex dates to no younger than 36 kya (Table 2). Interestingly, the closest radiocarbon date to the age of the wolf humerus (44, 650 + 950/-700) out of the Bunge-Toll 1885 collection comes from mammoth remains (47,600 + 2600/-2000).

This assemblage coincides partially with an interval during which mammoth population numbers in the Arctic were relatively high (Nikolskiy et al., 2011). Importantly, in Eurasia there are no

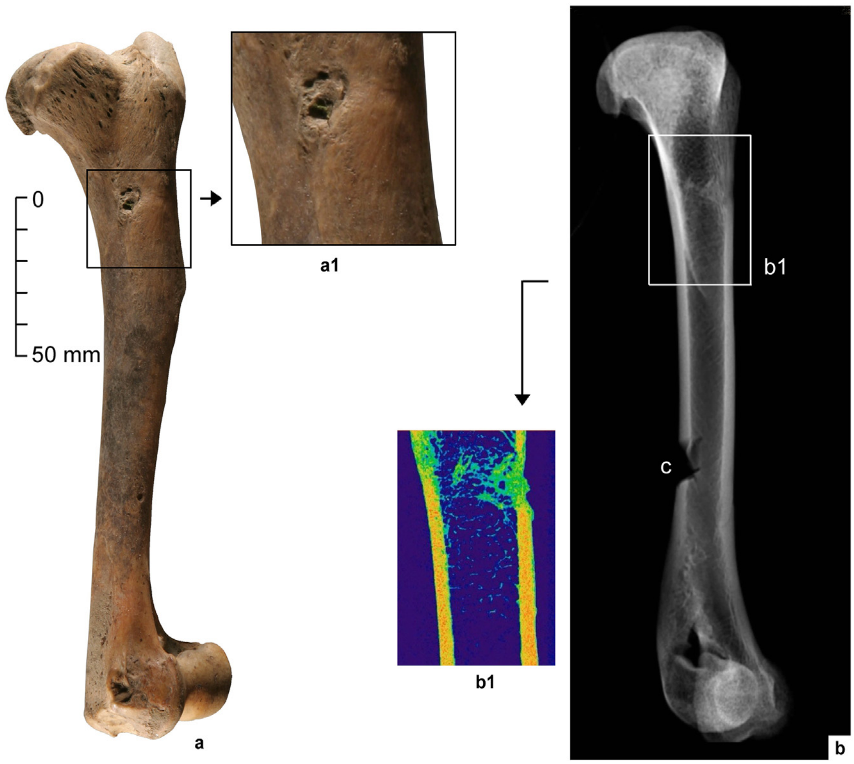

Fig. 6. Bunge-Toll 1885 site, Pleistocene wolf humerus with human-inflicted lesion: **a**, humerus with pathology; **a1**, close up of the sclerosis zone; **b**, X-ray photograph of the wolf humerus, same side as view (**a**), with a notch in distal area marking the AMS sample cut (**c**); **b1** – X-ray computed tomography slice of the damaged part of the bone.

Table 2
Radiocarbon dates from Bunge-Toll 1885 site (Note: GrA 57,022 is AMS ^{14}C).

N	Sample	Dated material	^{14}C age, uncalibrated years before present
1.	LE 9888	Bison, humerus	36,300 ± 640
2.	LE 9889	Woolly rhinoceros, rib	40,500 ± 1600
3.	GrA 57,022	Wolf, humerus	44, 650 + 950/-700
4.	LE 9887	Woolly mammoth, pelvic bone	47,600 + 2600/-2000

indisputable Middle Paleolithic sites associated with Neanderthals north of 55° N (Slimak et al., 2011). At the same time, there are claims on possible Neanderthal connection in Byzovaya site in the west slope of Polar Urals (Slimak et al., 2011, 2012). Its calculated mean age is 28,450 ± 820 ^{14}C yr B.P., according to Slimak et al. (2011), i.e. it falls within 34,580 to 31,370 cal yr B.P., or can be restricted to some broader interval around 30,600–34,700 years ago (Heggen et al., 2012). This age coincides well with the time of the most intensive habitation in Yana. However, the Neanderthal connection is based on stone tool morphology and then it was argued by several authors (e.g., Vishnyatsky and Pitulko, 2012; Zwyns et al., 2012).

But indeed some sites like Yana RHS and Byzovaya may retain archaic appearance in their lithic technologies and thus Yana has lithic industry of that kind, with almost no blades and bladelets but with highly developed flake-based technology which is to certain degree similar to Levallois preferential method. However, its ivory and bone technology, and highly developed manufacturing of personal adornments, decorations, and decorated artifacts leave no doubt in connection these finds to anatomically modern humans who populated the area starting early MIS 3 while archaic looking lithic technology is due to the function of the site and abundance of lithic raw material in form of cobbles and pebbles. Both sites are attached to mass accumulation of mammoth and both of them do have lithic raw material in cobbles. At least in the Yana case, it is easy to see that the site function largely consists in hunting and butchering the mammoth and processing of mammoth ivory (Basilyan et al., 2011; Nikolskiy and Pitulko, 2013; Pitulko et al., 2015). Seemingly, history of accumulation seen in Byzovaya, lithic tool morphology, and its fauna composition as well make such analogy possible, with no construction of Neanderthal refugia far north.

Additionally, it could be mentioned that Mamontovaya Kurya site that locates on the Arctic circle also west of Urals most probably represents another 'mammoth graveyard'. This accumulation of mammoth bones in paleo channel sediment matrix is accompanied by very few artifacts with poor morphology. Its age is though to be about nearly 40,000 years ago (Pavlov et al., 2001). Although slightly overestimated in age, Mamontovaya Kurya provides the oldest known evidence for human habitation at the Arctic limits prior the LGM. However, there are uncertainties about physical appearance of its settlers, too.

Furthermore, there is a newly discovered human fossil in Ust-Ishim at 57° N in West Siberia. That bone yielded an early modern human genome. This is the northernmost find directly documenting the spread of modern humans in sub-Arctic regions ca. 45,000 BP (Fu et al., 2014). It thus appears that the early (late initial) MIS 3 human migration into the Arctic can be attributed to our species. Notably, this timing generally corresponds to the emergence of the earliest Upper Paleolithic in northern Eurasia, both in its European (Anikovich et al., 2007) and Asian parts (Derevianko and Shunkov, 2004).

Apparently, modern humans' ability to survive in the Arctic environment, and their wide spread within the region as early as 45,000 years ago, demonstrates an important cultural and adaptation shift. Importantly, these groups moved far to the east, reaching the limits of Western Beringia around that time. We speculate that adaptation changes which ensured human survival there may be related to innovations in hunting large herbivores including mammoths. Upper Pleistocene tundra-steppe communities were providing optimal environmental conditions to support herd fauna. In such situation, sustained development of human populations secured by an unlimited food source would lead to their fast spread across Siberian Arctic while early arrival of modern humans in the area close to the Bering land bridge would be beneficial for entering the New World before the Last Glacial Maximum.

Human habitation in the Arctic during the middle of MIS 3 (40–30 kya) has not been documented yet. However, it has to be noted that Arctic Siberian environments were populated by diverse Upper Pleistocene large herbivores, whose population numbers clearly varied through time and space, but remained mostly high (Lorenzen et al., 2011; Nikolskiy et al., 2011). This herb-dominated mammoth tundra-steppe habitat with generally stable climate and vegetation (Sher et al., 2005; Willerslev et al., 2014) was capable of providing an unlimited food source for the Upper Paleolithic humans. Diversity in environments increases southward, with some advancement of larch forest in southern Western Beringia (Lozhkin and Anderson, 2011), which could have been driving mammoths out of such forested areas and thus slightly increasing their population density in the Arctic Siberia. Despite that, most of Siberia remained populated by mammoth at this time (Lorenzen et al., 2011; Willerslev et al., 2014).

1.2. Late MIS 3 archaeological record

Successful and long human habitation record in arctic Western Beringia is well-demonstrated by the Yana RHS complex (Pitulko et al., 2013a) and Buor-Khaya sites (Pitulko et al., 2014d) located north of 70° N (Fig. 1). More precisely, Yana RHS is situated at 70° 43′ N and 135° 25′ E. Migration range (or trade network) of these people was wide and reached at least several hundred kilometers (Pitulko et al., 2012a). It is obvious that the Yana settlers kept returning to the same place for a substantial amount of time, and camped there in different seasons or even occupied the place all year round. Surprisingly, they had left no sophisticated dwelling features (e.g., mammoth bones, cobbles and rocks, or piled antlers): not a single large mammoth bone relates to the habitation locales at the Yana site, despite numerous mammoth remains found in the Yana mass accumulation of mammoth (Basilyan et al., 2011) which is contemporary with the habitation areas and constitutes a part of the site's spatial structure (Pitulko et al., 2015). Instead, ivory, rib fragments, and hyoid bones present in the residential area indicate limited use of fresh meat on the one hand, and wide use of ivory as a raw material, on the other (Nikolskiy and Pitulko, 2013).

Mass procurement of mammoth is explained by prime targeting of ivory (Nikolskiy and Pitulko, 2013; Pitulko et al., 2015). Remarkably, human habitation in the Yana site area waned after 26,000 ^{14}C yr BP when the mammoth population in western arctic Beringia experienced a significant decline (Nikolskiy et al., 2011); people abandoned the area in the beginning of the LGM at around 22,000 years BP. This probably indicates that the Yana site area was chosen because of its convenience for mammoth hunting even if procuring mammoths was not an important activity for subsistence as a food source. At the same time, a study of the frequencies of distribution of dated mammoth remains in the northern Yana-Indighirka lowlands (Nikolskiy et al., 2011) demonstrates that the presence in these regions of people at 28,000 ^{14}C yr BP did not influence the local mammoth population: one of the peaks of relative abundance of these animals was exactly during this time.

Mammoth ivory was an important raw material not only for personal ornament manufacture, but, first of all, for tool-making. The importance of ivory for making hunting weapons is quite comparable with the significance of metals for the same function, as was demonstrated by Peterkin (1993). Yana RHS site provides an even better example since Yana's hunting equipment kit consists almost exclusively of ivory/bone tools including long points and foreshafts (Fig. 7). Some lithics have been also used, but perhaps

Fig. 7. Yana RHS osseous hunting tools: **a**, **d**, **e** – foreshafts; **b**, **f**, **g** – spear points; **c** – a fragment of long spear point (**a**, **d** – woolly rhinoceros horn; **b**, **c**, **e-g** – mammoth ivory).

only as tips for the ivory points (Nikolskiy and Pitulko, 2013). Remarkably, this high-quality hunting equipment, together with exceptionally well developed production of bone/ivory implements and personal ornaments, is accompanied by an archaic-looking lithic industry based on multidirectional cores, in which backed side scrapers constitute the main form.

Pointed rods (spear points) in the Yana site inventory are represented by many specimens with some variation in form. In general, these are needle-like points with a beveled base, the surface of which was carefully polished not so much for esthetic considerations as for an increase in the penetrating capacity of the objects, which also ensured quick retrieval after the blow if it was applied at close range. This simplest type of hunting equipment was exceptionally widespread and was evidently the basis for the Paleolithic hunters' equipment complex elsewhere over a long span of time (e.g., Bader, 1998; Bradley and Stanford, 2004; Sitlivy et al., 1997; Smith, 1966).

Hunting lesions on bones (Pitulko et al., 2013a, 2016a, 2016b) imply that these high-efficiency tools were appropriate for killing a diverse set of animals including mammoths. However, it appears that mammoth hunting also involved equipment tipped with lithic implements (Nikolskiy and Pitulko, 2013; Pitulko et al., 2016a,b), probably for better penetration through hide, fat, and muscles, and for greater ability to hit the bone deep inside the body. The hunting method used likely resembled the spear-fall strategy practiced by modern African hunter-gatherers (Turnbull, 1983).

It is also well known that Upper Paleolithic humans were capable of producing long shafts of ivory exceeding the length of a full-size thrusting spear. Examples of such artifacts, as finished artifacts or by-products, were found in Sunghir (Bader, 1998), Berelekh (Vereschagin, 1977), and in several sites on the Russian Plain: Kostenki, Avdeevo, Eliseyevichi, Khotylevo and others (Khlopatchev, 2006). The maximum length of the ivory shafts from Yana is 63 cm, but some of the Eurasian finds of this implement are much longer. For instance, the Berelekh shaft (Vereschagin, 1977), although incomplete, exceeds 90 cm, while ivory spears from Sunghir are about 2 m long. Although these are thought to be ritual objects (Bader, 1998), it seems likely that both full-size ivory spears and the idea of hunting with spears equipped with detachable foreshafts made of ivory or other suitable material arose as an adaptation to treeless landscapes. Wood shortage would force one to set a high value on this material and care more about a wooden spear shaft rather than about its stone or bone point. Additionally, people would have been forced to search for a substitute for this valuable material (Pitulko and Nikolskiy, 2012; Pitulko et al., 2013a, 2015). For example, historical Inuit of Thule, Greenland, who often found driftwood scarce, made spears of walrus and narwhal tusks. Some of the latter were 2 m long (Malaurie, 1989) and were used as hunting equipment, not for a ritual or ceremony. Mammoth ivory suited such use admirably as it was tough, dense, and could be cut into long thin shafts. Even a mid-size tusk could supply several shafts up to 2 m in length.

Hunting technology based on the use of mammoth ivory and rhinoceros horn foreshafts was well-developed in the late MIS 3 and documented in Arctic Siberia by the Yana weapon kit (Fig. 7). Without drawing direct analogies between the foreshafts of Yana RHS and those of North American Clovis (Bradley, 1995; Dunbar et al., 1989), which are separated not only by 3000–4000 km but also by > 15,000 years, we may still note that both were based on a type of hunting equipment employing a detachable spearhead. Somehow this idea must have reached the New World. In Arctic Siberia, this technology is found at the Late Paleolithic locality of Berelekh and at a number of the Holoocene Stone Age sites in the sub-Arctic regions (Fedoseeva, 1980, 1992). This type of technology persisted in Western Beringia until the end of the Stone Age and served as the foundation for the Eskimo harpoon complex during the late Holocene.

While mammoth hunting at Yana was targeted on getting the tusks for raw material rather than for the meat, all available species were hunted intensively. Faunal remains indicate intensive exploitation of many large herbivores, including woolly rhinoceros, Pleistocene bison, Pleistocene horse, reindeer, and Pleistocene hare, but bison, horse, and reindeer dominate the faunal assemblage. In addition, similarly to the Late Upper Paleolithic sites on the Yenisei (Goebel, 2004), mass procurement of hares is evident from the faunal remains from the Yana site. Since they are often found articulated and in correct anatomical position, it is likely that hares were hunted for fur to be used in underclothes, insoles, and inner socks, as many northern peoples do. According to Malaurie (1989), Inuit hunters of the Thule District in Greenland trapped as many as 1000 to 1500 hares each season to make clothing, but rarely ate them.

The Yana site assemblage demonstrates that humans who inhabited Arctic Siberia at the end of the MIS 3 were exceptionally well-adapted to this environment and landscape both on the group/social and individual level. Since their adaptations included the land use strategy, hunting technology, tool making, and clothing, they were ready to face much harsher environmental conditions of the LGM. These conditions affected their prey species, causing a decline in mammoths (Nikolskiy et al., 2011), but did not led to the total crash of the biome (Figs. 2 and 4), which was still providing enough food resources even in the northernmost areas of the Upper Pleistocene Arctic Siberia expanded to modern sea shelves by sea-level drop (Figs. 3 and 4) except perhaps during short episodes when mammoths totally abandoned Western Beringia (Pitulko and Nikolskiy, 2012).

Assemblage of late Pleistocene faunal remains found near the Orto-Stan River, Buor-Khaya Peninsula (Fig. 1) at N 71° 36′ E 132° 15′, expands the late MIS 3 human habitation record for the Arctic Siberia and indicates successful habitation in the High Arctic environment. Mammoth remains of at least five individuals, both adults and juveniles, constitute two thirds of the assemblage (Pitulko et al., 2014d). One of the pelvic bones has multiple engraved lines on the surface while two more show clear butchering marks located near the hip joint to facilitate its disarticulation (Fig. 8). Mammoth skull fragments bear possible kill marks next to the nasal opening, which may have resulted from the *coup de grâce* method, the same as detected for Sopochnaya Karga mammoth kill (Pitulko et al., 2016a,b) and the same as that practiced by the elephant-hunting Pygmies (Kulik, 1971) to finish the animal. The point of such action is to hit the elephant's trunk at its base to cause mortal bleeding.

Direct dates on two mammoth bones with human impact and a horse bone estimate site age at 27,000–27,600 ^{14}C yrs BP, which corresponds to the end of MIS 3 (Table 3), or slightly older if the horse bone belongs to the same depositional horizon. These ages indicate that the mammoth remains were accumulating for at least 500 years.

This evidence is sufficient to accept the Buor-Khaya/Orto-Stan site as a kill-butchery mammoth locale, and currently the northernmost Paleolithic site in the world, which sheds light on human dispersal across the Arctic Siberia at the end of MIS 3. Presumably, these were the same cultural group as in Yana but this is not important because the site indicates multiple pre-LGM habitations in the Arctic Siberia.

1.3. Early MIS 2 (LGM) archaeological record

During the Sartan stadial (MIS 2, 24-11 kya), due to an extreme global ocean level drop down to 120 m below modern, the Western

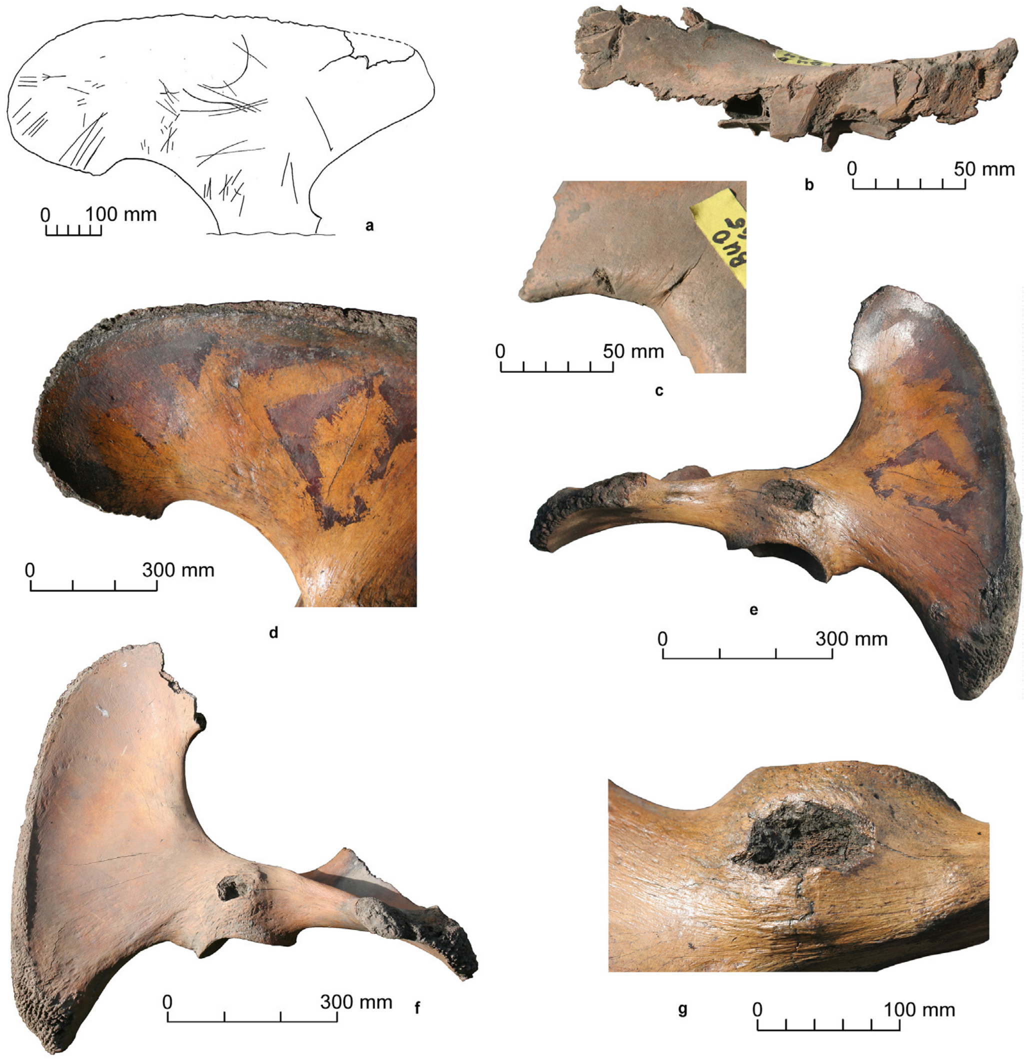

Fig. 8. Finds from Buor-Khaya site: **a**, engravings on the bone surface (sketch by Alla Mashezerskaya); **b**, **c** - mammoth skull fragment with cut mark; **d** - caudal surface with engravings; **e** - mammoth pelvic bone (right) with human impact (blind hole and engravings on caudal surface); **f** - mammoth pelvic bone (left) with human impact (blind hole) near the joint; **g** - close up for the blind hole.

Table 3
AMS ^{14}C dates for Buor-Khaya/Orto-Stan mammoth kill-butchery site.

Sample	Skeleton element	Species	^{14}C age, uncalibrated years before present [yrs BP]
Beta-362,946	Pelvic bone with a blind hole, right	Mammoth	27,080 ± 140 yrs BP
Beta-362,947	Pelvic bone with a blind hole, left	Mammoth	27,430 ± 150 yrs BP
Beta-362,948	Metatarsal III bone, right	Pleistocene horse	28,790 ± 160 yrs BP

Beringia shoreline moved even further north: in the region of the New Siberian archipelago it moved 200–220 km north, and near the Wrangel Island region - 50–70 km north (Fig. 3). Importantly, Arctic Siberia remained unglaciated throughout MIS 2 except for certain portion of the Kara Sea shelf in the west and possibly some limited mountain areas in central arctic Siberia (e.g., Clark et al., 2009; Svendsen et al., 2004).

Paleoclimatic and paleoenvironmental records (Figs. 2 and 4) indicate that by 24 kya climate deteriorated significantly: temperatures fell and humidity increased. Summer temperatures were lower than modern ones by 3.5° C, while the annual precipitation exceeded modern levels by 180 mm. After 23 kya summer temperatures continued dropping, as did the annual precipitation level. The climate became cold and dry. Lowest temperatures and maximum aridization occurred sometime between 20 and 16 kya when summer temperatures were lower than modern levels by 4.5–7° C, and annual precipitation was 50–100 mm less than today.

Vast open areas of western West Beringia lent themselves to open arctic pioneer and steppe herb-dominated tundra- and steppe-like environments. Cyperaceae, Poaceae, *Artemisia*, Caryophyllaceae and forbs dominated the plant communities (Andreev et al., 2011; Kienast et al., 2005; Pitulko et al., 2007, 2013b; Schirrmeister et al., 2002; Wetterich et al., 2011), but eventually floristic diversity decreased, leading to a decline in biological productivity of the landscapes and triggering population changes in the Upper Pleistocene herbivores. Generally, dense grass-sedge *Artemisia* tundra-steppe was gradually replaced by sparse grass-sedge tundra-steppe, as was noted by Andreev et al. (2011) for the Laptev Sea region. Consequently, mammoth populations in Arctic Siberia experienced a significant decrease during MIS 2 (see, e.g., Nikolskiy et al., 2011; Sulerzhitsky, 1995). However, several radiocarbon-dated remains of other species are known even in the northernmost limits of the area, whose presence would provide sufficient support for Paleolithic foragers at this time (Fig. 9).

Within the last few years, two localities dating to the LGM have been found in the arctic Western Beringia. The newest find at the Yana site comes from Yana Downstream Point (YDS) locality discovered in 2013 within Yana RHS site complex. This is a fragment of human-modified mammoth tusk, or ivory core fragment (Fig. 10) directly dated to 22,040 ± 100 ^{14}C BP (Beta-362,949), i.e. to the very beginning of the LGM. Its age is in agreement with the stratigraphic position and controlled by the age for both overlying and underlying deposits which is 18,990 ± 470 ^{14}C BP (LE 10,134) and 23,650 ± 850 ^{14}C BP (LE 10,133).

Another LGM site, called ISM-034, was found at N 70° 48′ and E 140° 42’ at Ilin-Syalakh River in the Yana-Indighirka interfluve (Pitulko et al., 2014b). About 15 bone specimens were found in the narrow spot (7–8 m wide). Pleistocene fauna is represented widely here and includes mammoth, bison, horse, reindeer and elk bones. There are rib and vertebra fragments and limb bones. The bone-bearing horizon produced a mammoth mandible that dates to 22,700 ± 300 ^{14}C yrs BP (LE 9506), mammoth ribs with clear

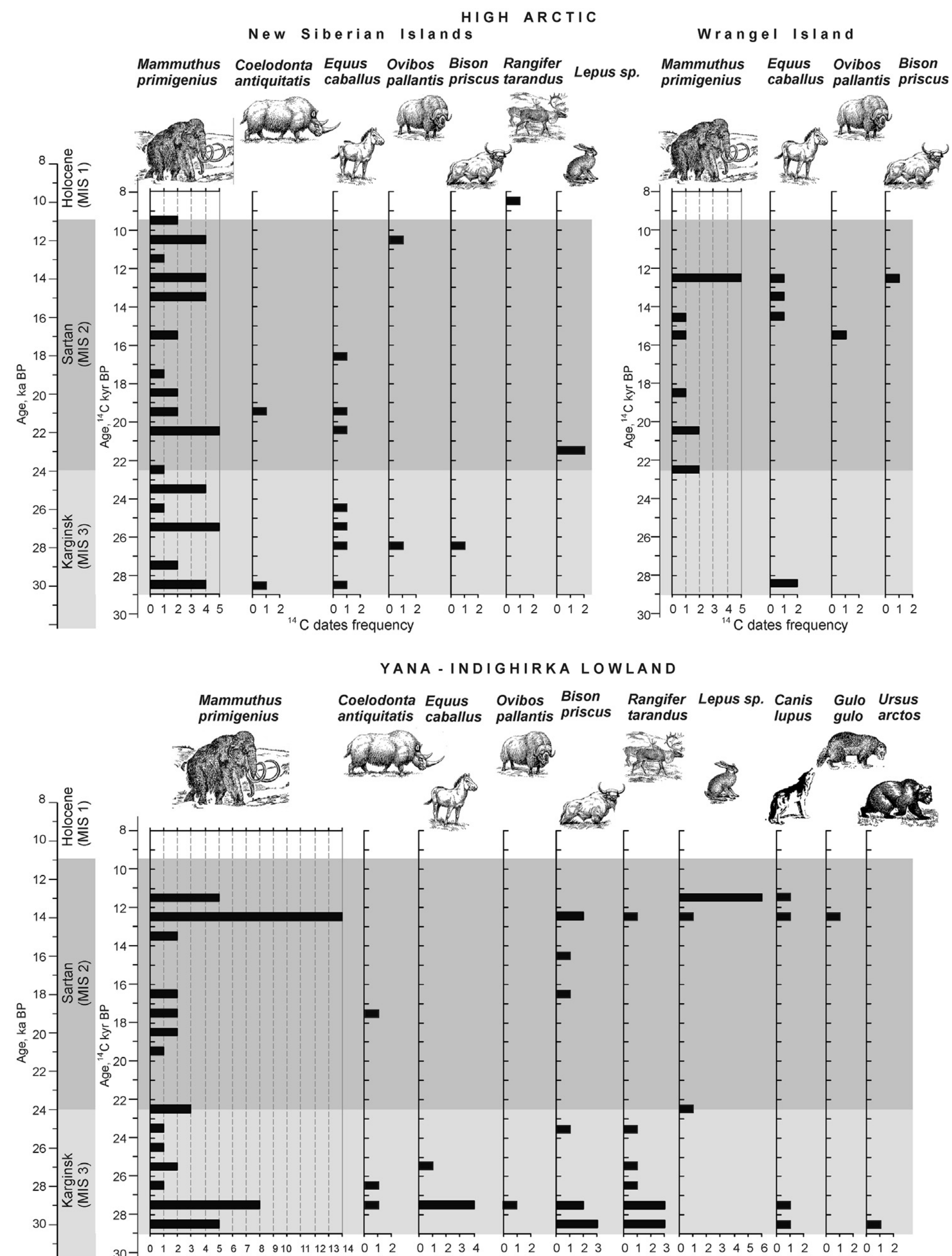

Fig. 9. Different Upper Pleistocene fauna species observed in Arctic Siberia (radiocarbon dated to MIS 2): top panel, High Arctic regions (modern New Siberian islands and Wrangel island), bottom panel – Yana-Indighirka lowland; data are based on Andreev et al. (2009), Basilyan et al. (2011), Makeyev et al. (1989, 2003), Nikolaev et al. (2000), Nikolskiy et al. (2011), Pitulko and Pavlova (2010), Pitulko et al. (2004, 2007, 2012b, 2013b), Sher et al. (2005), Stuart (1991), Sulerzhitsky (1995), Sulerzhitsky and Romanenko (1997, 1999), Vartanyan et al. (2008), Verkulich et al. (1989).

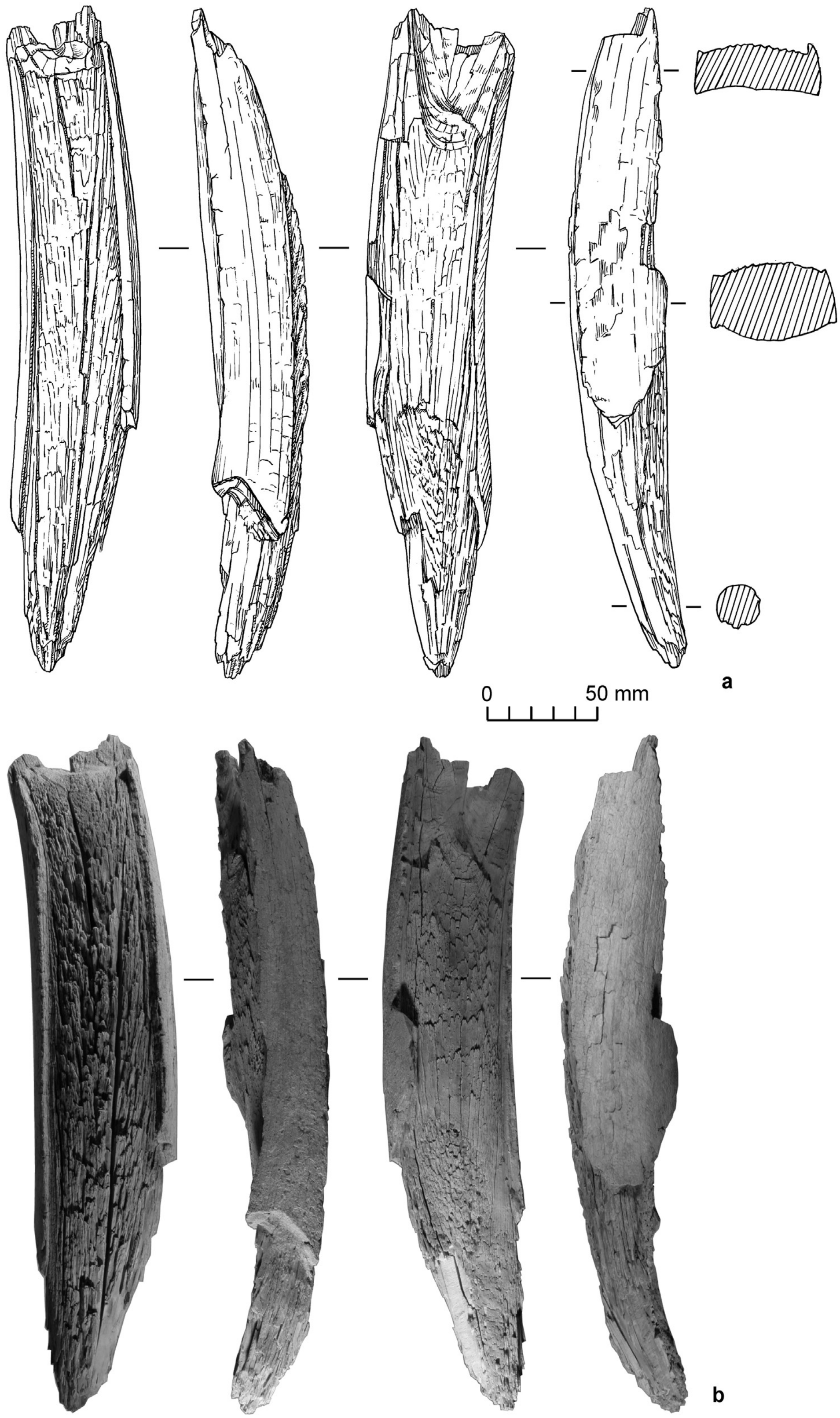

Fig. 10. Yana Downstream site, *in situ* find dated to the beginning of MIS 2 (Sartan glacial). Ivory core: a - drawing, b - photograph.

human-inflicted lesions or butchering marks (Fig. 11: d, e), and elk antler fragments.

There are no lithics associated with these finds; however, the lack of lithics may be explained by the shortage of high-quality lithic raw material in this region. This is typical for the younger sites found in Arctic Siberia (Pitulko et al., 2014a), and very typical for mass accumulations of mammoth found in West Siberia (Zenin, 2002; Zenin et al., 2006) or on the Russian Plain (Maschenko et al., 2006), where it is common for just a couple dozen lithic artifacts to be associated with thousands of bones. Thus, human exploitation of bone beds does not necessarily leave supplementary evidence (like numerous lithics), even when human involvement in the bone bed formation and human use of mammoth bones are indisputable.

The evidence for LGM human habitation in Arctic Siberia can be expanded by mentioning the find made by Romanenko on the Wrangel Island (Sulerzhitsky and Romanenko, 1999). A left mammoth shoulder blade with a hole in its distal (upper, in the anatomical position) part was found in the western part of the island, on the Mamontovaya (Mammoth) River. It is directly dated to 22,400 ± 200 ^{14}C years BP (GIN 8257), the very beginning of the LGM. This hole was interpreted by Sulerzhitsky and Romanenko (1999) as a human-inflicted injury but at the time their conclusion was not recognized widely (Fig. 11: c, c1). Based on the hunting lesions observed on mammoth bones in the Yana assemblage, and particularly on their locations within the scapula bones (Nikolskiy and Pitulko, 2013; Pitulko et al., 2016b), the Wrangel Island scapula damage appears indeed to be a hunting mark. Importantly, the bone also lacks the spine part, which is very typical for human-modified scapulae. Whether or not this conclusion will be recognized, human habitation in the Arctic Siberia is well demonstrated at least by the Yana ivory core and ISM-034 site findings.

Although the evidence for human presence in Arctic Siberia during the LGM is quite provisional for now, these sites are perhaps starting to fill in the «LGM gap» in the human habitation record of Northeast Asia. Additionally, there are two thought-provoking direct radiocarbon dates on the mammoth ivory artifacts, one from the Berelekh (Pitulko, 2011) and one from the Nikita Lake site,

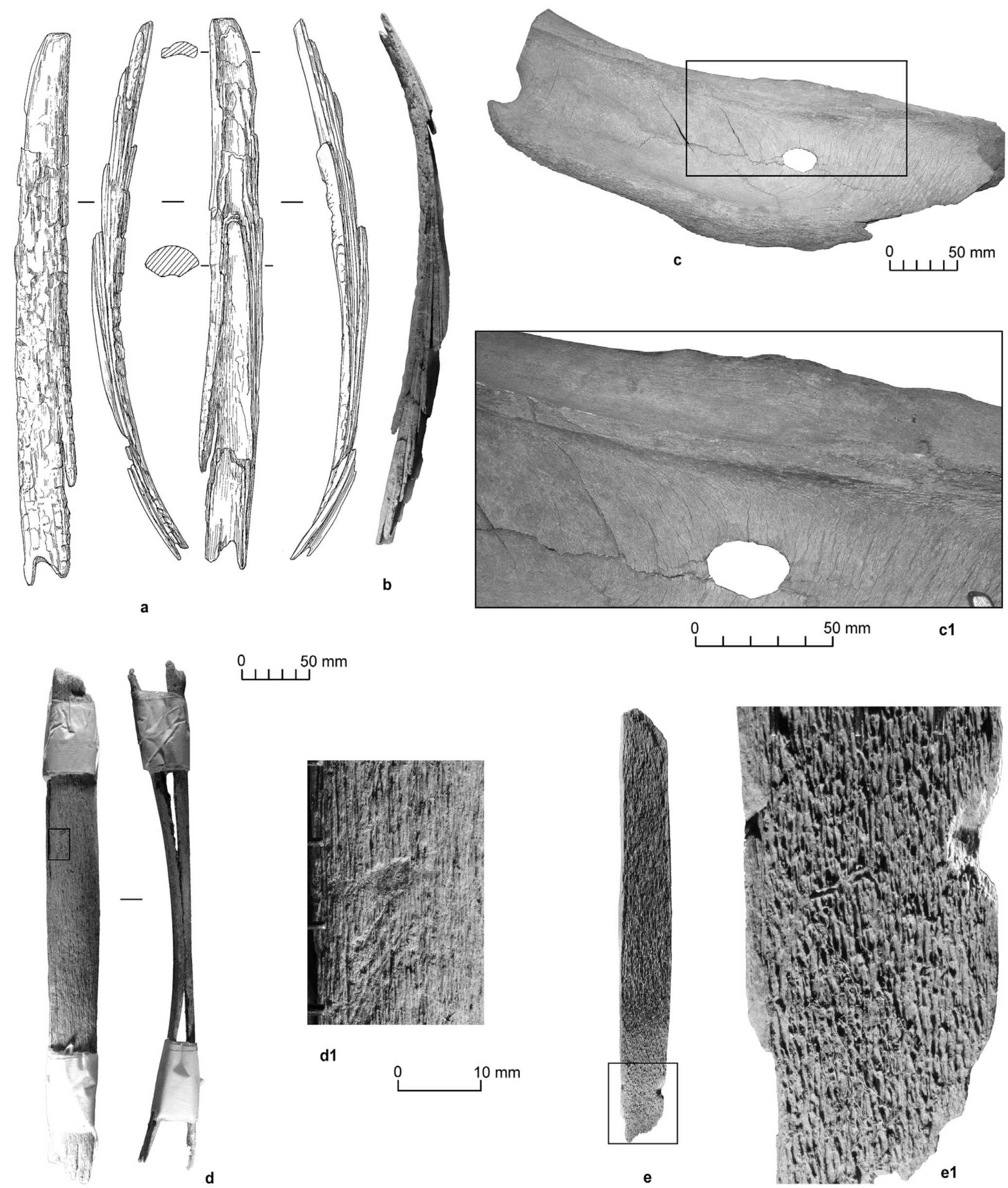

Fig. 11. Archaeological finds from Ilin-Syalakh accumulation of mammoth (**a, b**), Wrangel Island (**c**, **c1**), and Ilin-Syalakh-34 site (**d-e1**), all are attributed to MIS 2 by direct radiocarbon dating: **a**, **b** – spear point/foreshaft ivory preform; **c** – mammoth scapula with hunting lesion; **c1** – close up for (**c**); d, e – hunting lesions on the mammoth rib; **d1**, **e1** – close up for (**d**) and (**e**), respectively. Photo (c) and (c1) courtesy of F. Romanenko.

which fall within the LGM. Radiocarbon dates on mammoth are extremely rare for this time (Nikolskiy et al., 2011; Sher et al., 2005), indicating a significant depression of the mammoth population in Arctic Siberia (Nikolskiy et al., 2011). Accordingly, the ivory could have been used by humans more or less around each animal's time of the death (as opposed to some time later). However, for now such finds should be treated not as definitive evidence, but as more of a suggestion for human activity in this area during the LGM.

It is hard to say what kind of material culture may have been in use during this time, but most likely this was a Malta-type blade industry (Kimura, 2003). Remarkably all three cases (Yana Downstream point, ISM-034, and Wrangel Island) indicate that the importance of mammoth increases; their role, after the decline of the population, probably becomes more significant in terms of food supply. However, population numbers for musk ox, reindeer and horse generally increase in Siberia during MIS 2 (Lorenzen et al., 2011). For Artic Siberia, there are a number of MIS 2 dated remains of different species (Pitulko and Pavlova, 2013), which means appropriate food resources were still around at this time (Fig. 9). Nonetheless, human population in Arctic Siberia experienced significant reduction during the LGM, their occupation becoming more ephemeral and some parts of the area even becoming abandoned.

Decline of the mammoth population within Western Beringia after the LGM probably led to important cultural changes that are visible archaeologically. This is a time of dispersion of assemblages of the Beringian Microblade Tradition (Goebel and Slobodin, 1999; Slobodin, 2011; West, 1996), a phenomenon initially thought to be purely cultural (Mochanov, 1977; Dikov, 1979). It is now becoming clear that new technologies often had a distinct adaptive importance for the ancient populations of various historical epochs.

For example, for the Eskimo sites of Chukotka, Arutiunov and Sergeev (1972) established a dependence of the shape of harpoon heads and the ice cover conditions in the hunting area. Analysis of the distribution of various types of hunting tools for the Solutrean sites of Western Europe in relation to the past ecological niches (Banks et al., 2008) demonstrated a correlation between the type of the tools and the environmental characteristics of the reconstructed paleo-niches, such as the mean annual precipitation and temperature. Modifying these parameters affected the species diversity within the boundaries of these niches. The latter were significant for the species diversity within their boundaries. Identifying such correlations, Banks et al. (2009) also rightly emphasized that far from every change in the material culture could be explained by these processes.

Various researchers repeatedly note the possible adaptive nature of lithic technological change in the Siberian Late Upper Paleolithic. The diversity of the natural environments during the warm periods, particularly in the Karginsk time, was suggested as the possible reason for the cultural diversity of the early Upper Paleolithic sites of the Middle and Eastern Siberia (Pitulko, 2006). Potential signal of environmental changes is also seen by Kimura (2003) in the evolution of the Malta blade industry in Siberia, while the rise of microblade technology in north-central China is presumed to be related to the production of sophisticated cold-weather clothing necessary for mobile hunting adaptations in winter (Yi et al., 2013). It appears that the positive dependencies between the shapes of the Solutrean hunting tools and the specifics of the ecological niches established by Banks et al. (2009) provided evidence prompting further search for such regularities, including in the area of the change of knapping techniques.

The major technological shift in the Late Upper Paleolithic of Western Beringia – emergence of microblades from wedge-shaped cores – coincides with significant environmental changes during the LGM. Goebel (2002) had appropriate reason to define this phenomenon as the microblade adaptation and see it as a result of culture transformation due to the transition to the reindeer hunting practices during the Sartan cryochron cold maximum. However, in this case the "microblade adaptation" was not the result of the need to start hunting the reindeer, bison or horse, along with for various goats and sheep in the mountainous environments. All these animals existed and were hunted by people long before the LGM.

It appears that the deficit of the mammoth-based raw materials was the more important factor than the change of the food resource balance. The technological answer appeared in the shape of the mass spread of the microblade technology that started around the LGM from Southern Siberia. This technological diffusion follows the area populated by mammoth in a northerly direction when mammoth habitat shrinks to the 'northern belt area' in Arctic Siberia (Fig. 12) and finally transforms into refuges separated from each other (Pitulko and Nikolskiy, 2012). The main governing factor for the "microblade adaptation," thus, was not the introduction of a new element of the environment, but the disappearance of the well-known and relied-upon one, i.e. the changes to the mammoth habitat boundaries and the density of their populations ending with their complete extinction.

Such innovation could be either brought by newcomers or developed independently in different areas. By analogy with South Siberia, it seems likely Late Upper Paleolithic hunters in Arctic Siberia were becoming more mobile. As Graf (2010) found for the Yenisei area, local Late Upper Paleolithic foragers maintained sophisticated, complex technologies that facilitated a highly mobile, residentially organized land-use system focused on hunting herd fauna (bison, reindeer, horse) which occupied post-LGM habitats. This reasonable model could be applied to Arctic Western Beringia except that this way of life probably arrived later, following the decrease of the mammoth population, which was slower in the northern areas.

1.4. The late MIS 2 archaeological record

A sharp climatic change to warmer summers started in Arctic Siberia around 15,000 BP (Hubberten et al., 2004; see also Figs. 2 and 4 for summary data), as demonstrated by Sher et al. (2005) for the Laptev Sea region based on the pollen record and on the recovery of steppe insects that indicate the establishment of more productive variants of the tundra-steppe. This change resulted in a short but well-pronounced peak in mammoth population numbers (Nikolskiy et al., 2011; Sher et al., 2005). The climate, however, remained very dry, with cold winters. This rather short phase of increased biological productivity (15,000–12,500 BP) evidently predated the interval of favorable climate known as the Bølling-Allerod interstadial (ca 13,000–11,000 BP). With certain changes in floral diversity, grass-sedge dominated habitats and shrubs existed in protected places in the western part of the region after ca. 13,000 BP (Andreev et al., 2011; Kienast et al., 2005; Pitulko et al., 2007, 2013b; Schirrmeister et al., 2002; Wetterich et al., 2011). In the east, the vegetation is described as herb-dominated tundra, herb-shrub tundra, and abundant steppe communities (Anderson and Lozhkin, 2001; Lozhkin et al., 2007; Lozhkin and Anderson, 2011).

Increased summer temperatures at the end of MIS 2 could have triggered initial thermokarst processes in the eastern shelf lands. At around 12,500 BP, when the climate became more humid, general permafrost degradation began, accompanied by a dramatic change in vegetation from tundra-steppe to wet tundra and forest tundra, which greatly contributed to the megafaunal extinction.

The youngest group of archaeological sites to be discussed in this article belongs to the Late Upper Paleolithic of Arctic Siberia. It has to be stressed that all of them are accompanied by accumulations of mammoth bones commonly known as "mammoth

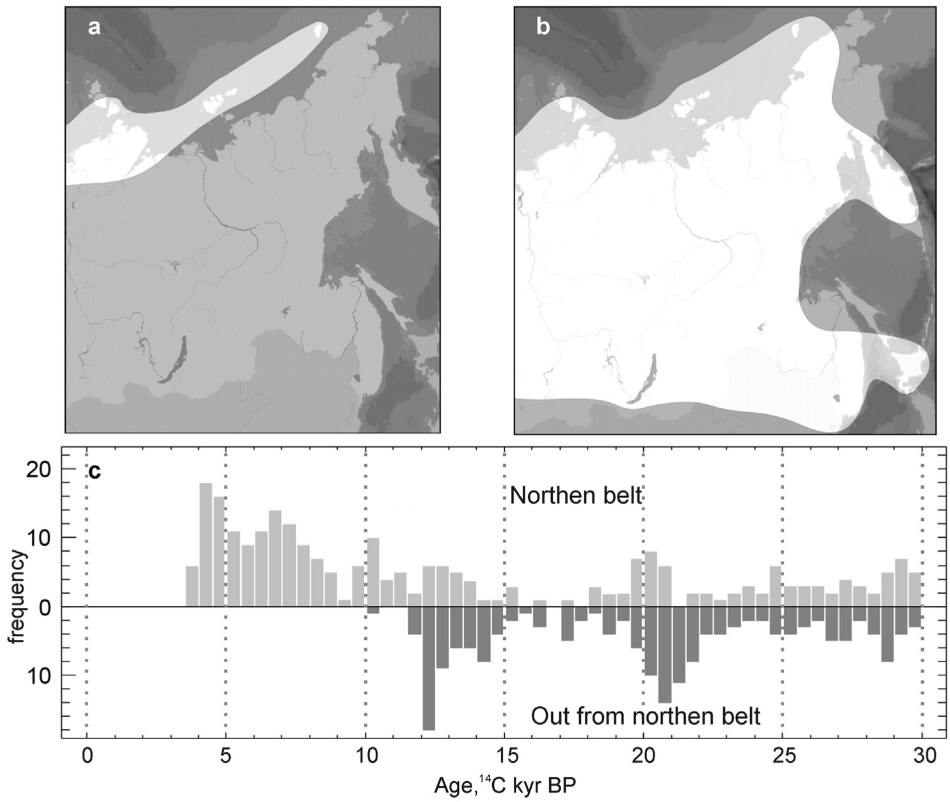

Fig. 12. Range of mammoth in Northeastern Asia over the last 30,000 years (top panel): **a**, minimal range within the 'northern belt' – Arctic Siberia at around Pleistocene/Holocene boundary; **b**, maximal range of mammoth in the Northeastern Asia at the end of MIS 3 which shrinks then to the 'northern belt'. Bottom panel: (**c**) the diagram that demonstrates time-related densities of mammoth-based ^{14}C dates from the "northern belt" and outside the "northern belt" (after Pitulko and Nikolskiy, 2012). Mammoth-populated areas are marked in white.

graveyards" (Fig. 1). Generally, they are located in the Yana-Indighirka interfluve. In addition to the previously known Berelekh (Pitulko, 2011; Vereschagin, 1977) and Achchaghyi-Allaikha localities (Nikolskiy et al., 2010), these are Ilin-Syalakh mammoth site (ISM), Nikita Lake site (NKL), and Urez-22 site (MK/UR-22) discovered in 2011–2013 (Pitulko et al., 2014b).

This first one, the Ilin-Syalakh mammoth graveyard, is located at N 70° 47′ and E 140° 45'. The bone bed, located at the base of the river terrace, yielded a set of almost exclusively mammoth bones along with a few woolly rhinoceros, reindeer, horse, bison, hare, and bird specimens. Presumably about ten mid-sized animals are represented, indicating prey selection by size. Radiocarbon dating of mammoth bones (12,260 ± 220 ^{14}C yrs BP, LE-9507 and 12,300 ± 85 ^{14}C yrs BP, LE-9494) indicates that the bone bed was accumulating from before 12,000 ^{14}C years BP. Past human activity is indicated by a distinctive ivory artifact: a 27 cm long three-edged preform for a thrusting spear (Fig. 11: a, b), typical for many Siberian sites.

MKR/UR-22 was found in the Maksunuokha River basin at N 71° 42′, E 141° 12' (Fig. 1). Bones and artifacts are found here within the deluvial-proluvial deposits backfilling the erosion channel made by a small stream. The site yielded ivory debitage, a spear point blank, and several stone flakes that indicate rejuvenation of lithic tools and possibly microblade core maintenance, but no tool production (Fig. 13: a-p). Regular lithic knapping is presented by true microblades while core technology is not recognizable. Bone remains collected at the site suggest that at least 12 mammoth individuals, both juveniles and adults, were killed (?) here around 12,370 ± 50 ^{14}C yrs BP (Beta-362,950).

The NKL site is in the same river system at N 71° 34', E 141° 37 and is located in a secondary context formed by a low-energy stream. Mammoth bones are associated with those of other herbivores (bison, horse, and reindeer) and carnivores (wolf, wolverine, and brown bear). There are at least 11 mammoth individuals, mostly adults and a few juveniles. Several mammoth ribs display unequivocal butchering marks and some have clear hunting lesions with embedded lithic tool fragments. Radiocarbon dating estimated the assemblage age at 12,000 ^{14}C yrs B.P. (12,050 ± 50 ^{14}C yrs BP, Beta-309157 and 11,960 ± 140 ^{14}C yrs BP, LE-9493). Artifacts are very few but characteristic: they include ivory debitage, spear point preforms, and formal lithic artifacts - tear-drop bifaces identical to the Berelekh specimens (Pitulko et al., 2014a,b,c,d) known in Northwest North America as Chindadn points (Easton et al., 2011; Goebel, 1992; Goebel and Slobodin, 1999). The NKL site fully replicates the Berelekh complex in geology, age, tool morphology (Figs. 14 and 15), and bone/artifact association.

The Berelekh geoarchaeological complex (70°30′ N, 144°02′ E) consists of an archaeological site and a mass accumulation of mammoth bones (Pitulko, 2011; Pitulko et al., 2014a), with no indication for human involvement in its formation. Mass radiocarbon dating demonstrates two distinct chronological intervals in the history of the Berelekh geoarchaeological complex. A short chronological overlap between the time of formation of the 'mammoth graveyard' and the human occupation episode spans from 12,000 to 11,800 years BP (Pitulko et al., 2014a). The site produced a limited number of artifacts, mostly lithics, of which Chindadn points, a fragment of a stemmed point, lithic pendants, and the ivory spear discovered by Vereschagin (1977) are the most interesting (Fig. 15). It is proposed that humans were using the mass accumulation of mammoth as a raw material (ivory) source,

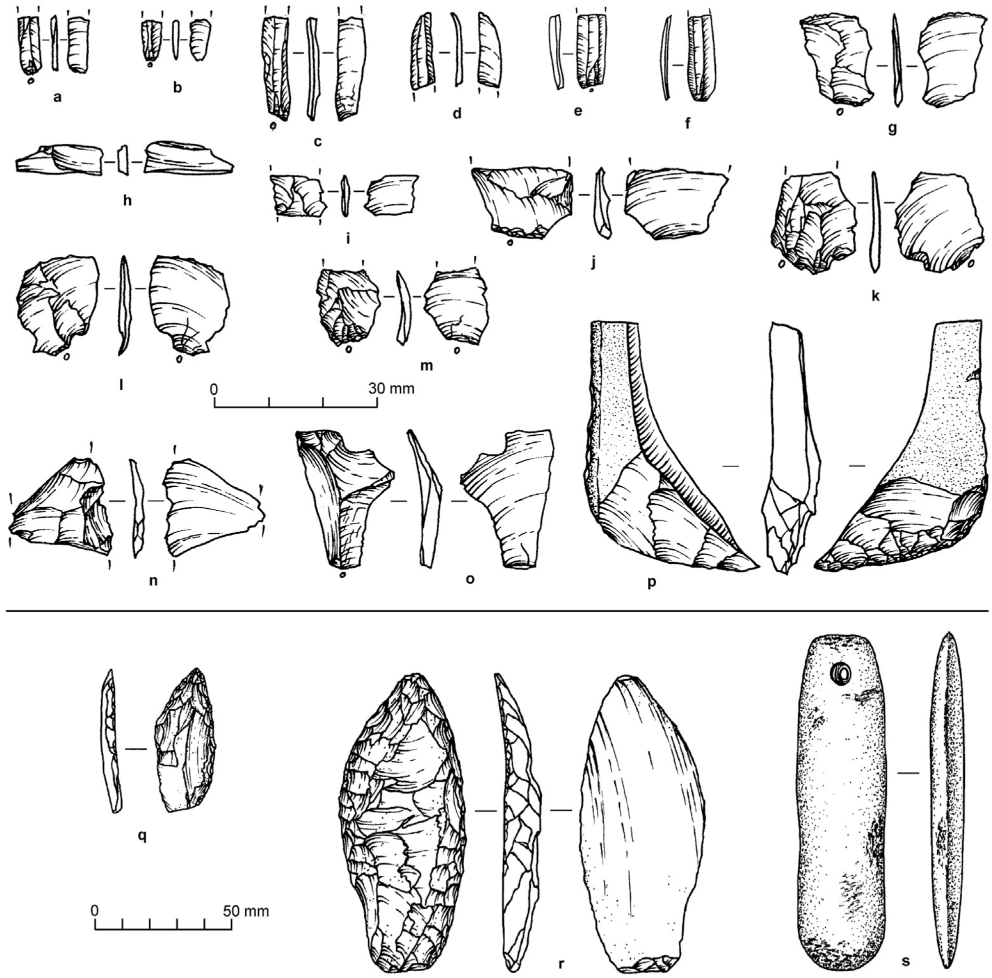

Fig. 13. Lithic material from Urez-22 site (a-p) and Achchaghyi-Allaikha accumulation of mammoth (q-s).

and then visited the site, perhaps after the mammoth bones were deposited.

Finally, Achchaghyi-Allaikha (70°32′ N, 147° 23′ E) mammoth accumulation on the Indighirka River (Nikolskiy et al., 2010) has also produced some evidence for presence of humans near the site: a few lithic artifacts, points or cutting tools, and a pendant (Fig. 13: q-s). Their age, obviously, cannot exceed that of mammoth remains and therefore should be estimated as not older than 12,400–12,500 ^{14} C years BP, based on the series of mammoth remain dates from Achchagyi-Allaikha (Nikolskiy et al., 2010). Curiously, there is a definite similarity between these objects and the stone implements of the Yana RHS site which is significantly older and dates to 28,000 BP (Pitulko et al., 2004, 2013a). This similarity could be interpreted as resulting from the same function for these tools rather than an indicator of “cultural links” between the sites which would be commonly suggested in such case. One of these tools (Fig. 15: n) can be termed a stemmed or tanged point. Elongated stone pendants in the final Palaeolithic of Northeast Asia are not represented anywhere else, except the Ushki sites on the Kamchatka Peninsula in the materials of Ushki I site, layer 7 (Dikov, 1979: Fig. 21, No. 5). These observations, to a certain degree, support the idea of potential cultural links between the lowest components of Ushki and Berelekh sites, stressed by Goebel (2004).

Many of the mammoth bone beds found in northern Yana-Indighirka lowland (Achchaghyi-Allaikha, Berelekh, Ilin-Syalakh, Nikita, and MKR/UR22) are roughly contemporaneous, forming between 12,600 and 11,900 ^{14}C BP, during the Bølling-Allerod warming (Nikolskiy et al., 2010; Pitulko et al., 2014b, 2016a). Bone remains in all of them are almost 100% mammoth, and often represent a small group (perhaps a family group). In general, the last peak of mammoth population in Arctic Siberia corresponds to this time, predating the animal's final decline, in which humans have certainly played a role (Nikolskiy et al., 2011) since they had inhabited the area widely. All these mammoth sites contain more or less well-pronounced archaeological material. In most of the cases mammoth procurement is evident, while for some (Berelekh and Achchaghyi-Allaikha) we could only demonstrate their use by people as raw material source (ivory) after the deposition. In any case, Arctic Siberian inhabitants were hunting the mammoth as long as it was around, making the final contribution to the species' extinction in this area. The extinction itself, however, was a long climate-driven process for which Upper Paleolithic hunters should not bear much responsibility (Nikolskiy et al., 2011; Pitulko and Nikolskiy, 2012).

2. Conclusions

From the very beginning, human habitation in Arctic Siberia was constantly driven by environmental changes whose effect on the human spatial distribution pattern, culture, and behavior are well-pronounced in the archaeological record. The open habitat created conditions for a number of revolutionary Upper Paleolithic

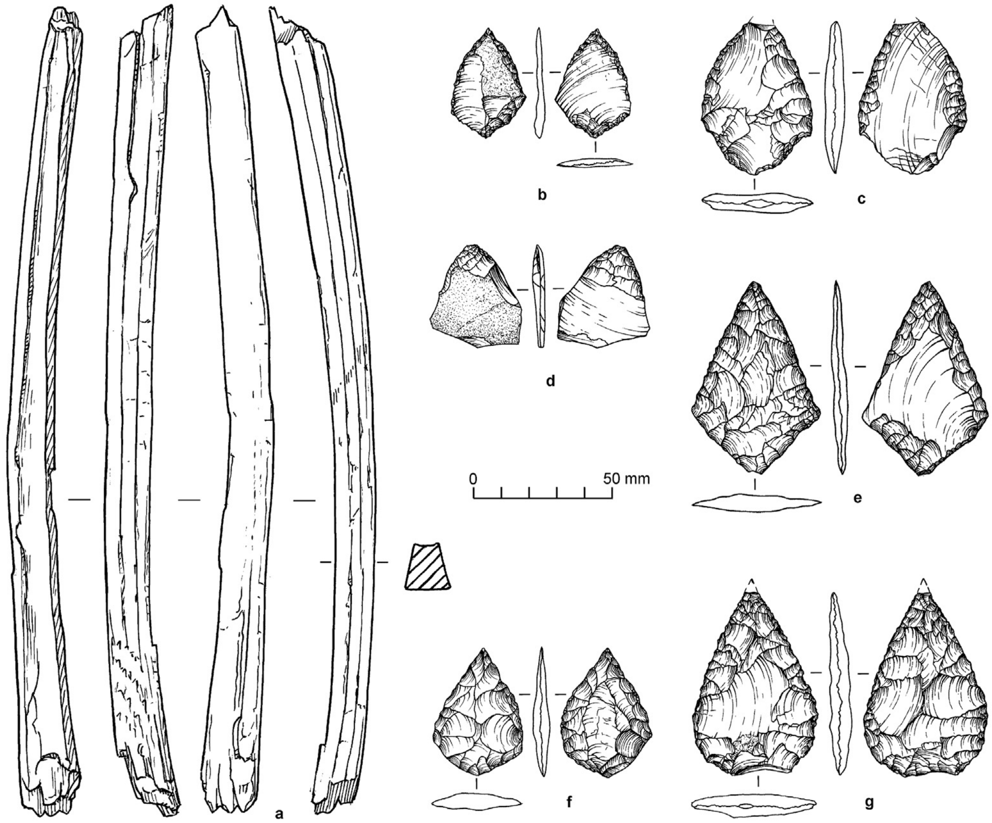

Fig. 14. Artifacts from Nikita Lake site: **a**, ivory preform for spear point; .**b**-**g**, Chindadn points (**d** – fragment).

technological innovations necessary to exist in a treeless, basically flat topography. Thus, unlimited use of bone and ivory tools became the greatest innovation of the Upper Paleolithic coeval to the time of the MIS 3 mammoth steppe formation. As soon as humans were armed with this technology, which allowed successful protection and subsistence in open landscapes, they became capable of quickly colonizing the mammoth steppe across northern Eurasia including the Arctic regions. A few lines of evidence indicate that it was anatomically modern humans who entered Arctic Siberia around 45,000 years ago (Fu et al., 2014), at the very end of early MIS 3. Early appearance of the anatomically modern humans in the Arctic Siberia and then in Beringia suggests that the settlement of Beringia was part of modern human dispersal in northern Eurasia, as concluded by Hoffecker et al. (2016). Remarkably it is well expressed in its European part where it is marked by Byzovaya and mamontovaya Kurya sites in the western side of Urals (Svendsen et al., 2010).

Upper Paleolithic finds north of the Arctic Circle are very rare elsewhere. In the arctic territories of West Siberia currently lack any examples. However, there are archaeological finds in the neighboring European Arctic in the northern Urals (Svendsen et al., 2010) including those discovered in Pechora River at the Arctic Circle latitude and dated presumably to around 40 ka ago. Together with radiocarbon-dated Pleistocene fauna remains collected in different regions of arctic West Siberia (Astakhov and Nazarov, 2010) and on the Vaigach Island (Markova et al., 2013), these finds allow the expectation of Upper Paleolithic archaeological material to be discovered some day in West Siberian arctic regions, too.

Importantly, in West Siberia, a human fossil with an early modern human genome was recently found at 57° N and produced a direct radiocarbon date of 45,000 BP (Fu et al., 2014). Although that bone was not found in an archaeological context, it remains an unequivocal indication for human presence in the areas immediately adjacent to the arctic regions. Actually, the newest archaeological evidence for early human habitation in the Arctic was discovered right on the border between West and Central Arctic Siberia (that is, basically, the Taimyr Peninsula).

Stone Age archaeological record in Central Arctic Siberia remains really scarce. Most of the finds date to Middle and Late Holocene (Khlobystin, 2006). However, the earliest known evidence for human habitation in this area dates now to almost 50 ka ago (Pitulko et al., 2016a,b). There are some indications for human presence in this area in the late MIS 3 associated with the remains of Kastystakh mammoth (Kirillova et al., 2012). Possible terminalPleistocene finds have been made in the Pyasina River headwaters (Khlobystin, 2006). Both tool morphology and geology of the area suggest the late Pleistocene age of the latter finds, probably 13-12 ka ago. Most Upper Paleolithic finds are located further east, in the eastern portion of Arctic Siberia.

The early occupants of Arctic Siberia were sparsely distributed, but their descendants presumably maintained successful survival throughout the middle MIS 3. By the end of MIS 3, they settled in the western part of Arctic Western Beringia in the lower reaches of the modern Yana River valley. They were not completely preoccupied with mammoth hunting, as indicated by a lack of mammoth mass kill sites. Their subsistence was based mainly on bison, horse, and reindeer while mammoth procurement was aimed largely at getting the tusks, an important raw material. Permanent shortage of wood typical for treeless landscapes stimulated wide use of ivory for tool making.

Early arrival of modern humans in the area close to the Bering land bridge and a long stay in this area would be advantageous for entering the New World before the Last Glacial Maximum. Although there is currently to definitive evidence for this model,

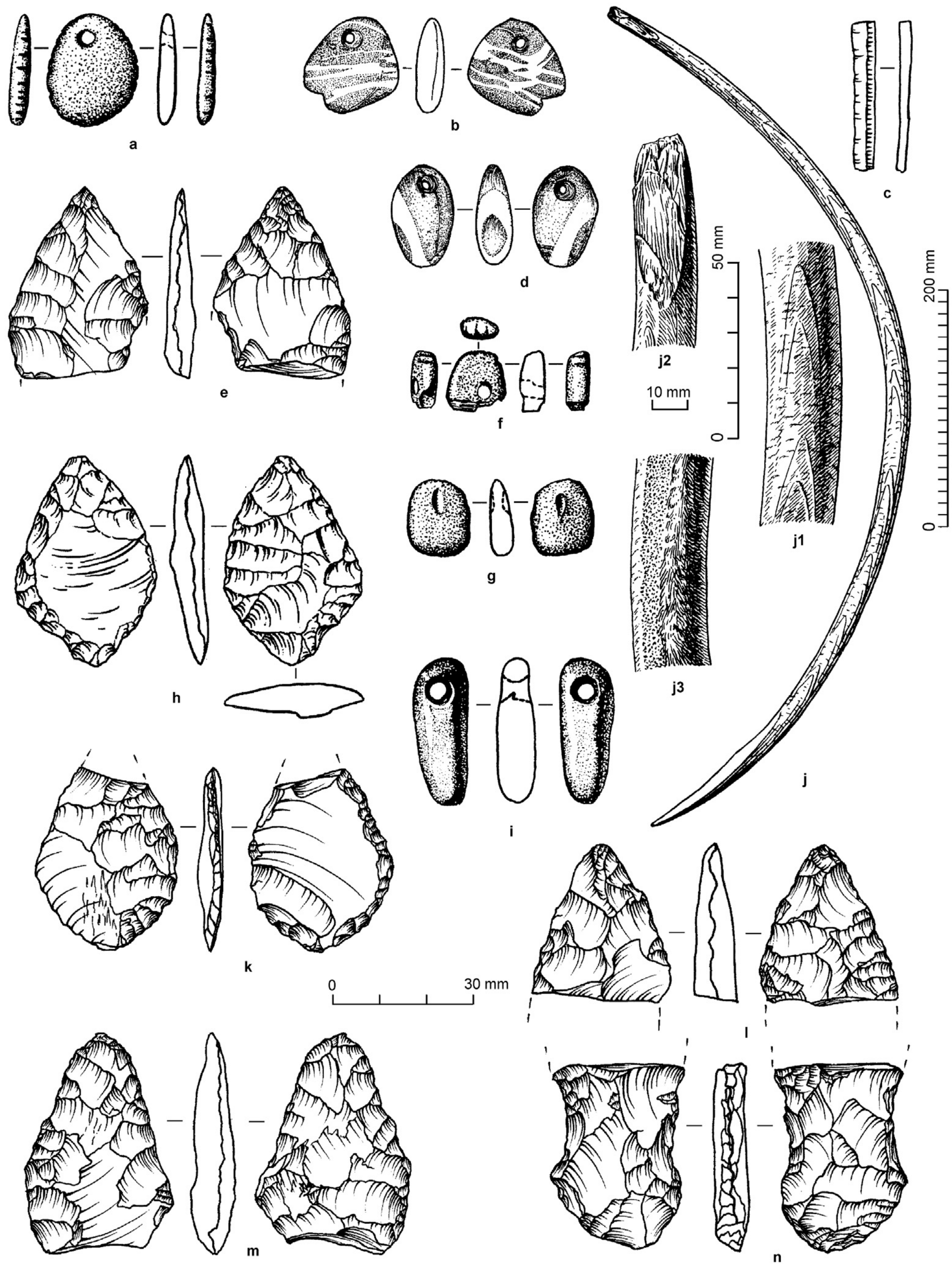

Fig. 15. Berelekh geoarchaeological complex: **a**, **b**, **d**, **f**, **g**, **i** – lithic pendants; **c** – microblade; **e**, **h**, **k**, **m** – Chindadn points; **l** – a fragment of bifacial point; **n** - bifacially worked basal part of stemmed point; **j** - an ivory rod; **j1** - surface of the tool with visible cone structure; **j2** - close-up of the broken end and surface of the tool (**j3**).

the possibility has to be taken into account. Alternatively, people may have stayed in the area, according to the Beringian Standstill model developed by Tamm et al. (2007). This model finds a certain support in the faunal record that identifies conditions of the Beringian isthmus as a constraint to the Late Pleistocene migration to the New World (Heintzman et al., 2016; Meiri et al., 2014). It also finds support in conclusions from the most recent ancient human mtDNA research by Llamas et al. (2016), who demonstrate that human dispersal into the Americas started around 16 ka BP, after isolation of this population in Beringia for several millennia.

However, the newest archaeological findings that show successful human habitation in arctic Siberia starting almost 50 ka ago (Pitulko et al., 2016a,b) put this model into question. At the same time, it is hard to say whether or not these groups had a chance to penetrate into the New World heading south to unglaciated North America through the ice-free corridor. For example, numerical modelling of the evolution of the North American Ice Sheet Complex during major Upper Pleistocene OIS stages, including OIS 3 (Stokes et al., 2012), does not suggest a possibility for human use of this pathway at around 40 ka ago.

Nonetheless, Dyke (2004) proposes a pre-LGM (late MIS 3) position of glacier margins that leaves the corridor ice-free and penetrable for humans for a certain amount of time before the coalescence of the Laurentide and Cordilleran ice sheets. Interestingly, there are sites of pre-Clovis age far south of the LGM Laurentide glacier margin whose ancestry remains unknown (Halligan et al., 2016; Waters and Stafford, 2013; Waters et al., 2011). In theory, they may have a pre-LGM progenitor whose presence is not archaeologically recognized yet. A long history of human survival in Arctic Siberia - that is, Western Beringia in a broad context – instills a decent amount of hope that some day it will be.

Traces of human habitation within this region that date to the LGM (MIS 2) were previously totally unknown, or not recognized widely, which appeared consistent with the human depopulation model developed for entire Siberia or for its certain regions (e.g., Goebel, 2002; Graf, 2009, 2010; Hoffecker and Elias, 2007), but criticized by different authors (e.g., Kuzmin and Keates, 2016; Pitulko, 2006; Pitulko and Pavlova, 2010). At first glance, this hypothesis is reasonably supported by the MIS 2 environmental record which reveals cold and dry conditions for the LGM. However, Astakhov (2014) concludes, that even through this coldest and driest period, the Siberian mammoth steppe biome remained supportive enough for large grazers providing sufficient forage resources for them.

Despite certain changes in biodiversity and in animal population numbers, the steppe-tundra grassland habitat was still comfortable for humans. For example, the decline in mammoth population in Arctic Siberia during the LGM (Nikolskiy et al., 2011) is compensated by growing bison population numbers (Nikolskiy and Pitulko, 2015). As a food source for the Upper Paleolithic settlers of Arctic Siberia, mammoth easily finds a substitution in bison. However, bison does not provide tusks, like mammoth.

Upper Paleolithic inhabitants continued living in Arctic Siberia during the LGM. At least at the beginning of it, they occupied the Yana-Indigirka interfluve and possibly the Wrangel Island. As demonstrated, the evidence for these occupations is linked to mammoth procurement in all cases, but currently lacks conclusive cultural attribution. In any case, these localities are documenting human survival in Arctic Siberia through the LGM and as such, undermine the human depopulation hypothesis.

Decline of the West Beringian mammoth population during and after the LGM probably led to important cultural changes that are visible archaeologically (Nikolskiy et al., 2011). Dispersion of the Beringian Microblade tradition follows the area populated by mammoth in a northerly direction when mammoth habitat shrinks. In the areas abandoned by mammoths, human occupants completely switch to the procurement of herd species. Thus, mammoth extinction serves as a trigger for archaeologically visible technological changes (Pitulko and Nikolskiy, 2012). Notably, the oldest known microblades in Arctic Siberia date to ~12,500 years BP.

The youngest pre-Holocene archaeological material in Arctic Siberia in all cases relates to mass accumulations of mammoth remains. Most of the sites suggest that people focused on mammoth hunting for the meat towards the end of the “mammoth era,” while in the millennia before they were more interested in the raw material this animal provided (ivory). Culturally, these sites reveal a stable trans-Beringian analogy - a Chindadn point. Chindadn connection for now is the only visible intriguing cultural link between Eurasia and the New World but is not solid evidence for human movement west to east. All such finds occur approximately at the same time that roughly corresponds to a transgression in the Bering land bridge area. In theory, these tools may be linked to migrations from the central part of Beringia when it became inundated, reflecting a movement of people back to Arctic Siberia after the bridge collapsed, but this is very speculative.

Interestingly, the early Holocene archaeological record for Arctic Siberia is limited to very few dated sites found either in the northern areas including today's New Siberian Islands (Pitulko, 2001), or in low mountain regions (Dikov, 1997; Kiryak et al., 2003). Thus, in the entire northern Yana-Indighirka lowland and in New Siberian Islands, which is an enormous area with a number of Late Pleistocene sites known, one can currently only name a single early Holocene site, located on the Zhokhov Island (Pitulko, 2013). This may indicate a significant decline in local human populations caused by both mammoth steppe biome collapse and the environmental changes enforcing degradation of the permafrost, changes in topographya and rapid evolution of plant and animal associations.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.quascirev.2017.04.004.

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