Global Journal of
Archaeology & Anthropology
ISSN: 2575-8608

Juniper Publishers
key to the Researchers

Research Article
Volume 14 Issue 3 - July 2025
DOI: 10.19080/GJAA.2025.14.555888

Glob J Arch & Anthropol

Explaining the Mammoth Economy, Smokehouses, and the Mezhyrich Map

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Submission: June 09, 2025**; Published:** July 2, 2025

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Abstract

This study explores a body of evidence regarding the hunting and meat processing of *Mammuthus primigenius* (woolly mammoth) in Eastern European river basins before, during, and after the Last Glacial Maximum. Evidence of mammoth mass and weight, river site selection, and the presence of all mammoth skeletal parts in technocomplexes provides a foundation for the arguments. The proposed mammoth economy encompasses five phases: procurement in rivers, river transportation (riverine transport hypothesis), butchery, food preservation through cold-smoking (smokehouse hypothesis), and meat storage. Mammoth-bone circles including large ovals and elongated structures are the remains of smokehouses for cold-smoking. Ubiquitous burnt bones represent fire fuel that slowed the speed of combustion for cold-smoking purposes. The Mezhyrich Map, which is perhaps the oldest process chart in the world, confirms the key sequences of docking the mammoth carcass, initial butchery, cold-smoking, and storage. Artifacts and site maps supporting the smokehouse hypothesis include charcoal, micro-lithics, ash, burnt and calcinated bones, floor dimensions consistent with quantities of meat, construction using large mammoth bones, rows of aligned flat hearths, and the absence of formal entranceways. The evidence and inferences in this study, backed by the process of elimination, provide the best explanations for the successful mammoth economy, smokehouses, and the Mezhyrich Map. This study explains how all parts of the mammoth carcass made their way to mammoth-bone circles settlements.

Keywords: Mammoth-Bone Circles, Mezhyrich Map, Mammoth Economy, Smokehouse Hypothesis

Problem: After the 1871 discovery of mammoth bones in Gontsy, Ukraine and subsequent archaeological excavations by distinguished archaeologists at some 70 locations, the entire mammoth economy and original use of the mammoth-bone circles in Eastern Europe have remained mysteries. Mammoth hunters have sometimes been characterized as scavengers and procurement by hunting doubted. Segments of the mammoth economy have been discussed in scientific literature, but the entire economic system has not been explained. Iakovleva et al. [1] wrote: "However, the real scientific target is the understanding of the system at the origin of the settlements and of the settlements at the origin of the peopling in a territory, the mammoth based economy of the system." Pryor et al. [2] agreed that it is "necessary to clarify how humans actually used these spectacular mammoth bones sites, making them less enigmatic and more accessible to archaeological investigation." Consideration of archaeological publications, mammoth weight, riverine site locations, the presence of all mammoth body parts in mammoth-bone circles, and basic meat science permit logistical understanding of all phases of the successful mammoth economy.

Introduction

Three key facts underpin understanding of mammoth-bone circles (MBC) in Eastern Europe: the significant mass and weight of killed or found woolly mammoths (*Mammuthus primigenius*), the placement of technocomplexes near navigable rivers, and the presence of complete mammoth skeletons at MBC technocomplexes [2-6]. These facts, data, many studies, and contextual analyses help explain all five phases of the mammoth economy: procurement, transportation of carcasses, butchery, food preservation, and meat storage. After procurement, each interdependent phase requires an action determined and forced by the previous and following phases. The segments or phases combined demonstrate the complete mammoth economic system, the understanding of which is a long-sought Paleoanthropological target [1].

The resulting efficient economic system was symbolized and defined by MBC predictably erected in the riverine technocomplexes. It is proposed that the circles, ovals, and elongated structures, together with their associated bones, skulls, tusks, loess foundations and walls, and other structural elements outlined, upheld, and ensured smoke containment designed to cold-smoke and dry mammoth meat. Multiple MBC were found at most of 70 dedicated settlements [5].

All lithic cultures in the studied region, both Neanderthal and anatomically modern humans (AMH), possessed functional tools such as points, scrapers, and axes that were adequate for sustaining a mammoth economy. Environmental determinism imposed by mammoths, terrain, river power, microbes affecting food safety, and climate structured production methods and architecture spanning 28,000 years, traversing and surmounting lithic cultures, races, and times. Furthermore, this environmental determinism explains similarities between Gravettian, Epigravettian, Willendorf, Pavlov, Kostenki, and Avdeevo cultures and the perception of Soviet archaeologists that a unity encompassed mammoth sites on the central Russian plain [7].

The Premises: Immutable Facts

Weight and Mass of Mammoths

In their European form, adult male mammoths weighed approximately six metric tons on average [8], while adult females weighed approximately four metric tons. The largest woolly mammoth (European form) weighed over eight metric tons [8]. A reasonable dressing percentage of 40% [9] equates to approximately 1.6–2.4 metric tons of butchered raw mammoth meat and fat from normal adult mammoths. Mammoth carcasses were too heavy to move on land.

River Site Selection

Hunters selected sites based on hunting and transportation value. Procurement, transportation of carcasses, butchery, food preparation, and storage–all five segments of the proposed mam-

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moth economy–were predetermined based on site selection in woolly mammoth territory, the weight of mammoths, and the necessity of meat preservation.

All mammoth sites or mega-sites with MBC, including larger oval MBC and elongated structures (hereafter, long smokehouses), were based on or near rivers. An assumed correlational coefficient of 1.0 exists between MBC and their host rivers over 28,000 years. Sites with MBC are concentrated in the Dnieper and Don River basins, although MBC are found outside those basins [10]. The Central European mammoth sites are also close to rivers and analogous to the MBC sites discussed; however, they do not contain as many MBC as those to the east [11], despite Klima finding eleven MBC at Pavlov [12]. Based on a simple map of Eurasian mammoth sites, some correlation between mammoth localities and rivers existed in all Eurasia [13] (Figure 1).

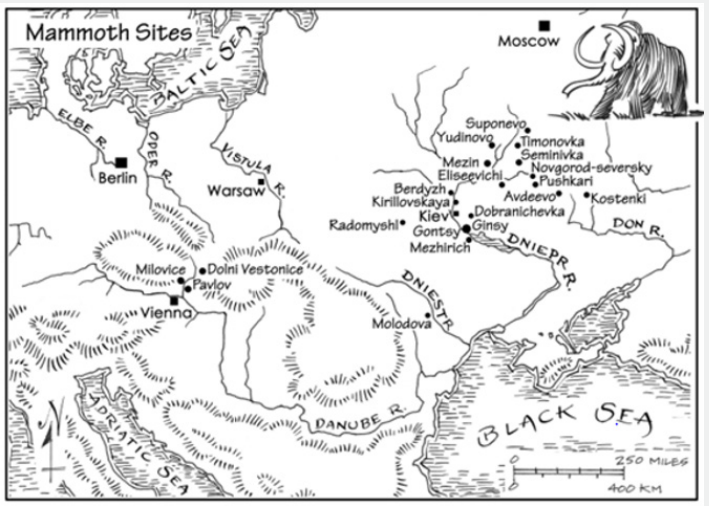

Figure 1: Mammoth site drawing by Jeffrey Mathison, used with permission of. Dr. Pat Shipman.

MBC are referred to by various names, such as dwellings (most common), huts, structures, yaranga dwellings or huts, chooms, or tipis. These settlements are variously called technocomplexes, mega-sites, settlement complexes, MBC settlements, Upper Paleolithic sites, and mammoth sites. Settlements contained more than the MBC.

Typically, MBC were built on "high river terraces or low mountainous areas in close proximity to water. Mid-slope locations with easy access to rivers are common" [5]. They were situated on "a promontory cut by ravines on the slope of a river valley" [1,14]. Iakovleva and Djindjian [15] referred to the ravines as palaeo-ravines and noted their close proximity to the mammoth-bone structures in several Dnieper Basin technocomplexes. The sites discussed in this study were built near the following rivers: Avdeevo (Seym & Rogozna Rivers), Dolní-Věstonice (Dyje River), Eliseevichi (Sudost' River), Gontsy/Ginsy (Udaï River), Ioudinovo/Yudinovo (Sudost' River, tributary of Desna River); Kostenki 1, Kostenki 4, Kostenki 11-1a/Anosovka 2 (Don River); Mezhyrich (Ros & Rosava Rivers, near Dnieper River), Moldova (Dniester River), Pushkari (Desna River), and Zaraysk (Osyotr River). Olga Soffer found that sites with more mammoth bones were more likely to have MBC [7].

According to Haynes [16], most of the Paleolithic proboscidean kill sites globally were located in or near bodies of water, rivers, streams, swamps, bogs, some brackish bodies, alluvial or fluvial environments, or within saline paleolakes. Finkel and Barkai [17] determined that water was a critical necessity and a reliable attractant for elephants. During the arid Ice Age, the demand for water was high because of the slower hydrological cycle. Riverbeds and associated springs contained water during arid glacial periods, when precipitation decreased and smaller streams froze [18]. In times of drought, elephants fight for water access and break tusks in the process [19]. Water, mineral requirements, and protection from winter winds drove mammoths down into naturally extended (and sometimes modified) riverbeds, with mud, water, ice, pits, crossings, ravines, and traps. In winter, river valleys were a primary source of mammoth food [20].

Surrounded by Russian Plain steppe-tundra vegetation exposed to full sun, which surprisingly had animal biomass and plant productivity almost equal in nutritional content to the African savanna, even in the coldest and driest grasslands [21], hunters encountered many well-fed animals in need of water, minerals, and passage. In one isotopic study, mammoths were found to have seasonally migrated 250–400 km from north to south to escape harsh winters [22].

Proboscideans moved to meet their nutrition, water, and mineral requirements [23]. Because of their size, they require more resources than other animals, with adult elephants needing approximately 9 mg of sodium per kg of body weight daily [24]. They obtain minerals from plants but also seek salt-rich soil, springs, licks, mineral oases, paleolakes, endorheic basins, solonetz or solonchak soils, or salt-laden food to prevent mineral deficiency

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[25,26]. Mammoths consumed dirt for minerals when necessary [25,26]. Soil minerals attracted mammoths and other game to riverbanks with exposed soil. In Ukraine and Russia, including Kostenki, mammoths consumed salty tephra from Campanian ignimbrite eruptions [25,26,27].

The prevalence of MBC is correlated with the size, navigability, and streamflow of the rivers hosting them. The many sites at Kostenki-Borshevo are directly on the Don River, downstream of much of that drainage basin, while of three seasonal sites without MBC per Iakovleva et al. [1], Semenivka and Fastiv were on minor tributaries and closer to the headwaters of their rivers, while Jouravka was upstream from Gontsy and Vilchanka. (Iakovleva 2016) (Figure 1).

All Parts of Mammoth Carcasses Brought to MBC

Upper Paleolithic mammoth sites were significantly more likely to contain all parts of the mammoth skeleton [3-6,11]. MBC sites contained all parts of the mammoth skeleton, including the skull, tusks, vertebrae, and largest bones, as visibly proven by MBC and bone bed components [1,11,28]. The arrival of all elements of the mammoth skeleton (and meat) at MBC sites necessarily means that the carcasses were brought as close to the technocomplexes as possible by water, with some human guidance or riding of the carcasses in the river likely desirable. The butchered parts were then hand-carried in manageable meat packages or as bones and placed within the largest structures in MBC sites, smokehouses, nearby work sites, or bone beds.

Rey-Iglesia et al. [29] performed a biomolecular analysis of bones from Kostenki 11-1a, discovered in 2014, in which the MBC contained 64 mammoth crania and was close to two other MBCs. Furthermore, he found that, "only a small number of the bones excavated in the structure are articulated, primarily vertebral bones (Dudin & Fedyunin, 2019), suggesting the mammoths did not die on site... Thus, we suggest the woolly mammoths at Kostenki 11-1a died off-site and were harvested and moved to the structure." Only one way to move the carcass was available.

Phases of the Mammoth Economy

The phases of the mammoth economy reveal in-depth "planned preservation treatment" [18], as follows:

Phase 1: Procurement

Ethnographic and ethnohistorical accounts reveal that hunter-gatherers hunt and kill elephants in many ways [30]. Shipman [5] reported that mega-sites or MBC sites were successful because they employed complex projectile weaponry and domesticated wolf-dogs.

Soffer found that the acquisition of mammoths was in or near floodplains and often near ravines [7]. The lower river floodplain, ravines, crossings, approaches, and wide trails formed by regular mammoth movements offered numerous ambush, trap, concealment, and disadvantage sites, some of which could have been constructed or modified [31]. According to Svoboda [14], mammoths were at times driven or trapped inside gullies and blind valleys. Slick, frozen, or flat slopes (natural, constructed, or containing barriers) kept mammoths in rivers because of their flat feet.

Investigators have not found many kill sites on land in the vicinity of the major MBC technocomplexes or upstream. Hunted mammoths were smart and old enough to avoid the smell, sight, and noise of human settlements; therefore, kill sites on land near technocomplexes were not expected. An absence of single mammoth kill sites, by process of elimination, helps confirm that mammoths were killed or found in the river or riverbed, upstream from the MBC sites. The river transport of carcasses depended on procuring the slaughter or discovery of mammoths in the river.

Phase 2: Transportation of Carcasses

There was only one way to move a whole mammoth carcass, whether killed, found, or scavenged, to a settlement: downstream by a flowing river, ensuring minimal inefficient land transportation of parts to smokehouses and bone beds and providing protection from predators in transit. Simple process of elimination negates other transport methods. The distance traveled by the carcass depended on the upstream location where the mammoth was killed or found.

The destination for large bones, with or without attached meat, was the bone bed of the settlement, usually in a ravine, where hunter-gatherers could continue to butcher, and exploit meat, bones, and other tissues. Many large bones, mammoth skulls, and tusks formed the MBC, indicating that they came most directly from whole carcasses.

Because rivers in this region froze for multiple months each year and perhaps dried up at times, the best mammoth hunting was probably restricted to warmer months after ice thaw, when river flow was sufficient. Drought could explain periodic site abandonment. Warmer weather and increased rainfall could explain re-occupation of sites or regions [32]. Soffer [7] wrote that the MBC sites were abandoned or sparsely populated from 20 kya to 18 kya, the Valdai Maximum, and that growth periods were before and after these two millennia. Dolukhanov et al. [32] agree that East European Plain Upper Paleolithic sites were more active during warmer periods, including three times of higher population density, 41-36 ka BP, 33-20 ka BP (with peak at 22 ka BP), and 20-15 ka BP (along major river valleys), but show some activity during the peak of the LGM.

Every major MBC technocomplex discovered thus far was located on a navigable river (or at the confluence of two rivers) capable of transporting mammoth carcasses downstream, at least during some times of the year. Through the process of elimination and based on mammoth weight, rivers were the only efficient, practical, and possible way to bring the full carcass to a single settlement, especially for the unwieldy vital and prized fat content in the brain, subcutaneous fat 10 cm thick, and bone marrow [33,34]. This fact supports the 1.0 assumed correlational coefficient between MBC and their host rivers. Maps show this very

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high correlation. Wood, bark, and trees could also be moved by river. Whether MBC people had boats or rafts is an open question.

Prohibitive physical land transportation costs, "staggering costs" per Soffer [7], included the weight of parts, transportation time (lost opportunity costs), number of trips necessary, distances per trip, uneven terrain, calories burned, limitations on butchery, problems securing loads, packs, containers, and packaging, difficulty in carrying fat, and high defense costs against predators along routes to smokehouses and at kill sites.

Transport of the mammoth carcass distinguishes the subject efficient sedentary mammoth economy from nomadic hunting. This phase brought carcasses to the MBC and its facilities rather than require nomadic hunters and gatherers and their vital possessions to travel to the carcasses. The creation of sedentary proboscidean hunting was an advancement over both nomadic hunting and the sedentary ambush hunting by Neanderthals at Neumark-Nord 125,000 ya, which required game to enter a small, designated killing zone [35]. Without river transport of carcasses, the MBC could not have been built. River transport explains why the MBC are constructed with the same large bones, skulls, tusks, jawbones, leg bones, etc., and have floor dimensions commensurate with the amount of meat brought to the settlement. River transport determined the main method of food preservation, as it deposited tons of raw mammoth tissues near the technocomplexes and required prompt mass preservation.

Phase 3: Initial Butchery

As shown on the Mezhyrich Map and Eliseevichi Ivory Plaque linked to the Mezhyrich Map by Soffer, driven by logistics, mammoths were butchered at river docks, so that meat and bones could be taken directly to smokehouses or bone beds via ravines. The location for initial butchery was the same for all efficient riverine technocomplexes: a point in the river maximizing river transport of carcasses and minimizing land transportation of mammoth or other animal parts to smokehouses, palaeoravines, and bone beds. Initial butchery and disarticulation, which were arduous tasks, would have been performed in the cold river after the mammoth carcass was docked at or near a paleoravine location closest to the settlement, as shown on the Mezhyrich Map and the Eliseevichi Ivory Plaque. This location provided a natural moat of river water to deter predators and with cold water and convective heat transfer kept the mammoth carcasses cool. River butchery kept the carcasses cleaner than other locations could provide. Except to the extent the hide or body had been punctured by hunting weapons, the carcass was initially sterile.

Phase 4: Processing of Mammoth Carcasses

The mammoth sites under consideration invariably had ravines that facilitated human foot traffic and the formation of bone beds in ravines. Meat was taken up to smokehouses, after primary or secondary butchery, while most bones were taken to the ravine bone bed. Fat was handled in unknown ways, although fat rendering, pemmican creation, and use with roasting or smoking meat seem most likely. Some smokehouses were conveniently located at the river edges; however, these were subject to flooding and left no archaeological record once washed away [36].

Initial butchery required disarticulation of most bones, as observed by Rey-Iglesia et al. [29]. Secondary butchery or some smoking could be performed in the bone beds, where hearths were found at some sites, but the bulk of meat went to the smokehouses.

Functional analysis should begin with the question, "What was done with all the meat and fat obtained from mammoths?" This will address the challenges arising from the large quantity of mammoth meat that required preservation sooner rather than later. In very general terms, moisture was removed from the meat and fat.

Cold-Smoking and Drying

Smoking predates cooking in containers [37] and is the natural result of fires in structures without chimneys or outlets for rising smoke. Cold-smoking is also more likely to occur in climates with problematic weather conditions [38]. Modern hunter-gatherers consume animal products almost exclusively in cold climates [39]. Modern meat science does not claim a perfect understanding of traditional smoking practices because of their variability [40].

Cold-smoking uses smoke from low and smoldering fires to gradually dry the meat, infuse it with smoke flavor, and bring it to a state where it can be consumed immediately, after aging, after heating or roasting over fire, or safely stored, frozen or unfrozen. No other food preservation or preparation methods available to Paleolithic meat processors preserved meat with these preparation and consumption options.

Cold-smoking smokes meat for hours, days, or weeks, depending on the intensity of the smoke, number of fires, smoke containment, size and consistency of meat packages, dry-aging, wood species or bone used as fuel, and desired outcome. Hot-smoking cooks meat; in contrast, cold-smoking dries and flavors the meat but does not cook it.

Wood Fuel

Wood smoke has antibacterial properties, contains multiple chemical compounds, and provides medicinal smoke [41]. "Smoking is a very ancient method of preserving food, no doubt known since the Paleolithic era. It consists of subjecting food to the action of smoke resulting from the pyrolysis of wood. The preservative effect of this technique is due to the reduction of the water activity of the smoked product and to the antioxidant and antimicrobial compounds of smoke that permeates the products" [42]. Dried and smoked meats retain the natural salt within muscle tissues, and thus, provide a measure of antibiotic protection after drying and smoking.

Bone Fuel

"Burnt bone, mostly spongy bone, is found on many archae-

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ological sites" [43]. Pidoplichko [44] found 40,000 pieces of charred bone in the first three excavated Mezhyrich huts. The discovery of many partially burnt bones throughout MBC regions substantiates the use of bones in cold-smoking, especially when nearby areas of forest existed, such as at Mezhyrich [45]. Animal bones combined with wood are effective in maintaining lasting and smoldering combustion [46,47], which are desired characteristics in cold-smoking fires. Higher inorganic mineral content retards combustion. "Calcined bones further indicate that the fire burned longer than the usual natural fire (David, 1990)" [3]. Based on bone burn patterns, Bosch et al. [3] found that bones were put on fires by humans.

Less Fuel and Labor, More Efficiency

Cold-smoking uses smoke, time, and drying, not heat, to prepare, flavor, and preserve meat. In terms of reducing energy and preparation costs, cold-smoking had clear economic, time-saving, resource-saving, and labor-saving advantages during the Ice Age. Cold-smoking can be a quick blackening of meat for exterior preservation, or a slower cold-smoking followed by lengthy dry-aging, as undertaken in 18th and 19th century smokehouses in the United States. Unlike cooking, slow cold-smoking does not require constant attention to either the meat or fire, can proceed intermittently, and does not have a precise preparation deadline.

Bones with fat or grease aid in combustion, as does dripping fat during the rendering process. Smoke from burning bone is chemically different from and probably had advantages and disadvantages compared to wood smoke.

Paleolithic smokers regulated the initial drying that formed the meat pellicle, any aging or dry-aging before or after smoking, heat, smoke, time, moisture, fuel, flavor, meat package size, and the type and immediacy of handling. If the temperature was approximately 4° C (40° F) or lower, and perhaps higher, the meat could have been left to age or dry in a smokehouse for several days or cold-smoked under a small fire. Cold temperatures provided greater flexibility for avoiding spoilage. After cold-smoking and subsequent dry-aging, meat can be flamed, roasted, or warmed. Cold-smoking, a form of partial drying, preserved and prepared meat for consumption, eliminated the storage step, and moved the meat package more efficiently from slaughter to final production and storage. Cold-smoking in 18th and 19th century in the United States was preceded by immersion in salt for some weeks; and after cold-smoking was followed by dry-aging for months to improve taste and allow enzymes to degrade the meat.

In Central Africa, elephant meat is routinely smoked after slaughter to prevent spoilage, reduce weight, and avoid detection [48]. "Very little meat was carried away fresh; it was almost always carried away smoked" [48]. In the Congo, Mbuti pygmies and nearby villagers smoke-dried their elephant meat to a blackened exterior for preservation and to reduce its weight before transporting it from the rainforest hunting camp to their homes [49]. Meat was smoked by different individuals during multiple fires, and not en masse. A blackened exterior covers most bush-meat sold in modern Africa.

This photograph of (treated) drying elephant meat (Figure 2) taken in Zimbabwe shows the physical Paleolithic impossibilities of cooking a ton of mammoth meat and provides an idea of the scale of structures needed for the mass drying or smoking of proboscidean meat.

Drying. Drying and cold-smoking are very similar processes, as both reduce moisture content and impart flavor. Drying meat in the Paleolithic era included smoke-drying, air-drying in the sun, or with fire [50]. To achieve faster drying, the meat was cut into strips. In the Paleolithic era, without salt, cooking, or the consumption of raw meat, drying and cold-smoking were the available preservation options. Cutting mammoth meat into strips was a labor-intensive chore compared to cold-smoking larger quantities. Drying in the sun was a labor-intensive method and amongst flying and large Ice Age predators and pests might not protect the meat. One efficiency of the proposed economy was protection of carcass contents from predators and insects, which rivers, fire, smoke, surrounding walls, and guarded settlements provided.

Figure 2: Photograph of drying elephant meat by Dr. Gary Haynes. Used with permission of Dr. Haynes.

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One medium-sized mammoth could feed 50 humans for at least three months [4]. Using this calculation, a group of 12 individuals could survive for an entire year on one bull mammoth, provided they could preserve the meat and fat. Mammoth people probably spent much less time hunting than in post-acquisition activities, which would advance their culture and probably equalize the workload of the genders. (Stopp, 2002).

Fat Rendering. Hunters with access to ungulates typically prize fat over lean meat [34], and in freezing weather, fat was necessary. Mammoths yielded plenty of both. Modern rendering processes "involve the application of heat, the extraction of moisture, and the separation of fat." (Meeker & Hamilton, 2006, p.2). The extraction of moisture is yet another method of drying. In bone beds, smokehouses or external fires, probably in warmer months, mammoth fat may have been rendered in fire-heated bones, bison or horse skulls, tusks, or other surfaces or containers loaded with mammoth fat, in addition to any marrow.

Pemmican. Pounded dried or smoked meat mixed with rendered fat and placed in a hide, Native North American "pemmican" [34,51], could have been prepared by Paleolithic hunter-gatherers 20,000 ya. In fact, they all could store pemmican in hair-out bison hides sewn shut, with or without currants, berries, or other vegetal resources. Mammoths contained large quantities of fat [52]. Smoked or dried meat could have provided half of the Paleolithic pemmican, with rendered mammoth fat providing the other half [34]. Dried meat was crushed with stones to prepare pemmican [34].

Due to their ancient use, versatility, availability, economy, food safety, and scalable capacity, cold-smoking and drying (including fat rendering) under multiple schedules and methods seem to be the universally applied methods of efficiently preserving proboscidean meat throughout millennia, and not to the exclusion of subsequent cooking, roasting, boiling, or heating.

Many nominal references to "dwellings" without analysis in the scientific literature refer to smokehouses, although dual or triple uses cannot be eliminated. Multiple uses for structures would have been more economical than single uses. Smokehouses may have been used as smokehouses for two, three, or four warm-weather months every year, and during winter may have stored plant food, firewood, or dry bone fuel for fires.

Other Meat Preservation Methods Inadequate or Incomplete

Hot Smoking. Hot-smoking cooks meat. Paleolithic smokers may have used this process for smaller quantities of meat for prompt consumption or after partial cold-smoking; however, this process required too much heat in the Ice Age tundra-steppe, could not process 1.6–2.4 metric tons of mammoth meat simultaneously, and did not sufficiently preserve the meat for storage [53].

Cold Water and Underground Storage and Freezing of Raw Meat. Fisher [54] found evidence of Paleolithic cold-water storage and subsequently proved its viability as a proboscidean meat storage method. Rivers were only suitable for mammoth meat storage when the whole carcass remained in the frozen river after being killed, dying, or falling through the ice. Cold water storage and freezing raw meat make bacteria dormant but do not kill them [55]. Paleolithic underground caches are associated with nomadic hunters and often had to be covered with rocks. These methods delayed final preservation and consumption, did not always protect meat from predators or microbes, may have required digging in permafrost, and were not timely or efficient.

Grilling, Frying, Roasting, Baking, Steaming, Boiling, and Cooking. Cooking with heat was not a mass processing option in Paleolithic times. It was not suitable for the volume of meat, cooking with high temperatures at one time, fitting within Paleolithic cooking facilities, or making the meat safe from microbes during later storage. These methods do not preserve meat because too much moisture is retained, and harmful bacteria still proliferate in cooked meat above 4º C (40º F). For the meat mass, none of the eight direct and indirect cooking methods described by Demay et al. [18] could have been used or applied simultaneously, but the first two preservation steps listed, "desiccation by air or sun" and "wood-smoking" were the main smokehouse preservation steps in the proposed mammoth economy [18]. Nevertheless, meat could be roasted and fat rendered in ventilated smokehouses, which would create an abundance of smoke and expedite cold-smoking of the mass of meat while selected meat roasted.

Artifacts, site maps, diagrams, MBC structures, meat science, and elimination processes indicate that cold-smoking, drying, and fat-rendering were the best and usually only preservation methods used in the MBC settlements.

Raw Meat. Raw meat and internal tissues provided abundant bait for hunting and unattended traps and snares to take foxes, wolves, bears, and wolverines for their furs, and voluminous rewards for any operant conditioning, dependency, eventual domestication, or meat-expensive feeding for or with wolves (*Canis lupus*), wolf dogs, or dogs [56]. Hoffecker [57] wrote that semi-sedentary technocomplexes were a prerequisite for dog domestication. Elevated meat caches could attract wolves for operant conditioning, capture, domestication, or fur acquisition.

Putrefied meat. Some ice-age populations may have tolerated or desired putrefied meat [34] although such consumption is more associated with nomadic foragers. (Stopp, 2002). Moist putrefied proboscidean meat would have required enormous storage capacity for the time that putrefied meat is safe to eat. Smoked meat packages were sealed, reduced in weight, and preserved for much longer than the shorter period during which putrefied meat is fit to consume. Meat draws a variety of flies that land or lay eggs, regurgitate, defecate, spread bacteria and multiple illnesses, and generally motivate prompt sanitary handling of meat. Cold-smoking deterred flies through prompt butchery, smoke, small fires, and the walls of the smokehouse. The pits around smokehouses

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may have been used to dispose and cover meat scraps as a sanitary measure, among multiple uses.

Phase 5: Storage

Elevated meat caches imply the necessity of smokehouses, the probability of year-round occupation, survivability, and greater social cohesion [58]. The elevated meat caches in the Mezhyrich Map and Eliseevichi Ivory Plaque indicate the presumed storage method for meat at MBC. Ferocious predators made storage of meat in dwellings unsafe. Subterranean caches are commonly found at MBC, but they were generally too small to hold a huge quantity of meat, fat, or tissues, and the larger ones mainly held mammoth, reindeer, and horse bones, flat bones, antlers, and tusks, bones being the "primary storable" [7]. The remains of elevated meat caches did not survive in the archaeological record, but their images survived in the Mezhyrich Map and Eliseevichi Ivory Plaque. Smokehouses created the need for meat caches, and meat caches infer the high production of smokehouses. Both were fundamental instruments in the delayed-return economy, and both can be rationalized through process of elimination.

Elevated meat caches largely negate seasonal occupation, especially at Mezhyrich, which had four of them. "[T]o the extent that people are immobilised by their supplies, storage fosters sedentism and inhibits residential flux" [59]. A question working against seasonal residence at MBC is: "Where would the people go?"

Artifacts and Architecture from MBC Sites Support a Smokehouse Hypothesis

The unique circular, oval, and elongated structures, flattened by the time of their archaeological discovery, are described consistent with elaborate smokehouses: circular or oval arrangement of bones; large diameters (up to 12.5 m for circles) or dimensions (up to 30 m and 40 m for long smokehouses); hearths in the middle or multiple hearths in a line; tusks used for supports; use of the largest bones for building foundations and bases capable of anchoring or holding long bones, poles, racks, or vertical hides; drilled holes in bones to better construct racks or hides; plenty of bones to construct meat racks or hooks; and ground pits located outside the structure ancillary to the meat-smoking operation [12,60].

The most telling architectural feature is that some of these circles, such as the large one at Kostenki 11-1a, were not designed or built with obvious ingress and egress features, doors, routes, or entrance flaps [2]. Pryor et al. [2] found a continuous circle with no entranceway, and photographs and diagrams of Kostenki 11-1a reveal no means of ingress and egress. This indicated humans did not often enter these structures, although mammoth people may have sought light smoke inside dwellings or smokehouses to avoid black flies, mosquitos, and other insects in the summers. Above all, it excludes status as a "dwelling," because all dwellings require ample egress under building codes, archaeological findings, and common sense. Gavrilov [61] and Pryor et al. [2] concurred that the structures they studied were not dwellings, which really means that they were not dwellings when abandoned. Structures were more likely dwellings if surrounded by loess walls, underground, below grade, or built in ravines, due to winter winds on the Russian Plain during an Ice Age.

Some MBC structures, such as those at Mezhyrich with constructed double ingress/egress, may have served multiple purposes, such as smokehouses for months or weeks, lengthy dry-aging, and then dwellings, or perhaps use for social, ritual, religious, childcare, plant food storage, or working purposes. Loess packed in the bones at the bottom of MBC was used as an insulating building material for the short or higher walls or bases surrounding most MBC [1,12]. The height of these walls when the structures were used is unknown. Loess becomes stronger and more rigid when the water within it freezes and stays frozen [62]. Blocks of frozen loess may have served as the equivalent of igloo blocks of snow, which would reduce the need for other insulation.

Iakovleva [12] provided a summary of the architecture of mammoth-bone technocomplexes and circular structures, which have common basic features: bone circles made with mammoth jaws and skulls and likely wooden poles sticking up from alveoli along with the tusks; central hearths and sometimes other hearths; pits around the circles (varying from 4 to 10 in number); overall architecture similar to large yaranga dwellings; walls or foundations built of loess packed inside flat bones, long bones, radius, ulna, jaws, and vertebrae in anatomical connection; some design and artistic value to the arrangement; separate bone beds in ravines that were exploited for material; and nearby butchery and lithic sites [12].

Most of the huts are at least six meters in diameter; however, "[e]xceptional huts are larger, around 8 m diameter, as at Ioudinovo, Kostenki 11, Anosovka 2, and in Gontsy" [12]. The Kostenki settlement complex consists of 21 Paleolithic sites, many in multiple layers, with occupation varying from 42,000 ya to less than 14,000 ya; hence 28,000 years of intermittent MBC use [60]. Kostenki 11-1a (22,000 ya) contains the publicized "Bonehenge" MBC consisting of bones from 64 mammoths, covering an area 12.5 m in diameter [2,10]. The subject structures at Avdeevo are 30 m and 40 m long and could easily have been hide tents with only a few mammoth bones for structure, weight, racks, or decoration.

Djindjian [63] observed different architectural styles based on the mammoth bones used: early Gravettian tipis used long bones, scapula, and pelvis, without skulls or tusks; Pavlovian MBC used the same materials with large bones and stones; Eastern Gravettian structures were built around lined hearths; and large Mezinian ovals had skull foundations and high walls of skulls (30 or more), scapula, pelvis, jaws, tusks, and long bones. Different architecture and lithic cultures did not alter the overall productive mechanisms and functional economy of MBC settlements.

Zheltova [60] noted the presence of post holes at various locations at these sites. The tipi-like aspects (conical chooms perhaps)

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referenced by Iakovleva [12], the presence of trees (birch, willow, and pine) in tundra, and the need for structural support suggest the use of one or more trees in Paleolithic smokehouses with branches serving as support members for racks, poles, hooks, and attachments to hold all the meat in workable, smokable packages and provide support for smoke retention hides (or glued birch bark, bones, or soil walls with bones).

Pryor et al. [2] found assemblages retrieved by the flotation of charcoal, burnt bone, and microlithic debitage at Kostenki 11-1a. The lithic debitage assemblage gathered, minute lithics, "microflakes and microblades with bulbs of percussion and striking platforms" [2], are fully consistent with small meat-slicing microliths used to divide, slice, cut and trim meat. Other artifacts include support structures within the bone assemblages, the presence of ivory, bone subjected to varying heat levels, multiple hearths, and pits outside smokehouses [2,60,64]. Some of the pits invariably surrounding every smokehouse probably held wood, brush, and birch bark to start fires, bone prior to burning, and sometimes ash thereafter. The possibility of multiple uses of MBC and dwellings cannot be excluded. Good uses after smoking season may have been to store firewood, bones, or plant food out of the elements, as meeting places, or for roasting food over fires in cold weather.

External hearths or long smokehouses with multiple hearths may have been covered by smoke-containment structures that were not made with bones or tusks. Some large external hearths ("hearth trampled areas") may have generated smoke under lightweight hide tents adjoining sturdier mammoth-bone structures [44]. A dried mammoth hide may have formed an entire smokehouse (or dwelling). Smoke-containment hides could have been repurposed when not required to smoke meat.

Hide-providing species, each with their own set of valuable resources, are found in faunal bone collections at mammoth sites. *Bison sp*. (bison), *Rangifer tarandus* (reindeer), and *Equus sp.* or *ferus* (horse) were common prey consumed by mammoth hunters [18].

Mezhyrich, Ukraine, and the Mezhyrich Map

In 1966, the Mezhyrich Map was discovered in Ukraine, then part of the Soviet Union. The original museum drawing below and the photographs and drawings of the ivory original in Figures 3 and 4, Marshack et al., [65], are the best representations. See also, Figure 5, Pidoplichko [44], p. 154, Plate 59.

The Mezhyrich Map is probably the oldest process chart or flowchart known, 15,000–14,300 conv BP per [66]. The map shows the prehistoric utilization of a mammoth carcass at a critical juncture in the meat production process and verifies the smokehouse and riverine transport hypotheses. The Mezhyrich Map was faintly scratched in ivory and drawn or traced with bold lines for a better visual appearance. Different, unique drawings exist, because deterioration of the worn curved ivory required microscopic inspection with hand drawings by different individuals.

Pidoplichko [44], the original Mezhyrich excavator who studied the durable construction of three of four huts, found the Mezhyrich Map to be a "complete composition" and he interpreted the four domed huts shown with depressed or V-shaped tops as being not inconsistent with the four huts found at Mezhyrich.

The Mezhyrich Map or Flow Chart proceeds in process order from bottom to top: Flotation, docking, initial butchery, removal of large bones, transport of meat packages to smokehouses (and return), cold-smoking, production of smoked meat packages, and finally storage in elevated meat caches. This functional and flowchart depiction of the process from bottom to top lends additional credence to the identification of individual objects depicted in ivory, as explained and interpreted below:

Docked and Connected Mammoth Near to the River Shore: The stylized mammoth at the bottom, depicted with straight tusks, has a wood or bone plank or dock connecting it to the riverbank. With the water flowing from left to right, as shown by the chevrons and consistent with the attachments, the wood or bone plank or dock is secured to the riverbank with a large "L" anchored on shore and attaching twice to the plank or dock connecting mammoth to shore. A single long member, rope, or cord connects the tail end of the mammoth to the shore. The lines within the stylized mammoth at the bottom of the chart are most likely butchery incisions made on the top of the floating carcass. The displayed length of the mammoth, incision marks, two lines for the tusks, river position, and perhaps one line for the trunk support this identity. The carcass is at the bottom of the Mezhyrich Map (or Process Chart), and subsequent preservation steps proceed in sequence order to the top of the chart or map. The mammoth carcass is not depicted in the drawing of the Mezhyrich Map in Marshack et al. [65] (1979, p.292, Fig. 42).

The Flowing River: The chevrons or parallel-angled lines above the stylized mammoth represent the river water flowing from left to right. Similar lines depict water in the Eliseevichi Ivory Plaque. Marshack et al. [65] related Russian Plain motifs to water-related imagery.

Bones on Shore: Temporary butchery bones on the shore are above the river shoreline in the drawing, likely bound for the bone bed.

Bone Bed: A ravine bone bed is depicted to the right of a small rectangle on the right side, and this may continue upward.

Up and Back Route: The up and back routes for meat are represented by two parallel lines stretching from the river through the bones onshore to the settlement, with six dots showing the turnaround humans of the settlement often made when marching meat to the smokehouses and then returning for more meat at the dock, carcass, or shore. This shows the shortest pedestrian route between the carcass and smokehouses. The slant of the parallel lines could represent the slant of the ravine penetrating the inland.

How to cite this article: John Dewar Gleissner. Explaining the Mammoth Economy, Smokehouses, and the Mezhyrich Map. Glob J Arch & Anthropol. 2025; 14(3): 555888. DOI: 10.19080/GJAA.2025.14.555888

Figure 3: Original Museum Drawing of Mezhyrich Map (see References – Mezhyrich Map).

Four Smokehouses or Dwellings: The four smokehouses in the Mezhyrich Map correspond to the four huts uncovered in Mezhyrich or perhaps for the adjoining smokehouses that seem to have been attached to the solid huts. The smokehouses have a "V" in their tops. The artist was possibly making room in the chart to show meat packages, but more likely the huts were shown with a smokehouse over their significant external hearths right outside the main hut entrance. According to the author's interpretation, the smokehouses at either end show completed, dark, smoked meat packages.

Above the Two Middle Smokehouses: In Marshack et al. [65] the two middle smokehouses show faint objects above those huts. The author speculates that these symbolize raw meat. The two middle raw meat packages, if that is what they are, are not shown in the original museum drawing. Two drawings of the Mezhyrich Map are provided by Hitchcock [10].

Bone Pattern at Base of Smokehouses: At the bottom of each smokehouse, lower jaws are depicted in the expected outer position with parallel backslash lines, but two rows of skulls were the inner strong foundation, with sturdy wooden poles on bone stakes or ends secured by foramens or alveoli [44]. The lines at the bottom of the depicted smokehouses were consistent with "The Mezhyrich bone hut in the initial excavation" photograph [10], especially in terms of their positions at the bottom of the smokehouse structures and with other photos on the referenced website.

Small Rectangles: One turnaround diagram and four small or somewhat tall rectangles were depicted on both ends and between all smokehouses. The small rectangles may signify the loading and unloading of smokehouses or represent summer smokehouses over outside hearths or their supports attached to the huts; however, this is speculation. Rectangles per Marshack et al. [65] are motifs in these ivory engravings.

Elevated Meat Caches: An elevated wooden (or possibly bone) meat cache in the right background appears to stand on approximately eight timbers or mammoth bones with cross-member(s) for stability. Elevated meat caches were common in remote northern regions with aggressive predators (Fair, 1997). The three shorter meat caches are depicted in the back, with only X-crossmembers tying them together, which probably means their supporting timbers or long bones are simply not depicted due to space limitations. Figure 6 [65] reveals 18 distinct "ladders" constituting the meat caches, three "ladders" on each of the two left-side meat caches, five on the next cache, and seven in the elevated meat cache on the right. The "ladders" are likely the sides of the meat caches, not functional ladders. Marshack et al. [65] wrote the "ladders" were incised at different times, which implies they were incised after construction.

The number of meat caches shown to be connected is fully consistent with the volume of smoked meat obtained from one, two, or three mammoths, and the necessity of structures sufficiently sturdy to withstand the elements and large predators [66]. Meat preservation is difficult to demonstrate in the archaeological record [67]. Therefore, direct graphic evidence of aboveground meat preservation should be valued as significant, forming the basis of the storage phase proposed herein.

Unidentified Portion of Map: The long parallel horizontal and short vertical lines directly above the smokehouses in the Mezhyrich Map are seen best in the close-up photograph and drawing in Figure 7, Marshack [65]. They are similar to the ladder motif in the meat caches above them but are more crudely and imprecisely drawn at different times.

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Depicted Bones: The long lines at the top of the diagram and behind or above the elevated meat cache represent long bones. Mezhyrich was one of the most successful sites in terms of the number of mammoths collected [5]. The far-right side of the riverbank portrays a bowed tusk. To the immediate upper left of the tusk, there appears to be a ravine bone bed, with bones laid at the same angle and direction and extending inland. Both the ravine bone bed and up-and-back route (also in a ravine) lean to the left as they proceed inland.

Findings at Mezhyrich: Marquer et al. [45] found an abundance of burnt bone and relative scarcity of charcoal in Mezhyrich, suggesting that this location produced a significant quantity of meat. Direct evidence of meat quantity is found in the incised images of elevated meat caches in the Mezhyrich Map and Eliseevichi Ivory Plaque, probably the only depictions of meat caches in the study regions.

Because two anthropogenic layers were discovered adjacent to Dwelling 4 and evidence of flint-knapping, sewing, workshops, and butchering of small animals was discovered inside, along with a central hearth, ash, and burned bone, Dwelling 4 was possibly a smokehouse at one point and at other times a dwelling, possibly with one central hearth serving in each mode [68]. The four sturdily built huts in Mezhyrich could easily be transformed from smoking huts into dwellings, worksites, or general-purpose shelters. At Mezhyrich, mammoth people could probably attend to their attached smokehouses without going outside, with a lower floor grade keeping most of the smoke and all of the insects out of their homes, regulating airflow through their secondary hut entranceway.

Pidoplichko [44] described in great detail the artifacts, varied hut construction, and especially the wide and deep outside flat hearths beside each Mezhyrich hut. He believed the outside hearths were only used in the summertime but noticed short paths from the main hut entrances to the large outside hearths, which had all the artifacts found in smokehouses. It appears that smokehouses at Mezhyrich were attached to the huts, which huts had two entrances, and which might also have been smokehouses at times. After use, external smokehouses might have served as awnings or additional covering for the huts, worksites, wood supplies, or meat-roasting. Inhabitants in the huts may have been below the smokehouse grade, where they could monitor the fires without constant smoke. Pidoplichko [44] suspected that many young and juvenile mammoths collected at Mezhyrich provided coverings for the three huts he excavated.

Interpretations: There are different symbolic interpretations of the Mezhyrich Map that do not address utilitarian purposes, one emphasizing sexual themes. One of those interpreters stated, "ancient people reproduced the most typical aspects of their activity" [69]. Walking up and down from the river butchery to the smokehouse and back until 1.6–2.4 metric tons of butchered meat were situated in the smokehouses was the most typical subsistence behavior, along with butchering, smoking, and protecting meat.

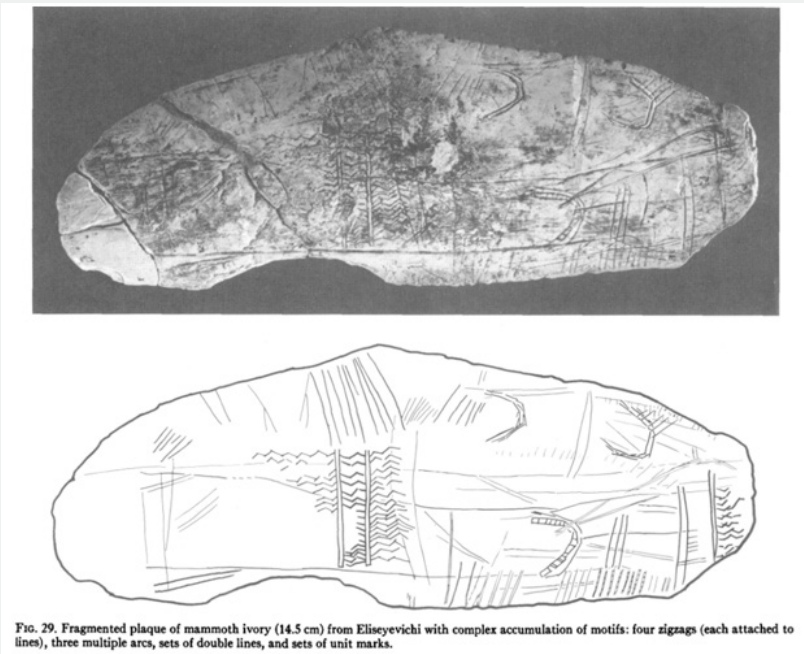

Fig. 29. Fragmented plaque of mammoth ivory (14.5 cm) from Eliseyevichi with complex accumulation of motifs: four zigzags (each attached to lines), three multiple arcs, sets of double lines, and sets of unit marks.

Figure 4: Permission granted by University of Chicago Press.

Eliseevichi Ivory Plaque.

Over a dozen ivory plaques were found in Eliseevichi, a site rich in artifacts [7]. The 14.5 cm Eliseevichi Ivory Plaque drawing and photograph in question, Figure 4 above (Fig. 29 in the original Marshack article), is found in Marshack et al. [65] (1979, pp.284-285, Fig. 29 & 30). Soffer [7] noted the "conceptual simi-

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larity" between the Mezhyrich Map and the designated Eliseevichi Ivory Plaque: "an illustration of the unity of the Denpr-Desna and Sudost' design repertoire. Both contain very similar elements, show great conceptual likeness to each other, and can be seen as material expressions of very similar concepts [7]". Like the Mezhyrich Map, the Eliseevichi Ivory Plaque as a process chart shows the mammoth at the bottom in the river and subsequent process steps in sequence above.

Figure 4 shows numerous bones, one or two bone beds, the river, carcass with a flat faced mammoth depiction, butchery details, connections from shore to carcass, no recognizable smokehouses, and multiple bones stretching across the carcass to what looks like a platform on the near side of the mammoth, as if they were butchering the carcass from four sides. Bands of river water are depicted on top of the mammoth carcass, indicating submersion of the head and heavy tusks and perhaps gas expansion of organs through decomposition in the opposing half of the carcass.

A Y-shaped structure, with multiple short lines projecting away to the right, perhaps supported by a tusk, is depicted in the upper right half. Perhaps the structure supports a smokehouse or elevated meat cache; the "faint ladder motif" at the top right per Marshack et al. [65] may be a distant row of meat caches.

A skimpy elevated meat cache in back at the top, slightly to the right, only has five or six supports below a horizontal line and two vertical lines above the horizontal line, representing a meat cache with no depicted functional ladder. The large arc or backward C seems to be a tusk upholding the elevated meat cache.

What looks like a central path up to the settlement is depicted with two parallel lines, although it ends at the top of the plaque. The carcass backward C (or "arc"), consisting of three parallel lines, likely portrays a large flap of thick mammoth hide (maybe with 10 cm of subcutaneous fat) shown with long bones or stout cords connected to the shore holding it back; the edge of the flap looks like a crude modern dental chart diagram of upper teeth. The backward C to the right of the elevated meat cache is drawn differently, without precise tiny lines, perhaps representing a tusk supporting the elevated meat cache.

Lines show the two carcass tusks secured to the riverbank. Multiple long bones appear to be securing the carcass to the shore or providing climbing assistance over the carcass. Other incisions may be represented by various lines on the carcass. Some 18 very short parallel lines rising from the river bank in a marked left-leaning row indicate a path of steps from the carcass or bone bed up to the settlement. The Eliseevichi Ivory Plaque shows greater detail of the main initial butchery area and butchery-associated objects than does the Mezhyrich Map.

Marshack et al. [65], p.283 state there are more lines on the Eliseevichi Ivory Plaque than shown in the drawing, indicating long use of the worn surface and difficulties in drawing all the faint lines seen during microscopic viewing. The difficulty of drawing the microscopic lines on tusk ivory is reflected in all drawings of the two ivory plaques in question.

Mezhyrich and Eliseevichi are both on tributaries of the Dnieper River, 362 km apart [7] (Table 4.6), and both were prosperous MBC settlements. The "great conceptual likeness" is a representation of the docking-butchery-smoking-storage process common to MBC. Both objects contain motifs common in Russian Plain MBC settlement ivory carvings: extremely common zig-zag lines usually representing water, ladder motifs, lines at right angles to the zig-zag lines, and parallel horizontal lines [65]. Russian Plain Upper Paleolithic symbols shown on multiple ivory pieces from different MBC sites include cross-hatching, double and parallel lines, fish-like, fish-scale, and stream-like motifs, counting marks, zigzag bands, water-related motifs, and vertical lines with attached branches [65].

While the two ivory plaques appear crude, they are much more detailed and organized than the miscellaneous lines drawn on other plaques from Eliseevichi [65]. The term Mezhyrich Map was long-established, and might be re-named Mezhyrich Process Chart, while the Eliseevichi Ivory Plaque might be re-named the Eliseevichi Process Chart.

Smokehouses with Multiple Hearths

Hominins have been controlling smoke since at least the Lower Paleolithic period [70], soon after fire control. The structures designed for smoke containment and age-drying varied in diameter, shape, length, width, perimeter, building materials, hearths, floor composition and potential dual or triple use. Mammoth people frequently installed multiple simple flat hearths in smokehouses, which hearths suggest simple cold-smoking fires.

Several floor plans are demonstrated in oval and elongated buildings, called "long houses" by Zheltova [60]. Several long houses had about nine hearths in a row under one roof. The arrangement of multiple hearths in a row is highly consistent with the cold-smoking of substantial quantities of mammoth meat, indicating that the structure was probably not used as a winter dwelling. The buildings were constructed to house the line of hearths, which appear equal in size, scope, spacing, and purpose. There is only one specialized subsistence activity that conforms to this architecture and performs a vital function in the settlement, although multiple uses were possible.

Molodova I, Layer 4, Ukraine

Demay et al. [64] found 15 hearths in a Neanderthal MBC at Molodova I, Layer 4, dated to 44,000 years BP and near a river. This is considered to be the oldest use of mammoth bones for structural purposes [64]. That Neanderthals employed the riverine mammoth economic system and smokehouses some 20,000 years before AMH demonstrated the clear natural advantages and expected development of the system under prehistoric conditions. Neanderthals were sedentary or semi-sedentary hunters 125,000 years ago at Neumark-Nord but did not transport mam-

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moth carcasses [35].

Dolní-Věstonice I (Absolon's Station), Czech Republic

Dolní-Věstonice I structures typically had thick ash deposits and were obviously used over long periods of time [71]. Unit A1, a kidney-shaped ash deposit, was 80–100 cm thick and 13 x 5 m in extent [71]. Ash deposits up to 100 cm thick suggest the continuous burning of small fires in a smokehouse, gradual accumulation of ash over time, and the procedure of distributing small amounts of ash on the floor of the smokehouse rather than carrying ash outside for disposal or use.

In the upper part of the Dolní-Věstonice I settlement complex a structure (KV1) with five (5) hearths, generally surrounded by flat stones, and one human burial, were found by Klíma [71]. In the middle part of Dolní-Věstonice I, "several hearths were grouped together into continuous burnt areas" [71].

Kostenki 1 – Layer 1, Russia

At Kostenki 1 [10,72], we observe nine hearths in a NW/SE line (see below) down the centerline of one structure:

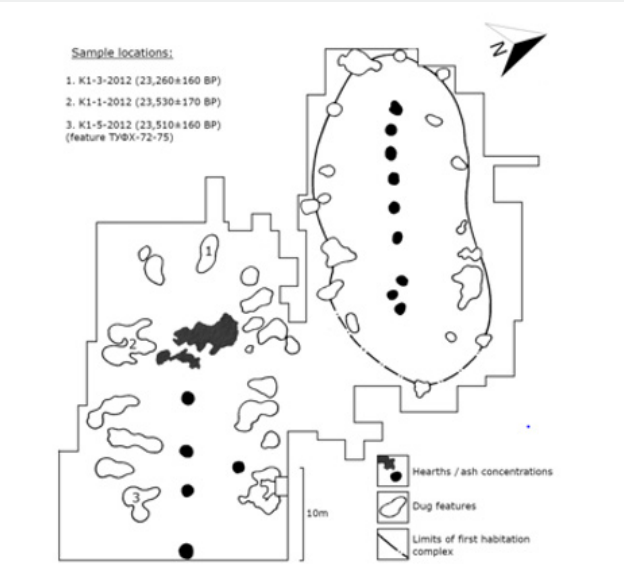

Figure 5: Map of hearths in Kostenki 1, Layer I. Obtained from Dinnis et al. 2021, Fig. 6. Open access.

Marxist scholars first thought that the linear hearth arrangement at Kostenki 1 (Boriskovskii, 1932; Efimenko, 1938) represented a massive communal longhouse typical of a matrilineal clan society in the context of the Marxist social evolutionary model [73].

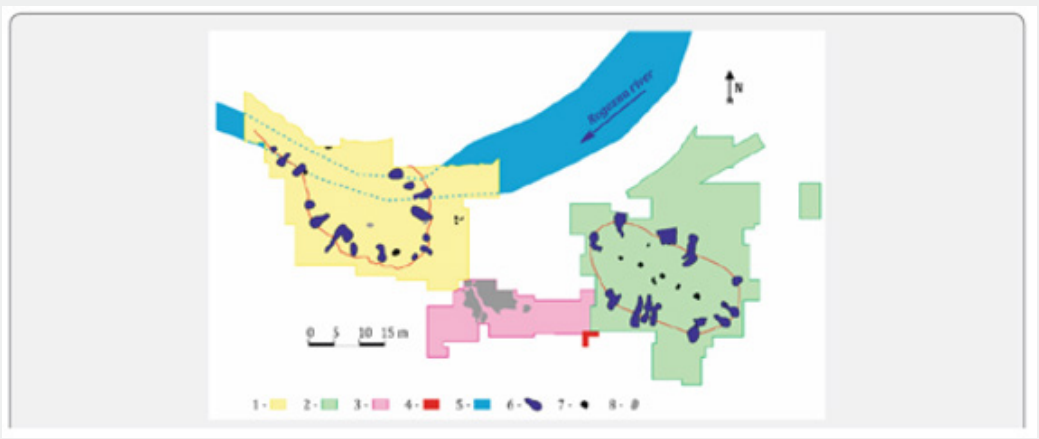

Figure 6: Hearths at Avdeevo. Open access.

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Avdeevo, Russia

Two large oval smokehouses, with multiple hearths in a linear arrangement on the NW/SE axis, were uncovered in Avdeevo, Russia, with carbon dating from 22,000 to 21,000 ya [36].

Unit B, 30 x 15 m, appears to have five hearths in a row [36].

Unit A, a larger oval, 40 x 20 m, was intersected by the Rogozna River, which destroyed the northern third of Unit A as the river moved southward after the initial investigation of the site. Only two hearths were well preserved in Unit A [36]. Unit A shows that some smokehouses were built very close to a river, undoubtedly convenient and labor-saving, and reducing land transport of raw meat close to zero.

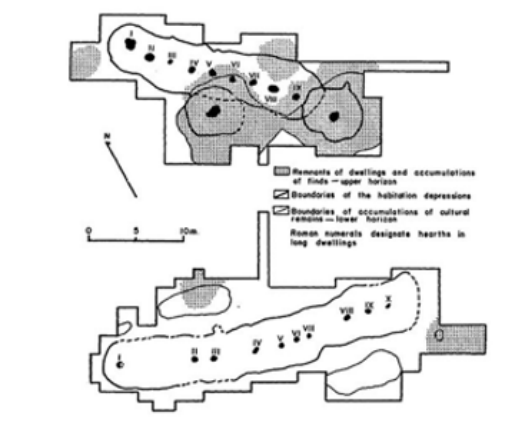

Figure 7: Hearths in Long Smokehouses at Kostenki 4. Obtained from Zheltova 2015, Fig. 1. Permission granted by Pergamom.

Kostenki 4, Russia

The floor plans of the two long structures at Kostenki 4 provide excellent evidence of smokehouses [74]. The sunken floor levels of the Kostenki 4 long smokehouses, similar to the absence of obvious ingress and egress at Kostenki 11-Ia, prevent easy pedestrian entry or exit, suggesting that humans did not enter these structures often, although to escape black flies and mosquitoes in the summers, mammoth people might tolerate some light smoke, perhaps worked at one end, or had fire tenders lying flat on the ground with access to fresh air. The Kostenki 4 smokehouses are by far the largest structures at the Kostenki 4 site [74].

Zaraysk, Russia

In the plan of the excavations for the 2nd stage of occupation of the Zaraysk site, the hearths are clearly marked along a NW/SE axis [75], which is the archetypical arrangement for Kostenki-Avdeevo hearths.

Pushkari 1 – exc. II, V, and VII, Ukraine

Pushkari shows a structure with three hearths aligned roughly on a NW/SE axis, occupying the centerline of the structure and spaced evenly [76].

Gontsy/Ginsy, Ukraine

"Many hearths have been found in the bone bed (ten hearths in the 80 m2 of Hangar 2) showing the important need for fire in the exploitation of the bone bed (meat defrosting, drying or smoking, skin burning?)" [1]. Iakovleva's survey of different structures includes the observation that, "The architecture of the eastern Gravettian dwellings is even more complex, with a line of numerous hearths inside an oval of pits of various size and depth" [1].

The Entire Production Process within the Mammoth Economy

Nomadic mammoth hunters needed to find their prey in vast territories; kill the mammoths where they found them or after lengthy tracking; bring tools, tents, and people to the kill site; battle apex predators; and sometimes surrender to or share carcasses with wolves (*Canis lupus*), brown bear (*Ursus arctos*), large cave hyena (*Crocuta crocuta spelaea*), scimitar cats (*Homotherium latidens*), or mammoth-hunting cave/steppe lions (P*anthera spelaea or Panthera leo spelaea*). Nomadic hunters generally processed larger game in the field rather than bringing carcasses to their shelters; however, they brought prized animal parts to their shelters [77].

Established riverine kill sites, river transport, initial riverine butchery of carcasses, and stationary smoking and storage structures and workshops were clear improvements in culture, economic efficiency, and defense against predators over nomadic methods, enabling fuller exploitation of carcasses.

The possibility of finding dead mammoths upstream in the rivers, drowned, frozen over the winter, or killed but not consumed by animal predators, cannot be excluded from the suggested production process. Those events could not be controlled in the same manner as hunting procurement. The number of discovered and processed carcasses was likely small compared to those hunted and killed.

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The mammoth meat and fat production process involved river procurement, followed by river transportation of whole carcasses. Rivers and butchering overcame the weight of mammoths. Once at settlement, the carcasses were butchered, and the bones were disarticulated. The meat was then transferred to a smokehouse for cold-smoking and drying. The fat was likely converted to pemmican [34]. The system efficiently utilized water transport and batch production methods; minimized labor, fuel, and transportation costs; streamlined nomadic hunting and processing; and maximized the preservation of mammoth meat, fat, and other useful materials.

Useful Objects. "Hunters tend to have uses for every part of the animals they harvest" [78]. MBC mammoth people had available 100% of the mammoth carcasses that they processed. Mammoth tissues offered numerous and voluminous organic substances for manufacturing, consumption, and control of the physical world. Carcasses provided material for many tools, such as catches, snares, traps, and bone staves [44]; bone lamps fueled with fat for light [44]; mattocks, bone scrapers, bone-polishing tools, shovels, borers, skewers, eyed needles, arrowheads, and awls [44]; weapons, paddles; superior projectile points made from tusks [79]; bone pins and brooches, anthropomorphic statuettes, beads, amulets, pendants, drawings, and sculptural representations [44]; process charts on ivory; and MBC structural members. Moreover, carcasses may have provided hide for footwear and dwellings; long hair for rope; intestines for cord and food containers [18]; brains for leather tanning; rendered fat to make candles and soap; bonechar and wood ash to control outhouse odor and flies or use as fertilizer; toys, drums, flutes; organs for storage of fat or transport of water; baskets; dry dung to start fires [18]; and useful dried objects made with mammoth hide. Birch trees supplied bark and mammoths supplied sufficient collagen glue [80] to create smoke containment partitions. One large woolly mammoth had 31 square meters of thick skin/hide [8] and abundant hair. These were valuable insulating resources whose utilization remains a mystery; however, providing shelter or insulation from the cold and elements seem the most likely uses. Mammoth hides were already in the river and might have been pulled into ravines for year-round homes out of the wind [81,82].

The MBC technocomplexes support the overkill hypothesis [83] but not to the exclusion of climate change [25,26]. Riverine locations and curvilinear hunting territories limited human range expansion into the much larger mammoth tundra-steppe habitat and did not significantly change the overall habitat occupied by mammoths [83].

Background

The First and Second World Wars, Russian Civil War, Soviet era, language barriers, and 2022 Russian invasion of Ukraine hindered the study of MBC [7], particularly for archaeologists arrested by Stalin. Artifacts disappeared along with people and their incomplete studies. Not all Russian studies have yet been translated. After 1991, better-organized Western archaeologists with more advanced methods were able to start visiting individual MBC sites but remained limited by remoteness, the number of MBC, and many constraints of specific grants. No comprehensive survey, study, or analysis for all 70 MBC sites, most having multiple MBC and often layers, has yet been conducted, nor is 70 an accurate number. Excavation is ongoing.

Proof Versus Refutation

This paper offers to explain (a) why all MBC were located on navigable rivers, (b) how the sedentary mammoth economy regularly worked successfully; (c) how all parts of mammoth skeletons were brought to the MBC; (d) how mammoth people preserved for future use great quantities of mammoth meat, fat, and tissues; (e) why ubiquitous burnt bone was usually found in MBC; and (f) how formidable predators were avoided at every step.

Arguments, conclusions, and findings are grounded on the premises and evidence of mammoth weight, invariable location of MBC near navigable rivers, transportation logistics and mechanics, 28,000 years of intermittent usage, location of all mammoth skeletal parts at technocomplexes, artifacts, site maps, and the supporting academic publications cited herein.

The riverine transport hypothesis can be falsified with any practical alternative way for all skeletal parts to move to the MBC. The smokehouse hypothesis can be falsified by any practical alternative way to preserve the meat from a whole mammoth carcass docked below the smokehouses and utilize most other mammoth tissues. Repeated characterization of these mammoth hunters as scavengers should yield to a far more accurate understanding of them as process-oriented industrialists.

The Mezhyrich Map and Eliseevichi Ivory Plaque are not necessary to support these hypotheses but help prove them. Better or at least plausible explanations are needed to refute the hypotheses, the proposed mammoth economy, and each of the five interdependent economic phases.

Discussion and Conclusion

Identifying the five phases of the mammoth economy and their interdependence clarifies how the MBC settlements operated. In addition to the weight of mammoths, invariable repeated riverine site locations of MBC, and the presence of all mammoth skeletal remains at MBC, the inferences, explanations, arguments, and conclusions stated herein, an explanation of the mammoth-based economy, are supported by (1) many artifacts; (2) meat science; (3) process of elimination; (4) the Mezhyrich Map and Eliseevichi Ivory Plaque linked by Soffer; (5) convergence upon and close conformance with common subsistence activities by different lithic cultures and races (Neanderthal and AMH) across 28 millennia; (6) the overcoming of apex predators and cold, arid, dusty, inhospitable conditions; and (7) the success of MBC settlements measured in their (a) abundant bone, tusk, and mammoth tissue accruals, (b) architecture, (c) cold-smoked meat production, fat

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use, surpluses, and trade goods, and (d) the highest concentration of Paleolithic art objects found in the USSR (Abramova et al., 1967, p.116). Societal advancements generally stem from economic efficiencies, food surpluses, trade, sedentarism, and access to tons of useful organic material. Through pyrotechnology, mammoth people effectively controlled the type and optical density of smoke, fire fuel schedules, rates and heat of combustion, temperature, wood species, bone types, drying, air flow for multiple hearths and smokehouses, and other variables [40].

There were no efficient or non-nomadic alternatives to killing or finding whole mammoths in the river, floating carcasses downstream, initial butchery in the river, cold-smoking or drying the mass of meat, and then storing surplus meat and pemmican in elevated meat caches. Mammoth hunters could hunt downstream of their own settlement if they had a cooperative arrangement with the downstream MBC settlement. All five steps created a proficient system without reverting to nomadic methods. The Ice Age severely limited options, and other explanations of the mammoth economy will be difficult to impossible to find. Over the course of 28,000 years, MBC were constructed within the outlined mammoth economy. The proposed economic phases of the mammoth economy, including smokehouses and elevated meat caches, and as shown in the Mezhyrich Map and Eliseevichi Ivory Plaque, are now the best explanations and the only explanation of the entire mammoth economy [84-91].

Smokehouses completed the basic subsistence behavior of the MBC settlements, the production of safe, palatable, flavorful, preserved, portable smoked meat packages created with labor-saving, time-saving, energy-saving, and resource-saving methods. Elevated meat caches held the surplus production from smokehouses, as we learn from the Mezhyrich Map and Eliseevichi Ivory Plaque. We can also reason from the quantities of meat involved that the MBC mammoth people used this proven elevated storage structure in cold regions against predators larger than today.

Paleolithic efficiencies in hunting, killing, transporting carcasses, smoking enormous quantities of meat, and full exploitation of *Mammuthus primigenius* help reconstruct these societies. The outlined mammoth economic system encompassed all aspects of mammoth hunting and utilization. These underappreciated mammoth people built MBC, the exteriors and structure of old smokehouses, including larger oval and long smokehouses, at approximately 70 different locations.

Hunting, meat consumption, and tool creation are associated with evolutionary developments in the human brain, suggesting progress and evolution while these hunter-gatherers adapted successfully to Ice Age conditions. Organized sedentary hunting, large-scale meat and fat processing, and the creation of many useful objects were steps toward modern humanity and away from nomadic cultures.

Acknowledgments

I would like to thank Dr. Ran Barkai, Professor, Department of Archaeology and Near Eastern Cultures, Tel Aviv University, for his encouragement, guidance, correspondence, wisdom, education of a deer hunter in Alabama, warnings, provision of books, articles, and film; for naming the smokehouse hypothesis, preserving focus, his published work, upon which I rely, and especially for being the first archaeologist in the world to agree with and provide friendly and positive early recognition of the smokehouse hypothesis. I am grateful to Dr. Pat Shipman for her correspondence and insightful review of the early manuscript, permission to use the Jeffrey Mathison "Mammoth Sites" drawing, and her published work, upon which I rely. I extend my gratitude to Dr. Gary Haynes for permission to use his photograph of drying elephant meat and for his published work, upon which I rely. I thank Michelle Elmore, Associate Professor at Auburn University's Cooperative Extension Service, and Mr. Vlad Litov for an initial review and some editorial comments, which resulted in re-arrangement of manuscript sections and editorial changes, providing academic studies to which I did not have access, and especially for his motivating criticism of the paper. Thanks to JSTOR for providing access. Finally, I thank all of the scholars who performed the work and published the studies, texts, diagrams, drawings, and data cited herein, for I am standing on their shoulders.

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DOI: 10.19080/GJAA.2025.14.555888

How to cite this article: John Dewar Gleissner. Explaining the Mammoth Economy, Smokehouses, and the Mezhyrich Map. Glob J Arch & Anthropol. 2025; 14(3): 555888. DOI: 10.19080/GJAA.2025.14.555888