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An ethnographic framework for identifying dog sledding in the archaeological record

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ABSTRACT

For at least 9000 years dogs have been pulling sleds across the Arctic, facilitating subsistence strategies and migrations. Despite the enduring presence of dogs in the Arctic there is an absence of comprehensive studies of the material culture associate with dog sledding, including the diverse technical elements needed for the activity. This study proposes a framework for the recognition of reliable archaeological indicators of dog sledding. The outcome is based on comparisons between ethnographic information of the dog traction technology and archaeological sites from the Arctic regions of Siberia, Alaska, Canada, and Greenland using multivariate analysis. These sites were selected as case studies to encompass the breadth of geographical and Inuit cultural diversity where dog sledding traditionally has been practiced. We argue, that by using this framework it is possible to study dog sledding in the Arctic prior to the Thule Inuit period and gain more knowledge about the origin of the practice. By combining sources from ethnography, history and archaeology, our framework identified items involved in dog sledding that were universal to the practice as well as items that were regionally specific. However, the most reliable evidence for dog sledding is the presence of both sled parts, dog bones and equipment for harnessing the dogs.

1. Introduction

Dogs have played important roles in human migrations and human survival in the Arctic, such as guarding, hunting, and transportation (Laugrand and Oosten, 2014). The earliest finds related to dog sledding derive from the excavations on the Zhokhov Island, in the Siberian High arctic. Through radiocarbon dating, samples of a sled runner revealed that the fragment can be dated to 6480-6175 BCE (Pitul'ko and Kasparov, 1996). During the excavations at the Zhokhov site, several dog bones were discovered which were dated back to 7000 BCE. Furthermore, a considerable quantity of dog faeces was retrieved from the permafrost soil (Pitul'ko and Kasparov, 1996; Pitul'ko and Kasparov, 2017). Despite artefacts linked to dog sledding being seen relatively frequently in archaeological contexts and ethnographic collections, the material culture remains only superficially studied. The existing research on sled dogs has focused on the genetic investigations of the linkage between human migrations with the movement of Arctic dogs (e.g. Ameen et al., 2019; Brown et al., 2013; A. Perri, 2016; A. R. Perri et al., 2021; Sinding et al., 2020).

The first migrations to the North American Arctic occurred during the Late Pleistocene from Siberia. Approximately 3000 BCE a second migration from Siberia followed that centred in the Arctic region. This wave of migration involved new cultures, known as the Paleo-Inuit or Pre-Inuit, related to the Arctic Small Tool Tradition from the west Bering Strait (Friesen and Mason, 2016). The Palaeo-Inuit cultural complex includes Denbigh, Pre-Dorset, Dorset, Saqqaq, and Independence (Bandi, 1969; Friesen and Mason, 2016). The Inuit rapidly migrated across the breadth of the North American Arctic, starting around 1000 years ago, taking as little as two centuries to reach Greenland from Alaska. Following the initial migration people continued to move at a smaller scale, which led to the spread and typological continuity of the dog sledding traditions (Ameen et al., 2019). Thus, knowledge and

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tradition are often more associated with a specific place rather than a certain group (Laugrand and Oosten, 2014). This also resulted in staggered relative phases of Inuit groups based on geography as it relates to earlier and later occupations.

This study proposes a methodological framework for recognising reliable evidence of dog sledding through a systematic review of existing ethnographic and archaeological definitions. Archaeological sites from the Arctic regions Siberia, Alaska, Canada, and Greenland have been selected as case studies to evaluate distribution patterns as they relate to universally consistent items, as well as regional and Inuit culturally specific items. The archaeological items in this study derive from excavation reports and collections, some of which remains unpublished.

Firstly, we present the observations of the Arctic dog sledding complex documented by ethnographic sources for an overview of the technological characteristics. Secondly, we review the items that can be used as a set of criteria for examining the archaeological record. A review of the practical function of these items will lead to a discussion on the reliability of the article's function as a frame of reference for establishing evidence of dog sledding. We will highlight the items that could serve as reliable identification of Arctic dog sledding in the context of archaeology based on ethnographic analogies. This framework has not been developed for the exclusion of sites from where dog sledding might have occurred, but rather to identify sites where it confidently was practised.

2. Ethnographical information on the arctic dog sledding complex

2.1. Defining the dog sledding equipment

The construction of the sled has some regional differences, reflecting a combination of factors, including tradition, material availability, local terrain, and climate (Handford, 1998). The two types of sleds most often referred to in the history of dog sledding are the *built-up sled* and the *low sled* (Fig. 1). The low sled is described as the 'traditional' sled by many anthropologists and archaeologists (Handford, 1998; Holtved, 1967). This type was mainly used in Greenland and Canada, and was often used for carrying heavy loads, such as carcasses and dried skins or for moving camp gear and umiaks across the ice or land (Mary-Rousselière, 1981; Sheppard, 2008). The *built-up sled* has a high rail on each side and is usually intended for transporting smaller items such as clothing (Fig. 1). Both types of sleds are assembled with lashes and stitches, often made of baleen and seal skin thong. The *built-up sled* was primarily associated with dog sledding in Alaska and Siberia (Oswalt and Vanstone, 1967; VanStone, 1989).

The sled consists of different components which have some regional differences in appearance and material. Common in all sleds are the cross pieces, also referred to as cross bars or cross beams, that connect the two parallel runners and are distributed evenly from the back to the front of the sled. Structural parts of the sled are typically fastened and tied together with thong through the binding holes. Underneath the entire edge of the runners, sled shoes are lashed or fastened with nails. The material used for constructing the sled is typically driftwood and the shoeing is generally made by fragments of whale jaws. Later, iron and nylon plastic became the primary material for sled shoeing. Usually, the runners are coated with ice or a mix of water and mud or snow to make them ride smoothly. In the back of the low sled the upstanders or uprights are lashed to the rearmost cross piece and are connected by cross straps and a crossbar. The harness rope is fastened at the front of the sled, consisting of the front strap, which is threaded through drilled holes on the inside of the runners or front cross pieces (Fig. 1) (Hansen, 2008; Holtved, 1967; Mary-Rousselière, 1981; Rosing, 1976).

2.2. Ethnographic definitions of the sled dog equipment

Together the harness, traces, buckles, swivels and clasps comprise the category referred to as *dog equipment* which are used to harness the dogs to the sled. The dogs are fastened to the sled with traces of different lengths. The clasp attaches the trace the front strap on the sled end and on the other a clasp fastens to a ring-shaped buckle attached to the back of the dog's harness. (Boas, 1888; Hawkes, 1916; Jenness, D., 1946). In Western Greenland, the ends of the trace are sometimes attached to a bone tube that is often located in the middle of the front strap

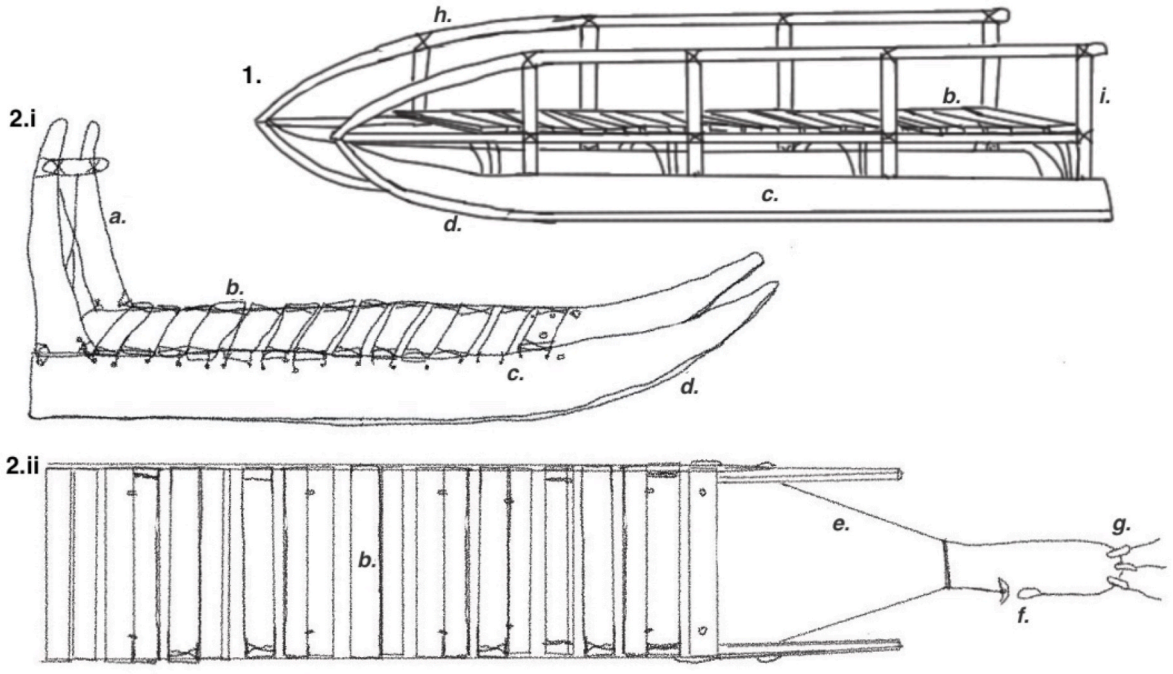

Fig. 1. Terminology of components of the built-up (1) and the low (2) dog sleds. a. Upstanders, b. Cross-pieces, c. Runners, d. Sled shoeing, e. Front strap/trace, f. Clasp, g. Buckles to attach the traces for the dog's harness, h. Rails, i. Stanchions. Types are based on those in Murdoch (1892) and Holtved (1967). Illustration by Emma Vitale.

(Birket-Smith, 1924, 1928; Thalbitzer, 1912). Swivels made of bone, ivory, or iron are sometimes placed on the trace to prevent tangling (Bogoras, 1904).

The harness is made of skin strips and usually consists of two loops joined by straps and ending in a connection towards the back part of the dog's body (Fig. 2). The dog's front legs are each placed in a loop, which are connected by crossing bands between the shoulder blades and across the chest (Hansen, 2008; Holtved, 1967; Rosing, 1976). Five other variations can also be found, such as the western Siberian harness, which is a circular single strap which surrounds the body of the dog like a belt (Jochelson, 1908). This method is not well-functioning, as the dog can only pull with the back part of the body. The second is the east Siberian harness or the 'oblique' which has only one short strap across the shoulder blades that is used by groups in Kamchatka and Amur Basin (Bogoras, 1904). Whereas the Amur harness utilises a single collar around the neck to affix the dog, so they would use their neck to pull. Unfortunately, they would easily become suffocated while wearing this type of harness. The final type of harness is the ancient Kamchadal type, which consists of a single loop without cross-straps, placed over the head and left foreleg resulting in the dog pulling with the right shoulder (Jochelson, 1908; Levina and Potapova, 1964).

Another key implement for dog sledding is the whip, used to guide and discipline. The lash is usually made of walrus or seal hide and is around 6–7 m long. The whip handle is made from bone, wood or whalebone varying in length from 30 cm to 1 m (Boas, 1888). The dog whips are predominantly used in areas where the fan-hitch method of harnessing is applied, such as Greenland and Canada, but little used elsewhere. Other forms of hitching dogs, including tandem hitching, commonly does not employ whips (Birket-Smith, 1928).

The dogs' feet are covered with small pieces of leather during the late spring, as the sharp ice will lead to sores on the paws of the dogs (Fig. 2) (Boas, 1888; Russell, 1898). Another common problem is the occurrence of frostbites in the groin where their fur is less dense. To avoid this, slices of soft skin are wrapped around the groin for protection (Bogoras, 1904).

2.3. Regional descriptions of the dog sled in the arctic regions

The ethnographic analysis consists of 33 written accounts of observations made in Canada (n = 10, 30%), Alaska (n = 8, 24%), Greenland (n = 8, 24%), and Siberia (n = 7, 22%). When reviewing the ethnographic material, the focus will be on the categories *sled parts* and *dog equipment*.

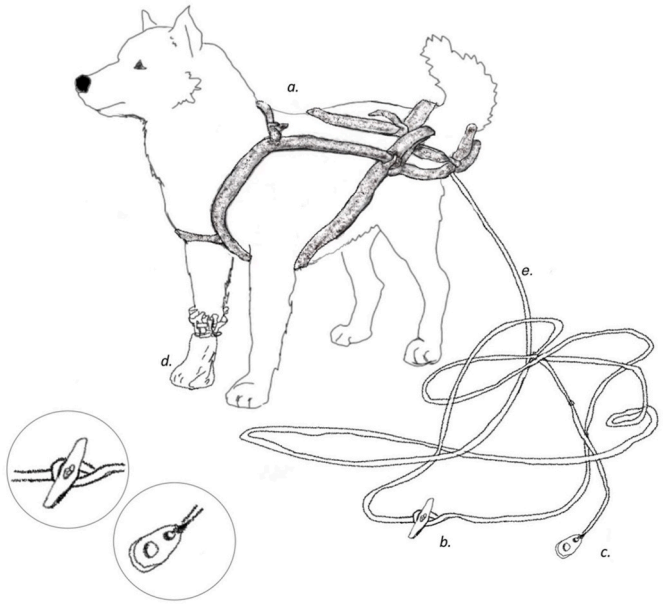

Fig. 2. Terminology of typical sled dog equipment: a. Dog harness, b. Clasp, c. Buckle, d. "dog shoes'' of skin, e. Trace line. Illustration by Emma Vitale.

Siberia: In Kamchatka, the Itel'mens used dog sleds that resembled the reindeer sled that had two pairs of curved stanchions and a saddle shaped seat. It has upward curving runners, that are around 15 cm in width (Levina and Potapova, 1964). In the northeast of Siberia, the dog sled has three or four sets of stanchions and was narrow and long. The end of the stanchions had a peg, which was used for connecting it to the runner. The parallel stanchions were connected by a circular stick. Planks are placed upon these sticks. The runners curve in the foremost part of the sled and are flat. In the front, a wooden bow is tied to the runners (Mason, 1887). A wooden bow is additionally fastened on the front stanchions, which prevents the sled from overturning and steers the direction. The runners are around 3–3.5 m in length, 3 cm in thickness and 8 cm in breadth (Bogoras, 1904). The different parts of the dog sled are often made of birch wood, if available, and are fastened with twisted lashings. The Arctic Chukchi also used American pine or oak from driftwood, whalebone was also used for shoeing the runners (Bogoras, 1904; Levina and Potapova, 1964).

Alaska: Both the built-up sled and the low sled are reported to have been used in Alaska. The built-up sled in Alaska is typically around 2 or 3 m in length, and 50 cm to 1 m in width, and the rails are usually no longer than 1 m in height (Murdoch, 1892; Nelson, 1899). Driftwood is used for the runners and in front the ends are lashed together with a piece of wood that extends to the rear part of the sled where it is tied together with the wooden rail. Curved pieces of reindeer antlers are sometimes attached to the top of the runners, crossing the stanchions. At the back is a wooden bow that is lashed together with two flat pieces of wood which forms the bed of the sled, the cross pieces are lashed to these pieces (Nelson, 1899).

Canada: The sled form thought to be the earliest Inuit sled in Canada, is the one that consists of two runners and cross pieces, despite the simplicity of the design it has been credited for the technical refinement (Arima, 1967). Anthropologist Franz Boas and archaeologist Therkel Mathiassen describe sleds made in eastern Canada as being made of two long wooden runners made of driftwood with a length between 1 and 5 m and a width between 0.5 and 1.5 m (Boas, 1888; Mathiassen, 1928). The curved runners are attached by cross bars made of bone or wood. Boas and Mathiassen both report the use of upstanders made of deer skulls with antlers attached, in the back of the sled (Boas, 1888).

As observed in other accounts, the people on Prince Wales Island often used different substitutes in the absence of wood, for instance skins of muskox, bearded seals, and polar bears were often used for sleds. In addition, the runners were sometimes made of frozen rolled-up skin and bones with cross-pieces of frozen fish and meat (Birket-Smith, 1945; Rasmussen, 1931). When constructing a sled out of skin, the skins are wetted and then sewed into a bag, once the bag has been formed and frozen to a firm mass, it can be used as a plank (Boas, 1888). In general the runners are shod with ivory, whalebone or the jawbones from a whale, and the shoes are either fastened or tied to the runner (Birket--Smith, 1945).

Greenland: Differences can be seen in the length and breadth of the sleds in Greenland, West Greenland sleds are shorter and wider than sleds from the northwest of Greenland. The longer sleds from North Greenland are a recent phenomenon and occurred simultaneously with wood becoming more accessible (Holtved, 1967). Furthermore, the long sled is said to be more suitable when travelling on flat sea ice, whereas for travelling inland the short sled with curved runners is better suited (Hansen, 2008). The typical low form of sled is overall the same throughout West Greenland, but with some variations in the different districts. The most important factor, when building sleds, is that it can pass clear in all concerning conditions, such as steep hills, rocky grounds, ice cut up by currents, or rough ice (Birket-Smith, 1928). In West Greenland, the cross bar between the upstanders are placed in the back, whereas in the North they are placed on the front. When the cross bar is placed on the back, it is possible to push the sled upwards in steep

inland terrain, where the sled is used in the West. The upstanders are often lashed with seal thongs which pass transverse through feet and runners (Holtved, 1967).

3. Materials and methods

In order to establish a confident set of criteria for identifying the dog sledding complex in the archaeological record, we compared ethnographic descriptions of the technical elements of the Arctic dog sleds and the related equipment to the archaeological material using multivariate analysis. The ethnographic analogies are applied to assist the interpretation and identification of the relevant archaeological items from sites in the areas defined as that of Inuit prehistory in the Arctic: Siberia, Alaska, Canada and Greenland (Friesen and Mason, 2016). To comprehend the chronology and technology of the dog sledding culture, it is necessary to include artefacts ranging from the earliest dating around 7500 BCE at the site of Zhokhov in the New Siberian Islands, to the objects from Polar expeditions in the early 1900, such as the Fifth Thule Expedition, 1921–24. In the reviewing of the archaeological artefacts, the following principles were used for the analogical arguments; 1) the subject and the cultures must be similar in relation to variables that could have affected the compared materials, behaviour, and processes, 2) there is a greater prospect of resemblances between two cultures if one culture is a historical descendant of the other, 3) the range of potential models should for comparison be expanded as much as possible, 4) one should look for several possible analogies, 5) hypotheses derived from the analogies should be tested in different ways, and 6) basis for the interpretation of the culture and the subject should be expanded (David and Kramer, 2001). There is a distinction between formal and relational analogies. The formal analogy suggests that if two objects have the same qualities, then they probably have other similarities as well. Relational analogies try to determine natural or cultural connections between different aspects. A formal analogy becomes more likely, the more that similarities are identified (Hodder, 1984). However, when using ethnographic analogies, it cannot be assumed that archaeological materials have had the same significance for people in the past as they have in ethnographic observations (Hardenberg, 2010).

The selected dog sled items fall into three main categories: *Sled parts*, *dog equipment* (items used directly with affixing and controlling the dogs for sledding), and *dog remains* (including dog faeces, skin hair and bones. Bones referring strictly to the presence or absence of faunal remains of dogs reported as number of identified specimens, NISP, and minimum number of individuals, MNI).

To gain an understanding of the breadth of material culture associated with dog sledding in the Arctic within the cultural context a review of ethnographic texts was undertaken. Observations of material culture associated with dog sledding were compiled from 33 texts written between 1755 and 1989, as seen in Siberia (n = 7), Alaska (n = 8), Canada (n = 10), and Greenland (n = 8) (appendix 1). Following the identification of materials mentioned in the ethnographic texts, a literature review of published archaeological site reports and the materials from the National Museum of Denmark's collections were analysed to quantify the presence of dog sledding materials on archaeological sites (n = 92) from Siberia (n = 17), Alaska (n = 16), Canada (n = 20) and Greenland (n = 39) (appendix 2). To further implement the criteria for determining the use of dog sledding by prehistoric cultures, 36 pre-Inuit sites were selected to test the criteria on sites from Siberia, Alaska, Canada and Greenland.

3.1. Multi-variate analysis on ethnographical observations and archaeological findings

We performed a multi-variate analysis to investigate regional patterns based on items from the ethnographical observations (n = 249) and the archaeological material (n = 12,617), of which 9216 of the findings are fragmented dog bones. Ethnographically informed indicators were collectively examined across the archaeological cases in order to perform a comprehensive comparative analysis. Principal component analysis (PCA) was presented for every type of item within the three categories associated with the material culture of dog traction: sled parts, dog equipment and dog remains. PCA was carried out, using tidyverse (Wickham et al., 2019), ggplot22 (Wickham, 2009) and base R in R (version 4.1.2). Cumulative variance for each PC was calculated based on standard variation from the eigenvalues of the PCA. Loadings from each region was calculated from base R function prcomp. By including this formal approach, the aim was to assess the role of the ethnographic analogies and provide an outcome that would lead to stronger implications regarding sled technologies, dogs and ancient mobility across the Arctic. For the archaeological findings we performed a log10-transformation to account for the high amount of dog bones found across the sites (Appendix 3).

3.2. Criteria for the recognition of dog sledding components

Through review of the ethnographic sources, several items from each of the two equipment categories were identified by repeated and consistent recordings. The criteria have been chosen with considerations for regional, technical, and analogical differences of the sled and the related dog equipment. Providing this set of criteria configured parameters that was used for examining the archaeological material. When increasing the amount and range of subjects for comparing archaeology and ethnography, for examining the relevance of comparisons, the reliability improves.

Components chosen to represent *dog equipment*, which have been summarised in the ethnographic accounts, consists of *buckles, clasps, dog shoes, harness, swivels,* and *whips*. In the category of *sled parts*, the selected components from the ethnographic records consists of the following: *cross-pieces, sled runners, sled shoeing, upstanders, sled arches, rails, pegs, stanchions, sled skin, brakes,* and *water bags* (Fig. 3). Items such as *iron bells*, *bone tube*, *dog collar,* and *groin protector* are not being used as a criterion for establishing evidence of the dogsledding culture due to singular observation in the ethnographic records (Fig. 3). Furthermore, some of these items can be difficult to recognise in the archaeological record due to poor preservation and can have been used for other purposes. However, if these items appeared in the archaeological context with other artefacts related to dog traction, they were included in the review.

4. Archaeological evidence for dog sledding: cases from the arctic regions

The study subdivided three broad categories associated with the material culture of Arctic dog traction: sled parts, dog equipment and dog remains. These are often interpreted as indicators of dog sledding culture, when found in the same archaeological site context. In this paper the focus will not be on an osteological analysis, but it is important to mention in relation to other indicators of dog sledding.

We reviewed material from a total of 92 sites from the following regions: Greenland (n = 39, 42%), Canada (n = 20, 22%), Siberia (n = 17, 19%) and Alaska (n = 16, 17%). Based on the appearance of items from each category, we argue that the evidence for dog sledding becomes more likely, i.e. it was essential to possess dogs, a sled, and dog equipment to perform the action. For example, dogs may have been used for other purposes, therefore dog remains alone cannot be the sole indicator of dog sledding. We determined that reliable evidence for dog sledding occurred on 21 of these sites (Fig. 4). The comparisons of archaeological assemblages and ethnographic observations have revealed which indicators are universal, as well as exposing the regional differences (Fig. 5). In PC1, we can see that items were separated, most likely by prevalence, which indicates that the sparsity of arefacts affects the results (Fig. 5b). On the other hand, PC2 distinctly separates by region, indicating that we have prominent regional indicators in the

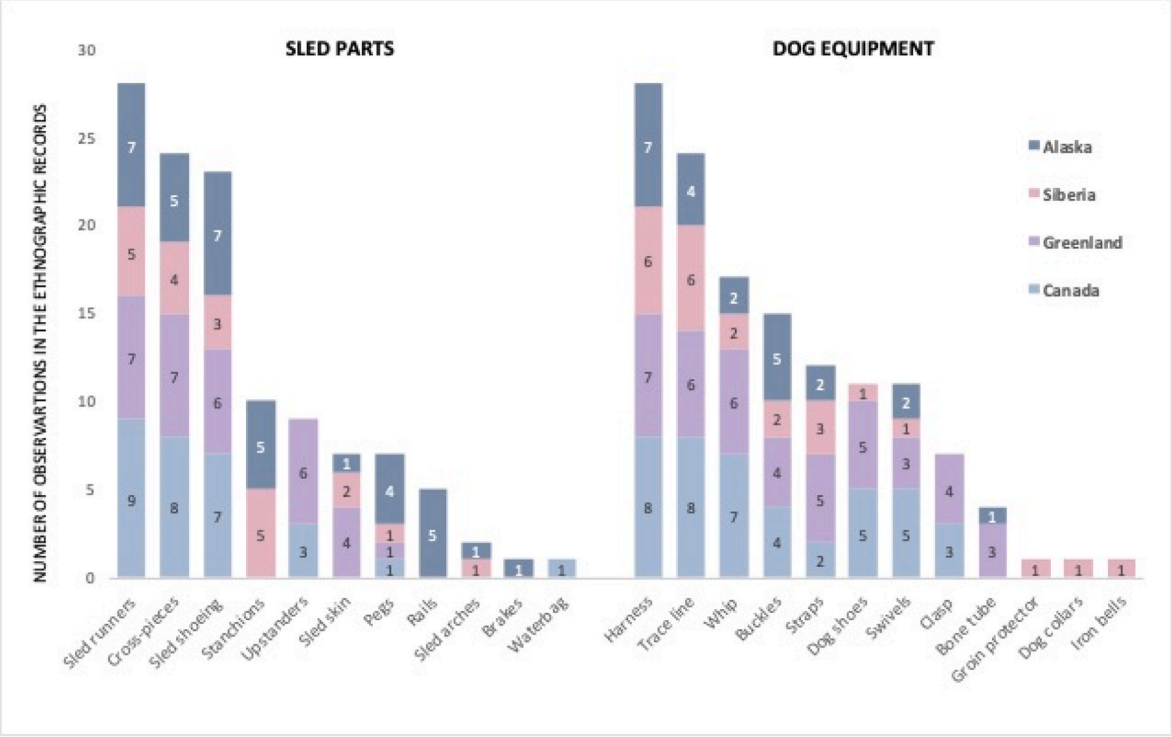

Fig. 3. The number of ethnographic accounts that contain observations of each item in the different regions.

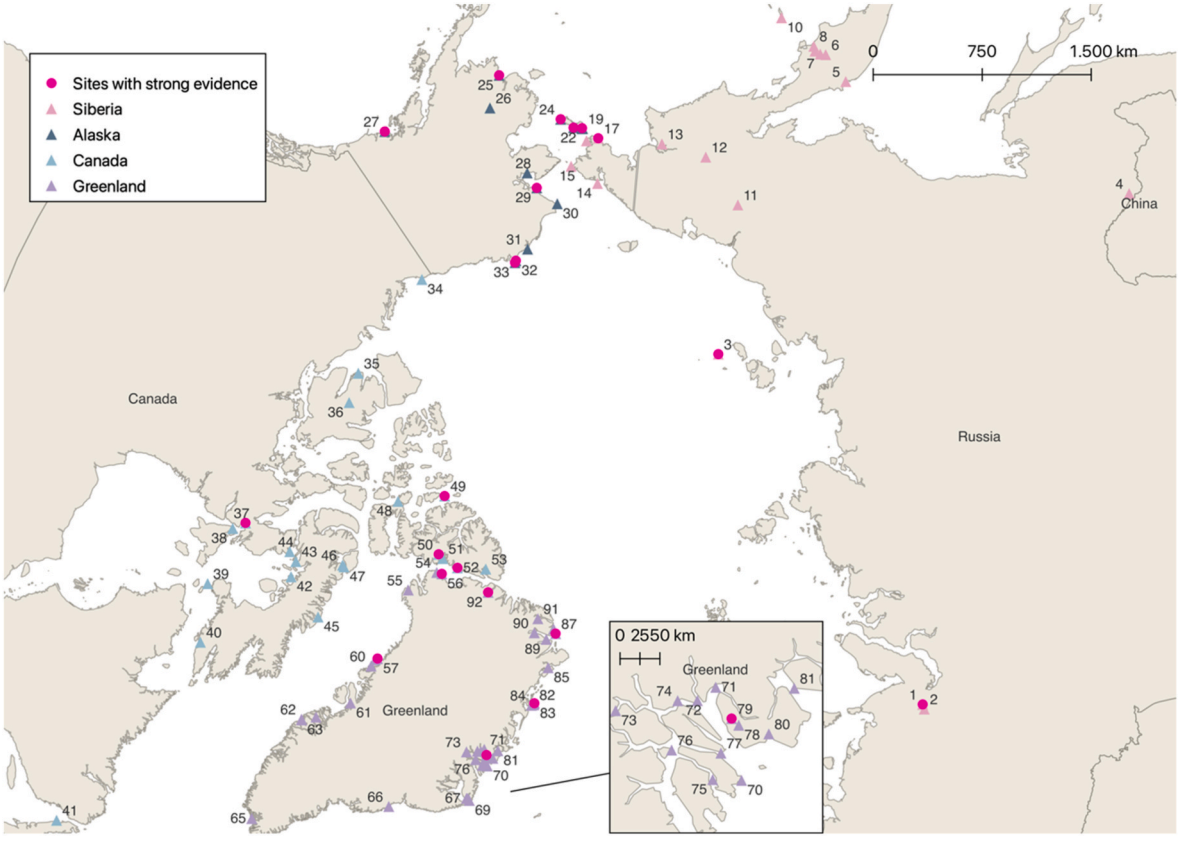

Fig. 4. The approximate location of the reviewed sites mentioned in text, where elements of dog sledding have been discovered. The 21 sites where this study find that dog sledding is confirmed are indicated with pink points.

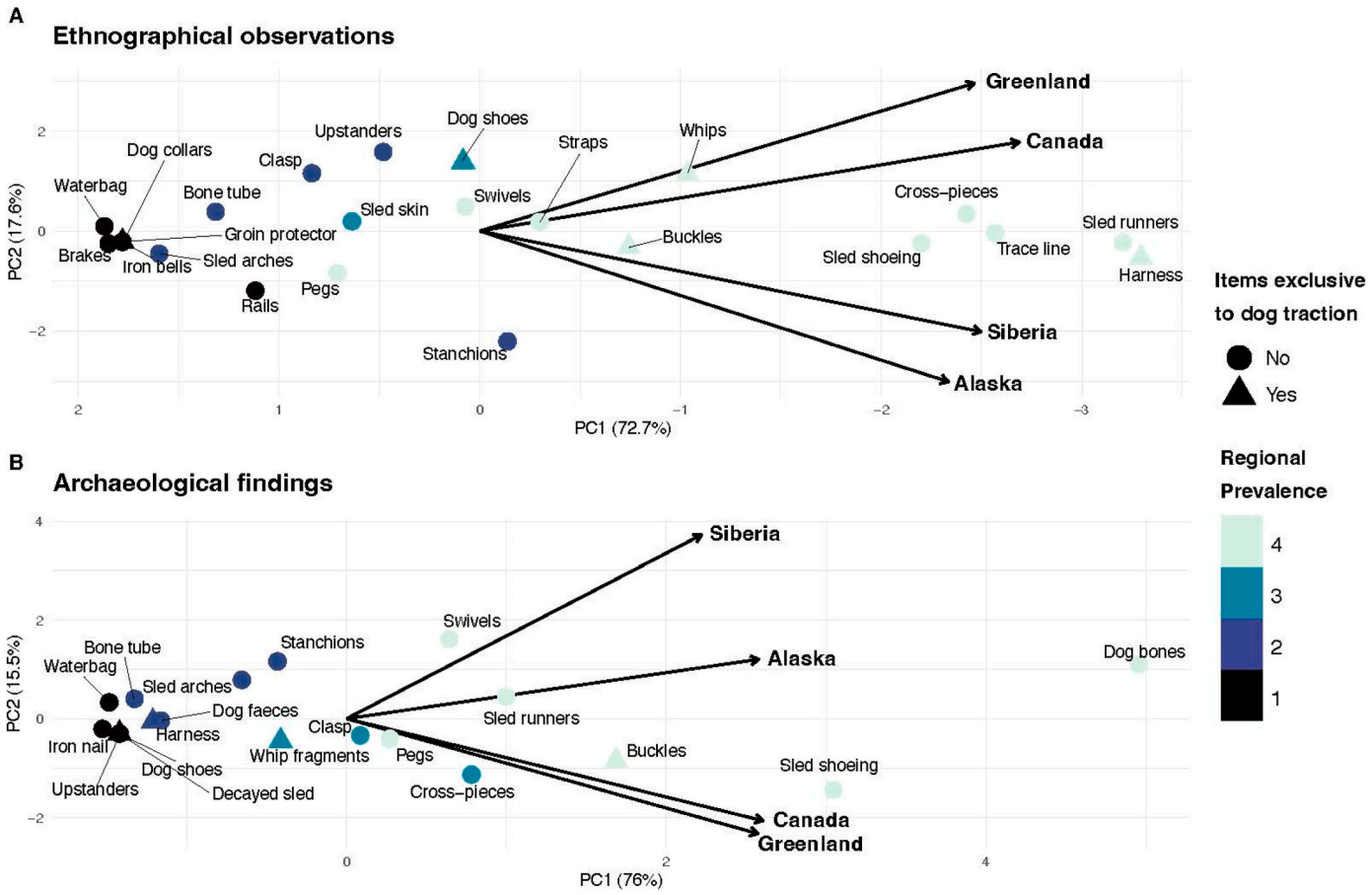

Fig. 5. Principal component analysis (PCA) of a) ethnographically recorded dog sledding related materials, and b) archaeological appearances of materials of potential use for dog sledding. The geographical prevalence of the items as indicated by colour drives PC1 while PC2 is driven by the regional appearance of materials unique to the East Arctic or the Western Arctic. Items exclusive to dog sledding are indicated with triangles. Colour and shape descriptions are illustrated for both PCAs in the legend.

dataset (Fig. 5b). As a part of the data analysis, we correlated PC2 (the separating PC between regions and the co-association between items) (appendix 3). Here we clearly see a correlation between the amount of artefacts of the specific regional indicators, such as swivels and upstanders, and regional separation (PC2). The clustering of the ethnographical items (Fig. 5a) indicates the components of a dog sled appearing in all regions. This corresponds with several of the items of the archaeological findings, including sled runners, sled shoeing and buckles (Fig. 5b). The following finds are considered to be universal indicators of dog sledding: the dog whip, harness, trace buckle and dog shoes (Fig. 6). However, the absence of a single or multiple of these indicators cannot be used directly to eliminate dog sledding in an archaeological context.

Ethnographic records report that whips were exclusively used in relation with driving with dogs (Hall, 1978). Furthermore, it has been mentioned in 52% of the ethnographic accounts (n = 17). The majority of these observations can be attributed to Greenland (18%, n = 6) and Canada (22%, n = 7). While there were very few recorded observations in Alaska (6%, n = 2) and Siberia (6%, n = 2). For comparison, a total of 17 whip fragments appear in 10% (n = 9) of the reviewed archaeological sites (Fig. 5a). The trace buckle was reported in 45% (n = 15) of the ethnographic records. In the archaeological record, trace buckles were recovered from 49% (n = 45) of the sites (Fig. 5b), with a discovery of 221 buckles in total. Besides being depicted in the PCA (Fig. 5), there has been a general consensus among scientists that the trace buckle has been established as a representative indicator for the practice of dog traction because of its general use and necessity (Jenness, 1946; Sheppard, 2008).

The harness' sole function was associated with dog traction, but it is typically made from skin straps, making it difficult to detect in the archaeological record due to limited preservation (Fig. 5b). The dog harness was mentioned in 85% of the ethnographic sources (n = 28), and in 3% of the reviewed archaeological sites (n = 3). The dog shoes are frequently mentioned in descriptions from Canada and Greenland having been observed in 50% of the ethnographic studies of Canada (n = 5) and in 62% of the observations in Greenland (n = 5), with only a single reference made in Siberia. Despite their organic material, dog shoes have been retrieved from one Thule site in Greenland. The presence of 'dog shoes' is considered robust evidence of the dog traction culture, as they were exclusively used for sled dogs.

This study determined that some elements can be categorised as regional or secondary indicators (Fig. 7). These findings include the swivel, upstanders, clasps and parts of the low sled. In 11% (n = 10) of the 92 sites, swivels described as dog sled related were discovered. In the category of dog equipment, the swivel was the most frequently recovered item with a total of 291 findings. The majority were found in Siberia and had a total of 273 documented swivels. The analyses demonstrated that the upstanders were a typical component of the dog sleds in Greenland and less common in Canada (Figs. 3 & 5a). Upstanders were mentioned in 27% (n = 9) of the accounts. The low sled has been described as compact and heavy, with some of them weighing up to 400 kg when loaded (Birket-Smith, 1928). These implications indicate that the compact low sled could be associated only with dog traction (Sheppard, 2008).

In addition to the universal and regional indicators (Table 1), there is another potential biological indicator that includes evidence of skeletal

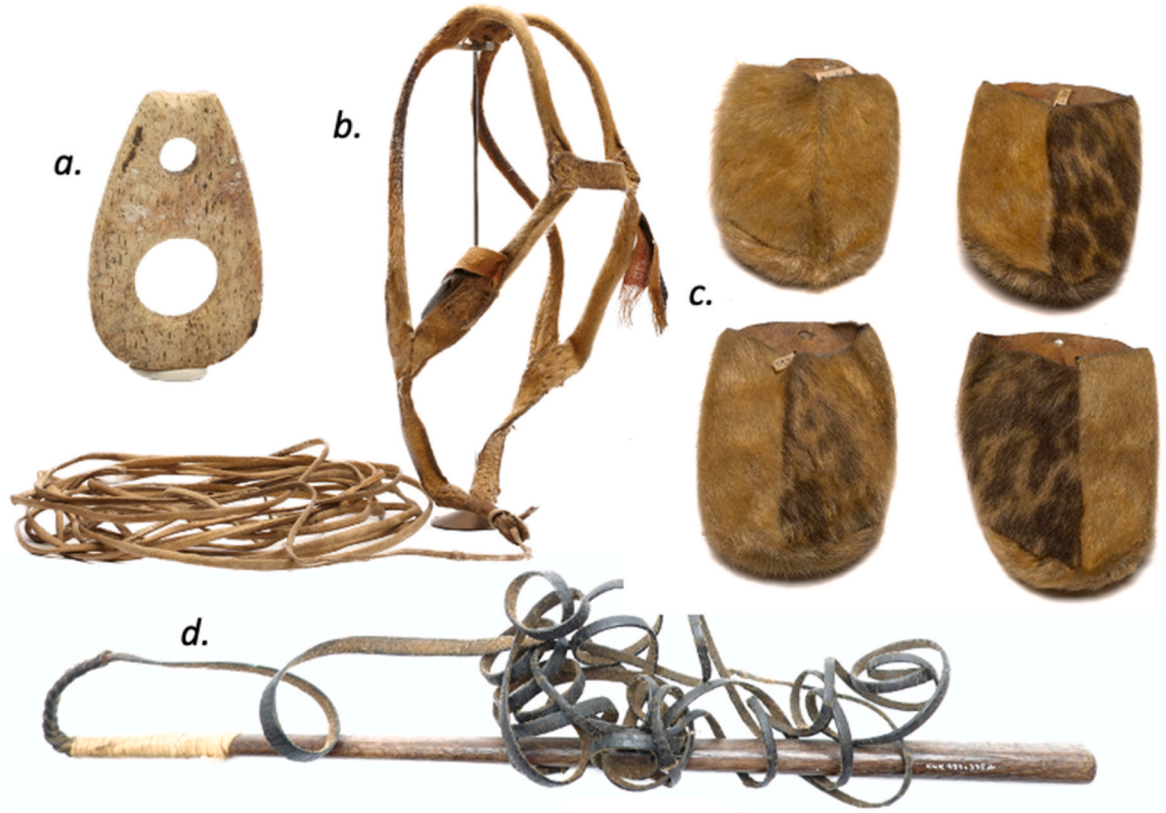

Fig. 6. The established universal indicators of the study: a. Trace buckle from Iglulik (1924), b. Dog harness, Inuinnait, Northwest Territories (1922), c. Dog shoes, Inughuit, Cape York, Northern Greenland, Cape York (1905), d. Dog whip from the National Museum of Greenland's Ethnographical Collection. CC-BY-SA, National Museum of Denmark.

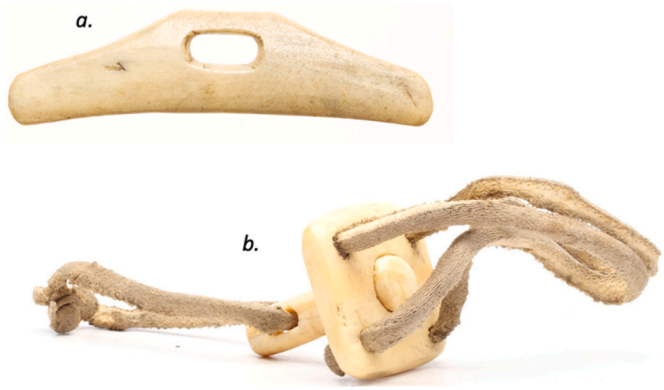

Fig. 7. The acknowledged regional indicators of dog sledding in the study: a. Clasp from Samoyed, Siberia (1927), b. Swivel from Kivallirmiut, Northwest Territories (1922). CC-BY-SA, Jesper Kurt-Nielsen, National Museum of Denmark.

deformations on dog skeletons. Scientists have suggested that spinal deformities in dog bones can be related to traction (Losey et al., 2018). However, there is an issue regarding the absence of baseline data of the dog's anamnesis. Given the limited systematic studies of skeletal deformities as relates to the dog's life history, it is difficult to distinguish typical abnormalities caused by sled pulling from other habitual activities (Sheppard, 2008).

5. Discussion

In the course of this study the majority of the sites examined were Thule Inuit sites 64% (n = 58), directly ancestral to the groups reported in many of the ethnographic sources, thus making the insight directly informative on the culture. In order to understand the history and development of dog sledding, it is critical to identify sites where the practice may have occurred. While it has been acknowledged that dog sledding predates the Thule Inuit period (1200–1850 CE), the robustness of this evidence has not yet been tested in a formal manner. There are many sites that have been purported to have evidence for dog sledding. By using the framework we developed in this study we tested prominent sites predating the Thule Inuit outside of North American Arctic contexts, such as Zhokhov, Ust' Polui, and the Sirenik site (Fig. 8). Each of these sites contained elements from two of the three categories, supporting that there is potential for dog sledding to have occurred. The oldest known site with potential evidence for dog sledding is the Zhokhov site in the New Siberian Islands, dated to 7000 BCE (Pitul'ko and Kasparov, 2017; Pitul'ko and Kasparov, 2017). The site contained both dog remains and fragments of a sled runner. Another remarkable discovery was made in the northern Fennoscandia, where a sled runner dated to around 8000 BCE was recovered in Heinola (Finland). This finding is probably the oldest sled runner yet discovered. However, it is most likely to have been part of a man-hauled sled and has not been associated with dog traction (Sørensen et al., 2013). At the Ust'-Polui site, dated to around 260 BCE - 140 CE, elements from each of the three categories were excavated (Cernetsov and Moszynska, 1974). While dogs were the dominant transportation animal in areas with adequate provision, such as the Ob River area which has rich fishery, domestic reindeer were also used for pulling sleds. The Ust'-Polui site contained 266 swivels and it is unlikely that the small-scale reindeer herds could account for these alone as domestic reindeer herds was relatively small before the 17th century CE (Cernetsov and Moszynska, 1974; Losey et al., 2018). Archaeological features involving dog traction from the Siberian Neolithic (4000 BCE - 1200 BCE) have been documented in the Kamchatka Peninsula. Artefacts associated with dog equipment and sled

Table 1
Eight identified indicators that represent reliable evidence of the dog sled complex, four regionally specific and four universal indicators and the count observations in the archaeological record.

Item Type	Universal Indicator	Regional Indicator	Number of Specimens	Regions Recovered
Whip	X		17	Siberia, Alaska, Canada, Greenland
Harness	X		4	Siberia, Alaska, Canada, Greenland
Trace Buckle	X		221	Siberia, Alaska, Canada, Greenland
Dog Shoes	X		2	Siberia, Alaska, Canada, Greenland
Low Sled Elements		X	N/A[a]	Canada, Greenland
Swivels		X	291	Alaska, Canada, Greenland
Upstander		X	2	Canada, Greenland
Clasp		X	36	Siberia, Canada, Greenland

[a] Runners and cross-pieces have not been distinguished in the archaeological record

parts have been recovered from the Kavran site, including three trace buckle fragments and one clasp. Furthermore, one piece of a sled arch and a piece of a sled runner was discovered, though the site did not yield any dog remains (Jochelson, 1908). Along the Taniurer River, the Chikaevskaia site yielded zooarchaeological evidence for one dog. The excavation also revealed two trace buckles from the Siberian Neolithic (Dikov, 2003) (Fig. 8).

Within the North American Arctic, there have been ongoing debates about the role of dogs in the region prior to the arrival of the Thule Inuit (Raghavan et al., 2014). Included in the dataset of this study were 20 sites from contexts prior to the North American Thule Inuit. Using our framework, we found that five sites in Alaska had artefactual evidence of dog sledding from the Old Bering Sea culture (300 BCE - 500 CE) and from the Ipiutak culture (100 BCE - 800 CE) (Collins, 1937; Larsen, 2001). The Gambell site contained sled shoeing and a trace buckle traced back to the Old Bering Sea culture, in addition dog bones were found reinforcing the robust evidence for the practice of dog sledding in North America before the Thule Inuit. Similar evidence was found at the Ipiutak site, at Tikiġaq (Point Hope). The Dorset site at Phillip's Garden, Northwestern Newfoundland, yielded 624 fragments of sled shoeing dated to the Middle Dorset (0–700 CE), but neither dog remains or dog equipment were discovered (Wells and Renouf, 2014). In Canada, the most ancient evidence derives from the Pre-Dorset site of Igloolik in Nunavut, where dog remains were found (Morey and Aaris-Sørensen, 2002). In a later period at Igloolik during the Late Dorset (500 C E – 1200 CE), a fragment of sled shoeing was recovered. Similarly, a Late Dorset site on Abverdjar Island, Canada, contained both trace buckles and sled shoeing indicating there may have been evidence for dog sledding on the site (Maxwell, 1985). However, together the presence of both of these items does not meet the requirements for reliable evidence for dog sledding, with the additional factor of the separate cultural associations of these items means that with the presented framework this does not qualify as reliable evidence of dog sledding. At several sites identified as belonging to the Greenlandic Saqqaq culture, including Nipisat I, Qaaja, and Qeqertasussuk, isolated dog remains have been recovered, but to date no dog equipment or sled elements (Gotfredsen and Møbjerg, 2004;

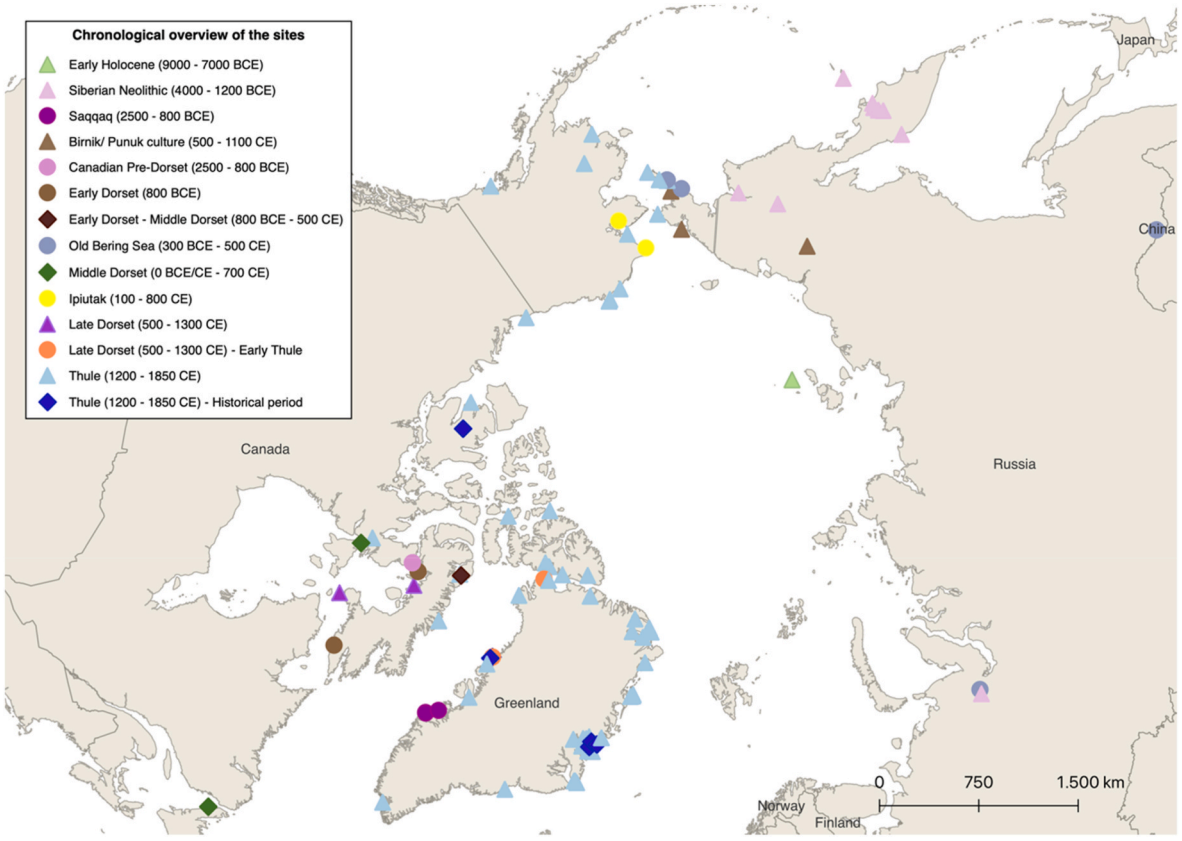

Fig. 8. Distribution map of the reviewed archaeological sites mentioned in text. The markers indicate the chronological dating of the sites. The time ranges for the cultural era are based upon the chronology in the article "The genetic prehistory of the New World Arctic" (Raghavan et al., 2014).

Møhl, 1986; Morey and Aaris-Sørensen, 2002). Some of the dog bones discovered at these sites, showed that they had been eaten. Given that the discovered bones only accounted for eight individuals, it is unlikely that dogs were considered to be a significant subsistent resource. There were no differences in measurements between dog bones from Qaaja compared to a modern sled dog, thus they had the physical capacity to be used in hunting and as pack animals. Despite the fact that dogs played a major role within the past Arctic societies, their pattern of visibility does not follow the expected general chronological sequence. As an example, they are largely absent during the Saqqaq period in Greenland and besides from the Inugsuk site, where dog bones from the Late Dorset were found, dogs seems to be completely absent in the Greenlandic Dorset period. However, their absence raises several questions of transportation for the Dorset people. There is the possibility where dogs were in small numbers and with an absence of sled material, that the dogs were still used for transportation as pack animals rather than traction for sledding a practice known to have been used by the Inuit, Koryaks, and other cultural groups (Mathiassen, 1927; Møhl, 1986; Morey, 2010).

There is a strong contrast between the Thule archaeological sites and the earlier sites, where the number of Thule sites are substantially higher. Evidence from earlier settlements is scarce, likely related to excavation strategies, different settlement and mobility strategies, such as the location of settlements in relation to resources (Helmer, 1992). The proportion of sites and assemblages with only one or two components is substantially higher in the Thule period, where 44,25% (n = 1000) of the findings, retrieved from 41 sites, can be dated to this cultural group. Only 0,09% (n = 2) can be traced back to the Early Dorset. Whereas 27,65% (n = 625) of the assemblages were dated to the Middle Dorset, but was recovered from just two different sites. For comparison, the earlier Siberian Neolithic has 4,25% (n = 96) of the assemblages, spread across 9 different sites, which potentially shows that there has been a time gap where dog sleds were used less frequently as a mean of transportation. A study previously found of approximately 200,000 bones examined from pre-Inuit sites only 79 could be identified as dog bones, demonstrating the scarcity of dogs in these cultural contexts (Morey and Aaris-Sørensen 2002). Another consideration is the issue of materials for sled construction, including the availability of driftwood which varied due to changing conditions of environment and climate. Thus, it can have been upcycled for other equipment, as wood was a very valuable resource due to the scarcity of the material (Alix, 2016; Birket-Smith, 1945). In sites like Qaaja and Qeqertasussuk, which are known for their rich preservation, the upcycling of original sled artefacts can be considered an explaination to the lack of finds.

There is a pattern for the use of driftwood in sled constructions. This can be seen in the distribution map (Fig. 4), where the majority of the sites containing sled parts are placed along the coastal areas. However, in the central part of Siberia, driftwood was also available along large rivers such as the Lena or Kolyma, where logs were transported along the rivers (Alix 2016). Similarly, the ready availability of marine resources for the provisioning of the dog teams required for pulling the sleds is reflected in the distribution map. This provisioning requires a constant supply of dietary resources through frequent acquisition or stockpiling, and is increasingly costly for larger populations of dogs. Analysis of carbon and nitrogen stable isotopes from dogs originating from pre- and post- European contact contexts reinforces the heavy reliance of humans on marine resources for provisioning dogs across the Arctic (Losey et al., 2018a; Losey et al., 2018b, Harris et al., 2020; McManus-Fry et al., 2018).

6. Conclusion and future directions

Based on the detailed ethnographic observations of the dog traction technology, this study has established a set of criteria for the recognition of reliable archaeological indicators of dog sledding. With this methodological framework it is possible to study the pre-Thule material for investigating the origin of dog sledding in the Arctic. The outcome of the formal analysis shows the importance of contextuality for interpreting artefacts, as many of the archaeological finds consist of small fragments and are easily overlooked. The main factors seem to be the availability of raw material in conjunction with adjustments regarding the differing local terrain. The results of our investigations concluded that the presence of a universal criteria should be recognized as reliable archaeological evidence of dog sledding. However, the most reliable evidence is the presence of components from all three categories: dog equipment, sled parts, and dog remains. Furthermore, the outline of dog sledding history provided by our analysis suggest correlation between the style of the oldest known dog sled find from Zhokhov to later dog sled instances. The potential distant origin of the technological tradition indicates that it was a part of the first migrations to the North American Arctic from Siberia, during the Late Pleistocene. There is evidence from various sites from before the Thule complex, that indicates that dog sledding may have been present. However very few sites contain items from all three categories of dog sledding. Therefore, evidence from sites prior to the Thule complex needs to be further investigated to establish the practice of dog sledding on these sites. Reassessing the assemblages of already studied sites to reconsider materials from earlier sites allows overlooked dog sledding material be recognized, for example in the Beringian region where very few sites have been identified with dog traction.

For future research, it would be relevant to consider new items which have been overlooked in previous studies. An interdisciplinary approach consisting of ancient DNA analysis and archaeological studies combined with ethnographic context could provide new insights to pre-Thule dog sledding and shed light on the ancient uses of dogs. Future work would benefit from implementing skeletal observations from prehistoric sites with the presence of dogs. The evidence of sled-related injuries, or other human-related evidence, would assist in understanding the complex relationship between humans and dogs in the Arctic. A similar combined methodology could be applied to evaluating archaeological evidence to identify the use of dogs as pack animals or other forms of tractions, such as travois. Furthermore, microanalysis of the use-wear on wood fragments to interpret whether they show signs of lashings from the sled assembly.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jas.2023.105856.

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