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Ancient migration routes: on the road to the Canadian and Greenlandic Arctic

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ABSTRACT

The question of human movements has always been complex and increasingly difficult to understand as we delve further into the past. The situation might seem somewhat easier to grasp in the Arctic, particularly in Canada and Greenland, due to the relatively limited cultural diversity with only four main cultural groups across the entire chronology. However, chronological challenges and the vast expanse of the territory make it difficult to reconstruct migratory trajectories and the motivations behind these large-scale human movements over considerable distances in relatively short timeframes. This article presents the dates, populations involved, and driving forces proposed to explain the two major migratory movements that took place around 2500 cal. BCE and the 13th century CE, respectively.

1. Introduction

The Inuit are among those contemporary peoples who, despite often being compelled to adopt a sedentary lifestyle, remain highly mobile, both for subsistence and for visiting relatives. Early accounts from explorers and ethnographers document the same practices, describing journeys covering hundreds, even thousands, of kilometers over the course of a few months (e.g., Boas, 1888; Stefansson, 1914).

Studying past Arctic settlement dynamics fundamentally involves understanding how ancient populations navigated through these largely ice- and snow-covered regions. Building hypotheses about these populations requires identifying their mobility patterns, including means of transportation, nomadic cycles, and group composition; motivations, such as the acquisition of food or of technical goods and the avoidance or attraction of specific places; their subsistence strategies, shaped by the balance between terrestrial and marine environments; and their social networks, encompassing both individual relationships and broader intra- and inter-group dynamics.

Access to different resources for food harvesting and craftsmanship (availability/predictability of terrestrial and marine species, accessibility of raw material sources) was closely tied to these mobility patterns. Some resources were scarce, and their locations sometimes very specific, allowing for tracing their diffusion over more than 3000 km: meteoric iron is maybe one of the best-known examples. Some resources are highly predictable (e.g., lithic outcrops), some quite predictable (e.g., driftwood on the beaches, polynya areas), and other more unpredictable (e.g., migratory animals). Past Arctic societies probably moved following seasonal or annual nomadic cycles, depending on their basic needs and their social activities.

Many questions are still open regarding past population movements in the Arctic, particularly regarding the two main generally accepted waves of migration for the peopling of the North American Arctic: the first Pre-Inuit colonization, around 2500 cal. BCE, pertains to the Arctic Small Tool tradition; the second, around the 13th century CE, corresponds to the spread of the Early Inuit (or Thule Inuit) who are the present-day Inuit ancestors. The large number of ephemeral and scattered archaeological sites found along the Alaskan, Canadian, and Greenlandic coasts suggests that during the Pre-Inuit period (~2500 cal. BCE – 1300 CE), and later during the Early Inuit period (from the 13th century CE onwards), migrants rapidly colonised the eastern Arctic coasts, covering more than 5000 km over few centuries (Friesen, 2016, 2021; Friesen and Arnold, 2008; Gulløv and McGhee, 2006; Maxwell, 1985; McGhee, 1996; Moody and Hodgetts, 2013; Morrison, 1999).

There are still pending questions yet to be answered regarding these

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migration waves: 1) What were the motivations and migration strategies of these early migrants, who came from Alaska to rapidly settle the Canadian and Greenlandic coasts (in four to five centuries for the pre-Inuit, two centuries for the Early Inuit)? 2) How did these movements take place, given the environmental constraints of the areas crossed? 3) What were their subsistence practices and technologies at the time of migration?

This study offers a focused bibliographic synthesis on Arctic migrations, supported by critical discussions grounded in archaeological, historical, and ethnographic data. While recent work by Desjardins and Jordan (2019) has provided a broad review of Arctic archaeology in relation to climate change, our objective here is to specifically concentrate on the dynamics of migration across the Arctic regions. Through an extensive review of the literature, we examine environmental and social contexts, technological and cultural frameworks, and the driving factors behind mobility and adaptation strategies. By placing these elements in dialogue, we aim to provide a nuanced understanding of how ancient Arctic populations moved, settled, and adapted over time. The review opens with a brief overview of climatic fluctuations relevant to the periods under study, in order to situate the two main migration waves—Pre-Inuit and Early Inuit—within their broader environmental and cultural contexts.

2. Arctic, not a desert but a network web

To understand the phenomena of Arctic migrations, it is essential to grasp the environmental context and the territorial occupation patterns of ancient populations. The Arctic context is particularly suited for studying human mobility because the treeline appears to have constituted a clear and lasting boundary (until the 18th century) between the Arctic societies and the Native Americans/First Nations peoples living in the forested areas. This relative isolation is confirmed by genetic evidence (Willerslev and Meltzer, 2021). But, far from the stereotype of an icy desert, polar territories are, in reality, complex environments in constant evolution, through which communities have been moving for several millennia, first in Asia, then in America (Fig. 1).

2.1. *Life finds a way: the Arctic as a living landscape*

The climate and weather are known to not forgive inexperience in the Arctic environments which exhibit both diversity and contrast, with nuances that have varied according to climatic fluctuations. Understanding these historical variations is crucial for contextualizing ancient migrations and the adaptive strategies of Arctic populations. Warmer conditions (reducing sea ice extent, expanding marine mammal population, and opening waterways) have first been considered favorable to human groups (McGhee, 1970, 1981) and at the origin of the migrations, the hunters following their preys (Mason and Friesen, 2017, p. 9). Other studies also demonstrate that colder temperatures and increased storminess might also be beneficial to the biological productivity (Mason and Baber, 2003), and consequently to human settlement. Coastal regions exhibit the highest levels of biological productivity, particularly in areas where marine currents bring nutrients to the surface (the open water polynyas in particular), thereby providing a significant amount of food to other marine species, whereas terrestrial zones appear comparatively poorer (for a review, Desjardins and Jordan, 2019, p. 281). Due to the relatively low faunal and floral diversity, any climatic or environmental disturbance can have immediate and dramatic effects on the entire food chain, as demonstrated by contemporary fluctuations (Desjardins and Jordan, 2019, pp. 282, 291).

However, reconstructing past environmental conditions in the Arctic poses significant challenges due to the relatively recent and sporadic installation of meteorological and climatic measuring instruments. Most available records provide high-resolution data only for the past century, limiting our ability to apply advanced methods to understand ancient migratory phenomena (Friesen et al., 2020). Consequently, palaeoclimatic reconstructions heavily rely on indirect records from glaciers, lakes, peat bogs, and dendrochronological data to cover the Pre-Inuit and Early Inuit periods.

Efforts to synthesize these data have been substantial, particularly over the last 2000 years, culminating in comprehensive databases such as the PAGES Arctic 2k. These studies have placed an even greater emphasis on the past millennium (McKay and Kaufman, 2014; Werner

Fig. 1. Main geographic regions of the Eastern Arctic relevant to ancient population migrations. This map presents the principal islands, peninsulas, and bodies of water (in italics) of the Eastern Arctic, including the Canadian Arctic Archipelago and western Greenland. Key areas discussed in the article are highlighted to contextualize ancient migration routes from Alaska to Greenland.

et al., 2018). However, it is important to note that the eastern Canadian Arctic and Greenland are more thoroughly documented compared to western regions (Friesen et al., 2020). For older periods, two publications from the Special Issue of Quaternary Science Reviews: PAST Gateways (Palaeo-Arctic Spatial and Temporal Gateways), synthesize the state of knowledge on the Alaskan region and Canada/Greenland perspective (Briner et al., 2016; Kaufman et al., 2016). In addition, multi-proxy data for the Holocene period at world scale are gather in the Temperature 12k database (Kaufman et al., 2020).

We provide here a synthesis of the main climatic trends observed during the periods relevant to the two Arctic migrations. However, it is essential to remember that the North American and Greenlandic Arctic spans a vast and diverse territory, and regional climatic variations can significantly differ over time.

This territory experienced an initial warming period, between approximately 7000-3000 BCE (Briner et al., 2016; Kaufman et al., 2016), called Holocene Climate Optimum (or Holocene thermal maximum).This period was marked by substantial ice sheets retreat, such as in Greenland between 3000 and 1000 BCE (Briner et al., 2016). The Pre-Inuit migration occurred at the end of this warming period (Finkelstein, 2016), and probably benefitted from the development of terrestrial and marine prey species (Friesen, 2016, p. 677). Over the past two millennia, the general climatic trend in the Arctic indicates a gradual cooling, except for the notable warming observed in the 20th century. This period has been marked by several significant climatic oscillations, including the Roman Warm Period (~200–400 CE), the Dark Age Cold Period (~600–800 CE), the Medieval Climate Anomaly (~950–1250 CE), the Little Ice Age (~1450–1850 CE), and the Contemporary Warm Period (post-1850 CE) (Friesen et al., 2020). The Early Inuit migration falls within the Medieval Climate Anomaly, just after the Dark Age Cold marked cooling period, varying in intensity depending on the region (Dyke et al., 2003; Haberzettl et al., 2010; Ross et al., 2012). The Medieval Climate Anomaly maximum peak temperature appears to have been reached between 920 and 1060 CE, before the onset of the gradual cooling around 1100 CE (Friesen et al., 2020; McKay and Kaufman, 2014; Shi et al., 2012). The Little Ice Age cooling phase followed closely, and was the most intense of the past millennia (Moore et al., 2001; Rolland et al., 2009). However, some lacustrine records suggest a warming peak between 1160 and 1360 CE around the Boothia Peninsula. As we say before, these temporal variations suggest different climatic evolution scenarios depending on the study region.

Another crucial factor is the notion of refugium and food predictability. Human presence has been most consistently and continuously recorded around polynyas— year-round open water areas sometimes covered by a thin layer of ice (Fig. 2). From a climatic perspective, the presence of polynyas—particularly those surrounding the Foxe Basin and the Melville Peninsula—appears to have contributed to a more pronounced continental climate, characterized by greater mean annual temperature ranges and lower precipitations than in the Baffin Region (Barber and Massom, 2007; Friesen et al., 2020; McKay and Kaufman, 2014). These environments offer a rich marine ecosystem hosting abundant, diverse, and sustainable fauna, and generally used as more food secure areas during the harshest climatic episodes (Appelt et al., 2016; Desjardins and Jordan, 2019, p. 288). The Igloolik region, north of Foxe Basin, is a prime example, as is the North Water Polynya in north-western Greenland. The islands of Igloolik have shown continuous human occupation from the pioneering Pre-Inuit cultures to the present day. Walruses appear to have been particularly abundant there, making this region a key source of ivory (Desjardins and Jordan, 2019; Houmard, 2011). Manufactured objects, in particular the harpoon heads, exhibit bigger dimensions than anywhere else in the Arctic (almost 10 cm long instead of 5–6 cm elsewhere). Around the North Water Polynya, walrus and narwhal tusks seem to have been more extensively exploited (Gotfredsen et al., 2018; Mønsted et al., 2023; Usher, 1965). Each polynya exhibits distinct characteristics, which contribute to ecological diversity but also pose challenges when attempting to extrapolate the findings from a local case study to broader regional or circumpolar scales.

Far from being a vast and static ice desert, the Arctic reveals a mosaic of environmental conditions shaped by long-term climatic oscillations and regional heterogeneity. It is this variability that has enabled life to take root and adapt, allowing both ecosystems and human communities to establish themselves in diverse and often challenging settings. Within this dynamic landscape, mobility was not merely a strategy but a mode

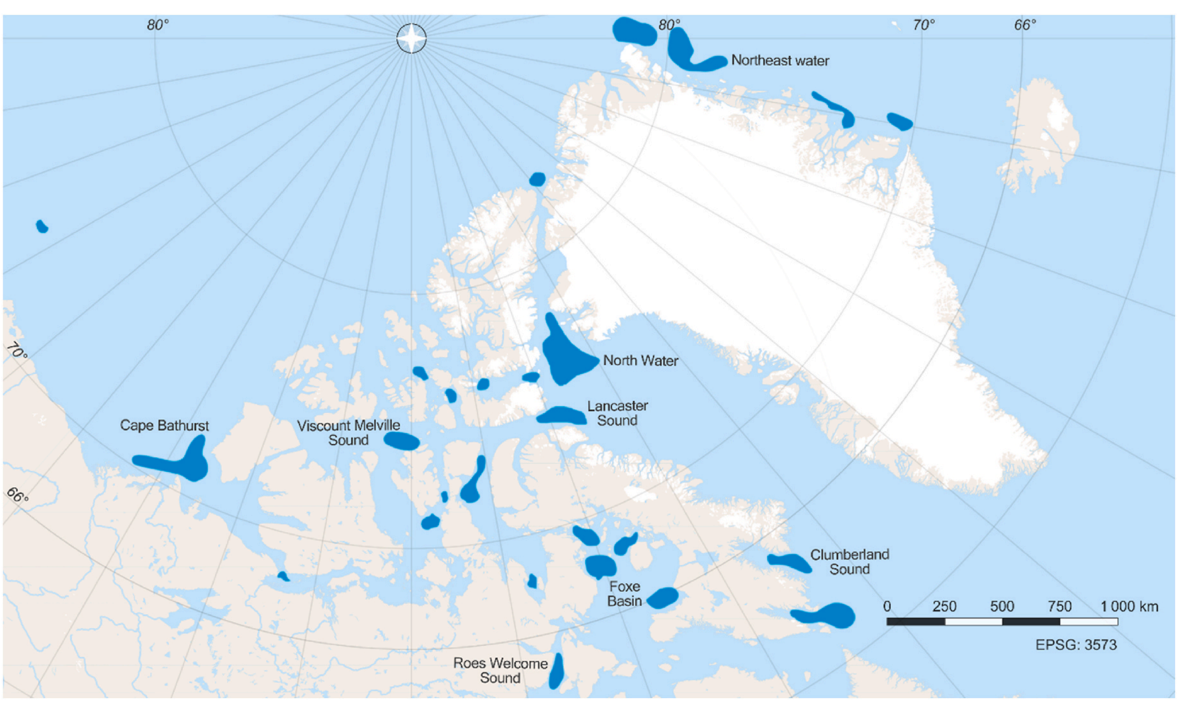

Fig. 2. Distribution of the main polynyas of Eastern Arctic. The polynyas are represented by the blue shapes. CAD: M. Martinet et Q. Verriez. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

of existence, an essential pattern that structured how Arctic populations moved, settled, and thrived.

2.2. Mobility is a way of life

For an Inuk, mobility is an integral part of his lifestyle. Even today, the Inuit consider travel not as an activity solely aimed at reaching a destination, but as a period of life during which all daily activities unfold: subsistence, provisioning, trade, marriage, birth, exploration (Aporta, 2004, 2009). We are approaching this aspect through the accounts of early Western explorers and more recent ethnographic researches. However, the evidence of mobility provided by the material culture of ancient populations may still resonate with modern patterns of movement. Excluding industrial-era means of transportation, if mobility-related technologies have not fundamentally changed, we may assume that the way these populations travel has not significantly changed either.

Every journey has a social dimension, with the duration varying according to weather conditions, and both humans and animals encountered on the way. This point was not always well understood by early explorers, who noted significant discrepancies in the accounts provided by different informants (Aporta, 2004; Parry, 1824). But they unanimously underlined the extraordinary geographic knowledge of the Inuit. Indeed, they frequently relied on Inuit guidance for their expeditions.

In the historic times, travel routes were orally transmitted from generation to generation through songs and narratives, with experienced men tracing winter paths by sled each year when snow and ice settled in the autumn. The landmarks include anecdotes and references to toponyms that refer to topography (e.g., lakes, rivers, islands, notable landforms, human markers) or mention specific activities. These oral descriptions detail everything essential to guide a traveler (Aporta, 2004; Collignon, 1996; MacDonald, 1998). Each stage of the journey is named according to the life activity involved: rest, hunting, fishing, raw material gathering, caches for storing equipment, or food. The mental maps of the historic Inuit cover vast territories, sometimes extending over more than 800 km in longitude.

Although routes vary according to the seasons and food availability, land routes often follow the same paths year after year, while those on sea ice adapt to the conditions of ice formation. Traditional routes leading to the locations where resources are abundant and predictable were likely used for centuries (Aporta, 2009). For that reason, routes of the Early Inuit might had trajectories similar to those used later on, because they used the same means of transportation than those used before the motorization. The routes followed by the Pre-Inuit pioneers are more difficult to draw, due to the difficulty to date the different site occupations and the poor preservation of substantial geographical area on the road to Greenland. However, some parameters such as polynyas, ocean currents, or fjords and mountains might not have changed significantly enough to substantially modify the landscape. Therefore, but with more caution, some extrapolation for the Pre-Inuit societies might be proposed.

Modern Inuit are able to travel 500 or even 1000 km on a single journey, either to gather raw materials or to migrate to another location. When travelling, the Inuit carry primarily material goods and usually no more than a single day's food supply. They hunted along the way, as they encountered game. Game is often encountered opportunistically during travel. However the need for a rare material, such as metal, wood, ivory, or soapstone can prompt travel over vast distances (Morrison, 1991; Nagle, 1984; Stefansson, 1914). The absence of caribou or, conversely, the sudden appearance of sought-after materials (drifted on the beach, or after a shipwreck for historic times) might prompt a group to move, temporarily or permanently, and adjust their nomadic cycle (e.g., Houmard and Bitrian, 2023; Usher, 1965). In recent times, long-distance journeys generally involved no more than three families, or about fifteen individuals. Whenever possible, they travelled lightly, with the load adjusted to the journey (duration, weather conditions, number of participants, and mean of transport). The migration conditions might have sometimes involved travelling with more substantial stuff.

Winter and summer travel patterns of course also differ. The sled is preferred for the autumn, winter and spring times when snow and ice conditions are good; during the summer, maritime transport using kayaks and umiat (plural of umiak) – enclosed narrow and large open boats, respectively – becomes more common (Morrison, 1999, p. 150; Park, 2023, pp. 10–12). Flexibility, maneuverability, and lightness are the main attributes of all Inuit means of transport. The beginning of winter and the end of spring often result in poor travel conditions, making travels more hazardous. Villages may become isolated for several days. The polar night in winter also does not favor travel, especially as one approaches the North Pole, where the situation is even more extreme than in the more southern regions. Consequently, migrations take place by sled during fall or, more commonly spring, and by umiat to navigate ice-free areas in summer. Understanding the trajectories and motivations of Arctic mobility, both past and present, is crucial to understanding the settlement patterns of the Arctic.

The Arctic, far from being a static landscape, has been a dynamic and interconnected network shaping the mobility and settlement of its inhabitants for millennia. Environmental contexts and territorial occupation reveal a complex interplay of climatic fluctuations, resource availability, and social networks. These historical variations are crucial for understanding ancient migrations and adaptive strategies. To explore the ancient Pre-Inuit and Early Inuit migrations, we should delve into their unique adaptations and the lasting legacies in the Arctic landscape.

3. Peopling the North American and Greenlandic Arctic

3.1. First peopling of Arctic: the Pre-Inuit migration

Based on the discreet nature of their occupations, the Pre-Inuit pioneers are considered highly mobile small-scale societies who may have gathered seasonally (Grønnow, 2017; Mason, 2016; Mason and Friesen, 2017, pp. 146–159). According to the most recent assessments, they first occupied the southern Arctic Archipelago and the adjacent mainland from Amundsen Gulf to the Melville Peninsula, likely marking a first step before they move further east towards the High Arctic, and finally Greenland. All the pioneering groups who settled in Canada have been named Pre-Dorset (Fig. 3). Once they arrived in Greenland, they split into two different subcultures, Independence I for the northernmost area, and Saqqaq for the western coasts, as well as more discretely the eastern shores. Among the motivations suggested for this migration are the pursuit of caribou and musk ox herds, or, the more favorable climatic conditions around 2500 cal. BCE (D'Andrea et al., 2011; Mason and Friesen, 2017, pp. 146–149).

3.1.1. Pre-Inuit mobility technologies and subsistence strategies

The pioneer Pre-Inuit groups were probably organised in egalitarian societies, consisting of highly mobile family units. An important part of their material culture was adapted to such a way of life. Their occasional settlements on islands, and the vast distances they crossed, suggest the use of sleds (without dogs) and kayak-like watercraft, although the material evidence related to these means of transportation do not exist for this pioneering Pre-Inuit period. Indeed, sled runners only appear in the material culture from the Dorset period onwards, around 800 cal. BCE, alongside miniature kayak models (Mary-Rousselière, 1979). Kayak-like watercraft would have facilitated the hunting of marine mammals using harpoons thrown with atlatls (notably found on the Saqqaq site) over distances of up to 40 m from the hunter, employing a line and floats to retain the prey (Grønnow, 2023). Other weapons, that seem to appear during the Late Pre-Dorset, such as toggling harpoons, also likely indicate seal hunting at breathing holes on the sea ice.

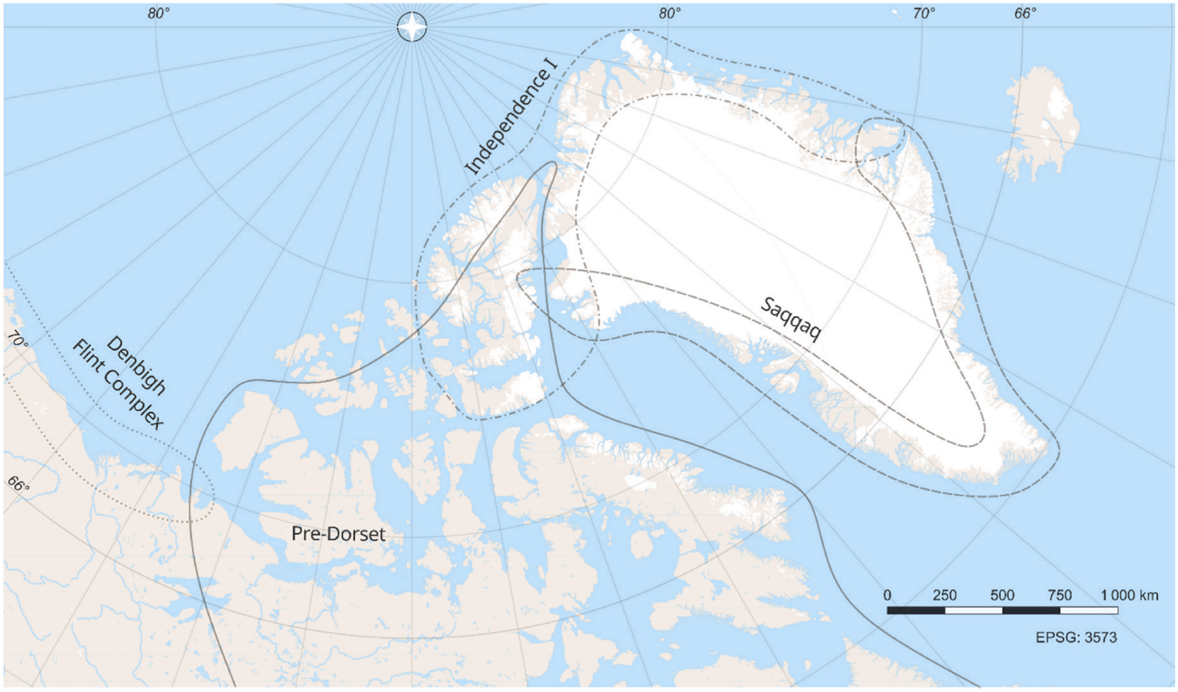

Fig. 3. Distribution of main Pre-Inuit cultural areas after Pre-Inuit migration (ca. 2500–1300 BCE). Adapted from Mason and Friesen (2016, 2017). This map shows the main cultural complexes associated with the first human migrations into the Eastern Arctic: the Denbigh Flint Complex (Alaska), Pre-Dorset (Canada), Saqqaq, and Independence I (Greenland). CAD: Q. Verriez.

In terms of subsistence, the faunal remains reveal that caribou and musk ox were the primary prey in the High Arctic, particularly in the Independence I phase, whereas the more southern Pre-Dorset and Saqqaq groups predominantly hunted small seals, caribous, small mammals, small cetaceans, birds, fish, and molluscs (Gotfredsen and Møbjerg, 2004; Meldgaard, 2004; Murray, 1999).

The most commonly identified architectural structures from the early Pre-Inuit occupations are tent rings measuring 7–12 m^2, probably sheltering single-family units. So they were probably highly mobile with lots of ephemeral occupations composed of one to three dwellings (McGhee, 1996; Murray, 1999, p. 468). However, some sites have yielded larger tent rings (up to 30 m^2) or clusters of up to twelve single-family tent rings, suggesting seasonal aggregations interpreted as intercultural exchange hubs, facilitating both genetic renewal and the transmission of information while reinforcing social and spiritual ties (Grønnow, 2017). Also, back-and-forth movements from interior to coast following the seasons seem to be observed for a number of sites, with more multi-seasonal occupations around the polynyas (e.g., Park and Milne, 2016, p. 696).

The lithic raw materials used indicate the movement of objects, and probably people, around particularly prized lithic sources, such as killiaq (silicified slate) in Greenland (Grønnow, 2017; Sørensen, 2012), or the Ramah chert in Nunavik and Labrador (Loring, 2002).

Generally speaking, the Pre-Inuit populations (Pre-Dorset, Independence I, and Saqqaq) demonstrate an exceptional cultural stability and homogeneity over periods sometimes exceeding 2000–3000 years, sharing a common foundational structure, likely cosmogonic in nature. This is evident in their architecture - e.g., mid-passage, material culture (e.g., standardised technical equipment-, and social organisation (e.g., similar subsistence patterns and settlement structures). The spatial organisation within dwellings and their construction methods reflect this uniformity (Grønnow, 2023). As a result, the definition of the various Pre-Inuit cultural groups is still a matter of debate within the archaeologists' community. As shown below, the main differentiating marker remains the territory commonly attributed to each group, which is most often linked to the arrival of a population on a new area.

3.1.2. *From Alaska to Greenland: the mosaic of Pre-Inuit cultures*

The pioneers of the Pre-Inuit North American Arctic migration, likely initiated around 2500 cal. BCE (and maybe as early as 3200 cal. BCE in Mason and Friesen, 2017, p. 147), are considered as derivating from the Denbigh Flint Complex in Alaska (Giddings, 1964; Grønnow, 2017). As currently accepted by archaeologists, the Denbigh Flint Complex (3200-1450 cal. BCE, after Mason and Friesen, 2017, p. 147; Tremayne and Rasic, 2016, p. 350) is the Alaskan regional variant of the Arctic Small Tool tradition that extends into Canada and Greenland. This archaeological culture is primarily characterized by its lithic industry, with poorly preserved organic remains. Identified in Alaska and north-western Canada, this culture is characterized by a maritime subsistence (seals, fish, birds), supplemented by terrestrial resources (elk, caribou, sheep, small furred mammals, picked berries). Archaeological remains also shown a range of tiny and precisely flaked tools and weapons sometimes made of obsidian, indicating long-distance exchanges between Alaska and Canada (Larsen, 1968; Tremayne and Rasic, 2016; VanderHoek, 2009).

It was during their eastward migration that this population gradually divided into three distinct regional cultural groups: Pre-Dorset in Canada (e.g., Helmer, 1994; Irving, 1968; Knuth, 1952; McGhee, 1984), Independence I in northern Greenland (e.g., Grønnow, 2016; Grønnow and Sørensen, 2006; Schledermann, 1990; Sørensen, 2012), and Saqqaq along the Greenlandic coasts, particularly the western shore (e.g., Grønnow, 2017; Meldgaard, 1996; Sørensen, 2012). Although they shared common origins and closely related traditions, these cultural groups are clearly distinguishable when present in the same geographical areas, revealing divergences in material culture whose origins remain largely unexplained (e.g., Desrosiers, 2009; Friesen and Mason, 2016 for the Alaskan and Canadian prehistory; e.g., Grønnow, 2017; Sørensen, 2012 for the Greenlandic prehistory). However, for some authors, if these three cultures would have been named presently, they would have belong to the same entity (Mason and Friesen, 2017, p. 145), the nuances being minor compared to other cultures such as the Thule Inuit.

From West to East, first the Pre-Dorset migrants spread in the almost entire Canadian archipelago, from High-Arctic to subarctic coasts, with the largest known concentration of sites around the Foxe Basin (Nunavut). Maybe mainly due to the history of the discipline, the Pre-Dorset culture was named after the Dorset culture because it is an older phase than the Dorset one in the same general area (Collins, 1954). Rather than a real definition of what is the Pre-Dorset culture, it is mostly from comparison with others, and especially the Dorset one, that it got its entity. Among the Pre-Dorset phase, three main different cultural traditions are usually distinguished, based on the geography, and interpreted as acculturative adaptations (Park and Milne, 2016, pp. 693, 703). The westernmost sites, for example, seem to show Alaskan Norton fishermen influences (see Le Blanc, 1994, p. 115). Similarly, Labrador sites might have integrated Saqqaq traits from western Greenland and Independence I (Cox, 1978; Fitzhugh, 1976; Tuck, 1975). Finally, the subarctic Barrenlands and northern Boreal Forests show unusual woodworking tools, a production presumably influenced by the woodcraft of the Amerindian Na-Dene southern groups (Gordon, 1975; Meyer, 1971).

The Pre-Dorset variability is usually explained not only by other cultural influences, but also by resource and environmental variability: a 'core-area' versus 'fringe areas' have been debated several times, both for the Pre-Dorset and its Dorset development, with advocates and opponents (see Park and Milne, 2016; Ryan, 2016 for a summary of the debate). This 'core-area' corresponds to the main concentration of sites around the Foxe Basin. Following the different beach ridge elevations, in this area are spread: the Pre-Dorset (from 95 to 23 m above the sea level, asl), then the Dorset (from 22 to 8–13 m asl), and finally the Thule Inuit occupations (from 8 to 11 m to the shore line). Surveying the Igloolik area, Savelle and Dyke (2014) numbered no less than 837 structures at Igloolik, 511 on Jens Munk Island, 305 on Rowley Island, 212 on Koch Island, 118 at Alarnerk, 22 at Cape Thalbitzer, and 21 at Rowley River (Savelle and Dyke, 2014, p. 255). For the two main islands (Igloolik and Jens Munk), about 1000 structures have been identified for the Pre-Dorset period, about 220 for the Dorset, and about 70 for the Thule Inuit occupations.

Maybe because of the subsequent isolation following the migration, the two cultures identified in Greenland, Independence I and Saqqaq, are considered more homogeneous. The Independence I is the earliest archaeological culture, spread in the northernmost area, from the Canadian High Arctic archipelago to Northeast Greenland, and discretely along the northwestern coast (Grønnow, 2016; Grønnow and Jensen, 2003). The Saqqaq culture is the most important Greenlandic Pre-Inuit culture, both in number of sites and expansion, from West and Southeast Greenland (2500-800 BCE). Its main area is West Greenland, from the Thule district to the Nanortalik district in the south; on the eastern coast, only the southern areas have been populated, from the tip to the Scoresby Sound (Grønnow and Pind, 1996). While attempts to subdivide this culture have been proposed (Gotfredsen and Møbjerg, 2004; Møbjerg, 1999), the changes seem to be progressive and endogenous. Saqqaq is even described as the most conservative regional tradition in the Arctic in terms of the material selection (Sørensen, 2012, p. 338). The emergence of the Saqqaq and Independence I, has been questioned (Sørensen, 2012, p. 332). As contemporaneous sites have been identified in West Greenland, the Saqqaq culture is presumed to have developed in that area. While the subsistence of the Independence I groups is considered to be more terrestrial, the Saqqaq subsistence seemed to be more maritime-oriented (Appelt, 1997). A cooling period seems to sign the end of the Saqqaq culture (Jensen, 2016; Ryan, 2016). These two cultures were finally replaced by subsequent Dorset migrants coming from the northeastern Canada, becoming the Greenlandic Dorset along the Greenlandic coasts (Grønnow, 2017; Jensen, 2016).

3.1.3. *Emergence and expansion of the Dorset culture in Canada*

The Dorset culture likely emerges from the Igloolik 'core-area' (Nunavut, Canada) where a huge concentration of sites around the Foxe Basin have been observed. In this particular area, the shift from the Pre-Dorset to the Dorset phase is observed between the 23 and 22 m terraces asl (e.g., Houmard, 2018, 2011; Meldgaard, 1962). New technologies and equipment seem to suddenly appear, such as specific ice gear (e.g., ice creepers, snow-knives, sled runners, ice scoops), as well as potential watercraft (e.g., kayak models) and art (e.g., animal figurines, shaman-related artefacts), and the likely disappearance of the bow and arrow technology (e.g., Houmard, 2018; Ryan, 2016 for a summary). But, more than a simple evolution of the morphology of the artefacts, a substantial change in the subsistence can be observed. The Dorset groups still relied on seasonally available resources, but seem to be more sedentary showing an increased diversity in the architecture of the dwellings, from light structures to bigger houses, the size culminating at the end of the Dorset period with the so-called long-houses (reaching up to 45 m in length) (Damkjar, 2000, pp. 170–172; Park, 2003).

While some authors saw an abrupt change, and the existence of a transitional period (Nagy, 1994; Ryan, 2016; Savelle and Dyke, 2014), a progressive development from the Pre-Dorset to the Dorset culture has been recently demonstrated (Houmard, 2011, 2018; Nagy, 2015). Consequently, an incursion of Norton fishermen populations from Alaska for explaining the Pre-Dorset to Dorset transition (e.g., Savelle and Dyke, 2014) is now rejected. This shift has earlier been explained by an ecological stress (Meldgaard, 1962, pp. 92–93), or as now accepted, at least a period of climate instability. This Dorset culture probably emerged in the Foxe Basin and then spread in both directions, the eastwards new wave of migration reaching the Nunavik and Newfoundland areas (e.g., Desrosiers, 2009), as well as Greenland where the Dorset culture become the Greenlandic Dorset (e.g., Jensen, 2016).

3.1.4. *Pre-Inuit migration synthesis*

One of the key challenges in dating Arctic migration events lies in the so-called marine reservoir effect, which causes radiocarbon dates from marine organisms to appear artificially older than their true age. This discrepancy can lead to significant overestimations of the timing of human occupations that relied heavily on marine resources. Following the Danes' decision to only consider the dates for which radiocarbon was in equilibrium (i.e., from terrestrial material, including terrestrial mammal bones, antlers, and local plants), the first wave of pioneering Pre-Inuit migration might not have exceeded four to five centuries (Grønnow, 2017) (Fig. 4, Table 1). The absence of the open boats –umiat– at that time suggests a land-based migration on foot and by sled (without dogs) because the kayaks are not best suited for transporting huge loads. Pre-Inuit settlement patterns indicate a near-continuity of occupation in the Canadian Arctic, especially in the Igloolik area, north of Foxe Basin. In contrast, in Greenland, there appear to have been phases of expansion and retreat in response to climatic fluctuations. The Saqqaq and Independence I cultural groups seem to have disappeared around 1000-600 cal. BCE, making way for a new wave of Dorset migration around 800-400 cal. BCE, originating from the Canadian Archipelago. A radiocarbon plateau from 790 to 400 cal. BCE is blurring the exact scenario of population replacement; it is not yet possible to confirm whether the former Saqqaq/Independence I societies ever met the new Greenlandic Dorset migrants (Grønnow, 2017). While cultural continuity is demonstrated, for example, in the Igloolik region (Houmard, 2011, 2018), the arrival of the Dorset population in Greenland (Greenlandic Dorset phase) is marking a discontinuity with the preceding Pre-Inuit occupations.

3.2. *Following the trails again: the Early Inuit migration path*

The Early Thule Inuit migration is perceived as a flux of people leaving Alaska to Canada for reasons that need to be better understood. Not only the timing but also the motivations and the mobility patterns involved are still debated. While the nature of the migrants is no longer a matter of debate, the Thule Inuit culture being the only one accepted for unifying all these newcomers, the routes, the climate conditions, the trajectories, and the demography lack precise and precious information

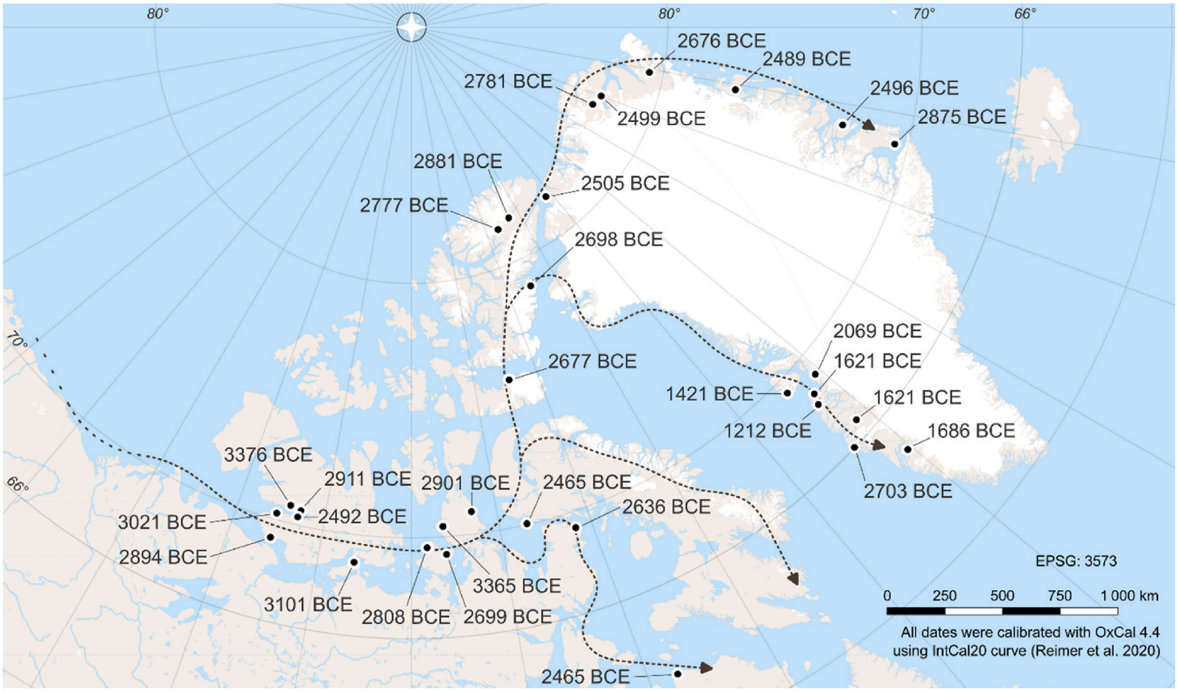

Fig. 4. Pre-Inuit migration routes. Dotted arrows indicate probable routes taken by Pre-Inuit populations from the northern Alaskan coast to the Canadian Arctic Archipelago and Greenland, following known settlement locations (black dots). CAD: Q. Verriez.

across the 5000 km from West to East, due to the imprecision of the chronology and the variability of preservation and to research history. Only the general sketch is accepted by the archaeologists, i.e., a general population movement from Alaska to Canada and Greenland, i.e., the Eastern Arctic, at the beginning of the second millennium (between the 11th and 14th centuries depending on the authors).

After about 3000 years of relative isolation and stability among the Pre-Inuit cultures, the eastern Arctic is again the scene of new migration moves. The Early Inuit migrants might have encountered the Last Dorset groups in Canada, based on contemporaneous radiocarbon dates (Friesen, 2020). The Early Thule migrants are considered genetically distinct from Pre-Inuit populations (Gilbert et al., 2008; Raghavan et al., 2015; Rasmussen et al., 2010), though some intermixing might have occurred (Flegontov et al., 2019; Helgason et al., 2006). So, a replacement of population occurred sometime between the 11th and 15th centuries, with a likely avoidance behavior based on the parsimony of the evidence suggesting Dorset/Early Inuit interactions (e.g., Mason and Friesen, 2017, pp. 187–188; Park, 2023 for recent summary).

From the recent radiocarbon date assets, the Early Thule Inuit migration from Alaska to Canada and Greenland occurred around the 13th century in the middle of the Medieval Warm Period (Friesen and Arnold, 2008; McGhee, 2000), using sleds and/or umiat. Some scholars favor the terrestrial route (e.g., Morrison, 1999), others support the maritime route (e.g., Friesen, 2013; Krupnik and Chlenov, 2009; Mason, 2020) while still others suggest a combination of both modes of transport (McGhee, 2009).The kayaks might be used as well, in particular for the subsistence activities along the route, especially for sea mammal and bird hunting. Based on radiocarbon dates and the material culture (e.g., harpoon heads, pottery), the migration route to Greenland might have passed through Amundsen Gulf, Foxe Basin and Smith Sound (e.g., Mason and Friesen, 2017, p. 182).

3.2.1. *Early-Thule Inuit mobility technologies and subsistence strategies*

Two primary means of transportation were employed for these migrations: the sled, the main means of transportation for the 9–10 months of snow cover and frozen ground, and the umiak, a skin-covered open boat, during the summer when large extents of ice-free water facilitated faster maritime transport (Mason, 2020; Morrison, 1999; Park, 2023). However, these skin boats have the disadvantage of absorbing water, which requires constant re-oiling and several days of drying between the different steps, preventing immediate travel back to the sea after each leg of the journey (e.g., Nelson, 1902). The relative fragility of the wooden frame, as well as the walrus/bearded seal skins used to cover it, also necessitate regular repairing and raw material procurement/availability, particularly in terms of driftwood, not so common in the Eastern Arctic (Mason, 2020).

In terms of technology, the Dorset craftsmen were excellent stone tool makers, while the Thule Inuit preferred to use metal tools, though they did not master metallurgy. The lithic technology of the Thule Inuit is considered as coarse, and interpreted as a loss of skill due to the introduction of the metal blade. Because sources of iron and copper are rare in the Arctic, such supplies always required long-distance travels and exchanges, thus leading to contacts and cultural interactions (Buchwald, 2001; Buchwald and Mosdal, 1985; Jolicoeur, 2020). However, such circulations are no easy to observe due to the very bad preservation of metal in the Arctic.

While the presence of the dog is confirmed for the Dorset period, its use for transport seems to be a Thule innovation (although the dog traction is not attested in the Western Arctic in the material culture). The whaling technology is the other major innovation, and both technologies are linked to mobility: the skin-covered open boat umiat not only allow an intensive exploitation of cetaceans, particularly bowhead whales (*Mysticetus borealis*), but also a faster navigation with more substantial loads. However, whaling is not attested in all Thule Inuit Alaskan sites (e.g., Mason, 2020 for a recent summary).

In terms of subsistence, they mostly relied on sea and terrestrial mammals, as well as birds and fish, with variation depending on the geographical location and seasonality (Mason and Friesen, 2017; Whitridge, 2016, pp. 839–842). The summer and fall seasons are usually dedicated to fishing, bird hunting and whaling, as well as caribou hunting, the surplus of accumulated food being stored for the harsher winter times, and spent in the qarmat (men's houses) and sodhouses (Whitridge, 2016, p. 839). Winter time is mostly focused on seal hunting.

Table 1
Radiocarbon dates used in this study for Pre-Inuit sites across the Eastern Arctic. Only the oldest date for each site. The table compiles radiocarbon determinations for key archaeological sites, including their cultural attribution (PD: Pre-Dorset; ID1: Independence I; SAQ: Saqqaq; IGI: Igloolik Island), material type, and laboratory number. BP values are presented with associated standard deviations and $\delta^{13}C$ values when disponible in data source. Calibrated dates (2 standard deviation) were recalculated using OxCal v4.4.4 (Bronk Ramsey, 2021) and the IntCal20 calibration curve (Reimer et al., 2020), and are mentioned in cal. BCE. Only samples from terrestrial materials (bones of terrestrial mammals, antler, and plant remains) were considered to avoid marine reservoir bias. References correspond to the original publication or data source.

Site	Cult	Lab. No.	Layer	Material	BP	±	$\delta^{13}C$	Calib. 2	Reference
DCA-188b	PD	AA-40591	NA	Charc.(*Salix* sp.)	4557	45	NA	3376-3098	Savelle and Dyke (2002)
OcLb-6	PD	AA-61958	Feature 6	Bone (caribou or musk-ox)	4486	62	−16.32 (high!)	3365-3010	Savelle and Dyke (2009)
NfNg-9	PD	UCI-AMS-300358	Feature 4	Charc. (*Salix* sp.)	4415	20	NA	3101-2925	Dyke and Savelle (2009)
DCA-26	PD	AA-40576	NA	Charc. (*Salix* sp.)	4247	51	NA	2936-2833	Savelle and Dyke (2002)
DCA-35a	PD	AA-40577	NA	Charc. (*Salix* sp.)	4237	43	NA	2816-2669	Savelle and Dyke (2002)
OfJo-24	PD	UCI-AMS-43960	Feature 3	Charc. (*Salix* sp.)	4230	15	−24.5	2901-2867	Dyke et al. (2011)
DCA-151a	PD	AA-40587	NA	Charc. (*Salix* sp.)	4216	51	NA	2911-2662	Savelle and Dyke (2002)
DCA-175a	PD	AA-40863	NA	Charc. (*Salix* sp.)	4197	41	−25.8	2822-2663	Savelle and Dyke (2002)
NjLg-25	PD	UCI-AMS-30371	Feature 2	Charc.(*Salix* sp.)	4195	15		2808-2749	Dyke and Savelle (2009)
NhPl-2	PD	AA-41518	NA	Charc. (*Salix* sp.)	4172	58	−25	2894-2618	CARD
OcLb-1	PD	AA-61366	Feature 1	Bone (caribou)	4164	58	−15.62 (high!)	2890-2580	Savelle and Dyke (2009)
OdPc-26	PD	AA-40584	NA	Charc. (*Salix* sp.)	4163	45	−25.2	2886-2622	CARD
DCA-146a	PD	AA-40585	NA	Charc. (*Salix* sp.)	4154	45	−26.3	2882-2621	Savelle and Dyke (2002)
DCA-150	PD	AA-40586	NA	Charc. (*Salix* sp.)	4133	42	−26	2787-2580	Savelle and Dyke (2002)
NjLg-33	PD	UCI-AMS-30372	Feature 6	Charc. (*Salix* sp.)	4110	15	NA	2699-2579	Dyke and Savelle (2009)
NhLa-14	PD	UCI-AMS-30367	Feature 1	Charc. (*Salix* sp.)	4100	15		2696-2576	Dyke and Savelle (2009)
NfNg-17	PD	UCI-AMS-30359	NA	Charc. (*Salix* sp.)	4070	15		2637-2567	Dyke and Savelle (2009)
West Wind	ID1	S-2214	NA	Charc. (*Salix* sp.)	4055	80	NA	2881-2451	Sutherland, 1996 (CARD)
NiNf-57	PD	Beta-171162	NA	Bone (goose)	4020	40	NA	2636-2461	CARD
Røde Hytte	ID1	AAR-1184	NA	Charc. (*Salix arctica*)	4030	90	NA	2875-2341	Sandell and Sandell (1996)
Camp View	ID1	TO-994	Feature 2	Charc. (*Salix arctica*)	3990	70	NA	2698-2290	Schledermann (1990)
Qeqertasussuk	SAQ	K4823	18L	Herbal turf	3980	85	−25.0	2703-2276	Grønnow (2017)
DCA-30b	PD	AA-40850	NA	Charc. (*Salix* sp.)	3973	42	NA	2581-2342	Savelle and Dyke (2002)
DCA-186a	PD	AA-41515	NA	Charc. (*Salix* sp.)	3971	46	NA	2582-2339	Savelle and Dyke (2002)
DCA-146c	PD	AA-40861	NA	Charc. (*Salix* sp.)	3970	46	NA	2581-2338	Savelle and Dyke (2002)
NfHg-6	PD	UCI-AMS-30356	Feature 1	Charc. (*Salix* sp.)	3960	15	NA	2498-2454	Dyke and Savelle (2009)
Pearylandville	ID1	K-938	24	Charc. (*Salix* sp.)	3950	120	NA	2781-2138	Knuth, 1984
Silja Ø	ID1	AAR-18512	LB21, C	Charc. (*Salix arctica*)	3946	25	−26.6	2496-2343	Jensen (unpubl.)
Lakeview	ID1	TO-993	Feature 30	Charc. (*Salix* sp.)	3940	70		2624-2204	Knuth (1984)
QkHn-13	PD	S-2484	NA	Bone (caribou or musk-ox)	3930	95	−20	2677-2138	Helmer (1991)
Kettle Lake S	ID1	K-1260	M-3	Charc. (*Salix arctica*)	3930	130		2777-2126	Knuth (1984)
NfNf-10	PD	UCI-AMS-30363	Feature 1	Charc. (*Salix* sp.)	3925	15		2471-2395	Dyke and Savelle (2009)
DCA-92a	PD	AA-40578	NA	Charc. (*Salix* sp.)	3911	42	−26.2	2492-2284	Savelle and Dyke (2002)
NfNH-3	PD	UCI-AMS-41498	Feature 2	Charc. (*Salix* sp.)	3910	15		2468-2342	Dyke and Savelle (2009)

(*continued on next page*)

Table 1 (*continued*)

Site	Cult	Lab. No.	Layer	Material	BP	±	$\delta^{13}C$	Calib. 2	Reference
Portfjeldet 1	ID1	K-928	NA	Charc. (*Salix* sp.)	3890	120		2492-2284	Knuth (1984)
KcFr-5	PD	Beta-357957	1-E	Caribou Bone	3880	30	−15,4	2465-2284	Nagy (2015)
Solbakken 2B	ID1	K-3366	NA	*Ovibos moschatus*	3870	85	−18.8	2505-2131	Grønnow and Jensen (2003)
DCA-30a	PD	AA-41498	1	Charc. (*Salix* sp.)	3859	45		2465-2201	Savelle and Dyke (2002)
OaHt-7	PD	UCI-AMS-71591	Feature 3	Charc. (*Salix* sp.)	3835	20		2350-2201	Dyke et al. (2011)
Deltaterrasserne 14	ID1	K-4497	NA	*Ovibos moschatus*	3850	90	−18.6	2499-2113	Grønnow and Jensen (2003)
Midternæs	ID1	K-3364	6	*Ovibos moschatus*	3830	85	−19.3	2489-2033	Knuth (1984)
OaHu-1	PD	UCI-AMS-53269	Feature 3	Bone (caribou or musk-ox)	3810	20	−18.5	2304-2196	Dyke et al. (2011)
OfJc-24	PD	UCI-AMS-42206	Feature 4	Bone (caribou or musk-ox)	3805	15	−18.1	2294-2197	Dyke et al. (2011)
DCA-36	PD	AA-40854	NA	Charc. (*Salix* sp.)	3804	41		2353-2134	Savelle and Dyke (2002)
Qajaa	SAQ	K-3899	Lowermost	Twigs	3550	80	−25.6	2069-1685	Grønnow (2017)
Angujaartorfik	SAQ	K-5193	NA	Bone (caribou)	3190	75	−17.6	1621-1281	Kapel (1996)
Niivertussannguaq	SAQ	T-12917	Feature 11	Charc. (*Salix* sp. and ericales)	3160	85	−26.1	1621-1214	Jensen (2006)
Itinnera	SAQ	K-1193	NA	Charc. (*Salix* sp. and *Betula nana*)	3140	120		1686-1055	Jensen (2006)
Nipisat	SAQ	AAR-3572	NA	Bone (caribou)	3065	40		1421-1221	Gotfredsen and Møbjerg (2004)
Niaqornaarsuk	SAQ	K-518	NA	Charc. (*Betula nana*)	2760	100		1212-776	Jensen (2006)

In terms of architecture and settlements, winter sites vary from few to about fifty houses, i.e., up to about a hundred residents (Savelle, 2000; Whitridge, 1999). The architectural diversity is reflected by the different types of dwellings, such as the winter semi-subterranean sod-houses (iglu, in Whitridge, 2016, p. 832), the snow houses (igluviat, plural of igluviak), the men's house (qarmat, plural of qarmaq), and the summer and early fall tents (tupit, plural of tupik, Whitridge, 2016, pp. 832–833).

The tools and weapons manufactured and used in each type of house of course depended on the duration and the type of activities performed. The more sedentary the camp was, the more diversified and quantitatively important the material culture: worn out tools, and objects too heavy or unnecessary at the next settlement were probably abandoned at the time of departure, and then could be found in the houses during the archaeological excavations. It is mostly that material culture that has been found by the archaeologists and on which all the subsequent interpretations are based. Unfortunately, few summer habitats have proportionately been discovered and excavated, and those that have been, only contained around twenty artefacts (e.g., Holtved, 1944). The semi-subterranean dwellings, occupied for 9–10 months of the year, have received the most attention because being more easily recognizable and richer (e.g., Mathiassen, 1927). Located along the shorelines, these dwellings concentrated most domestic and winter activities. Because the outside areas surrounding the houses were usually not excavated (an exception is the new excavations led in Nuulliit, Mønsted et al., 2023), relatively few mobility-related items were discovered. Kayak elements found inside are rare, and even rarer are umiak components, as boats were generally stored outside. Sled frame components are also not so common, except for sled runners, as wood was often recycled for making other tools or used as fuel. It is most often the dog sled harness loops that attest to the use of sled dogs. Thus, few direct evidence of the means of transportation would permit to discuss the Thule Inuit mobility patterns.

3.2.2. The time and nature of the Late Dorset/Early Inuit contact

After approximately 3000 years of endogenous development, the Pre-Inuit population, especially the Pre-Dorset who had developed into the Dorset culture in Canada, appears to have disappeared relatively abruptly (in about a century) during the last millennium (~14th century CE, Friesen et al., 2020), for reasons that remain poorly understood (e.g., Houmard, 2015; Labrèche, 2015; Park, 2023). The extinction of the last Dorset groups coincides with the arrival of new Thule migrants, who also originated from Alaska and are thought to have followed similar migration routes. Within just a few generations, Thule Inuit expansion covered almost the entire territory previously occupied by the Dorset people in Canada (except for Newfoundland) and Greenland. Late Dorset settlements were distributed from Victoria Island to northern Labrador, and are present as far as northwest Greenland (Friesen et al., 2020, p. 144). During the Late Dorset phase, the living conditions might have been harsher than before since this people distribution is reduced compared to the Middle Dorset phase. During this warmer period, the polynyas and the High Arctic seem to have played a role of refugium for the Late Dorset, although they still inhabited southern areas such as the northern shores of Nunavik at the time of the Early Inuit arrival (e.g., Appelt et al., 2016, fig. 33.1; Friesen and Arnold, 2008).

The Dorset/Early Thule Inuit material culture differs typologically, allowing clear distinction between the different craftsmen practices. For example, in sketching the main differences between Early Thule Inuit and Late Dorset practices, the newcomers came with pottery and metal tools, dog sleds and umiat used for whaling while the preexisting Dorset where good flintknappers, living in longhouses. However, craft practices and gestures remained highly stable; only the style of the tools changed, as well as a shift observed in the manufacturing tools, from lithic to metal blades. Having lost the sophisticated flintknapping techniques of their predecessors, it is reasonable to consider that the Thule Inuit were quite dependent on metal for working bone materials. As a result, they could not easily replace metal tools with similarly effective lithic ones.

The question of the metal use and introduction in the Thule Inuit times would merit to be nuanced. The last Dorset groups also started using meteorite iron for tool manufacture just before or around the time of the Thule migration, near the only identified source of high-quality iron, located at Cape York on the northwestern coast of Greenland (Friesen, 2004; Svensson et al., 2021). Since metal artefacts are poorly preserved in the Arctic, their discovery is rare. One of the most telling indirect pieces of evidence for their use remains the traces left by tools on waste materials, supports, blanks, and finished objects made from bone, or the interior grooves of handles that held these blades (Houmard and Grønnow, 2017; Jolicoeur, 2020).

Tracing the trajectories of objects during the annual cycle is therefore not straightforward, as the evidence needed to trace the origin of most equipment is sparse The most reliable markers are iron objects—whether meteoritic, terrestrial, or of European origin—and, to a lesser extent, native copper from the central Arctic, because of distinct chemical compositions which enable the determination of their provenance (Buchwald, 1992). Meteoritic iron from Cape York has been found over 2500 km from its point of origin, and native copper from the central Arctic has been found at some sites on the northwest coast of Greenland, such as Inuarfigssuaq (Holtved, 1944). These remains are unfortunately rare due to their poor preservation and were most likely the most widely traded items.

3.2.3. *Early-Thule Inuit migration synthesis*

The Early Thule Inuit migration (around the 13th century CE) is generally perceived as a unidirectional demographic expansion, from Alaska to Canada and Greenland, with no confirmed bidirectional contacts between eastern and western regions after the time of migration (Friesen, 2016; Friesen et al., 2020) (Fig. 5, Table 2). However, the timing and trajectories of this migration remains a subject of hot debates.

Initially placed around 1000 CE (Mathiassen, 1927), following new radiocarbon assays it has now been rejuvenated to the 13th century (Friesen and Arnold, 2008; McGhee, 2000). The emergence of the Thule Inuit culture in Alaska is estimated around 1000 CE (Mason, 2016) or even around the 12th–13th centuries CE (Alix et al., 2015), with the first Thule occupations in central Canada appearing around the 13th century CE (Friesen, 2016). This model is however challenged by some authors such as Park (2023) who considers improbable a such rapid flow from Alaska to Greenland within few decades or less than 200 years, and thus posits an earlier date for the departure.

Although relatively recent (less than 1000 years old), even the precise origin of these Early Inuit migrants remains unclear, likely the northwestern coasts of Alaska or Siberia, though with little further precision (Mason and Friesen, 2017). However, the variability in material culture is widely recognised and supports the hypothesis of a polymorphic migration originating from different regions (Friesen, 2016; Gulløv and McGhee, 2006; Mason and Friesen, 2017; McCullough, 1989; Morrison, 1999). For Mason (2020), two different pathways have been followed, a central route crossing the northern shores of Victoria Island and the High Arctic to end up along the northwestern coasts of Greenland, and a secondary route across the Coronation Gulf, following the southern coasts of Victoria Island, crossing the Boothia Peninsula and the Melville Bay to end up in the Baffin Island and Igloolik area (Mason, 2020, Fig. 2).

While some authors remain sceptical, radiocarbon evidence suggests a rapid eastward migration. Small-scale occupations appear nearly contemporaneous across the Arctic, from Banks Island to the High Arctic, and eventually to the northwestern coast of Greenland (Grønnow, 2017; Mason, 2020; Mason and Friesen, 2017; McCullough, 1989; Morrison, 2009). Many Early Thule Inuit sites are relatively small and yielded fragile artefacts (such as pottery pots) or Alaskan-like style weapons, especially harpoon heads (Mason, 2020; Mason and Friesen, 2017, pp. 182–183).If the time span of the Early Thule migration is extended, tool styles would have had time to be modified according to the principle of copying modifications (e.g., Schillinger et al., 2016). Later moves to southern areas such as Nunavik and Labrador are proposed and dated around 1350 CE (Fitzhugh, 2020, p. 95) or even 1500 CE (McGhee, 2009, p. 84; Ramsden and Rankin, 2013, pp. 304–305).

In terms of climate conditions, the Early Thule Inuit migration seems to be linked to a period of increased duration and expanse of open water (warming period) which would have benefitted to both bowhead whales and open skin boat navigation (Friesen et al., 2020, p. 151). Conversely, the sled transportation might have been riskier.

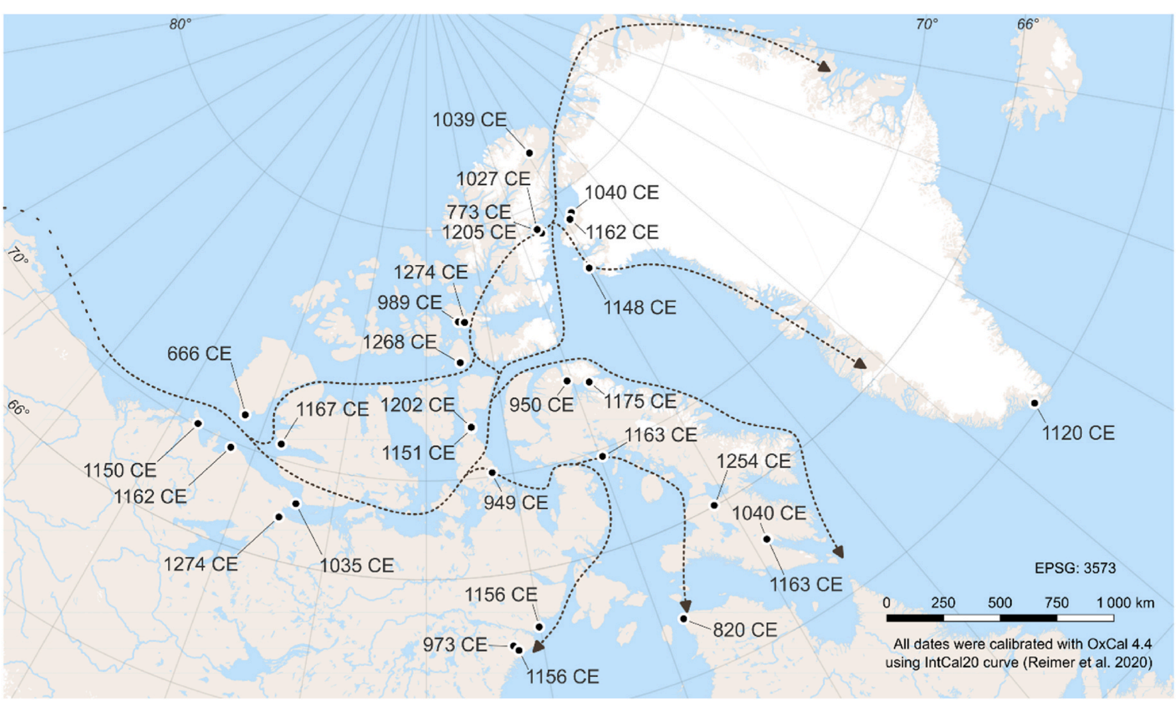

Fig. 5. Early Inuit migration routes. Dotted arrows indicate probable routes taken by Pre-Inuit populations from the northern Alaskan coast to the Canadian Arctic Archipelago and Greenland, following known settlement locations (black dots). Dates on the map are the oldest of the 2σ standard margin error of the oldest radiocarbon date obtained on a given sites. They do not date the Early Thule Inuit migration and do not reflect the generally accepted 13th century arrival. CAD: Q. Verriez.

Table 2

Radiocarbon dates used in this study for Early Inuit sites across the Eastern Arctic. Only the oldest date for each site. The table compiles radiocarbon determinations for key archaeological sites, including their archaeological layer, material type, and laboratory number. BP values are presented with associated standard deviations and $\delta^{13}C$ values when disponible in data source. Calibrated dates (2 standard deviation) were recalculated using OxCal v4.4.4 (Bronk Ramsey, 2021) and the IntCal20 calibration curve (Reimer et al., 2020), and are mentioned in cal. CE. Only samples from terrestrial materials (bones of terrestrial mammals, antler, and plant remains) were considered to avoid marine reservoir bias. References correspond to the original publication or data source.

Site	Lab. No.	Layer	Material	BP	±	$\delta^{13}C$	Calib. 2σ	Reference
PaJs-3		Feature 20	Caribou Bone	1275	50		658–779	Gallant et al. (2024)
PaJs-13		Feature 1	Caribou Bone	1185	70		757–993	Gallant et al. (2024)
Nuvuk	Beta-180329	Nuvuk 1	Antler (*Rangifer tarandus*)	1140	40	−18.8	820–994	McGhee (2009)
OhRh-1	RL-1665	Natchuk phase	Bone (*Ovibos moschatus*)	1130	110	−20	666–1051	
SfFk-5	GSC-3553		Willow (*Salix* sp.)	1110	60	−25,7	773–1029	Schledermann (1990)
RbJu-1	Beta-219189		Caribou antler	1000	40		989–1160	McGhee (2009)
PgHb-1	S-882		Caribou bone	930	100		950–1277	McGhee (2009)
OaJn-2	S-2200		Caribou bone	920	105		949–1281	McGhee (2009)
SgFm-4	GSC-3379	House 25	Willow (*Salix* sp.)	920	50	−25.8	1027–1220	McCullough (1989)
KgJm-8	S-1313		Caribou bone	905	100		973–1284	McGhee (2009)
Kap Kent	KIA-16942		Musk-ox horn	892	36		1040–1223	McGhee (2009)
Qeqertaaraq	KIA-17726		Caribou antler	891	29		1120–1222	Appelt (2003)
Nuulliit	79V1-000-12		Musk-ox horn	884	25		1148–1224	Appelt (2003)
KkDo-3	AECV-1708		Caribou bone	880	50		1040–1233	McGhee (2009)
OaRw-2	TO-3716		Musk-ox bone	850	40		1150–1273	McGhee (2009)
NcPf-12	S-3369		Caribou bone	850	75		1035–1279	McGhee (2009)
KkJg-1	SI-768 B		Caribou bone	825	45		1156–1279	McGhee (2009)
NkRi-3	Beta-148601		Caribou bone	820	40		1162–1277	McGhee (2009)
TlAt-8	I-12340		Musk-ox bone	820	75		1039–1284	McGhee (2009)
KkDo-3	AECV-1708		Caribou bone	800	50		1040–1233	McGhee (2009)
PaJs-2	Beta-104641		Caribou antler	780	65		1151–1317	Whitridge (1999)
MaDv-11	AECV-728		Caribou bone	770	120		1254–1289	McGhee (2009)
PaJs-13	AA53793		Caribou antler	761	47		1202–1303	Douglas et al. (2004)
KfJm-32	S-1317		Caribou bone	755	70	−22	1156–1328	McGhee (2009)
SfFk-4	GSC-3038	House 15	Woollen cloth	750	50		1205–1309	McGhee (2009)
OdPp-2	Gif-8180		Caribou bone	750	60		1167–1321	McGhee (2009)
PeFr-1	Beta-111668		Caribou bone	740	60		1175–1324	McGhee (2009)
NjHa-1	K-1079		Caribou bone	740	100		1163–1329	McGhee (2009)
QeJu-1	Beta-146776		Caribou Bone	680	40		1268–1328	McGhee (2009)
Ruin Island	K-1489	House 6	Wool	680	100		1162–1439	McCullough (1989)
MkPk-3	Beta-219193		Caribou antler	670	40		1274–1328	Douglas et al. (2004)
RbJr-1	Beta-219197		Musk-ox tooth	670	40		1274–1328	McGhee (2009)

4. Discussion

4.1. Dating the undatable? Methodological limits in tracing arctic migration phases

4.1.1. The lasting influence of the marine reservoir effect on radiocarbon dating

The inherent issues related to absolute dating and its calibration (for samples that incorporated old marine carbon) support the widely accepted stance of extreme caution in using such dates to establish the chronology of migration (Park, 2023). Nevertheless, they remain the only means for large-scale comparisons, as typology also has its limitations in terms of relative chronology. Indeed, for Arctic archaeology, only the weapons have been seriated because of their diversity and evolution, while the domestic tools have been neglected. Moreover, numerous sites that have yielded a substantial number of typologically diagnostic archaeological remains were excavated in earlier periods, between the 1920s and 1980s, and the accuracy of the information about the contexts in which the objects were discovered is now partly called into question (e.g., Houmard and Grønnow, 2017). Ultimately, the perceived relative uniformity of some collections sometimes reveals significant divergences, and palimpsests of occupations are frequently noted (Desrosiers, 2009; Desrosiers et al., 2008; Houmard, 2011, 2015; Houmard and Grønnow, 2017). Thus, the preferred approach for more precisely dating migration phenomena now appears to be a combination of diagnostic criteria of relative chronology and absolute dating, complemented whenever possible, by provenience studies to trace routes and gain a better understanding of movement patterns, particularly distinguishing terrestrial from maritime travel (Friesen, 2012, p. 19). Western Canadian sites such as Nelson River and Brooman Point, for example, contain, at least in some of their dwellings, typologically ancient material evidence, likely attesting to precursor movements of Thule migrants (Friesen and Arnold, 2008; McGhee, 1984). It is important to remain cautious, as this does not imply that all dwellings on the site are ancient or date from the same period. The Naujan site (Repulse Bay) illustrates this point, revealing discrepancies of several centuries between the occupation of Houses VI and VIII, which were not perceived (Mathiassen, 1927) before the typo-technological reassessment of the collection (Houmard and Grønnow, 2017). Park's comment (2023, p. 3) holds true: radiocarbon dates will not and probably never provide a final argument concerning the timing of the Thule migration, although they remain and will continue to be the focus of the researchers as long as better chronological markers would be lacking.

4.1.2. Occupation sites, migrant stories? Reassessing the material traces of movement

Comparisons between the point of origin of the migration and the Thule settlement in the Eastern Arctic are complicated by the fact that, shortly after their departure, the migrants seem to have drastically changed some of their habits. This was probably largely due to variability in the raw materials needed to build houses, as well as to the relative abundance of certain organic materials over others (wood versus bone).

While Thule houses in Alaska were mainly built of driftwood, this material became scarce in Canada and Greenland, where houses were built of peat, stone and whale bone (Alix, 2009; Mason, 2020). This change in building materials seems to have had a direct impact on the shape of houses, from quadrangular to more rounded forms, except in the North Water polynya region, where rectangular stone structures are still attested for the Early Thule phase.

Likewise, tool handles, most often made of driftwood in Alaska, are more regularly made of caribou antler in the Eastern Arctic (Mason, 2020). The lack of high-quality clay and fuel also led to the rapid abandonment of pottery in Canada and Greenland, with Thule Inuit people preferring soapstone and probably skin containers (Mason, 2020). As driftwood was also needed to make umiat and sledges, its scarcity – or at least its lower quality in the East – probably also led to necessary adaptations (either in terms of long-distance exchange networks, or by substituting other materials) to ensure operational means of transportation.

Some answers are likely to be found in provenance analyses of resources, which – whether metal, clay, driftwood, bone or lithic materials – can help tracking the movement of objects, and therefore indirectly of people, even if objects may have passed from hand to hand. Certain climatic and environmental changes, or written accounts (e.g., Icelandic sagas) can also provide *terminus ante quem* or *post quem* dates, helping to date migration, or at least certain stopover points.

Moreover, better defining the function and duration of occupation, as well as the approximate size of the group at each site at the time of the Early Thule Inuit migration, is a necessary step forward in our understanding of migratory patterns. Indeed, recent studies show that sites considered to be homogeneous and inhabited at the same time by a dozen or more households (e.g., Mathiassen, 1927), were in fact occupied for much longer than previously thought, and by only 4 or 5 households at the same time (e.g., Naujan site, Houmard and Grønnow, 2017). Such data dramatically changes our view of the site occupation, as well as demographics at the time of Early Thule Inuit migration. In the absence of greater precision from radiocarbon dating, revisiting field notes and archaeological collections, as well as new analyses of provenance exotic materials will probably help resolve some of the misunderstandings about this Early Thule Inuit migration. New excavations – particularly in the less explored areas around the dwellings rather than inside them – could also shed new light, as recently demonstrated by research at the Nuulliit site (Mønsted et al., 2023).

4.2. Why moving: driving forces

Two primary motivations generally drive migration: 'pull factors' and 'push factors' (see Friesen, 2016, p. 683; Friesen et al., 2020; Mason, 2020, pp. 325–330; Park, 2023 for recent reviews). 'Pull factors' refer to the attraction of specific resources. This requires a prior knowledge of the locations and types of sought-after resources, as well as information on travel conditions (such as routes) for reaching them. The spirit of adventure often lies at the intersection of 'pull' and 'push' factors, playing a significant role in accepting the risks inherent of any migration, which involves managing numerous uncertainties with limited fallback options and human resources in unknown territories. 'Push factors', on the other hand, encompass all forms of dissatisfaction with the current situation that motivate the departure. These factors are often social tensions related to ethnic, political, religious, cultural, economic, social, or environmental causes, with the most extreme being famines and/or conflicts. In such cases, the primary objective is to leave the place of distress and seek a more stable environment, whether nearby or at distance even if considerable. While these migrations might be deliberate, they did not necessarily have a predetermined goal beyond escape; the final destination was not always planned or known, though settling near a relative or acquaintance in an already stable situation is usually preferable. This basic view is of course simplistic, and a combination of factors might probably have been involved in the understanding of both Pre-Inuit and Early Thule Inuit migrations.

4.2.1. No push, just pull? Motivations behind the Pre-Inuit settlements

The model of 'push' and 'pull' factors is rarely applied to Pre-Inuit migration, as the available evidence remains limited. As currently presented and accepted, it is rather *pull* factors that are implicitly suggested. Following the melting of ice after the Holocene Thermal Maximum, newly exposed lands would have been gradually populated by animals and then by human groups who followed them. Current dating evidence points to a relatively rapid migration into these unoccupied territories. The poor preservation of sites on the Alaskan side (especially of organic materials) makes it difficult to properly characterize the lifestyle of populations of the Denbigh Flint Complex, and consequently, to determine whether environmental and/or social stressors may have pushed part of the population to migrate eastward into neutral territory. This migration appears to have occurred at the end of the Holocene Climate Optimum. It is possible that increasingly unpredictable weather conditions and the search for game became contributing factors and trigger the migration.

The only thing that seems well established is that once the population moved eastward, the majority remained there and did not maintain regular contact with their point of origin in Alaska. What is striking in the pre-contact history of the North American Arctic is the parallel and independent development of Alaska versus Canada/Greenland. In the West (Alaska), cultural complexity persisted and was maintained through regular contacts with groups on both sides of the Bering Strait, whereas once in the Eastern Arctic (Canada and Greenland), both Pre-Inuit and Thule Inuit populations appear to have evolved in relative self-sufficiency, with no evidence of "institutionalized" conflict.

This sharply contrasts with the more tense atmosphere that appears to have prevailed around the Bering Strait from at least the end of the first millennium CE (Mason, 2020, 2009; Mason and Friesen, 2017, p. 99).

4.2.2. Driven by conflict, Drawn by resources: thinking Early-Thule Inuit movements

The conflict-ridden context at the turn of the first millennium is often cited as a possible motivation for leaving Alaska, due to a lack of security. By the 13th century CE, Alaska was relatively densely populated and experienced a period of warfare, evidenced by the development of fortified sites and protective equipment such as armour. Human remains also bear witness to this violent climate, with skeletal remains showing embedded projectile points (Mason, 2009). This argument is the primary "pushing factor" invoked to explain the migration. This notion of 'push' and 'pull' driving forces is therefore primarily used and debated in relation to the Early Thule Inuit migration.

Among the "pulling factors," two main hypotheses have been proposed. The first is the pursuit of bowhead whales as a substantial food resource, with whale hunting remaining a defining characteristic of Thule Inuit subsistence strategies—unlike the pre-Inuit populations of Canada and Greenland, who did not develop this practice. This hunt was made possible by the umiak, a vessel enabling collective deep-sea hunting (McGhee, 1970). The nutritional importance of bowhead whales and their central role in the Thule cosmology have been demonstrated through archaeology, isotopic studies, and zooarchaeological analyses (Coltrain, 2009; Coltrain et al., 2016). However, since this technology and the presence of these cetaceans predate the 13th century CE, this factor is no longer considered a primary driver of migration (Friesen, 2016). Moreover, some Early Thule Inuit Alaskan groups, especially in the Utqiagvik area from where the migration is presumed to have originated, did not hunt whales (e.g., Walakpa site, Stanford, 1976).

However, if, as postulated by Park (2023), the migration starting date is considered older than admitted now, it is possible that this hypothesis would emerge again. The Early Thule Inuit presence in the Somerset Island area (Nunavut, Canada) around the 11th–13th centuries is suggested by new environmental analyses (Gallant et al., 2024). According to their analyses of lake sediments, a pronounced human impact is suggested at the time of intense caribou hunting, that would correspond to the arrival of the Early Thule Inuit migrants as early as around 1185 CE. However, Dorset occupations are also identified in the surrounding areas. The link between confirmed human presence in the late 12th century and the arrival of the Early Thule Inuit population nevertheless deserves to be strengthened. Why should we exclude the possibility of a Late Dorset presence and favor the hypothesis of an Early Thule Inuit arrival 200 years earlier, especially since this date more or less corresponds to the emergence of this new cultural group in Alaska?

The second proposed “pulling factor” is the quest for metal, particularly iron (Gulløv and McGhee, 2006; McGhee, 1984), as no population in the North American Arctic had mastered metallurgy. This hypothesis implies some preliminary contacts between Late Dorset in the Eastern Arctic and Alaskan Early Thule Inuit (or predecessors) since the migrants must to be aware of the presence of this meteoric spot at the northwestern coast of Greenland to motivate the migration. Arguments contradicting this hypothesis are the total absence of meteoritic or Norse-origin iron in Alaska, as well as Eastern Arctic artefacts style in Alaskan sites, with a distance of about 1500 km to the closest known Dorset sites (Mason, 2020, p. 330; Park, 2023, p. 9). But the presence of metal itself is quite rare in Alaska, whatever the origin. So, it is difficult to use this argument, as well as to discard it. The region surrounding the Cape York meteorite remains one of the primary locus of the earliest and most numerous Early Inuit sites in the Eastern Arctic, reflecting the consistent interest of Thule populations in metal resources, especially iron (McCullough, 1989).

Among the “push” factors, the main motivation is to leave Alaska and visit new areas, even unknown, but this does not explain why such distances (i.e., 5000 km) have been travelled. To escape a zone of conflicts, it would have been enough to reach the nearest safe zone with food and resources. Such a migration to a new area would suggest that there was one objective to reach, what else if not food or resources? People fleeing an area do not necessarily consider that it would be for ever. They might be willing to see family members from their homeland as well as visit their usual and customary territories. Many migrants suffer from homesickness after a couple of years.

4.2.3. One wave or many? Revisiting the Early Inuit migration model

The emergence of Thule culture in Alaska is estimated around 1000 CE (Mason, 2016) or the 12th–13th centuries CE (Alix et al., 2015), with the first Thule occupations in central Canada appearing around the 13th century CE (Friesen, 2016). For this reason, earlier radiocarbon dates obtained from northwestern Greenland (11th–13th centuries CE, and even 8th-10th taking the oldest dates of the 2σ margin error in several places) (McCullough, 1989) have been dismissed. However, the rejection of these dates as *ante quem* (and therefore anomalous) does not seem entirely justified (Park, 2023). Dates obtained from marine samples can be reasonably dismissed due to the reservoir effect, which artificially ages marine samples by 400–700 years, making calibration particularly challenging in circumpolar regions (Heaton et al., 2020). However, those obtained from terrestrial samples are not expected to have been contaminated and should not be dismissed so readily without further scientific argumentation (Park, 2023). A recent publication demonstrates human occupation on Somerset Island (PaJs-3 and PaJs-13) from lacustrine sediments and caribou bone samples as early as 1185 CE (for PaJs-3 1075–1257 CE and for PaJs-13 1061–1314 CE with 95 % confidence interval). These occupations are attributed to the Thule people by the authors (Gallant et al., 2024). Therefore, both the date of the emergence of the Thule Inuit in Alaska, the origin of the Early Thule Inuit migration and the arrival of the migrants in Canada and Greenland are again questioned. Among the rhythm of the Thule expansion, it seems that some areas such as Labrador and Hudson Bay might have been occupied later on (Friesen, 2017, 2020; Kaplan and Woollett, 2016; McGhee, 2009; Ramsden and Rankin, 2013).

Earlier research suggested that the migration began around 1000 CE, but recent redating of key sites, combined with the rejection of problematic dates from marine materials or driftwood, has led to a reevaluation, now firmly placing the migration in the 13th century for most of the Arctic archeologists (Friesen, 2016; Friesen and Arnold, 2008; McGhee, 2000, 2009) (Table 2). By 1300 CE, most of the Central Arctic, as well as the northwesternmost region of Greenland, had been settled by the Early Thule Inuit. The discrepancy in migration dates—1000 CE versus 1200–1250 CE—has significant implications for the interpretation of the potential role of climate change in its initiation, a point that will be revisited below. However, as recently stated, this scenario is contested from the new lacustrine analysis from the Somerset Island, associated with the nearby Thule archaeological sites (Gallant et al., 2024). The puzzle is far from being resolved (Table 2).

Revisiting the Early Thule Inuit migration would thus imply to work both on the old collections and re-date the keysites, and more precisely the house and even the different potential occupations in the same house.

Due to all the difficulties cited above, it is presently difficult to answer the question of one or many waves and on the timing of the two Pre-Inuit and Early Thule Inuit migration without working on the modelling of the migration process in the Arctic. All the parameters would need to be taken into account at the same time, and a holistic reflection about the way to deal with the “missing pieces of the puzzle” is still necessary. Rare are the new studies on the material culture, most of the recent analyses being focused on bioarchaeology and environmental sciences. An essay of modelling the different pathways of the Pre-Inuit and Thule Inuit migrations would imply to use computational analyses for integrating as much parameters as possible from the climate and environmental conditions (including the evolution of the ecosystems at different geographical scales) to the way of life (e.g., subsistence, transport, universe, politics) and demography of the different cultural groups involved in the migration processes, all of these being positioned in a reliable chronology. Lots of attention and efforts have recently been paid on climate change impacts with no substantial progress for the understanding of the migration problems. Maybe going back to the human sciences is also now needed for supplementing the general archaeological questions dealing with human movements?

5. Conclusion

Both migration waves might have been preceded by exploratory incursions but they largely followed trajectories leading to unknown destinations—perhaps only vaguely described by intermediaries in the case of the Thule migration, given the thousands of kilometers involved. Pre-Inuit populations were true pioneers, discovering these new lands firsthand (e.g., Friesen, 2016). In contrast, the Early Thule Inuit migrants benefited at least from material markers in the landscape and possibly even visual and/or oral information from contacts. However, such contacts remain presently minimally evidenced, both genetically (Willerslev and Meltzer, 2021) and culturally (Appelt et al., 2016; Friesen, 1999; Houmard, 2015; McGhee, 1997).

Over the last 100 years, many researchers have been working on these two Pre-Inuit and Early Thule Inuit migrations without being able to agree on one specific scenario. Even what could be considered as the core data on which the interpretations have been built are not completely accepted. So, as all the preceding publications dedicated to this question, the present conclusion of this review article of the Pre-Inuit and Thule Inuit peopling of the Arctic remains that there are still lots of fields to explore and combine for being able to progress in the understanding of these American Arctic migration processes.

CRediT authorship contribution statement

Quentin Verriez: Conceptualization, Methodology, Formal analysis, Writing – original draft, Visualization, Validation. **Margot Martinet:** Visualization. **Anna Tomasinelli:** Formal analysis, Visualization, Writing – review & editing. **Claire Houmard:** Conceptualization, Methodology, Writing – original draft, Validation, Project administration, Funding acquisition.

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.

Data availability

All data and/or code is contained within the submission.

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