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Spatiotemporal Variability in Arctic Climates of the Past Millennium: Implications for the Study of Thule Culture on Melville Peninsula, Nunavut

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Abstract

During the last millennium, climatic fluctuations occurred in the Arctic that presumably affected ecosystems and people. Paleoclimatologists recognize that the impacts of these fluctuations were not consistent across space or time; however, archaeologists often cite climatic fluctuations as an impetus for Thule migration and more recent regionalization across the Arctic. An interdisciplinary International Polar Year project is examining possible correlations between climate and cultural changes on Melville Peninsula. To better evaluate the role climate played in cultural change on Melville Peninsula and to place emerging data in context, we present here new syntheses of paleoclimatic and archaeological data from adjacent regions to determine how the data sets articulate. A comparison of high-resolution paleoclimatic records suggests dissimilarities in climatic histories across this transitional area, with Little Ice Age cooling possibly occurring 1–2 centuries earlier west of Melville Peninsula than to the east. Although paleoclimates in the Baffin region to the east may have been more variable, the maritime climate may have contributed to a resource-rich environment, resulting in continuous human occupation. The more stable, and possibly cooler, continental climate to the west of Melville Peninsula could explain the relatively fewer Thule sites. This area, however, was relatively densely used throughout the coldest part of the past millennium and the historic period, likely owing to technological specialization and access to European material culture.

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Introduction

Climatic changes have been well documented for the past millennium in the Arctic (e.g., Bradley, 1990; Overpeck et al., 1997; Lamoureux et al., 2001; Gajewski and Atkinson, 2003; Wolken et al., 2005), and these changes may have affected human migration and settlement patterns (Barry et al., 1977). During the past millennium, the ancestors of the modern Inuit, the Thule, rapidly expanded eastwards across the Arctic from Alaska (Morrison, 1999; McGhee, 2000; Schledermann and McCullough, 2003). A hypothesized warmer climate during the time of the initial westward migration of the Thule, between A.D. 1000 and 1200, could have resulted in less severe sea-ice conditions and easier access, across a wider region, to bowhead whales (*Balaena mysticetus*), a key resource for Thule people (McGhee, 1972, 2000; Morrison, 1999). The hypothesized colder climates of subsequent centuries could have reduced local availability of resources, in particular whales, resulting in site abandonment or socioeconomic change during a time which can be referred to as Modified Thule phase (Schledermann, 1979; Maxwell, 1985; Schledermann and McCullough, 2003). It is also possible that these cultural changes were caused by social factors (Yorga, 1979; McGhee, 1984, 1994).

Recently, new high-resolution paleoclimatic records have become available from regions of archaeological significance in the Canadian Arctic (e.g., LeBlanc et al., 2004; Briner et al., 2006; Lamoureux et al., 2006). These records provide an opportunity to reevaluate the role of climatic changes in Thule history in different parts of the Arctic. Synergistic analyses of archaeological and

paleoclimatic data from the same region are required to better understand the role of climate in Thule settlement and economy, yet there have been few studies that specifically link the two data sets within the same region (e.g., Barry et al., 1977; Jacobs, 1985; Henshaw, 2003; Woollett, 2003).

We address here the role of climatic changes during the past millennium in relation to Thule migration and cultural change by examining modern and paleoclimates in the region surrounding Melville Peninsula in the eastern Canadian Arctic, the focus of our ongoing International Polar Year (IPY) research activities. Melville Peninsula has many substantial Thule sites, few of which had been examined in detail prior to our current IPY initiative. We present a meta-analysis of available paleoclimatic data from this region of cultural importance, with an emphasis on spatial and temporal variability in modern and paleoclimates from Melville Peninsula and adjacent regions. We then discuss these data in the context of available archaeological data (dates and locations of Neo-Eskimo sites) across these regions to provide new information on the possible influence of (1) the climatic changes of the past millennium, and (2) the spatial variability in the timing and magnitude of these climatic changes on cultural history.

Melville Peninsula area is a promising location to investigate the relationship between culture and climatic change because the area is transitional between the more continental climates to the west and maritime climates to the east and therefore may provide a sensitive record of climatic fluctuation over the past millennium. Furthermore, the area possesses a considerable Thule archaeological record to examine changes in material culture and zooarch-

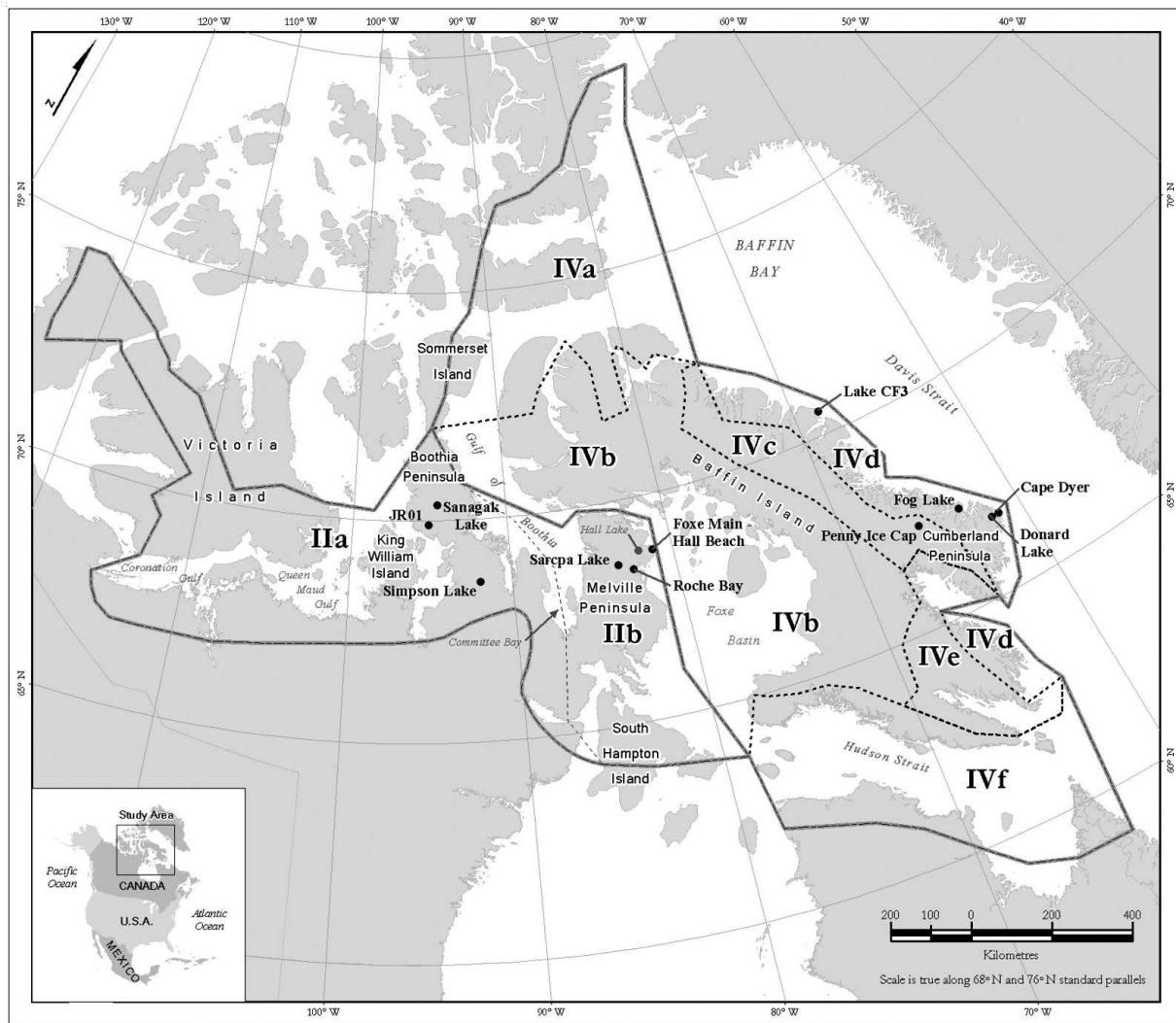


FIGURE 1. Map of the Canadian Arctic showing (in Roman numerals) modern climate regions and sub-regions delineated by Maxwell (1980), and locations of sites discussed in the text.

aeological remains that could relate to fluctuation in climate. This synthesis paper is the starting point for our IPY work on Melville Peninsula.

Physiography and Late Quaternary History of the Study Region

Melville Peninsula is situated on the eastern Arctic mainland of Canada (Fig. 1). Surface features and glacial history of the peninsula have been comprehensively surveyed by Dredge (1995). Ice sheets covered Melville Peninsula well into the Holocene, persisting in the vicinity of Hall Lake until 6000 yr B.P. (Dredge, 2001). Isostatic processes caused a marine transgression to about 140 m above present sea level, well inland of Hall Lake. Following ice retreat, significant uplift of the coastal margin has taken place. The sea-level curves of Dredge (1995) indicate an uplift rate of ~70 cm per century at Hall Beach since emergence about 1000 years ago. Dredge (1995) also describes a prominent marine trimline on the escarpment, marking the position of maximum marine inundation. This erosional feature was noted only at locations open to the Foxe Basin, suggesting that the coastal zone was more dynamic in the mid-Holocene when sea level was higher, possibly because of less ice cover in the Foxe Basin relative to

today (Dredge, 1995). Decreases in sea-ice extent could increase the availability of marine resources. Geological evidence, coupled with archaeological evidence in the form of whale remains at sites at Hall Beach (Ross, 2007), suggest that sea-ice extent in the Foxe Basin may have changed over time.

Modern Climate

Modern climates vary considerably across the Canadian Arctic (e.g., Atkinson and Gajewski, 2002; Serreze and Barry, 2005). The patterns of contemporary climate variability surrounding Melville Peninsula presumably also existed in the past and therefore need to be considered in the interpretation of paleoclimatic and archaeological records.

Atmospheric and ocean circulation, latitude, and surface albedo broadly determine regional temperature, precipitation, and wind regimes. Through the study of these major climatic controls, and the examination of historical (1953–1972) data from available weather stations, Maxwell (1980) delineated five distinct climatic regions for the Canadian Arctic (two regions shown in Fig. 1). Most of Maxwell's climate regions also contain sub-regions, capturing variability at the mesoscale (tens to hundreds of kilometers), which occurs in response to local topography,

physiography, and proximity to water or ice (Atkinson and Gajewski, 2002). The climate regions designated by Maxwell (1980) continue to be widely cited in studies of the physical environment in the Arctic (e.g., Freitas et al., 1997; Lamoureux and Gilbert, 2004; Clark et al., 2007).

Maxwell's classification indicates a major climate boundary in the Foxe Basin, separating the more maritime climates of the Baffin region (Region IV) from the more continental climates of the South-Central Arctic Archipelago (Region II) (Fig. 1). More recent efforts have produced modeled or interpolated climate surfaces that confirm a transition between continental and maritime climates in the vicinity of Melville Peninsula (Atkinson and Gajewski, 2002). Maxwell (1980) correlated this boundary with the maximum westward extent of the cyclonic storm tracks from the south that frequently move northward through Davis Strait and Baffin Bay. To the west of this boundary, anticyclonic activity dominates. The specific location of the boundary between these two different climate regimes is likely influenced by local factors, notably sea-ice regime, thus it may shift on a variety of time scales. We concentrate here on Maxwell's Regions II and IV, encompassing Melville Peninsula and surroundings (Fig. 1).

REGION II: SOUTH-CENTRAL CANADIAN ARCTIC

Maxwell's Region IIa is characterized by low-relief, anticyclonic activity and a continental climate resulting from large land masses and narrow, shallow inter-island channels. Multi-year ice can persist in Coronation Gulf and Queen Maud Bay, although summer open water is observed, particularly in coastal areas (Maxwell, 1980). The continental effect that characterizes this sub-region creates the second largest mean annual temperature range in the Canadian Arctic ($\sim 45^\circ\text{C}$). As this region is dominated by anticyclonic activity, annual precipitation is very low ($<100\text{ mm}$) (Maxwell, 1980). Key subsistence resources in Region IIa can be divided into terrestrial resources such as musk-ox, caribou, fish, and birds, and marine resources, mainly the smaller sea mammals such as ringed seal and bearded seal (Richard, 2001).

Region IIb includes Melville Peninsula and is transitional towards the more maritime climates of the eastern Arctic. Multi-year ice readily accumulates on the western side of Melville Peninsula in the "sea-ice cul-de-sacs" of the Gulf of Boothia and Committee Bay (Dyke et al., 1996). The Foxe Basin to the east of Melville Peninsula is dominated by first-year ice and has extensive summer open water, especially in the coastal regions (Maxwell, 1980). Sea-ice regime, the extent of summer open water, and associated feedbacks related to albedo changes and heat absorption are likely important in setting the location of the boundaries of Region IIb. Cyclonic activity begins to take hold in Region IIb; mean annual temperature range is lower than to the west ($36\text{--}39^\circ\text{C}$), and precipitation is higher ($\sim 200\text{--}300\text{ mm}$) (Maxwell, 1980). Subsistence resources located in Region IIb include several seal species, the most common being ringed and bearded, narwhal, whale, walrus, caribou, few musk-ox, fish, and birds (Richard, 2001). The availability of narwhal, whale, and walrus in Region IIb is a key difference with IIa.

REGION IV: EASTERN CANADIAN ARCTIC

This climate region is the largest and most heterogeneous of the five delineated by Maxwell (1980). Cyclonic activity influences most of the region; regional climate is also determined by the presence of mostly first-year ice, and persistently open water (polynyas), which lead to a lower annual temperature range than

in most of Region II. The mountainous terrain is another distinguishing feature, contributing to high precipitation relative to the rest of the Canadian Arctic (Maxwell, 1980), the prevalence of glaciation, and diverse local weather.

In Sub-Region IVb, immediately adjacent to our study area, the presence of mountains to the east and hills and plateaus to the north protects the area in and around the Foxe Basin from cyclones moving northward from Davis Strait, resulting in lower precipitation on the western side of Baffin Island ($\sim 200\text{--}300\text{ mm yr}^{-1}$) compared to the eastern side ($>300\text{ mm yr}^{-1}$).

Sub-Region IVc, just east of Sub-Region IVb, covers the mountain ranges of central Baffin Island. Cyclonic activity combined with proximity to the moist air provided by open water, and high elevation, results in the persistence of ice caps and local glaciers. Sub-Region IVd encompasses the east coast of Baffin Island and experiences the greatest maritime influence in all of the Arctic Islands, with low mean annual temperature range, milder winters, and precipitation often in excess of 400 mm yr^{-1} . Williams and Bradley (1985) suggested that the Baffin region is particularly "sensitive" to climatic change relative to other areas of the Arctic, meaning that small changes in atmospheric circulation or sea-ice regime could cause large changes in temperature, moisture, or glacier mass balance in this region. This sensitivity is partly explained by the mountainous terrain of Baffin Island, presently at the "threshold" of glaciation. Small climatic changes can lead to substantial changes in ice cover and associated feedbacks.

Region IV hosts all Arctic species exploited by Neo-Eskimo hunters; however, musk-ox are not present on Baffin Island (Richard, 2001). While Melville Peninsula is located within climate Sub-Region IIb, archaeological evidence shows that the economy of the Thule on Melville Peninsula depended heavily on resources in and around the Foxe Basin to the east, in climate Sub-Region IVb (Ross, 2007; Porawski, 2008). Thus, processes in both climate Regions II and IV were likely important in Thule resource procurement, settlement, and site abandonment. Hence, the complementary analysis of paleoclimatic and archaeological data on Melville Peninsula, situated at the juncture of two major climate regions, may provide new insights into human responses to climatic change and new insight into spatial variability in Arctic paleoclimates. Because of the location of Melville Peninsula with respect to modern climate variability, we synthesize the paleoclimatic records below from across this transition.

Paleoclimates of the Past Millennium

Paleoclimatic reconstructions and climate models demonstrate that climate varies on time scales from yearly to supra-millennial (Ruddiman, 2001). Climatic changes at the sub-millennial time scale are likely caused by a combination of variability in ocean-atmosphere dynamism, volcanism, solar variability, and/or fluctuations in atmospheric trace gas concentrations (Rind and Overpeck, 1993; Hunt, 2006). Climatic changes on these time scales are most relevant to the study of Thule cultural history as Thule occupied the central and eastern Arctic during the past millennium. This period has often been divided climatically into three parts: an initial warm phase (Medieval Warm Period = MWP), followed by a cold phase (Little Ice Age = LIA), and the recent phase characterized by anthropogenic global warming.

There was, however, considerable spatial and temporal variability in these climatic changes at global, hemispheric, and even regional scales; also, climatic changes during the past

millennium manifested themselves regionally in more complex ways than simply warmer or cooler temperatures, in response to local factors. For these reasons, Jones and Mann (2004) have argued that the terms “Medieval Warm Period” and “Little Ice Age” have limited utility as they imply synchronous events that were global or hemispheric in scale, whereas the paleoenvironmental evidence indicates substantial differences between regions in terms of the nature of climatic changes associated with the MWP and LIA, their timing, and their magnitude. Notwithstanding this variability, many studies provide compelling evidence for regional or local climatic changes during the past millennium that were significant enough to affect people (Grove, 1988). We reanalyze here the available paleoclimatic data from our study region to evaluate the extent of spatial and temporal variability in the past millennium across this region of archaeological interest.

Given the heterogeneity of modern Arctic climates, we expect that paleoclimates themselves, as well as the rates and magnitudes of paleoclimatic change, also varied spatially across areas occupied by Thule. A synthesis of many studies confirms that paleoclimatic changes are heterogeneous across the Arctic (e.g., Kaufman et al., 2004), although the density of well-dated, high-resolution records remains sparse relative to the size of the region. A clearer understanding of these regional differences in paleoclimatic change will provide the baseline needed to evaluate the possible role of climate in Thule migration and cultural change.

PALEOCLIMATES TO THE EAST OF MELVILLE PENINSULA

Baffin Island is one of the better studied regions of the Canadian Arctic for both contemporary and paleoclimates. Paleoclimates of the past millennium in this region have been reconstructed using oxygen isotopes, melt percentages, and sea salt concentrations from ice cores, biological proxies (diatoms and pollen) preserved in lake sediments, and the thicknesses of annually deposited sediment layers in lake sediments (varves). We discuss here only records with sub-century sampling resolution for the past millennium from the climate regions adjacent to Melville Peninsula (Maxwell’s Regions IVb, IVc, IVd).

Since ice cores can provide annually resolved records, they are useful in developing robust paleoclimatic reconstructions. The concentration of sodium ions derived from sea salt (ssNa^+) in dated ice cores from the Penny Ice Cap (PIC) on the Cumberland Peninsula has been used as a high-resolution proxy for the extent of spring sea ice in Baffin Bay (Grumet et al., 2001). Lower ssNa^+ concentrations indicate mainly an increase in sea-ice extent, and generally colder temperatures. A weaker relationship was also shown between ssNa^+ and fluctuations in the intensity of the North Atlantic Oscillation, which could influence the degree of storminess on Baffin Island and in the area surrounding the Foxe Basin (Grumet et al., 2001). PIC sea salt concentrations were compared to $\delta^{18}\text{O}$ values and summer melt records from the same ice core, and show reasonable agreement with these paleotemperature proxies (Grumet et al., 2001). The PIC sea salt record shows a marked decrease in ssNa^+ concentration around A.D. 1400, suggesting an increase in sea-ice extent (Fig. 2). Around this time, nearby glacier advances and the expansion of snowfields have also been inferred using lichenometry (Davis, 1985). For the next six centuries, sea salt concentrations in the PIC remained generally low, but were more variable than between A.D. 1000 and 1400. Increased sea salt concentrations around A.D. 1650, 1740, 1820, and the early 20th century are interpreted as less severe sea-ice conditions and warmer intervals during a period generally

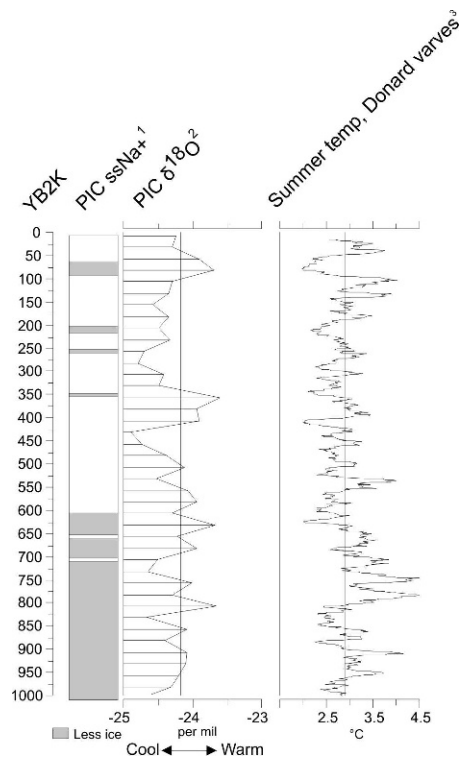


FIGURE 2. Summary of published high-resolution paleoclimatic data for the past millennium from adjacent climate regions east of Melville Peninsula: sea-ice extent derived from Penny Ice Cap (PIC) marine aerosol concentrations (ssNa^+) redrawn from Grumet et al. (2001, Fig. 2) with gray bars indicating relatively less sea ice, white bars more sea ice, based on departures from 2000-yr mean; 25-yr average PIC $\delta^{18}\text{O}$ (Fisher et al., 1998); paleotemperatures ($^{\circ}\text{C}$) derived from Donard Lake varve thicknesses (Moore et al., 2001) with a vertical reference line to indicate the 2000-yr mean ($\approx 2.9^{\circ}\text{C}$). The y-axis (YB2K) indicates years before A.D. 2000. Key to data sources: 1 = Grumet et al. (2001); 2 = Fisher et al. (2003), Penny Ice Cap Ice Core Data, IGBP PAGES/World Data Center for Paleoclimatology, Data Contribution Series # 2003-093, NOAA/NGDC Paleoclimatology Program, Boulder, Colorado, U.S.A.; 3 = Moore et al. (2003), Baffin Island 1250 Year Summer Temperature Reconstruction, IGBP PAGES/World Data Center for Paleoclimatology, Data Contribution Series # 2003-075, NOAA/NGDC Paleoclimatology Program, Boulder, Colorado.

characterized by more extensive sea ice in the context of the past millennium (Grumet et al., 2001) (Fig. 2).

Similar climatic variations are seen for the past millennium in the record from glacially fed Donard Lake on the Cumberland Peninsula (Fig. 2), where annually resolved, clastic, varved sediments were analyzed (Moore et al., 2001). The varve chronology at the site was verified by a radiocarbon date on plant material. Varve thicknesses were calibrated to temperature using the instrumental record (A.D. 1959–1990) from the Cape Dyer DEW Line station, allowing for a quantitative reconstruction of summer air temperatures for the past 1250 years. The Donard Lake record indicates generally warmer temperatures, compared to the 1000-yr mean of 2.9°C , between A.D. 950 and 1350, with maximum temperatures for the millennium between A.D. 1175 and 1350 (Fig. 2). The generally warmer climate between A.D. 950 and 1350 was initially variable, as warmer decades with inferred summer air temperatures of 3.9°C occurred around A.D. 975 and A.D. 1100, while cooler periods of ~ 50 years’ duration were recorded from A.D. 980 to 1025, and from A.D. 1125 to 1175 (Moore et al., 2001). Around A.D. 1175, the largest climatic

transition of the millennium was recorded, with reconstructed summer temperatures rising by >2 °C in two to three decades (Fig. 2) (Moore et al., 2001). As in the PIC $ssNa^+$ record, the warming in the vicinity of Donard Lake ended by \sim A.D. 1400 with the onset of a period of summers on average cooler by about 1 °C than the previous period, and lower temperature minima, interpreted by the authors as the LIA (Moore et al., 2001).

In another study from the same region, diatom analysis was used to reconstruct summer water temperature at Fog Lake (Joynt and Wolfe, 2001). A quantitative water temperature reconstruction based on a 62-lake modern calibration set from Baffin Island indicates that lake water temperature was ~ 2 °C colder between A.D. 500 and 1850 relative to the reconstructed water temperatures of the mid-Holocene (5000–1500 yr B.P.) (Joynt and Wolfe, 2001). With an average resolution of 60 years between samples for the past 1000 years, the diatom-inferred water temperature reconstruction does not show strong trends between A.D. 1000 and 1850 to indicate the timing of climatic changes in this time period. Ordinations indicate diatom assemblage shifts and lower valve concentrations between A.D. 1650 and 1750, interpreted by the authors as the coldest part of the Neoglacial, a period of long-term cooling which began ~ 2000 yr B.P. (Wolfe, 2003). The PIC $\delta^{18}O$ record also shows strong negative departures between A.D. 1650 and 1780 (Fisher et al., 1998), suggesting that this period may have been the coldest of the last millennium.

Diatom analyses of the sediments of Lake CF3 on the Clyde Foreland in the north Baffin Bay region were used to reconstruct Holocene lake water pH (Briner et al., 2006). These data indicate minimum Holocene pH values between A.D. 1500 and 1850. Since lower lake water pH can be associated with prolonged ice cover (Wolfe, 2002), the results of Briner et al. (2006) could be interpreted as indicating colder temperatures at this time. The record from Lake CF3 does not show elevated pH at the time generally assumed to correspond to the MWP; the reconstructed pH values for A.D. 1000–1500 are variable, but show a decreasing trend, reflecting long-term Neoglacial cooling.

SUMMARY OF PALEOCLIMATES TO THE EAST OF MELVILLE PENINSULA

Paleoclimatic reconstructions that span all or most of the Holocene in this region indicate long-term cooling since about 2000 years ago in the Baffin Region (Fisher et al., 1998; Miller et al., 2005). The climates of the past millennium reflect a general continuation of this trend. While warmer temperatures (relative to the Neoglacial) from A.D. 950 to 1350 are recorded in the high resolution record of Moore et al. (2001), available biological proxies show few changes during this period (Joynt and Wolfe, 2001; Briner et al., 2006). Ice core and varve records from the Cumberland Peninsula suggest abrupt cooling from about A.D. 1400 (Grumet et al., 2001), with further cooling between A.D. 1650 and 1750 shown in diatom analyses (Joynt and Wolfe, 2001), a period often interpreted as the maximum LIA. The available quantitative air temperature reconstruction suggests that summer air temperature fluctuations in the Baffin region during the past millennium may have approached 3 °C (Moore et al., 2001), and lake water pH may have changed by ~ 0.5 pH units (Briner et al., 2006).

PALEOCLIMATES TO THE WEST OF MELVILLE PENINSULA

There is considerably less information available on paleoclimates to the west of Melville Peninsula. There are currently no ice

caps in the region, therefore no annually resolved ice core records are available. Paleoclimates of Boothia Peninsula, in Sub-Region IIa of Maxwell's classification, have been reconstructed through microfossil records in lake sediment cores (LeBlanc et al., 2004; Zabenskie and Gajewski, 2007) and varve thicknesses (Lamoureux et al., 2006). Lamoureux et al. (2006) provided an annually resolved varve thickness record from A.D. 1500 for Sanagak Lake (Fig. 3). Although the record only spans half of the past millennium, we discuss it here because of its annual resolution and the small number of records available from the region. Based on modern hydrological measurements at this site, varve thickness is most closely (and positively) related to snow water equivalent (SWE) and spring discharge (Lamoureux et al., 2006). The plot of cumulative departures from mean varve thicknesses shows an increase in varve thickness beginning around A.D. 1650, suggesting increased SWE from that time (Fig. 3). A general decrease in the cumulative departures from mean varve thickness occurred following A.D. 1820, suggesting a possible decrease in SWE. While the relationship between SWE and temperature is not straightforward, these data indicate two periods of hydrological changes beginning around A.D. 1650 and A.D. 1820. These changes may have been in part climatically driven, with reduced varve thicknesses possibly associated with lower discharge in warmer years due to greater evapotranspiration and greater capacity for drier soils to retain meltwater (Lamoureux et al., 2006).

Using the diatom record of LeBlanc et al. (2004) from Lake JR01 on Boothia Peninsula, we used ordination by Detrended Correspondence Analysis (DCA) of the samples spanning the past millennium to determine the timing of major changes in diatom assemblages. The first DCA axis explains 62% of the variance in the data set and shows marked changes in diatom assemblages beginning around A.D. 1850; diatom production as measured by valve concentration increased at that time as well (Fig. 3). The changes recorded in diatom assemblages in the millennium preceding A.D. 1850 were comparatively slight. The second DCA axis, explaining 18% of the variance in the data, further confirms large changes in diatom assemblages since A.D. 1850, relative to the past millennium (Fig. 3). Around A.D. 1250, a small increase was recorded in the ratio of two common diatom taxa (*Staurosirella pinnata* to *Staurosira venter*). Elsewhere, an increase in this ratio has been linked to cooler climates (Finkelstein and Gajewski, 2008). While climatic cooling at this time could explain the subtle shift in diatom assemblages, the record is at insufficient resolution to draw firm conclusions. The concentration of diatom valves reached minimum values around A.D. 1820 (Fig. 3). Since diatom concentrations have been positively linked to temperature (e.g., Michelutti et al., 2007), this finding suggests particularly short growing seasons and cold temperatures around this time. The timing of this minimum corresponds closely with maximum cumulative departures in varve thicknesses, and maximum inferred snow water equivalent, in the Sanagak Lake varve record (Lamoureux et al., 2006).

Zabenskie and Gajewski (2007) produced a pollen record from Lake JR01 and a quantitative reconstruction of July air temperature at the site since 7000 yr B.P. These results indicate long-term cooling since ~ 3000 yr B.P. The past 1000 years reflects a continuation of this long-term trend; the changes in pollen assemblages and concentration in the past millennium are subtle relative to the rest of the record (Zabenskie and Gajewski, 2007). Between A.D. 1200 and 1350, a decrease in percent abundance of *Salix* pollen and small increases of pollen of Mid- and High Arctic herbs (*Cassiope*, *Dryas*, *Oxyria*, *Saxifraga*), were interpreted as indicative of the onset of cooler temperatures and shorter growing seasons that favor High Arctic plant communities (Zabenskie and

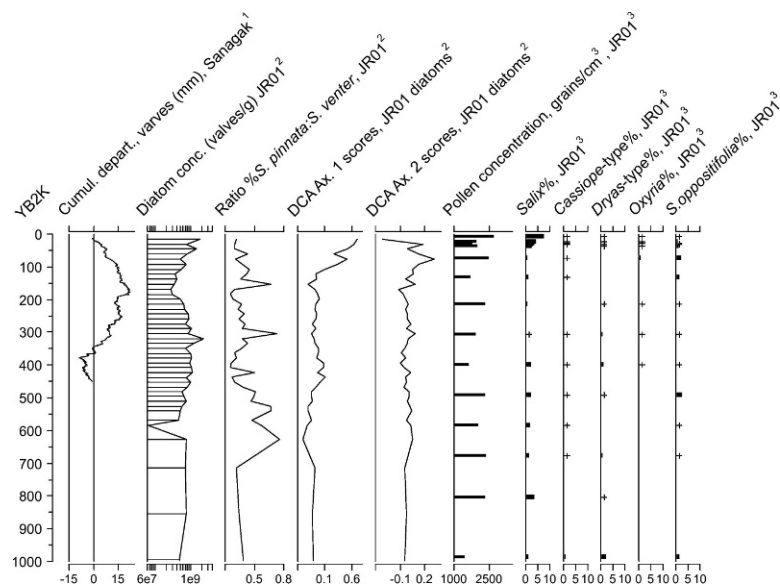


FIGURE 3. Summary of published high-resolution paleoclimatic data for the past millennium from adjacent climate regions west of Melville Peninsula: varve thicknesses (cumulative departures in mm) from Sanagak Lake (Lamoureux et al., 2006); diatom data from Lake JR01 (LeBlanc et al., 2004): valve concentrations (log scale), ratio of *Staurosirella pinnata* to *Staurosira venter* diatom taxa, sample axis scores derived from ordination by DCA of diatom assemblages (0–1100 yr B.P.); pollen data from Lake JR01 (Zabenskie and Gajewski, 2007): pollen concentration; % *Salix* pollen and % pollen abundance for Arctic herbs appearing at $\geq 1\%$ in any one sample (% calculated on the basis of the total count in the sample). The y-axis (YB2K) indicates years before A.D. 2000. Key to data sources: 1 = Lamoureux et al. (2006); 2 = LeBlanc et al. (2004), data available at <http://www.lpc.uottawa.ca/data>; 3 = Zabenskie and Gajewski (2007), data available at <http://www.lpc.uottawa.ca/data>.

Gajewski, 2007) (Fig. 3). The pollen-based July air temperature reconstruction suggests temperature fluctuations of $<1^\circ\text{C}$ during the past millennium on Boothia Peninsula (Zabenskie and Gajewski, 2007).

SUMMARY OF PALEOCLIMATES TO THE WEST OF MELVILLE PENINSULA

Diatom and pollen records from Lake JR01 provide limited evidence for cooling beginning between A.D. 1200 and 1300, with minimum temperatures recorded between A.D. 1800 and 1850 (LeBlanc et al., 2004; Zabenskie and Gajewski, 2007). There is little evidence in these records for elevated temperatures before A.D. 1200 corresponding to the MWP but there are too few records at high resolution to conclude firmly. The records from JR01 and Sanagak Lake both indicate hydroclimatic and/or ecological changes beginning around A.D. 1850, which were pronounced relative to the subtle changes recorded between A.D. 1000 and 1850. Pollen-based temperature reconstructions suggest small changes in summer temperatures during the past millennium ($<1^\circ\text{C}$).

COMPARING PALEOCLIMATES TO THE EAST AND WEST OF MELVILLE PENINSULA

The syntheses of Miller et al. (2005) and Kaufman et al. (2004) suggest more pronounced late Holocene cooling in the eastern relative to the western and central sectors of the Canadian Arctic due to the heavy influence, and associated feedbacks, of fluctuating sea-ice conditions in Baffin Bay on climates of the eastern Canadian Arctic. Our analysis shows differences in the paleoclimate records to the east vs. the west of Melville Peninsula both in terms of the timing of climatic changes (i.e. the onset of

LIA cooling), and in terms of magnitude of climatic fluctuations during the past millennium. According to the paleoclimate records, climatic cooling in the last millennium may have occurred earlier on Boothia Peninsula, between A.D. 1250 and 1300, while the transition into the colder LIA climate occurred closer to A.D. 1400 on Baffin Island. More high-resolution records, however, are needed with more replication in the dating to confirm this difference. The available records also indicate a more fluctuating climate during the past millennium in the Baffin region, with larger magnitude changes. The records from Boothia Peninsula, by contrast, suggest lower magnitude changes and a more stable climate during the past millennium. Melville Peninsula is situated between two regions that likely differed in paleoclimatic history for the past millennium but no paleoclimatic records are available from Melville Peninsula. While it is therefore difficult to interpolate the paleoclimate space between the Baffin and Boothia regions, these findings show the potential for paleoclimatic records from Melville Peninsula to provide new information on the changing boundaries between climate regions in the past.

How did these fluctuations then influence the terrestrial and the marine ecologies that the Neo-Eskimo people depended on? For Arctic hunters and gatherers, issues of survival are more focused on timing of sea-ice formation and breakup, which relates to temperature, winds, bathymetry and currents, types of ice or the presence of polynya within a region, timing and nature of precipitation and how it will influence the survival of terrestrial resources, and daily weather conditions that prohibit or promote the hunt and a safe return, such as storms or fog (Krupnick and Jolly, 2002). Much of the available climate proxy data do not yet provide clues to these culturally relevant environmental changes. While Maxwell's climate regions provide a breakdown of general environmental characteristics of the Arctic as a whole, even the sub-regions do not account for the local variability present in environmental attributes which might influence resource avail-

TABLE 1

Number of archaeological sites, and cultural designation, for sites recorded in the Canadian Museum of Civilization Site Database within Maxwell's climate Regions II and IV (Maxwell, 1980). "Historic Thule Inuit" and "Ethnographic Inuit" have been grouped as "Inuit." Data source: Archaeological Survey of Canada (1972). Database accessed 2004.

Climate Region	Neo-Eskimo	Thule	Classic Thule	Modified Thule	Inuit	Total # sites
II	196	172	2	2	652	1024
IIa	152	137	1		560	850
IIb	44	35	1	2	92	174
IV	294	442	3	12	497	1248
IVa	147	209	2	1	101	460
IVb	58	86	1	1	140	286
IVc		2			2	4
IVd-1	7	31		10	24	72
IVd-2	1	14			12	27
IVe	18	51			123	192
IVf	63	49			95	207
Total # sites	490	614	5	14	1149	2272

ability. For example, some key variables relating to marine resource availability are based on microtopography of coastlines, which influence ice attributes (Woollett, 2003, pp. 120–124). Since Region II has over 8000 km and Region IV has over 26,000 km of coastline, it is beyond the scope of this work to investigate variations at this nuanced level. Our goal is to assess broader-scale changes within Neo-Eskimo history while acknowledging that environmental particularism of different regions must be considered for finer-scale analyses, as in Woollett (2003) and Henshaw (2003).

Cultural History

DATA SOURCES AND LIMITATIONS

To assess the possible consequences of spatiotemporal variability in Arctic paleoclimates of the past millennium on cultural changes across our study area, we queried two databases to summarize the number of archaeological sites, date ranges and cultural affiliations for all Neo-Eskimo sites in Maxwell's climate Regions II and IV (Tables 1 and 2). These databases are the Canadian Museum of Civilization Archaeological Site Database (ASD) (Archaeological Survey of Canada, 1972) and the Canadian Archaeological Radiocarbon Database (CARD) (Canadian Museum of Civilization, 2004). The regional data provided in these repositories are critical to understanding whether climate

influenced the ability of different phases of the Neo-Eskimo culture to utilize different regions at different levels of success.

There are several limitations associated with the databases of which only the most critical for this discussion will be identified. The main limitation of the CARD database is the fact that the inclusion of dates in CARD is voluntary and therefore the date ranges are not necessarily inclusive of all dates; and the quality and quantity of metadata for each date varies, influencing the accuracy of calibration. In addition, whether a sample was submitted to date the end or beginning of a period is not consistently stated and often cultural affiliations provided are general such as Thule as opposed to specific such as Early Thule.

There are more limitations associated with the ASD, which was established in the 1970s. Records associated with sites for which there is active research being conducted are updated; however, often the data in the site records do not reflect current archaeological thought, the level of detail of the research conducted at any given site differs considerably, and the sites in the database do not represent a systematic survey of the regions. Therefore it is acknowledged that the number of sites in a given region could be an artifact of past research agendas, as opposed to actual use in prehistory. An additional limitation with the ASD most relevant to this study is the potential ambiguity of the cultural affiliation assigned by the researcher to the site, since in this study the affiliation is used to provide a chronology in the absence of radiocarbon dates. It would also be ideal if the data in

TABLE 2

Summary of the duration of radiocarbon dates on archaeological materials at sites associated with the Neo-Eskimo culture in Climate Regions II and IV (Maxwell, 1980). Source: CARD database (Canadian Museum of Civilization, 2004). Bracketed numbers given beside the age ranges indicate the number of dates available to determine the duration of occupation. Dates in italics indicate that fewer than 4% of the sites in that particular climate region have been dated.

Climate Region	Neo-Eskimo	Thule	Classic Thule*	Modified Thule	Inuit**	Time span of occupation
IIa	<i>850–550 (4)</i>	1050–1650 (3)	×		×	850–1650
IIb	×	×	×	1250–1400 (2)	×	1250–1400
IVa	1300–1450 (1)		900–1400 (17)	×	×	900–1450
IVb	1050–1400 (3)	<i>1200–1400 (2)</i>	1050–1400 (3)	×	×	1050–1400
IVc		×				n/a
IVd	1300–1400 (1)	×		×	×	1300–1400
IVe	1050–present (9)	×			1300–present (16)	1050–present
IVf	1000–1650 (9)	1050–1650 (3)			×	1000–1650

* Combines Early Classic Thule and Ruin Island Phase. These groups have different material culture but for the purposes of this paper both are considered Classic Thule.

** Dates are generally unavailable for Inuit sites due to difficulties dating modern materials with radiocarbon.

the ASD could be used as a proxy for past population; however, currently this is impossible and therefore we only investigate density of use of the regions based on site count. Despite these limitations, the ASD and CARD databases remain the best means to summarize the Canadian Arctic archaeological record, much of which has never been published.

General chronological information about undated sites in the ASD can be obtained through the assigned cultural designation. Three general divisions of Thule culture can be made (McCartney and Savelle, 1985; Park, 1994): Classic Thule, Modified Thule, and Ethnographic Inuit, but the timing of these cultural phases remains amorphous. The first phase of the Thule culture was the Classic Thule phase, originally thought to have occurred in the 11th century. The 13th century, however, is increasingly used as the newly accepted standard entry date of Thule into the Canadian Arctic (McGhee, 2000; Douglas et al., 2004; Friesen, 2004; Dugmore et al., 2005; Helgason et al., 2006; Friesen and Arnold, 2008). Sites associated with the migration are assigned, in the published literature and in the ASD, affiliations which include Early Classic Thule, Classic Thule, and the Ruin Island Phase (Canadian Museum of Civilization, 2004); while the Ruin Island Phase is normally separated from Classic Thule, for the purposes of this paper they are dealt with together. The durations cited for this period vary (McCartney, 1979; McCartney and Savelle, 1985; Morrison, 1989; Park and Stenton, 1998; Dawson and Levy, 2006; Friesen and Arnold, 2008), but it can safely be said that the Classic Thule phase lasted from at least A.D. 1200 to 1400. The Classic phase is characterized by an overall similarity of material culture across the eastern Arctic with large houses constructed with boulders, whalebone, and sod; it also represents the greatest spatial extent of Thule people (Maxwell, 1985, p. 298; Morrison, 1999).

Classic Thule are known as Thule whale hunters and, as the name implies, whales at least in some areas make up a significant portion of the resources utilized; however, this analysis is complicated by the use of whale bones as structural elements (Savelle, 1996; Whitridge, 1999; Savelle and McCartney, 2002). Resource extraction was not limited to whales, and in areas peripheral to core whaling regions, terrestrial resources and other marine mammals (walrus, narwhal, ringed and bearded seals) were the subsistence focus (Whitridge, 1999; Savelle and McCartney, 2002). There are also Early Thule sites that are known to have subsisted predominately on ringed seal (Morrison, 1983b).

The Classic phase was followed by the Postclassic modification, the Modified Thule or the Postclassic Thule. There are fewer dates put forward for the initiation of this phase. The two sites in CARD range from A.D. 1250 to 1400; McCartney (1979) indicated this phase started after A.D. 1300; McCartney and Savelle (1985) later suggested A.D. 1200 to 1400 for all areas except the open water areas of eastern Baffin Island and Labrador for which it lasted until A.D. 1700; Morrison (1989) suggested A.D. 1250 to 1600; and Park and Stenton (1998) provided A.D. 1200 to 1600 as a date range for Modified Thule. If migration is accepted as occurring at A.D. 1200, it would seem that the modified phase cannot have started at the same time. A combination of the dates provided by Friesen and Arnold (2008), Morrison (1989), and Park and Stenton (1998) is likely the most suitable, and the Modified phase or process is likely best placed as starting at ~A.D. 1400.

Because the change from Classic Thule to Modified Thule was a process and not an event, artifact assemblages cannot always be clearly assigned to one phase or the other (Morrison, 1989; Park, 1994) and in fact the need to “modify” did not occur everywhere in the Canadian Arctic, as whaling continued on

Somerset Island (McCartney and Savelle, 1985). It is best to clearly conceptualize the Modified Thule phase as the transition between Classic Thule and Ethnographic Inuit and not as a static middle phase. It has been proposed that the Modified Thule phase was a time in which Thule whale hunters, who had been established in the Canadian Arctic for 200–300 years, started to develop cultural regionalism, which in some cases involved the cessation of whaling and occupation of new ecological niches such as the hunting of ringed seals at breathing holes (Morrison, 1983b; Fitzhugh, 1997; Park and Stenton, 1998). In other areas, the key subsistence resource was caribou. In addition to caribou, however, most available species would also have been taken. Another obvious change during this phase is the abandonment of coastally located sod houses for snow houses on the sea ice, as was the settlement pattern in Historic times, providing an overall increase in mobility. Climatic changes or over-hunting have been suggested as explanations for this shift as well (Fitzhugh, 1997).

The Modified Thule period intersected temporally with European exploration of the Canadian Arctic. The earliest contact, excluding contact with the Norse in the Classic Thule phase, can be cited as A.D. 1576 with Frobisher’s voyages around Baffin Island (Maxwell, 1985, p. 295). When and how contact with Europeans influenced the lifeways of Inuit varied with location and intensity of European activity (Kaplan, 1980; Hickey, 1984). In the Baffin region, European whalers exerted a significant influence on Inuit culture from A.D. 1850 (Fitzhugh, 1997).

DISTRIBUTION AND CHRONOLOGY OF ARCHAEOLOGICAL SITES

Over 2200 sites were recorded in climate Regions II and IV (Table 1; Fig. 4). Of these, 490 sites were given only the general designator “Neo-Eskimo,” thus may represent either Thule or Inuit archaeological remains. Sites in the “Thule” category represent either Classic or Modified Thule occupations. All sites designated “Thule,” “Classic Thule,” “Modified Thule,” or “Inuit” are assumed to follow the general chronology set out above. The relatively low number of sites given specific cultural designation such as Classic or Modified Thule, and the scarcity of radiocarbon dates, limits the extent to which correlations between cultural and climatic changes can be made.

Climate Region II has a substantial archaeological record for the past millennium, with 1024 sites recorded in the ASD; this averages approximately 0.0013 site km⁻² or 1 site per approximately 770 km² (Table 1). Thule sites (including those labeled Classic and Modified Thule) make up 21% of the sites in the ASD, while Inuit sites make up 79% for this region. The nine available radiocarbon dates on terrestrial material from CARD indicate that Region II was occupied from A.D. 850 to 1650 (Table 2). Although there are no radiocarbon dates post-dating A.D. 1650, there are sites with Inuit designations including Historic Inuit ($n = 340$), Ethnographic Inuit ($n = 78$), and Recent Inuit ($n = 102$); therefore, it can be concluded that the area was occupied after A.D. 1650.

Even during the coldest part of the past millennium, Region II likely remained occupied, and the density of sites was high relative to Region IV (see below). There is yet no clear paleoclimatic evidence to explain the high density of sites in Region II, since the overall abundance of resources may have been lower in Region II during the Classic and Modified Thule phases given a likely cool, continental, stable climate and extensive multi-year sea ice. Whales would not have inhabited the majority of the areas adjacent to the coastlines of Region II, excluding the east

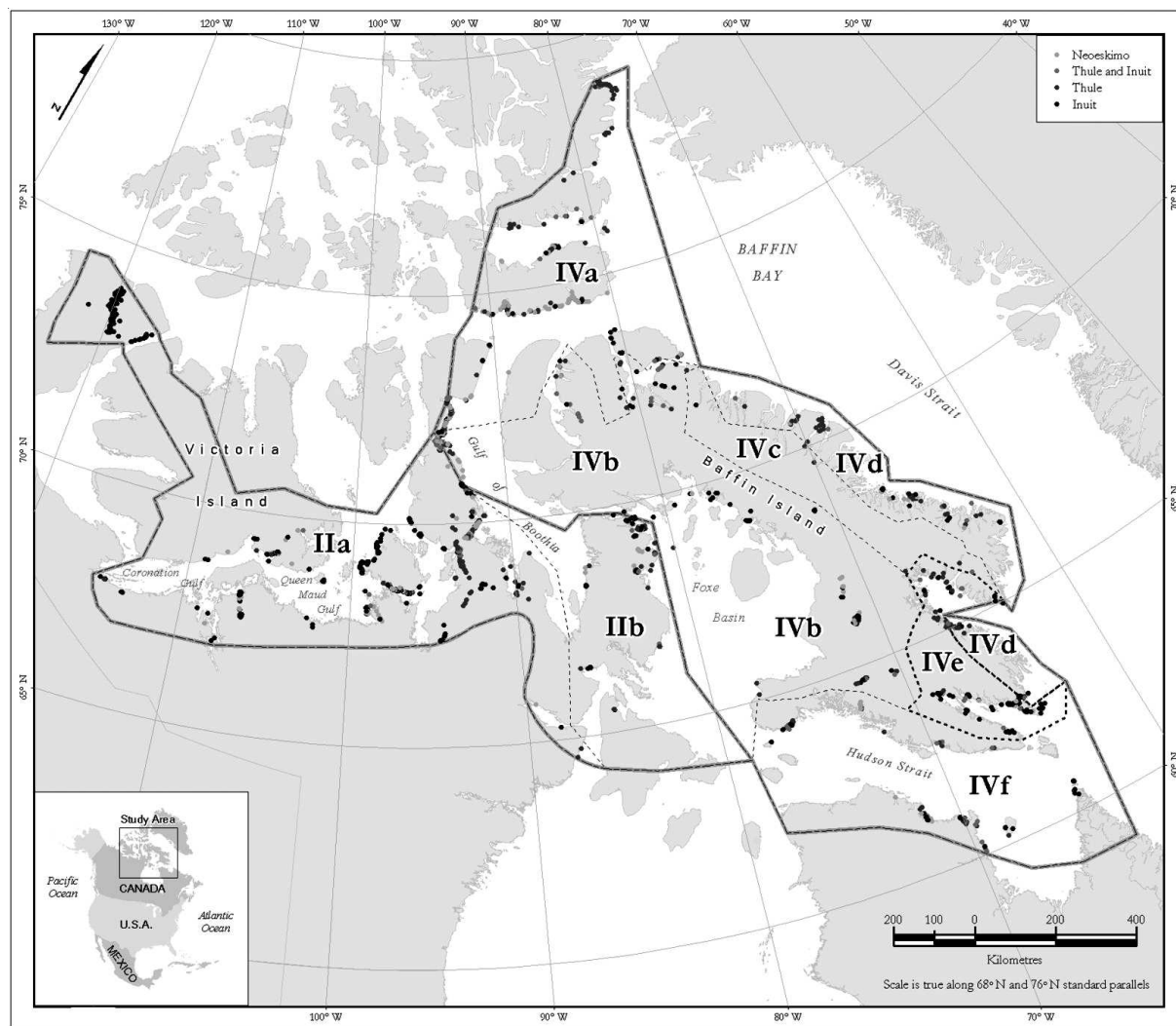


FIGURE 4. Distributions of archaeological sites for climate Regions II and IV associated with Neo-Eskimo, Thule/Inuit, Thule, and Inuit cultural affiliations from the Archaeological Sites Database.

coast of Melville Peninsula and Southampton Island (Richard, 2001). This would have made Region II less attractive to migrating Thule whalers; in fact Morrison (2000) referred to Coronation Gulf and Queen Maud Bay as areas that are marginally inhabitable. However, there are early Thule sites with a subsistence focus on floe-edge sealing (Morrison, 1983a, 1983b). Recent evidence coming from zooarchaeological analysis from Melville Peninsula suggests walrus may have played a key role in the early Thule economy in region IIb, although whale was available (Porawski, 2008; Desjardins, 2008).

Region II contains proportionally more Inuit than Thule sites and the majority of the Inuit sites are located in IIa. There are two likely causes for this, neither of which relate to climate, but perhaps both supported by climate changes. Since it has been suggested that breathing hole sealing was developed during the Modified Thule phase (Morrison, 1983b), it could be that a combination of this technological adaptation and a warmer climate from ~A.D. 1850 resulted in more abundant resources and therefore more sites affiliated with Inuit in particular along Coronation Gulf and Queen Maud Bay. Warmer conditions could have led to a reduction in the extent of multi-year ice and improved ice conditions for ringed seal which inhabit fast ice (*aulajuq*), cracks in the ice along shore (*qumngniit*), and pack ice

(*tuvaq*) (Richard, 2001) (Inuktitut terms provided by L. Otak, Igloodik).

There is a cluster of 225 Inuit sites in the northwestern portion of Region IIa; all are assigned a Copper Inuit designation with varying degrees of researcher certainty and are thought to span the prehistoric and historic period. These sites are proximally located to where the HMS *Investigator* was abandoned in A.D. 1853 (Hickey, 1984; Johnson, 2005). There are no Thule sites recorded in this region, therefore it can be concluded that the subsistence resource base of the area was not an attractant; the attractant seems to have been the abandoned ship. It is possible that warmer conditions could also have benefitted caribou and specifically musk-ox in the area providing a more secure food supply while resources were being scavenged from the ship. However there is not yet enough detail in the paleoclimate record to discuss seasonality of warmth, and changes in precipitation, both of which affect plant resources and grazing conditions.

Climate Region IV has 1248 archaeological sites recorded in the database; this averages approximately 0.0007 site km⁻² or 1 site per 1430 km² (Table 1). Of the 954 sites firmly classified as either Thule (including Classic and Modified Thule) or Inuit, 48% are Thule, proportionately more than in Region II, and 52% are Inuit. Available radiocarbon dates on terrestrial material from

CARD indicate that Region IV was occupied from A.D. 900 to present day (Table 2). There are 38 dates distributed between sites with Neo-Eskimo, Thule and Early Thule, and Inuit designations.

Our analysis of available data indicates that paleoclimates of Region IV fluctuated during the past millennium. The migration period around A.D. 1200 occurred in the middle of a phase that may have been relatively warmer in that region—A.D. 950–1350—as suggested by varve thicknesses in the sediments of Donard Lake (Moore et al., 2001). This warmer climate supports the previously posited idea that milder temperatures may have reduced ice extent, improving conditions for whales, a key resource for migrating Thule. Climate in Region IV was more fluctuating during the past millennium than in Region II, but temperatures were likely moderated by marine influences and open water in Baffin Bay. Since highly fluctuating and unpredictable weather patterns is one aspect of climate change that modern Inuit cite as difficult to adjust to (Krupnick and Jolly, 2002), it would be expected that climate fluctuations would have been difficult to adjust to in the past. While there are fewer sites per square kilometer in Region IV than in Region II, the density of sites does not suggest a difficulty in adapting to climate fluctuations.

One possible factor contributing to the relative stability of occupation, excluding the northern portions of Region IVa, throughout the Thule to Inuit phases in Region IV (particularly Sub-Regions IVe and IVf) is a more hospitable environment with greater resource diversity and microniche availability based on varying coastal topography (Richard, 2001). A milder climate relative to Region II during the coolest phase of the past millennium may not have resulted in large enough increases in sea-ice extent to negatively influence resources, and the greater diversity of resources in Region IV may have allowed for a shift in resource exploitation. There is paleoclimatic evidence for climate cooling in Region IV after A.D. 1400 (Grumet et al., 2001), and this coincides with the proposed timing of the Modified Thule phase and, interestingly, the termination of radiocarbon dates in Sub-Regions IVa, IVb, and IVd (Table 2). While these sub-regions may not have been completely abandoned after A.D. 1400 (there are sites in all these sub-regions in the ASD assigned Historic and Recent Inuit cultural designations), the coincidence that dates from several sub-regions end at A.D. 1400, albeit the assigned culture designation for these sites varies, is likely because this points to an accurate transition marker that may have been climatically influenced in Region IV. Dates from the more southern coastal Sub-Regions IVe and IVf indicate a longer occupation, to present day and A.D. 1650, respectively. The maritime-influenced environment of Sub-Regions IVe and IVf, and the southerly latitudes of these sub-regions, may have facilitated their continuous occupation in a region considered rich and stable in terms of resources (McCartney and Savelle, 1985).

The CARD also indicates occupation of Sub-Region IIb, which includes Melville Peninsula, until A.D. 1400, while the dates for Sub-Region IIa indicate it was used until A.D. 1650 (Table 2). The temporal coincidence of dates ending at A.D. 1400 on Melville Peninsula and the adjacent Sub-Regions IVa, IVb, and IVd suggests a similarity between Melville Peninsula and the Baffin region both in terms of paleoclimates and cultural history. For Sub-Region IIa, the reason for this longevity is not as clear. The sites from which the youngest dates come are large Thule winter sites on King William Island, which have a focus on caribou hunting, fishing, and sealing. It could be that trade as suggested by McCartney and Savelle (1985) with Thule focused on whaling from Somerset Island (Sub Region IVa) prolonged the use of Sub-region IIa.

The initial Thule migration was probably multi-causal, but one possible set of explanations for the initial migration is social: these include unrest or over-crowding in the Alaskan homeland, and/or an awareness of the resources, be they iron or whales, available in the Canadian Arctic and beyond (Yorga, 1979; McGhee, 1984, 1994; Maxwell, 1985; Morrison, 1999). Potentially warmer climate of the proposed Medieval Warm Period has also been consistently cited as either the cause or a factor in this migration (Fitzhugh, 1997; Morrison, 1999). Our review of paleoclimates shows that warming associated with the MWP is not often evident in the proxy records; the past millennium as a whole has been cool relative to previous millennia, suggesting at least some role for cultural factors in the initial migration, although there is some indication of warmer conditions when the Thule arrived in Region IV.

In addition to the subsistence change away from whaling, further adaptations to specific ecological niches culminated in the lifeways of the Inuit groups met by explorers and whalers (Yorga, 1979; McGhee, 1984, 1994; Maxwell, 1985; Morrison, 1999). Climate cooling is the most often cited cause for changes in material culture, shifts in resource utilization, and the subsequent modification in settlement pattern that define the Modified Thule phase around A.D. 1400 (Maxwell, 1985; Fitzhugh, 1997; Park and Stenton, 1998). While this timing is suggested in the paleoclimate records from the Baffin region, cooling may have already begun 100–200 years earlier in the central Arctic. In that sense, cultural and climatic changes are not always synchronous. A non-climate cause for the changes seen in this period was forwarded by McGhee (1994), who suggested that even limited early contact with Europeans might have caused an increase in mortality in Thule populations owing to disease. This potentially resulted in a loss of traditional knowledge and skills and a reduction in the population available for whaling.

A key for determining the extent to which climate played a role in Thule migration and subsequent cultural changes is to assess a region's paleoclimatic and archaeological records to determine if there was correlation between these changes. Our analyses show that in some cases, such correlations do exist. For example, the cessation of radiocarbon dates after A.D. 1400 in three sub-regions of Region IV and one adjacent sub-region of Region II coincides with intensification of cooling shown in the paleoclimatic records for that region. In other cases, the correlations are weaker, as in the timing of the initial Thule migration and density of Thule sites in the central Arctic, where there is little or no evidence for MWP warming.

While climatic changes and their spatial variability may have contributed to short-term site abandonment or socioeconomic changes (Morrison, 1983b; Maxwell, 1985), cultural factors remain essential to consider alongside paleoclimatic data in the interpretation of the Thule archaeological record. This is particularly relevant in the context of the past millennium, characterized by cold and severe climate relative to previous millennia when Paleo-Eskimos occupied many parts of the Arctic.

Conclusions

The comparison of modern and paleoclimates from the Baffin region with those of Boothia Peninsula confirm spatial variability of climates through time in the region surrounding Melville Peninsula. The available high-resolution paleoclimatic records spanning the past millennium from the eastern and central Arctic suggest the possibility of time-transgressive climatic changes, with earlier changes in the central Arctic relative to the eastern Arctic;

more well-dated records, however, are required to confirm this finding. Our comparison also indicates differences in the magnitudes of climatic changes in these two climate regions, with larger changes in the more maritime-influenced eastern Arctic, and more muted temperature changes in the vicinity of Boothia Peninsula with a more continental climate and more extensive sea ice. Available archaeological site counts and radiocarbon dates indicate that while climate change does not comprehensively explain cultural changes, having access to high-resolution paleoclimatic records does result in a better understanding of the roles both culture and climate played in changes seen in the Neo-Eskimo archaeological record of the Canadian Arctic. Although our analysis was constrained by the lack of refinement for archaeological cultural designations, our results indicate that multi-causal explanations for settlement patterns and cultural changes are more reasonable than explanations that rely on climate only.

Paleoclimatic records are lacking from Melville Peninsula, situated at the transition between the central and eastern regions discussed here. Thus, the study of paleoclimates from Melville Peninsula may prove important in mapping shifts in the boundary between two important Arctic climate regimes and interpreting the emerging archaeological data from Melville Peninsula. Records from Melville Peninsula may also provide new insights into the Arctic climate system and the mechanisms that set the boundaries between climate regions. Our future research in this region in the context of IPY will include the production of the first late Holocene paleoenvironmental records from lake sediments in the central Melville Peninsula, providing new information to better understand migration and settlement patterns of Thule people in the central and eastern Canadian Arctic.

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