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The Little Ice Age in the North Atlantic Region

Part V: Greenland

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Abstract

The first paper in this series introduced methods of studying past climate change. Subsequent papers addressed the historicity of the Medieval Warm Period and Little Ice Age, the importance of the Little Ice Age in understanding climate change and constraining climatic models, and an account of effects of the Little Ice Age in Iceland and Norway. This paper presents a summary of the climate change record in Greenland, especially for the Little Ice Age.

The Uniqueness of Greenland

Greenland is the focus of much attention in the climate change debate. It is referred to as a "subcontinent" because the island verges on the size of landmasses we refer to as continents. Its high latitude and place between the North Atlantic and Arctic Oceans make it of particular value to this study. Nearly the entire island is covered by ice (Figures 1 and 2), approximately two miles (three km) thick in the central region. This is the world's second largest ice sheet. If it were to melt, it would result in a rise in sea level of more than six meters (about three fathom). The Antarctic ice sheet is more than an order of magnitude larger than Greenland's ice sheet, while Vatnajökull in Iceland, the third largest, is 0.1 percent the size of the Greenland ice sheet and typically referred to as an "ice cap." Evaluation of data from the Greenland ice sheet has been provided elsewhere (Oard, 2005); this paper focuses on the features and history of Greenland as they relate to the Little Ice Age.

Greenland shares our North Atlantic study area with Iceland and Norway (Figure 2) but is much larger. Iceland is relatively small and surrounded by ocean (with some sea ice); Greenland is large and surrounded by sea ice (and some open ocean). The combination of ocean island, continental peninsula, and subcontinent makes it possible to distinguish regional from hemispheric or global climatic effects in the study area.

Greenland lacks a good historical record. The few written accounts come mostly from Iceland, as very few written records have survived from Greenland from the time of the Little Ice Age. Proxy data therefore have greater importance for Greenland than for Iceland or Norway. Proxy data, including foraminifera, pollen, insects, and oxygen isotope ratios, therefore have greater importance for Greenland than for Iceland or Norway. As described in part I of this series, proxy data are useful but greatly inferior to historical records.

Greenland and World Climate Change

Greenland has a prominent place in current world climate research. Figure 3 shows locations of important ice core projects. Data from ice cores, particularly oxygen isotope ratios, are used to infer the climatic history (i.e., paleoclimate) of Greenland and by extension the world. While methodological problems

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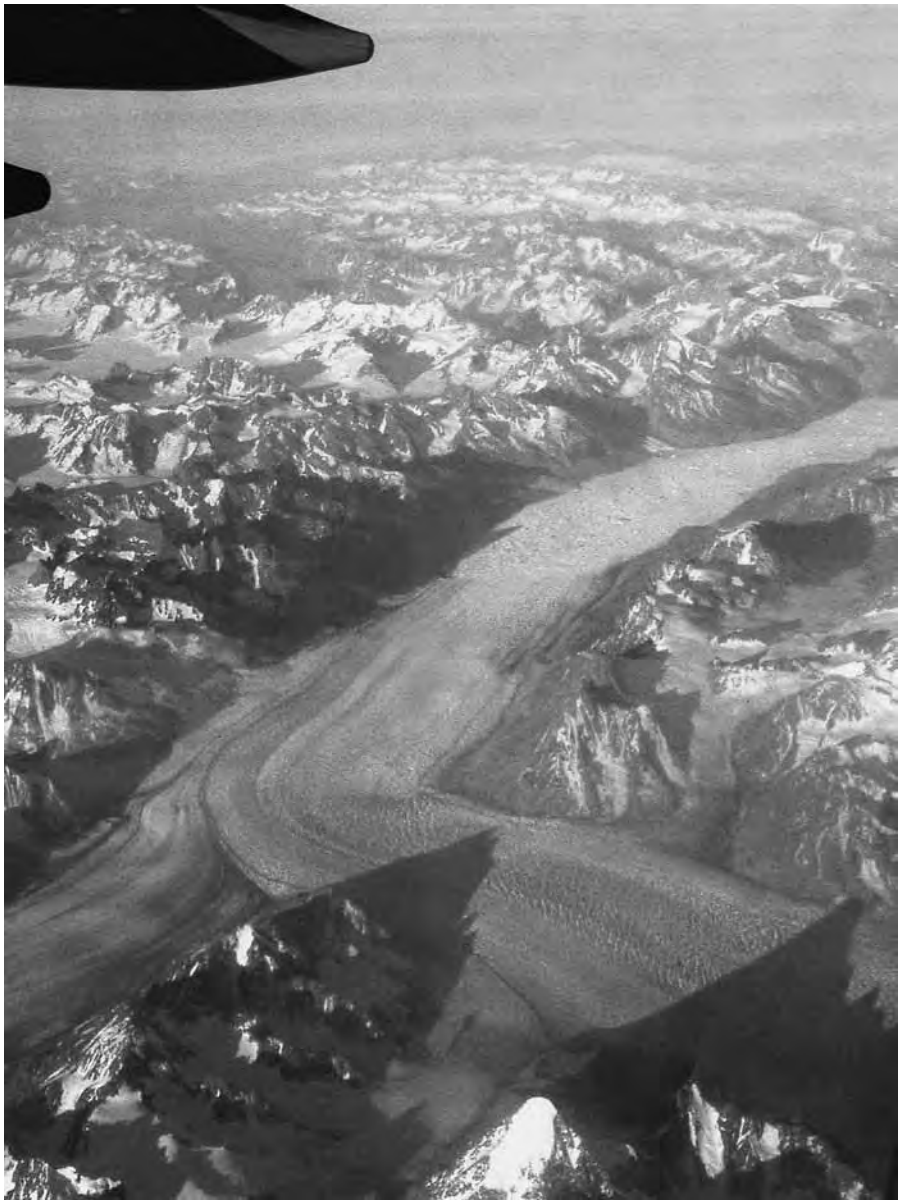

Figure 1. Southern Greenland from 35,000 feet (10,000 m). The river of ice is an outlet glacier draining the Greenland Inland Ice (ice sheet).

are not insignificant (Vardiman, 1997), and results become virtually unusable at significant depth (Oard, 2005), we believe the top few centuries' worth of ice provide reasonably reliable paleoclimatic data. These centuries include the Little Ice Age.

This paper summarizes the history of Greenland, a history that is far shorter than evolutionists realize, and a history marked by significant climate change.

History of Habitation

At least three peoples have settled Greenland in its history: at least two Hamitic peoples from the west, and one Japhethetic people from the east (Genesis 11). It is possible that seven or more cultures have existed on the main island and the smaller islands that make up the country of Greenland (Table I and Figure 4): Independence I and II, Saqqaq, Dorset I and II, Norse, and Thule (Andreasen, 2003; Gabriel et al., 2002; Høegh-Knudsen et al., 2003; Jensen, 2002; Jensen et al., 2008; Raahauge et al., 2003, 2005; Sørensen and Pedersen, 2004). It is also possible that some or all of the first three, for which we have only archaeological evidence, may not have been separate cultures (Andreasen, 2003).

Postdiluvial Settlement of Greenland

It is reasonable to infer that the early postdiluvial climate of Greenland was very hospitable, more supportive of plant, animal, and human life than at any time thereafter (Oard, 1990). Whether people actually reached Greenland during that time is unknown; if they did, evidence of occupation would have a low probability of surviving the Great Ice Age that likely followed. Thus, evidence for human habitation is likely to be from after the Great Ice Age—a position shared by both evolutionists and creationists.

Norse *Landnám*

We know a good deal about Eirík Rauða (Erik the Red). His life and the founding of Norse Greenland are recounted in *Eiríks soga Rauðu* (Saga of Erik the Red) and *Grönlendingesaga* (Saga of the Greenlanders), which are available sources (Ingstad and Ingstad, 1996). He and his father were banished from Jæren in Norway for killing a man, so Eirik settled in Iceland. Later, a feud arose when Eirik retaliated against a neighbor over the death of one of his servants. Banished from Iceland, he sailed westward in search of land that had been sighted by other Icelanders, the nearest part of which was known as Gunnbjørnsskjær (Figure 5). Eirik was gone from AD 983 to 985. During that

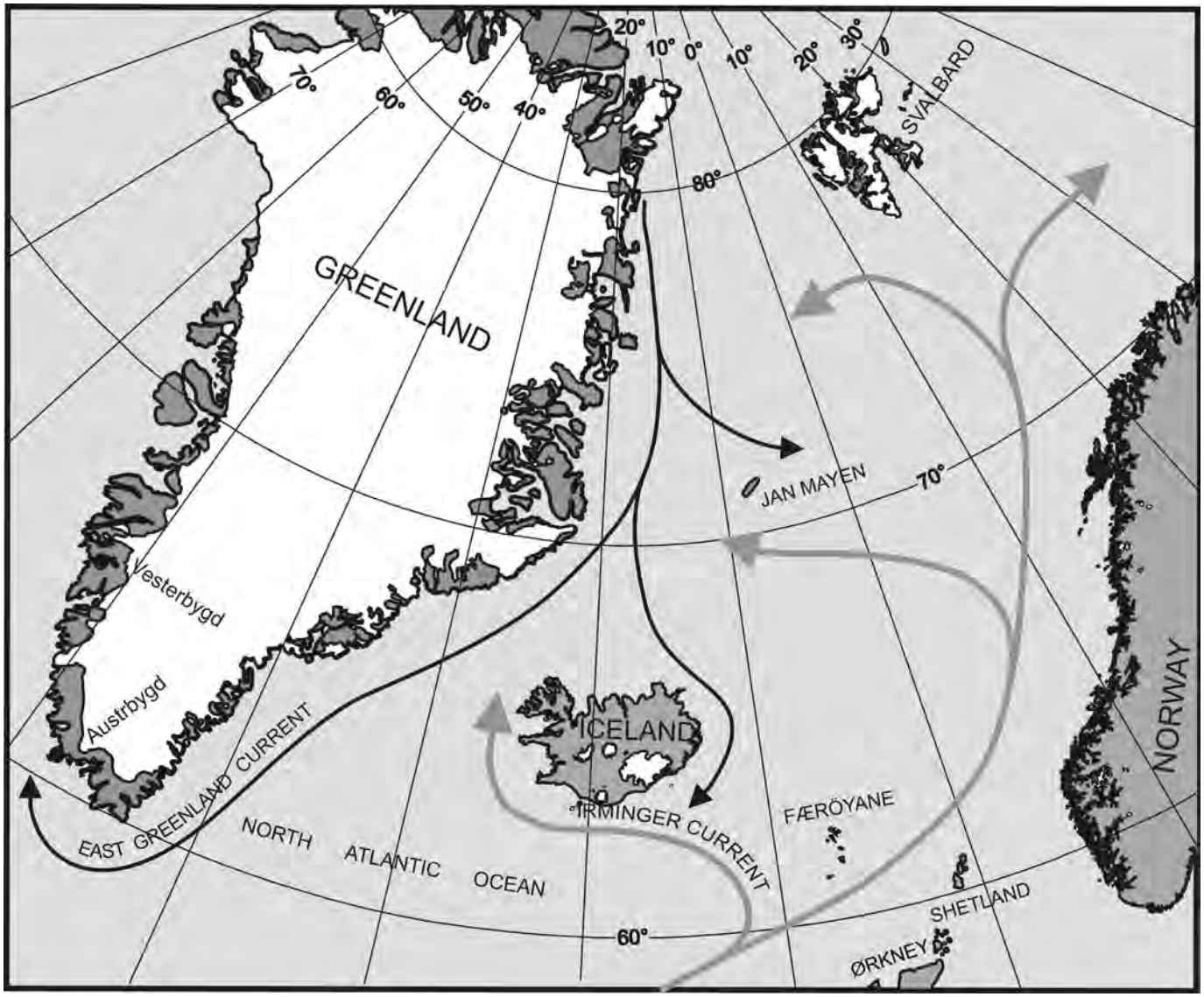

Figure 2. Map of North Atlantic Region. Austrbygd and Vesterbygd were the medieval Norse settlements in Greenland. Warm currents are shown by gray arrows and cold currents by black.

time, he explored the entire west coast as far as Disko Island (Norðrsetr, modern Qeqertarsuaq—see Table II). He then returned to Iceland and recruited a sizeable number of his former neighbors to immigrate to Greenland.

The Norse settlement of Greenland was a true *landnám*, i.e., settlement of a previously uninhabited country. When Eirík explored Greenland, he found the country devoid of people, but he found evidence of earlier human habitation. In today's terminology, these artifacts would be described as Independence I, Saqqaq, or Dorset I (Figure 4). While it is possible that Dorset people were in northernmost Greenland at the time, no one was in the more habitable south. Did they leave during the Medieval Warm Period to continue their cold weather ways? No one knows. Greenland's climate would never have been what one would call balmy, even during the Medieval Warm Period, and the sources say Eirik called the country "Greenland" to make it attractive to settlers, but it also seems that it really was greener than it is now. Dwarf birch (*Betula pubescens*), which is bigger than a bush but small for a tree, grew much more widely, and trees were

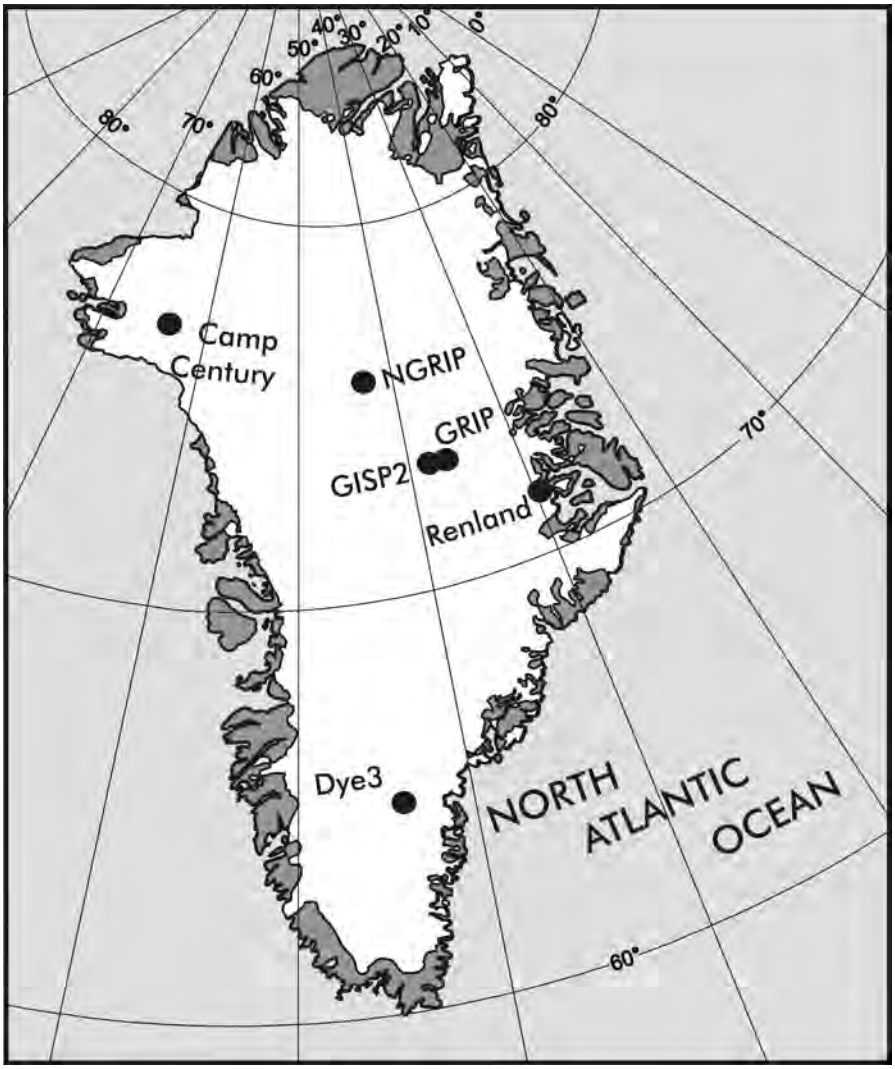

Figure 3. Ice core drilling locations on Greenland.

Table I. Peoples of Greenland	
Estimated Dates	**Culture**
2000–800 B.C.	Independence I
2000–800 B.C.	Saqqaq
ca. 800–1 B.C.	Independence II
700 B.C.–200 A.D.	Dorset I
800 A.D.–1300 A.D.	Dorset II
986–ca. 1540 A.D.	Norse
1150–2010 A.D.	Thule

larger than later (Ingstad, 1959). Even today, the areas settled by the Norse respond well to the short summers and are capable of supporting large flocks of livestock (Ingstad, 1959). For the Norse, the most important crop was grass. The chieftains or clan leaders (hövðingar) chose the best farm sites, with those from the lower social strata settling in the less desirable areas (Arneborg, 2002). As the leader of the immigration, Eirik became the recognized leader of the tiny new nation (Figure 6).

Medieval Greenland

The sagas indicate a stable, hierarchical society. Archaeological research confirms this (Arneborg, 2002; Ingstad and Ingstad, 1996; Møller and Madsen, 2006). Like contemporary European society, the Greenlanders had to struggle to survive. Eirik's saga provides insight that life was often difficult, with bad years when many hunters failed to return, and food could be scarce.

The Greenlanders ranged widely, and it was not long after the settlement of Greenland that Leifur Eiríksson (aka Leif Erikson or "Leif the Lucky") bought a ship and explored the coasts of Helluland, Markland, and Vinland, known today as Baffin Island, Labrador, and Newfoundland. In the 1960s, the Ingstads excavated what is probably Leif's Vinland settlement at L'Anse Aux Meadows and established the veracity of the history provided by sagas, history long discounted by academics and even denied long after excavation was finished (Ingstad and Ingstad, 1996)! L'Anse Aux Meadows was forested in AD 1000 when the Norse settled there, but the climate later became too cold to support woodland. Pollen analyses indicate that while it was measurably warmer in 1000 than later—and possibly than today—it was not dramatically warmer than now (Ingstad and Ingstad, 1996).

Norwegian traders sailed to both Austrbygd and Vestrbygd (Figure 2), though the journey from Iceland to Greenland

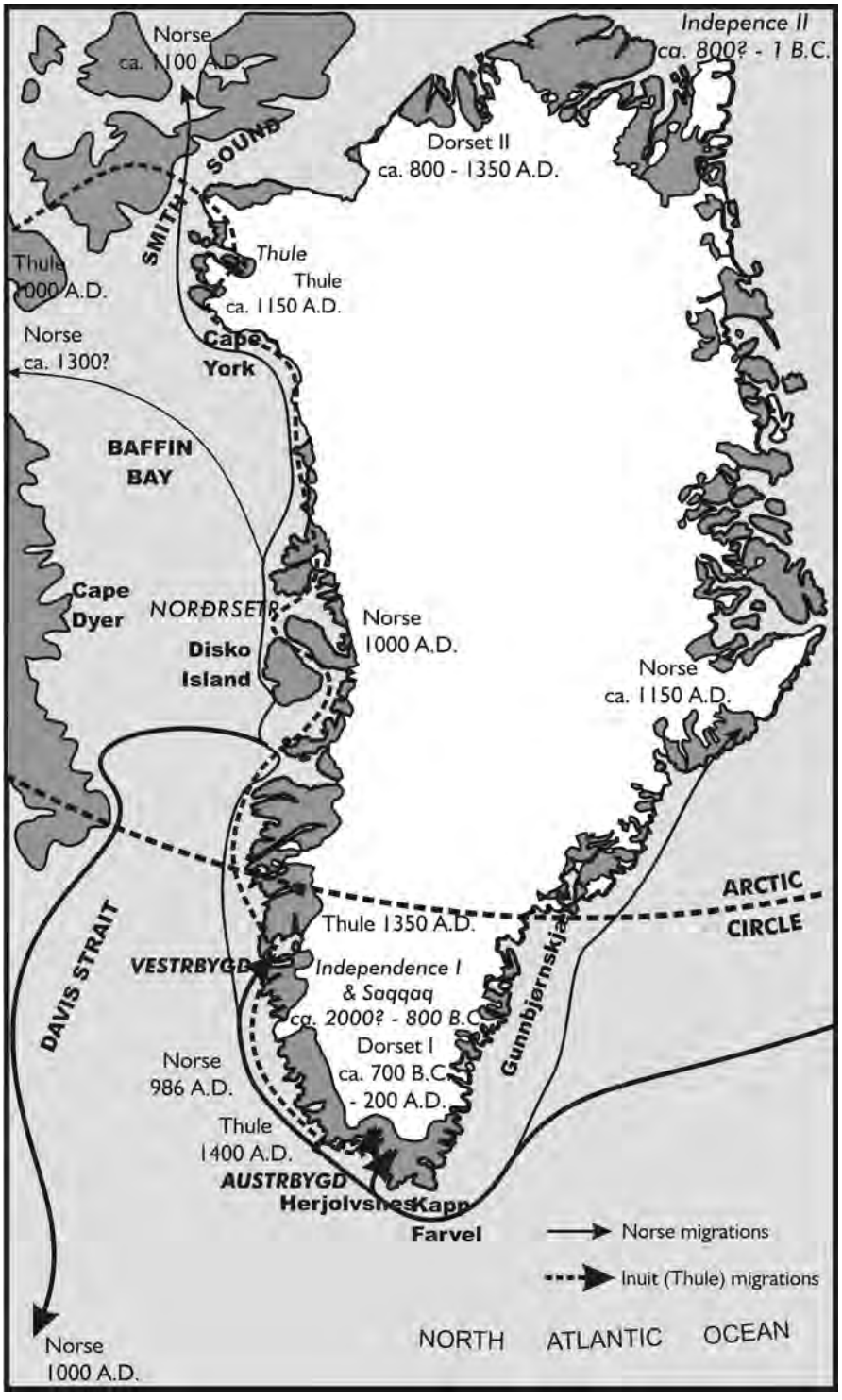

Figure 4. Map of Greenlandic cultural history. In southern Greenland, Eirik discovered earlier human settlements described as Independence I, Saqqaq, or Dorset I.

was replete with dangers. While sailing as far up the coast as Vestrbygd was clearly feasible, ice sometimes blocked the mouth of the fjords on Greenland's southwest coast, as noted in *Einar's þáttur*, an account from the early 1100s. Trade was at first quite regular between the trading center of Bergen in Norway and Greenland. Over time, at least four factors worked against this trade: increasing sea ice, the Black Death, Scandinavian politics, and German hegemony in trade (Bjørvik, 1994; Fagan, 2000; Helle, 1994; Heyerdahl and Lilliestrom, 1999; Ingstad, 1959). Sea ice forced the route south, made the voyage more dangerous, and shortened the trading season. The Black Death was imported to Norway from England via Bergen and decimated the population. Scandinavian politics resulted in Greenland being "forgotten," and the German Hanseatic League took power over virtually all trade through Bergen. A Norwegian ship did arrive from Greenland in 1410, but it had been blown off course on its way to Iceland (Ingstad, 1959). Another is recorded from 1484—the crew was said to have been murdered by the German merchants for breaching their monopoly, but Ingstad (1959) finds this story doubtful. The value of walrus ivory and furs, the most valuable trading wares of the Greenlanders, also sank steadily through medieval times (Bjørvik, 1994). Climate appears to have been an important factor but far from the only one in the decline in trade.

Clergy in medieval times were generally the only people who were literate, but runic inscriptions from Greenland indicate that some of the laity also were literate. Whereas church records are an important historical source for European history, those from Greenland are rare; the most famous is the wedding record from the Hvalsey church in 1408 (Ingstad and Ingstad, 1996). The main churches in Greenland were all destroyed by fire (Arneborg, 2001; Heyerdahl and Lilliestrom, 1999). *Einar's*

þáttur (*Einars þáttr sokkasonar*) records the Greenlanders' decision to request that the king of Norway assign a bishop to Greenland. At this time (1123), Vestrbygd was an important community with leading men, a fact confirmed by the nature of archaeological discoveries at Sandnes (Arneborg, 2001). The first Roman Catholic bishop to visit Greenland was likely Erik Gnupson, who apparently established his see in Sandnes in Vestrbygd; he went to Vinland in 1121 and never returned (Ingstad and Ingstad, 1996). The last ecclesiastical head to live at the see in Garðar is believed to have been Alf (bishop 1367–1377), though Bishop Anders may have been there in 1406 (Ingstad, 1959). Records indicate that ecclesiastical levies for building Saint Peter's Cathedral in Rome and for paying for crusades were collected by Bishop Arne (bishop 1314–1343). Others were named bishop of Garðar clear up to 1537, but none apparently went there after 1400. "An old priest" was said to have officiated in Hvalsey in 1408, the time of the last surviving document.

Climate apparently contributed to the demise of the see of Garðar. A Vatican letter from 1492 expressed belief that no ship had ventured to Greenland in eighty years (Fagan, 2000). That must refer to trading ships or ships that Catholic officials could use to reach Greenland, as a papal record from 1448 speaks of "foreign ships that raided Austrbygd and destroyed the holy buildings"(Ingstad and Ingstad, 1996, p. 100).

Grove (1988, p. 1) believes grain was grown in Greenland, though others dispute this (Ingstad, 1959; Seaver, 2010). The *Konungsjugsá*, a literary source composed ca. 1250, mentions efforts by *hövðingar* at growing grain in Greenland, apparently without success (Ingstad, 1959). Grain was an import ware, and Greenlanders were not accustomed to eating it; they subsisted on a diet largely of meat, fish, sour butter or cheese, and various native plants (Ingstad, 1959). Diet varied with social status, and common people would not have eaten grain. If grain was a marginal crop at *landnám*, it is likely the interior fjord areas of Austrbygd at that time had a climate similar to the south coast of Iceland today, i.e., milder than the present climate. There is no doubt that after 1350 at the latest, grain cultivation would have been impossible.

Figure 5. Photographs from the air of southeastern coast of Greenland (Gunnbjørnsskjær?). Need one wonder why this region has never been the site of significant human habitation?

Table II. Equivalent Place Names		
Norse	**Inuit**	**Danish**
Anavík	Ujarassuit	Anavik
Austrbygd	Nanortalik, Qaqortoq, and Narsaq	Østerbygd
Bjarney	Qeqertarsuaq	Disko øer
Brattahlið	Qassiarsuk	Brattahlid
Einarsfjörðr	Igalikup Kangerlua	Einarsfjorden
Eiríksfjörðr	Tunuglliarfik	Eriksfjord
Eysunes	Nfgssuaq	Ildnæs
Garðar	Igaliko	Gardar
Herjolfsnes	Ikigaat	Herjolfsnæs
Hvatnahverfi		Vatnahverfi
Karlsbuðir	Arfersiorfik	Nordre Strømfjord
Kvalseyfjörðr	Qaqortukulooq	Hvalseyfjord
Langey	Tugtutôq	
Lysufjörðir	Kangerlussuaq	Søndre Strømfjord
Midtfjörðir	Sermilik	
Norðrsetr		Nordresæter
Nyland, Duneyar	Ittoqqortoormiit	Scoresbysund
Sandnes	Kilaarsarfik	Sandnæs
Straumfjörðr	Niaqungunaq	Fiskefjorden
Vestrbygd	Nuussuaq	Vesterbygd
	Qaanaaq	Thule
	Paamiut	Frederikshåb
	Narsarsuaq	"Bluey One"
	Nuuk	Godthåb
	Nanortalik	Lichtenaufjord

Arguments have been made that Norse diet changed to an increasingly marine one with time (Arneborg et al., 1999). These studies are hamstrung by attempting to compare human remains from different locations, times, and social strata, without mentioning dependence on radiocarbon dating. However, if true, this dietary change would provide circumstantial evidence for climatic deterioration.

Seaver (2010) tells of some Icelanders who in 1540 happened across the body of a man in Austrbygd who had recently died. The description of his clothing matches that of many bodies disinterred from Norse graveyards, and the description of the poor state of his knife matches what could be expected in fuel-starved Greenland. She disputes details of the story but accords it a basis in fact. If true, it is at present the last record of contact with Norse Greenland—such as it was. Seaver (2010, p. 99) also argues that a "large festal hall" at Herjolfsnes near the southern tip of the subcontinent could not have been built before the middle 1400s, and evidence appears to support a functioning Norse community at Herjolfsnes into the 1500s (Ingstad, 1959), but a German expedition in 1542 found Greenland uninhabited (Ingstad, 1959). The Arctic explorer Frobisher apparently did not encounter Norse during his 1576–1578 expedition, nor did the Danish Dannels expedition in 1652–1654.

In 1721, Hans Egede Saabye obtained royal permission to go to Greenland as a missionary to the Greenlanders. When he arrived, he found no Norse. So he mastered the Inuit language, translated the Bible into Inuit, and spent the rest of his life ministering to them. His son Paul recorded accounts of the Inuit (Ingstad, 1959). Some of the Inuit believed the Norse were still in Greenland just as Hans Egede had expected. They told of peaceful coexistence but also of ships that sailed into Austrbygd and attacked the farmers. A Dano-Norwegian expedition in 1481 had written of encountering "pirates," though it is difficult to interpret their descriptions, which could easily have been skin boats. The Inuit were neither well-armed nor practiced in war and would make unlikely "pirates." Evidence points to peaceful coexistence between Norse and other peoples (Ingstad, 1959; Seaver, 2010).

Modern Greenland

Most of today's Greenlanders are Inuit. They are descendants of the Thule people who reached Greenland from the Canadian Arctic in medieval times

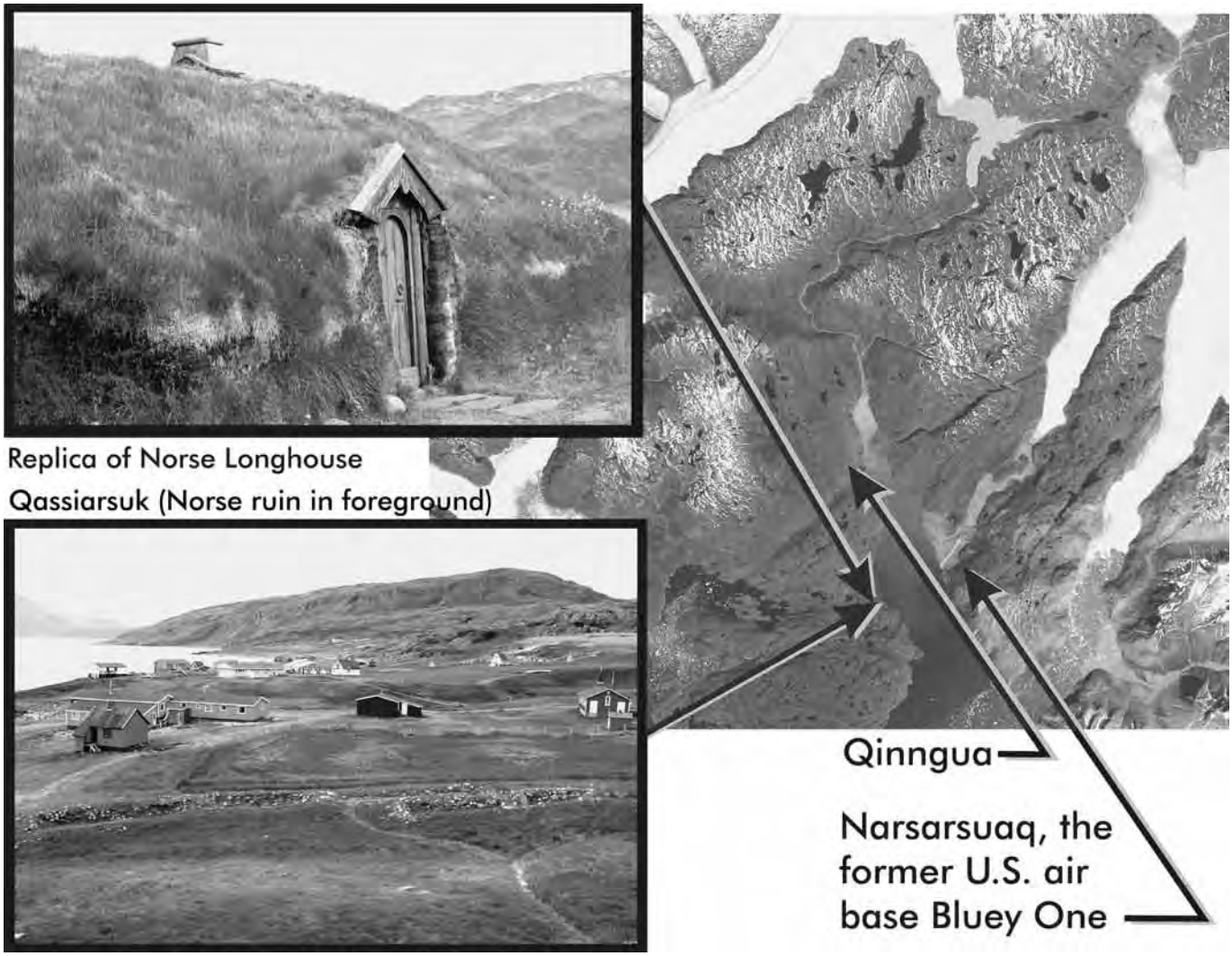

Figure 6. The most famous Norse Greenlandic farm was Eirík the Red's Brattahlið on Eiríksfjörðr (Eriks Fjord). Note on the satellite photograph that a lake traps calving ice so that this fjord is free of icebergs at its head and with the best climate for agriculture in the region. Qassiarsuk is the traditional site for Brattahlið, but another possibility is nearby Qinngua. Aerial from NASA Earth Observatory, other photographs from Can Stock Photo.

and continued expanding their range southward along the west coast until they were living side by side with the Norse (Fagan, 2000; Raahauge et al., 2002). When the Norse disappeared (see Appendix A), the Inuit continued their traditional existence.

As a Danish protectorate, Greenland has long had significant Danish influence and a sizable Danish minority. Most archaeological investigations and investigations of Greenlandic cultures have been conducted by the Danish National Museum. Work has also progressed on measuring glacial fluctuations and investigating the ice sheet. Widespread extension of glaciers from late medieval times, with minor recession during the twentieth century, is evident and matches observations from elsewhere in the world (Grove, 1988). Although the media frequently report stories of receding glaciers in Greenland, recent decades have actually been cooler than "normal" in both air and sea temperatures (Fagan, 2000). "The past 40 years' cooling trend in Southern Greenland shows that climate change is far from a simple, even process" (Hansen and Cappelen, 2003, p. 1).

Greenland's history provides important data for climate change research. Interpretation of these data is not without difficulty and controversy, but in general it agrees with Grove's (1988) interpretation that the Little Ice Age was a global phenomenon.

Proxy Data

Oxygen isotope dating of tooth enamel and benthic foraminifera have been used as proxies for the temperature history of Greenland (Grove, 2001), but the primary data come from ice cores. These proxies are limited but seem to reinforce the Little Ice Age timing seen elsewhere in the study area (Johnsen et al., 2001). Data from GISP-2 (Figure 3) are interpreted to show a particularly cold period in the mid 1300s (Fagan, 2000). Diatom evidence from cores in Austrbygd (Figure 2) indicates an overall cooling from the Medieval Warm Period to the Little Ice Age and significant cooling after 1350 (Jensen et al., 2004). The Little Ice Age peaked (as defined by ice extent) around 1750, but a second peak in Greenland occurred around 1880 (Grove, 1988). This was true for both the inland ice margin and outlet glaciers, east coast and west.

The Little Ice Age

Evidence for the Little Ice Age in Greenland corresponds with climatic change elsewhere in our study area. "But the climate continued to be mild from about 1000 until the middle of the 1100's, during the time the country was settled, and later it vacillated between milder and colder periods until the middle of the 1440's, when it became significantly colder"(Krag, 1994, pp. 42–43).

Permafrost at Hvalsnes

Bodies disinterred from the cemetery at Herjolfsnes indicate the ground was permanently frozen after 1350 (Grove, 1988). This may indicate a markedly colder climate, though some dispute this (Ingstad, 1959) and believe the climate became only slightly cooler.

Changes in Fishing and Sea Routes

While sea ice fluctuates from year to year, Barðarsson's account that the trade route had to be moved farther and farther south indicates a decadal to centennial scale for this change. Disappearance of cod and their return in recent decades is a clear sea temperature signal (Fagan, 2000).

Advancing Ice

Eyewitness accounts from the 1700s tell of rapid expansion of Greenland outlet glaciers. Fast advances were also observed in the late 1800s, both in inland ice and outlet glaciers, with temperature as the main control (Grove, 1988). We are not aware of any eyewitness account of farms actually being overrun by glaciers, and they are usually destructive of archaeological material. An exception is Gården under Sandet in Vesterbygd, which was preserved under glaciofluvial sediments. Ingstad (1959) presents evidence that the caribou/reindeer herd of northeastern Greenland died out because their habitat was covered by snow and ice during the Little Ice Age.

Disappearance of Norse Greenlanders

The disappearance of the Norse Greenlanders remains a mystery. Many of the theories are climate related, but it is impossible to prove their disappearance was caused by climate change (Appendix A). Migration of the Inuit (Thule people) south during the Little Ice Age may have been due to population growth, depletion of game, reduction in game due to climatic deterioration, or a combination of these factors. In any case, they came to live in the same areas as the Norse and competed with them for seal, caribou, and other resources. Unfortunately, it was then that cooling climate increased the need for resources. The Inuit survived and have remained in Austrbygd to this day, but there is much evidence for starvation and deprivation (Ingstad, 1959).

Glacial Studies

Melting glaciers is a popular theme in the media. Scientific studies attempt to quantify changes through mass balance comparisons, studying the accumulation of snow on the inland ice and the ice lost at outlet glaciers. Accurate results are hampered by the form of Greenland's coast (Figure 2). The feet of glaciers are easier to observe and have been studied for the past couple of centuries, though with greater scientific rigor in recent decades. Studies show that Greenland's glaciers advanced contemporary with Little Ice Age advances in Europe, but unlike Europe Greenland's glaciers have been slow to retreat or even advanced through the 1970s (Gordon, 1981). Mass balance studies for the ice sheet indicate slightly negative to slightly positive overall mass balance, but with significant differences between regions (Dietrich et al., 2005; Simpson et al., 2011; Tarasov and Peltier, 2002).

Much study has been directed to ice cores and their proxies over the past few decades to reconstruct paleoclimates. A summary of the problems with the assumptions and methods behind these reconstructions was presented by Oard (2005). Recent studies emphasize computer modeling to infer ice cover changes for Greenland and other regions, much of which is based on ice core interpretations (Tarasov and Peltier, 2002). These are now focused on recent centuries to interpret data from isostasy with greater temporal precision, as will be described later in this paper.

Altered Currents?

The countries in our study area are dependent on the transport of heat via ocean currents to moderate their high-latitude climates. As shown in Figure 2, the Irminger Current moderates the climate of Iceland, while the East Greenland Current causes the arctic landscape of Figure 5 at the same latitude that barley and fruit trees grow in Norway. Thor Heyerdahl posited that Gunnbjørnskjær was not the frigid coast shown in Figure 5 but rather an island (*skjær* can be translated as bank, reef, skerry, or island). He hypothesized that this was a volcanic island reported to have erupted in 1332 and "burned up completely" in 1456 (Heyerdahl and Lilliestrom, 1999, p. 350). The last eruption, he said, was in 1783. Without the impediment of the island, sea ice moved more freely and abundantly south with the East Greenland Current. To our knowledge, no research has been pursued to confirm or deny Heyerdahl's hypothesis.

Isostasy

Dramatic isostatic changes in Greenland may have contributed to the disappearance of Norse society. The beach at Brattahlið in Austrbygd (Figures 2 and 6) is now 3–4 m (10–13 ft.) below sea level (Sparrenbom et al., 2006), and the prominent church at Sandnes in Vestrbygd has seen a rise in sea level or drop in land elevation of 6 m (19 ft.) in the several centuries since it was built (Weidick, 1996). Recently, global positioning system (GPS) and satellite data have been tapped to determine rates of vertical motion. These data have been combined with data from radiocarbon-dated elevated shorelines to refine glacial models. While many of the assumptions made by researchers are questionable and the models are sensitive to assumptions of earth structure (Bennike et al., 2002; Fleming and Lambeck, 2004; Tarasov and Peltier, 2002), an increase in the Greenland Ice Sheet during the Little Ice Age is clearly indicated (Bennike, 2002; Weidick, 1996; Weidick et al., 2004). Many believe the present ice margin represents an advance of 25 to 80 km (15 to 48 miles) beyond the minimal margin preceding the Medieval Warm Period (Bennike, 2002; Dietrich et al., 2005; Simpson et al., 2011; Sparrenbom et al., 2006; Wahr et al., 2001). Greenland shows an isostatic pattern opposite to that of Scandinavia: it appears to have risen most at the coasts and actually subsided near the ice margin, indicating a thickening ice sheet and rebounding coasts (Wahr et al., 2001; Weidick, 1972; Weidick et al., 1990). Isostatic adjustments have significant implications, as summarized in Appendix B.

Regional or Global?

The North Atlantic Oscillation (NAO) is a major meteorologic phenomenon in the North Atlantic region and can explain many observed weather patterns. Typical winter lows over Iceland and highs over the Azores channel westerly winds to Europe. Reversing this pattern weakens the winter storm track. Figure 7 illustrates the "Greenland above effect," with high barometric pressure over Greenland. This results in warmer winter temperatures in Greenland and colder temperatures in Norway and usually most of the rest of Europe. The "Greenland below effect" is the opposite situation.

The NAO can explain asynchronicity in winter temperatures between Greenland and Europe; it cannot explain growth of ice in Greenland contemporary with growth of ice masses elsewhere. The NAO is, however, linked with weather patterns in the North Pacific (Van Loon and Rogers, 1978; Rogers and Van Loon, 1979). The Little Ice Age appears to have been at least hemispheric based on Greenland evidence, which is part of the motivation for ice core research. Proxy data indicate declining temperatures in later medieval times, and advances in inland ice and coastal glaciers in Greenland coincided with the growth of glaciers in Iceland and Norway (Grove, 1988; Klevberg and Oard, 2012a, 2012b).

The NAO or oscillatory weather patterns do not explain growth of the ice sheet inferred from isostatic data or the advance of the ice margin during recent centuries. Retreat of glacial fronts during recent decades has not equalled the advance of the Greenland ice margin during the Little Ice Age, nor has that margin melted back to its Medieval Warm Period position. As pointed out in previous papers of this series (Klevberg and Oard, 2011b, 2012a, 2012b), temperature is but one climatic variable, and Weidick (1972) attributes much of the observed change in the Greenland Ice Sheet to changes in precipitation and storm tracks. This fits well with contemporary observations for the Little Ice Age in Iceland and Norway (Klevberg and Oard, 2012a, 2012b).

Summary

The Greenland Ice Sheet is the world's second largest, forming a huge heat sink that modulates climate on a global scale. Both historical and proxy data indicate that Greenland in AD 1000 was warmer than at present, and that it cooled significantly during the Little Ice Age. Recent warming has been uneven, with a general cooling trend in southwestern Greenland over the past few decades. The Little Ice Age cooling cannot be attributed to the NAO; only decadal differences between Europe and Greenland can be explained by the NAO. In general, the timing of glacial advance coincides with Iceland and Norway, though recession has been later and to a lesser scale in Greenland. It is difficult to quantify climatic changes in Greenland from changes in equilibrium line altitude (ELA), since data are

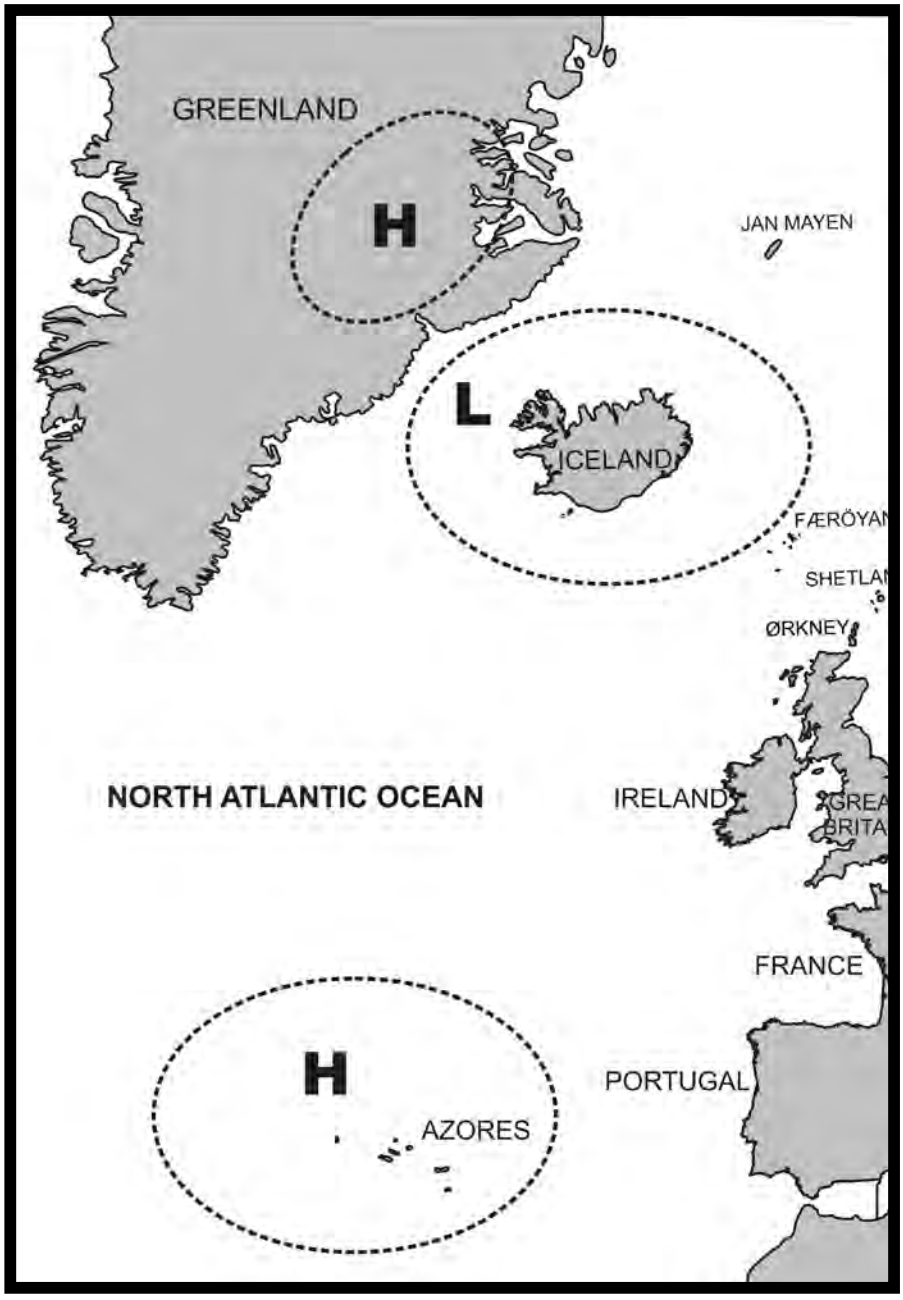

Figure 7. The North Atlantic Oscillation. The N.A.O. is shown in "positive" or normal mode; a "negative" N.A.O. index would have high barometric pressure over Iceland and low over the Azores. The "Greenland above" effect is illustrated, with high pressure over Greenland and warmer-than-average temperatures in Greenland coinciding with lower-than-average temperatures in Scandinavia. The "Greenland below" effect is the opposite.

often imprecise and the ELA is low to begin with. More reliance on somewhat problematic proxy data, particularly ice cores, is therefore necessary in studying paleoclimatology in Greenland. However, recent work on isostasy indicates that the Little Ice Age had a profound impact on Greenland.

Acknowledgments

We thank David Sunwall and Arve Misund for help in acquiring scientific papers and graphics. Reviewers' comments made this a more concise paper. We are grateful for the assistance of Al Gore and the Nobel Peace Prize committee in generating widespread interest in our research. *Deum laudamus* (Acts 17:26).

Glossary

Hanseatic League (Hansa) – A trading monopoly based in northern German cities that controlled much of northern European trade and exerted great political influence during medieval times.

hövðingar – Norse aristocracy, consisting mostly of local chieftains, feudal lords, or clan leaders, though *hövðingar*, especially of higher rank, typically ruled over people unrelated to them, in addition to slaves and servants.

isostasy – gravitational equilibrium between lighter continents and denser oceanic crust and mantle; loading of the surface by ice causes depression of the earth's surface, and unloading causes the surface to rebound and rise (isostatic adjustment).

landnám – Norse word for settling a country that was previously uninhabited.

References

CRSQ: Creation Research Society Quarterly

Andreasen, C. 2003. Paleoeskimo dwellings in Greenland: a survey. *Etúdes Inuit* 27:283–306.

Arneborg, J. 2001. Kirke, kristendom og storbønder i Grønland–et nyt forskningsprosjekt [in Danish]. In Bisgaard, L., and R.S. Christensen (editors), *Kristningen av norden–et 1000-års jubilæum.* pp. 8–25.

Center for Middelalderstudier, Syddansk Universitet, Odense, Denmark.

Arneborg, J. 2008. Resources, mobility, and cultural identity in Norse Greenland AD 980 - 1450. Annual Report to the Comission for Scientific Research in Greenland. National Museum of Denmark, Copenhagen, Denmark.

Arneborg, J., J.T. Hansen, and C. Paulsen. 2002. Kirkearkæologiske undersøgelser: ruingruppe 60V2-IV-620/Ø48 - Igaliku, Narsaq, ruingruppe 61V3-III-522/Ø33 - Qorlortoq, Narsaq, ruingruppe 61V1-III-529/Ø35 - Qorlortup Itinnera, Narsaq [in Danish]. Feltrapport 5, Sila - Nationalmuseets Center for Grønlandsforskning, Copenhagen, Denmark.

Arneborg, J., J. Heinemeier, N. Lynnerup, H.L. Nielsen, N. Rud, and Á.E. Sveinbjörnsdóttir. 1999. Change of diet of the Greenland Vikings determined from stable carbon isotope analysis and ^{14}C dating of their bones. *Radiocarbon* 41:157–168.

Bégin, Y., D. Bérubé, and M. Grégoire. 1993. Downward migration of coastal conifers as a response to recent land emergence in eastern Hudson Bay, Québec. *Quaternary Research* 40:81–88.

Bennike, O. 2002. Late Quaternary history of Washington Land, North Greenland. *Boreas* 31:260–272.

Bennike, O., S. Björck, and K. Lambeck. 2002. Estimates of South Greenland late-glacial ice limits from a new relative sea level curve. *Earth and Planetary Science Letters* 197:171–186.

Bjørvik, H. 1994. *Folketap og sammenbrudd 1350–1520*. (Volume 4 of *Aschehougs norges historie*) [in Norwegian]. Aschehoug & Co. (W. Nygaard), Oslo, Norway.

Brasen, T. 2001. The farm under the sand. *Folio* 38(16), http://www.folio.ualberta.ca/38/16/03.html (accessed January 27, 2014).

Christensen, D.V. 2002. Handel og kommunikation i Nordatlanten: rapport om prøveundersøgelser på den formodede atlanthavn, Sandhavn ved Maakkarneq, Nanortalik Kommune. Feltrapport 3, Sila - Nationalmuseets Center for Grønlandsforskning, Copenhagen, Denmark.

Diamond, J. 2005. *Collapse: How Societies Choose to Fail or Succeed*. Viking, New York, NY.

Dietrich, R., A. Rülke, and M. Scheinert. 2005. Present-day vertical crustal deformation in West Greenland from repeated GPS observations. *Geophysical Journal International* 163:865–874.

Einars þáttr sokkasonar [*Einar's þáttur*, in Old Norse]. Downloaded from www.heimskringla.no/original/islendingesagaene/graenlendingathattr.php (accessed December 31, 2008).

Fagan, B. 2000. *The Little Ice Age: How Climate Made History 1300–1850*. Basic Books, New York, NY.

Fell, M. 1999. *And Some Fell into Good Soil: A History of Christianity in Iceland*. Peter Lang, New York, NY.

Fleming, K., and K. Lambeck. 2004. Constraints on the Greenland Ice Sheet since the last glacial maximum from sea-level observations and glacial rebound models. *Quaternary Science Reviews* 23:1053–1077.

Gabriel, M., B. Grønnow, U. Odgaard, C. Pasda, and K. Pasda. 2002. Bosættelsesmønstre i det centrale Vestgrønland: rapport om undersøgelserne i Angujârtorfiup Nunâ, Manitsoq Kommune, sommeren 2001 [mostly in Danish]. Feltrapport 4, Sila - Nationalmuseets Center for Grønlandsforskning, Copenhagen, Denmark.

Gordon, J.E. 1981. Glacier margin fluctuations during the 19th and 20th centuries in the Íkamiut Kangerdluarssuat area, West Greenland. *Arctic and Alpine Research* 13:47–62.

Grove, J.M. 1988. *The Little Ice Age*. Methuen, New York, NY.

Grove, J.M. 2001. The initiation of the "Little Ice Age" in regions round the North Atlantic. In Ogilvie, A.E.J., and T. Jónsson (editors), *The Iceberg in the Mist: Northern Research in Pursuit of a "Little Ice Age"* pp. 53–82. Kluwer Academic Publishers, Boston, MA.

Hansen, N., and J. Cappelen. 2003. Avkøling I det sydlige Grønland [in Danish]. Danish Meteorological Institute, http://www.dmi.dk/dmi/afkoeling_i_det_sydlige_groenland (accessed November 27, 2010).

Hebsgaard, M.B., M.T.P. Gilbert, J. Arnebord, P. Heyn, M.E. Allentoft, M. Bunce, K. Munch, C. Schweger, and E. Willerslev. 2009. "The farm beneath the sand"–an archaeological case study on ancient "dirt" DNA. *Antiquity* 83:430–444.

Helle, K. 1994. *Under kirke og kongemakt 1130–1350*. (Volume 3 of *Aschehougs norges historie*) [in Norwegian]. Aschehoug & Co. (W. Nygaard), Oslo, Norway.

Heyerdahl, T. 2000. *Jakten på Odin* [in Norwegian]. J.M. Stenersens Forlag, Oslo, Norway.

Heyerdahl, T., and P. Lilliestrøm. 1999. *Ingen Grenser* [in Norwegian]. J.M. Stenersens Forlag, Oslo, Norway.

Høegh-Knudsen, P., C. Krause, and N.A. Møller. 2003. Palæoeskimoer i Sydgrønland: rapport om undersøgelserne på Illussat (60V2-II-26) Nanortalik Kommune, sommeren 2002 [in Danish]. Feltrapport 10, Sila - Nationalmuseets Center for Grønlandsforskning, Copenhagen, Denmark.

Ingstad, H. 1959. *Landet under leidarstjernen*. Gyldendal, Oslo, Norway.

Ingstad, H., and A.S. Ingstad. 1996. *Oppdagelsen av det nye land* [in Norwegian]. J.M. Stenersens Forlag, Oslo, Norway.

Jensen, E.L. 2002. Uunup Saqqaa–kontakter mellem Øst- og Vestgrønland: rapport over forundersøgelse og arkivsøgning, oktober 2001 - marts 2002 [in Danish]. Feltrapport 7, Sila - Nationalmuseets Center for Grønlandsforskning, Copenhagen, Denmark.

Jensen, J.F., B. Grønnow, A.B. Gotfredsen, B.H. Jakobsen, A. Kroon, M. Meldgaard, and M. Sørensen. 2008. GeoArk 2005 og 2007: rapport over rekognosceringer i Nordøstgrønland [in Danish]. Feltrapport 27, Sila - Nationalmuseets Center for Grønlandsforskning, Copenhagen, Denmark.

Jensen, K.G., A. Kuijpers, N. Koç, and J. Heinemeier. 2004. Diatom evidence of hydrographic changes and ice conditions

in Igaliku Fjord, South Greenland, during the past 1500 years. *The Holocene* 14:152–164.

Johnsen, S.J., D. Dahl-Jensen, N. Gundestrup, J.P. Steffensen, H.B. Clausen, H. Miller, V. Masson-Delmotte, A.E. Sveinbjörnsdottir, and J. White. 2001. Oxygen isotope and paleotemperature records from six Greenland ice-core stations: Camp Century, Dye-3, GRIP, GISP2, Renland and NorthGRIP. *Journal of Quaternary Science* 16:299–307.

Klevberg, P., and M.J. Oard. 2011a. The Little Ice Age in the North Atlantic region–part I: introduction to paleoclimatology. *CRSQ* 47:213–227.

Klevberg, P., and M.J. Oard. 2011b. The Little Ice Age in the North Atlantic region–part II: magnitude, extent, and importance of the Little Ice Age. *CRSQ* 48:49–58.

Klevberg, P., and M.J. Oard. 2012a. The Little Ice Age in the North Atlantic region–part III: Iceland. *CRSQ* 48:224–238.

Klevberg, P., and M.J. Oard. 2012b. The Little Ice Age in the North Atlantic region, part IV: Norway. *CRSQ* 49:43–55.

Krag, C. 1994. *Vikingtid og rikssamling 800 - 1130*. (Volume 2 of *Aschehougs norges historie*) [in Norwegian]. Aschehoug & Co. (W. Nygaard), Oslo, Norway.

McGovern, T.H. 1991. Climate, correlation, and causation in Norse Greenland. *Arctic Anthropology* 28:77–100.

Mikkelsen, N., A. Kuijpers, and J. Arneborg. 2008. The Norse in Greenland and late Holocene sea-level change. *Polar Record* 44:45–50.

Motyka, R.J., 2003. Little Ice Age subsidence and post Little Ice Age uplift at Juneau, Alaska, inferred from dendrochronology and geomorphology. *Quaternary Research* 59:300–309.

Møller, N.A., and C.K. Madsen. 2006. Nordboerne i Vatnahverfi: rapport om rekognoscering og opmåling af nordboruiner i Vatnahverfi, sommeren 2005 [in Danish]. Feltrapport 24. Sila-Nationalmuseets Center for Grønlandsforskning, Copenhagen, Denmark.

Møller, N.A., L. Lund Johansen, C.K. Madsen, L. Felding, P. Baltzer Heide, and K. Smiarowski. 2007. Udgravninger i norrøne kirkegårde og møddinger: rapport om opmålinger og utgravninger i Vatnahverfi, sommeren 2007 [in Danish]. Feltrapport 26, Sila - Nationalmuseets Center for Grønlandsforskning, Copenhagen, Denmark.

Oard, M.J. 1990. *An Ice Age Caused by the Genesis Flood*. Institute for Creation Research, Dallas, TX.

Oard, M.J. 2005. *The Frozen Record: Examining the Ice Core History of the Greenland and Antarctic Ice Sheets*. Institute for Creation Research, Dallas, TX.

Panagiotakopulu, E., P. Skidmore, and P. Buckland. 2007. Fossil insect evidence for the end of the Western Settlement in Norse Greenland. *Naturwissenschaften* 94:300–306.

Raahauge, K., M. Appelt, H.C. Gulløv, H. Kapel, C. Krause, and N.A. Møller. 2002. Tidlig Thulekultur i Sydgrønland: rapport om undersøgelserne i Nanortalik Kommune, sommeren 2001 [in Danish]. Feltrapport 1, SILA: Nationalmuseets Center for Grønlandsforskning, Copenhagen, Denmark.

Raahauge, K., P. Høegh-Knudsen, H.C. Gulløv, J. Møhl, C. Krause, and N.A. Møller. 2003. Tidlig Thulekultur i Sydgrønland: rapport om undersøgelserne i Nanortalik Kommune, sommeren 2002 [in Danish]. Feltrapport 9, Sila - Nationalmuseets Center for Grønlandsforskning, Copenhagen, Denmark.

Raahauge, K., E.L. Jensen, B. Grønnow, and H.C. Gulløv. 2005. Bopladser langs konebådsruten mellem Vest- og Østgrønland, rapport om besigtigelser fra Pamialuk til Aluk, sommeren 2004 [in Danish]. Feltrapport 19, Sila - Nationalmuseets Center for Grønlandsforskning, Copenhagen, Denmark.

Rian, Ø. 1994. *Den nye begynnelsen 1520–1660*. (Volume 5 of *Aschehougs norges historie*) [in Norwegian]. Aschehoug & Co. (W. Nygaard), Oslo, Norway.

Rieck, F., J. Dencker, H. Kapel, and K. Raahauge. 2002. Skib, naust og maritime aktiviteter i det norrøne Grønland: rapport om prøveundersøgelser af et formodet skibsnaust og en smedje ved Ikigaat/Herjolfsnæs, Nortalik Kommune, sommeren 2001 [in Danish]. Feltrapport 2, Sila - Nationalmuseets Center for Grønlandsforskning, Copenhagen, Denmark.

Rogers, J.C., and H. Van Loon. 1979. The seesaw in winter temperatures between Greenland and Northern Europe. Part II: some oceanic and atmospheric effects in middle and high latitudes. *Monthly Weather Review* 107:509–519.

Ross, J.M. 1997. Paleoethnobotanical investigation of Garden Under Sandet, a waterlogged Norse farm site, Western Settlement, Greenland (Kaiaallit Nunaata). M.A. thesis, University of Alberta, Edmonton, AB.

Sandgren, P., and B. Fredskild. 1991. Magnetic measurements recording late Holocene man-induced erosion in S. Greenland. *Boreas* 20:315–331.

Seaver, K.A. 2010. *The Last Vikings*. I.B. Taurus, New York, NY.

Simpson, M.J.R., L. Wake, G.A. Milne, and P. Huybrechts. 2011. The influence of decadal- to millenial-scale ice mass changes on present-day vertical land motion in Greenland: implications for the interpretation of GPS observations. *Journal of Geophysical Research* 116:B02406 (doi: 10.1029/2010JB007776).

Sparrenbom, C.J., O. Bennike, S. Björck, and K. Lambeck. 2006. Holocene relative sea-level changes in the Qaqortoq area, Southern Greenland. *Boreas* 35:171–187.

Sørensen, M., and K.B. Pedersen. 2004. Killiaq kilder og palæo-eskimoer: arkæologisk rekognoscering af nordkysten af Nuussuaq, fra Serfat til Qaarsut, Uummannaq Kommune [in Danish]. Feltrapport 17, Sila - Nationalmuseets Center for Grønlandsforskning, Copenhagen, Denmark.

Tarasov, L., and W.R. Peltier. 2002. Greenland glacial history and local geodynamic consequences. *Geophysical Journal International* 150:198–229.

Thomson, A.M., I.A. Simpson, and J.L.

Brown. 2005. Sustainable rangeland and grazing in Norse Faroe. *Human Ecology* 33:737–761.

Van Loon, H., and J.C. Rogers. 1978. The seesaw in winter temperatures between Greenland and Northern Europe. Part I: general description. *Monthly Weather Review* 106:296–310.

Vardiman, L. 1997. Rapid changes in oxygen isotope content of ice cores caused by fractionation and trajectory dispersion near the edge of an ice shelf. *Creation Ex Nihilo Technical Journal* (now *Journal of Creation*) 11(1): 52–61.

Vebæk, C.L. 1991. Hunting on land and at sea and fishing in medieval Norse Greenland. *Acta Borealis* 8:5–14.

Wahr, J., T. Van Dam, K. Larson, and O. Francis. 2001. Geodetic measurements in Greenland and their implications. *Journal of Geophysical Research* 106:16,567–16,581.

Weidick, A. 1972. Holocene shore-lines and glaciated stages in Greenland–an attempt at correlation. Grønlands Gbeolgiske Undersøgelse *Rapport Nr. 41.*

Weidick, A., H. Oerter, N. Reeh, H.H. Thomsen, and L. Thorning. 1990. The recession of the inland ice margin during the Holocene climatic optimum in the Jakobshavn Isfjord area of West Greenland. *Paleogeography, Paleoclimatology, Paleoecology* 82:389–399.

Weidick, A. 1996. Late holocene and historical changes of glacier cover and related relative sea level in Greenland. *Zeitschrift für Gletscherkunde und Glazialgeologie* 32:217–224.

Weidick, A., M. Kelly, and O. Bennike. 2004. Late Quaternary development of the southern sector of the Greenland Ice Sheet, with particular reference to the Qassimiut lobe. *Boreas* 33:284–299.

Appendix A: The Mystery of the Disappearance of the Greenlanders

For centuries, a few thousand Norse Greenlanders occupied hundreds of remote farms and hunting camps in southwestern Greenland and traded with European voyagers at Herjolfnes and other locations. The population of Vestrbygd vanished about 1350, but the larger Austrbygd community was still populous in the early 1400s, and still in existence to at least 1540. It, too, was gone without a trace by 1721, when Hans Egede Saabye came to bring the gospel of Jesus Christ to them. Finding Inuit rather than the Norse he had expected, he learned their language and ministered to them. Why the Norse Greenlanders disappeared remains a mystery. As shown in Table III, more than a dozen theories have been devised to explain this disappearance, either alone or in combination.

Was the Little Ice Age the Cause?

No clear evidence exists that the Little Ice Age affected Greenland strongly enough to bury most Norse farms and put an end to their civilization. Alternative ideas include some that involve climate change and some that do not. The likelihood or unlikelihood of these theories helps to provide some degree of insight into the effects of the Little Ice Age on Greenland.

Theories for the Disappearance of the Norse Greenlanders

Of the theories shown in Table III, only two are blatantly climatic. Eight are primarily political or cultural, and four could be called "natural" without necessarily being directly climate related.

Annihilation by Inuit

Ivar Barðarsson, who led the expedition from Austrbygd in the 1300s to rescue Vestrbygd, believed the Norse there had been attacked by Inuit. Ingstad (1959) provides evidence that the possibility of this is remote. While there were accounts of Inuit attacks on Norse, these were very rare, and relations appeared to have been nearly always friendly. Inuit were known to form friendships with Norse and even to have rescued some in time of calamity.

Assimilation by Inuit

Fridtjof Nansen, the famous explorer who skied across Greenland, was a "uniformitarian" who disputed the existence of the Little Ice Age prior to its end. He thus did not adhere to a climate-related theory but instead believed the Norse had simply assimilated into Inuit culture. However, evidence indicates that the genetic contribution of Europeans to the present Greenlandic people stems from the much smaller group of Danes and Norwegians who settled in Greenland after 1750 and married Inuit women.

Overrun by Ice

Advancing ice did threaten, if not destroy, Norse farms (Grove, 1988) and probably overran many of the more inland sites (Weidick, 1972, 1996). That the ice continued to advance into the eighteenth century and beyond is attested to by records of interviews with Inuit hunters (Grove, 1988). As noted above, the inland ice appears to have advanced up to 80 km (48 miles) from its post-Great-Ice-Age minimum. However, many sites did not suffer from glacial advance, and the growth of glaciers could not have constituted a sufficient condition for the disappearance of the Norse Greenlanders, though it may have contributed to the demise of their society. Advancing ice, increasing permafrost, and glacial erosion would all have challenged the Norse Greenlanders. Ice advance is certainly a climatically governed factor.

Table III. Summary of Theories for Demise of Norse Greenlanders				
Theory	Notable Promoters	Climate Related?	Likelihood	Contributing Factor?
Annhilation by Inuit	Barxarsson	No	Remote	No
Assimilated by Inuit	Nansen	Possibly	Low	No
Overrun by Ice	Weidick	Yes	Localized	Probably
Insect Plague	Ingstad*	No	Low	Possibly
Isostatic Depression	Ingstad*	Probably	High	Possibly
Soil Erosion & Deforestation	Popular**	Possibly	Low	Possibly
Colder water, shorter growing season, lack of driftwood	Fagan*	Yes	High	Probably
Loss of Trade	Fagan*	No	High	Very likely
Pride and Starvation	Popular**	Yes	Remote	Probably not
Disease		Possibly	Low	Probably not
Inbreeding & Lack of Vitality	Norlund	Possibly	Low	Probably not
Ecclesiastical Greed	Ingstad*	No	High	Probably
Pirates	Ingstad*, Heyerdahl	No	High	Probably
Outmigration	Ingstad*, Heyerdahl	Probably	High	Very likely

*Provided as suggested contributing factor but not adequate explanation in itself.
**Most popular Establishment explanations, so promoters are common (e.g. McGovern, 1991; Diamond, 2005).

Insect Plague

It may seem strange that an insect plague could erupt in the chilly climate of Greenland, but infestations of caterpillars have been observed in recent decades that resulted in denudation of large areas of vegetation (Ingstad, 1959). Such has been suggested for the reason Vestrbygd was abandoned, as one winter without hay would mean death for man and beast, whether cold weather or insects were responsible. However, this does not explain why livestock were roaming free when Ivar Bárðarsson and company arrived from Austrbygd, nor does it explain the disappearance of the considerably larger Austrbygd community a couple of centuries later.

Isostatic Depression

Ingstad (1959) provides considerable documentation of the drop in land relative to sea level. This has amounted to 5–6 m (15–20 ft) since the settlement of Greenland and appears to be isostatic depression, since sea-level rise was apparently not more than 40–50 cm (16–20 in) during the Little Ice Age (Fagan, 2000), and Norway continued to rise out of the sea during this same period. While isostatic depression would not have been catastrophic nor adequate cause for abandoning their homes, the Norse would have lost considerable real estate, some of their best land, and probably some hard-earned buildings to the sea (Mikkelsen et al., 2008). Isostatic depression would therefore have been a contributing factor, not a sufficient condition, for the demise of Norse Greenland. Isostatic depression could be the result of significant ice build-up during the Little Ice Age or dramatic crustal cooling; no other cause is evident. As noted above, a significant amount of the relative sea-level rise (i.e., isostatic depression) appears related to the Little Ice Age and actually appears to be overprinted on isostatic rebound from ice melting after the Great Ice Age.

Soil Erosion and Deforestation

As mentioned in part III of this series, Iceland experienced damaging soil erosion during the Little Ice Age, the effects of which are still visible. Demand for fuel increased at the same time the growing seasons were shortened, and deforestation and soil erosion went hand in hand. Starving people tend to think little of the long-term effects of overgrazing and deforestation. This has been suggested as a major factor in the demise of Norse Greenland (Fagan, 2000; Sandgren and Fredskild, 1991), though many data appear to indicate

that climatic deterioration at least played a role in erosion (Arneborg, 2008) and that Greenlandic farmers, like many other Norse, were actually good and skilled stewards of their land (Ingstad, 1959; Møller and Madsen, 2006; Thomson et al., 2005; Ross, 1997). Harsher climatic conditions and advance of ice during the Little Ice Age would have contributed to soil erosion, however, and less availability of driftwood would have increased the pressure on the limited dwarf birch woodland. Thus, while probably not a major factor, to the extent that soil erosion and deforestation increased pressure on the Norse community, they would have served to contribute to its demise.

Colder Water, Shorter Growing Season, Lack of Driftwood

Fagan (2000) notes that only a slightly colder seawater temperature than at present would have driven cod from Greenland's southwest coast. While some claim the early medieval Norse Greenlanders had an aversion to fish (Diamond, 2005), this assertion indicates ignorance of Norse practices with fish byproducts and flies in the face of historic evidence that fish always formed a fundamental part of the Greenlanders diet (Ingstad, 1959). In 1770, E. Þórhallesen discovered a fish-drying place that remained from the Norse community (Ingstad, 1959). Loss of this resource would have hit the community hard. Climatic deterioration would have made life more difficult for livestock, another fundamental source of sustenance for the Norse. Demand for driftwood for fuel and lumber exceeded replenishment. As the Little Ice Age commenced, this demand would have increased at the same time that Greenlanders would have had to go farther and farther in search of it. This also made smelting of iron difficult and expensive. Coal was even imported to Vestrbygd from present-day Rhode Island (based on chemical and mineralogical analysis), apparently for this purpose (Ingstad, 1959). A shorter growing season would have affected caribou (reindeer) just as it did domestic livestock, with less game meat for the larder. Loss of driftwood meant less fuel to heat with during increasing long and cold winters, and while blubber could substitute for some of that, lack of good driftwood for boat building or constructing houses could have been devastating. On the other hand, right up to the time of its disappearance, the Vestrbygd community obtained wood from Labrador (Ingstad and Ingstad, 1996). Their boats were smaller and grossly inferior to the famous oak Viking ships of Norway in which the first settlers arrived, and these later Greenlandic boats were held together by wooden pegs and sinews as fuel for smelting iron became scarce (Ingstad, 1959). Yet one of these 18-man boats was blown off course from Markland (Labrador) and ended up in Iceland in 1347, right about the time the Vestrbygd community probably disappeared. So while these climate-induced factors would have complicated life, they would not have been sufficient conditions for the end of the Norse settlements.

Loss of Trade

Trade meant much to support a population of thousands in such a challenging landscape. Trade helped lift their standard of living and brought them valuable items such as sewing needles and iron for tool making (Christensen, 2002; Rieck et al., 2002). The loss of trade would not in itself make life impossible, but it would have made it more difficult. Loss of trade was not solely the result of climatic deterioration, but climate did play a role.

Pride and Starvation

Today, the most popular theory for the demise of Norse Greenland is that they were cultural holdovers who insisted on being European and refused to adopt Inuit lifestyles (Diamond, 2005; McGovern, 1991). They looked down on the natives, calling them *skrælingar* ("wimps") and starved to death rather than stoop to the *skræling* way of life. This cultural suicide may have been speeded along through bad farming practices and other unsustainable resource development or perhaps by deteriorating climate, though some dispute the role of climate at all (McGovern, 1991). Target species and hunting equipment of the Inuit, which some think could have saved Norse society, do not seem to have been adopted by the Norse Greenlanders (McGovern, 1991; Vebæk, 1991). Fagan (2000) provides a detailed description of archaeological evidence for this position based on Nipaatsoq, a small farm near Sandnes in Vestrbygd, which shows evidence of squalor and starvation.

Fagan's description notwithstanding, this argument carries little if any weight. Not only were livestock roaming about Vestrbygd when Barðarsson and his men arrived, they slaughtered and hauled back as many as they could. Arguments similar to Fagan's continue to be made, but evidence from the nearby Gården Under Sandet (GUS), which was excavated in recent years, appears more typical of Vestrbygd and differs significantly from Nipaatsoq (Brasen, 2001; Ross, 1997). Refined methods utilized at GUS are providing a fuller and perhaps more complicated picture (Hebsgaard et al., 2009; Panagiotakopulu et al., 2007). A single farm in Vestrbygd such as Nipaatsoq could also have been inhabited by an *utlægr* (banished outlaw) and may not be indicative of the community as a whole. Much remains shrouded in mystery, and the prevailing view is simplistic at best.

It is true that the Norse called the natives they encountered in Vinland *skrælingar* and provoked some confrontations with them. However, they had remarkably peaceful relations with the Thule people (Ingstad, 1959). The Thule people had their own *skræling*-like word, and true to their traditions, made up tall tales of how they chased

Figure 8. Fishing on Storfjord, Sunnmøre, Norway. Klevberg's farmer friend Harald Haugen sets nets from a boat built from timber harvested from his small dairy farm at Viset. Farms too small to be otherwise viable have been the norm in Norway for centuries; fishing and hunting have always been combined with farming. This kind of multifacted economy prevailed in Norse Greenland. The *naust* (a type of boathouse built above high-tide line) in the middle right photograph is a typical Norwegian wooden structure; in medieval Greenland, a *naust* would have been built of turf and stone with minimal wood. Greenlandic boats were built with spruce from Labrador fastened with sinews (Ingstad, 1959). Winter fishing and fish preservation methods practiced for millenia in Norway were taken with the Norse to Greenland and provided vital nutritional support for the Norse Greenlanders. The large fish shown here (middle left photograph) is a cod, the staple Nordic fish. The Little Ice Age resulted in disappearance of cod from Greenlandic waters (Fagan, 2000). Most of photographs by Harald Haugen.

out "giants" when they came to Greenland. This lends credence to belief that Dorset II culture was present in northern Greenland in medieval times, as the Dorset were noticeably larger than the diminutive Thule people yet ran away when confronted (Ingstad, 1959).

The "pride and starvation" argument reveals considerable academic ignorance, if not revisionist arrogance. As pointed out long ago (Ingstad, 1959), Norse culture involved making use of virtually all of the same resources that the Inuit did, with hunting a major source of food and materials from the very beginning. In addition, the Norse had livestock; they had a more diverse and secure base than did the Inuit. To this day, a combination of fishing, hunting, and farming is traditional in Norway (Figure 8). The Greenlanders dug pits in the permafrost to act as freezers for meat and other foodstuffs (Ingstad, 1959). Yet toward the end of Norse Greenlandic society, they were described as barbarians who wore furs and ate raw meat, with a standard of living that differed little from the Inuit (Heyerdahl and Lilliestrom, 1999; Ingstad, 1959). It is ironic that in the early 1900s, the Inuit had so decimated the wild game population that they had to adopt sheep raising to avoid starvation (Ingstad, 1959).

Disease

An intuitive idea for the disappearance of the Norse in Greenland is the bubonic plague. It killed at least two-thirds of Norway's population and about that in Iceland. Might it not have done the same in Greenland? The Black Death harried Norway at the same time Vestrbygd was abandoned, so it cannot be the cause of that community's disappearance, since it could not have spread there by that time. The Black Death hit Iceland hardest about 1400, so it could have spread to Austrbygd from Iceland thereafter. However, evidence of mass deaths has not been uncovered in either

Figure 9. The church ruin on Hvalsey, southwestern Greenland (Austrbygd), is the best preserved church ruin in the country (Can Stock Photo).

Vestrbygd or Austrbygd (cf. the various archaeological reports in the bibliography of this paper). Some researchers speculate that depopulation of Europe by the Black Death tempted Greenlanders to emigrate (Ingstad, 1959).

Inbreeding and Lack of Vitality

The early archaeologist Nørlund popularized the idea that inbreeding and lack of vitality led to the slow death of the Norse civilization in Greenland. The evidence he proffered from Herjolfsnes has since been refuted (Ingstad, 1959). The Norse population of 3,000 to 9,000 (probably 4,000 to 5,000) was adequate to avoid any significant inbreeding issues (Ingstad, 1959); also, the church's teaching prohibiting marriage between relatives was strict (Rian, 1994).

Ecclesiastical Greed

A century before the Reformation, the Roman Catholic Church owned up to two-thirds of Austrbygd, and it was the best land (Ingstad, 1959) with the best buildings (Arneborg, 2001; Fagan, 2000; Møller et al., 2007—cf. Figure 9). The bishop held the hunting rights for the best caribou (reindeer) hunting sites and regulated the harvest. Could loss of land ownership and increasingly onerous taxes have contributed to the abandonment of Austrbygd? This would have been particularly difficult during a time of climatic deterioration.

Pirates

Pirates in the ice-infested waters off Greenland? You have got to be kidding! That was the lead author's reaction when first coming across this theory. Heyerdahl (Heyerdahl and Lilliestrom, 1999) had become too radical this time, and the academics were justified in dismissing him. But not so: we have documentation that Algerian pirates raided Torshavn in the Færoes and Heimaey in Iceland, and English pirates burned the homes of impoverished farmers in Iceland in the early 1400s (Fell, 1999; Ingstad, 1959). Basque and English fishermen had ventured to Greenland and Newfoundland and even stopped to trade with the Norse (Ingstad, 1959; Seaver, 2010). Inuit preserved stories of pirates who attacked Austrbygd, were repulsed with difficulty, but returned the next year to burn Austrbygd (Ingstad, 1959), at least the churches (Arneborg, 2001). Many of Austrbygd's inhabitants were taken as slaves, but some eventually made their way back home (Heyerdahl and Lilliestrom, 1999). Whether enough of them escaped or returned to recreate a functioning society is another question. One Inuit account tells of Inuit rescuing a Norse woman and children. They returned months later to find the area destroyed and uninhabited, so those rescued were adopted by the Inuit (Ingstad, 1959). It seems that pirate raids had little to do with climate change, except that the ice must not have increased enough to block access to the southwestern fjords.

Outmigration

As is widely known, the Norse built a settlement in Newfoundland in AD 1000. Their explorations and settlement over wide portions of eastern Canada have been confirmed by Canadian archaeologists and others (Ingstad and Ingstad, 1996). Why, then, is there such opposition to this evidence among academics (Seaver, 2010)? Why does the Establishment seek to limit the Norse presence to L'Anse Aux Meadows and the briefest period possible? Why are they so opposed to evidence for widespread communication between peoples in ancient times elsewhere in the world (Heyerdahl, 2000; Heyerdahl and Lilliestrom, 1999)?

The scope of this paper does not allow a thorough evaluation of Establishment bias or the evidence for the Norse presence in North America. Most creationists are probably aware of this bias, whether it be against design in nature or for biblical history rather than the gradual "cultural evolution" of isolated groups of "primitive" people. One's view of history—natural or cultural—has a

great deal of relevance to many scientific debates, including the topic of climate change.

The first Norse to settle in North America got themselves into trouble with the natives through their "shoot first, ask questions later" policy. The American Indian cultures were not the same as the Nordic cultures they were used to. To what extent the different peoples were able to later understand each other, we do not know. We have little historiography to work from in evaluating medieval Norse immigration to North America. Yet it is clear that in the 1100s and the 1300s, Norse were in North America, and as conditions worsened in Greenland, it would have been only reasonable to consider moving to the other side of the Davis Strait.

The Greenlanders' 18-man boats would not have been large enough to transport much for the dangerous, three-day voyage over the Davis Strait, so if the inhabitants of Vestrbygd moved en masse to North America, they would have had to leave the majority of their livestock behind. There would have been no reason to harm the animals, and they would have been left roaming loose, just as Ivar Barðarsson found them. This seems the most likely explanation for the disappearance of the Vestrbygd community.

Austrbygd continued another two hundred years after the disappearance of Vestrbygd. While the inhabitants of Vestrbygd seem to have vanished, Austrbygd seems to have withered away. There is, however, evidence not only of people kidnapped from Austrbygd but also of some who willingly left for England (Ingstad, 1959) and what is now the New England states (Heyerdahl and Lilliestrom, 1999). Various means of outmigration were available to the final Norse Greenlanders (Seaver, 2010).

Significance of Norse Mystery to Little Ice Age

Vestrbygd, the northern community, may have been prompted to leave due to climate change. If a year or two without fodder occurred, a major crisis would have resulted. This does not appear to have been the case for Austrbygd. If life became difficult due to a combination of factors—loss of private ownership of land, increasing taxes, worsening climate, attacks by pirates—then people would be inclined to leave a family or two at a time. This may have been the case. We will probably never know with certainty why this society disappeared, but the most likely theories are linked to the Little Ice Age. Thus, while there is no unequivocal evidence for climate as "the cause" for the disappearance of the Norse Greenlanders, it very likely played an important role.

Appendix B: Implications of Isostasy

The remarkable rate of isostatic rebound in some regions (Klevberg and Oard, 2012b) and isostatic depression in others (as described in this paper) has wide-ranging implications for earth science research, implications far beyond the scope of this series of papers. While various glacial models have been referenced in this paper, we caution readers to be aware of the following pitfalls in these models.

- Glacial models are natural history scenarios, not scientific fact. They incorporate into them assumptions about Earth history, including "deep time," which are refuted by biblical chronology and often by more recent historical accounts.
- Glacial models are commonly based on standard interpretations of ice core data, interpretations that are seriously flawed (Oard, 2005).
- Unique solutions are not possible with glacial models, as these models are dependent on input assumptions regarding the structure of the earth. This is one of the areas of greatest ignorance hampering models (Fleming and Lambeck, 2004).
- Relative sea-level curves are derived from limited deposits that are accessible and amenable to dating. Problems with radiocarbon dating have been extensively covered by creationists (e.g., Klevberg and Oard, 2011a). Even with correction for the marine reservoir effect (Weidick, 1972) and variations over time (Fleming and Lambeck, 2004), errors are certainly introduced into the modeling process, especially the farther back in time dates are inferred.

As speculation of future climate change has encouraged efforts to refine models and test them against historical data, considerable improvement in modeling has occurred. One of the results has been downward revision of some of the assumed values for viscosity of the mantle based on rapid isostatic adjustment from the ice growth and recession over the course of the Little Ice Age, not only in Greenland, but also in Hudson Bay and Alaska (Bégin et al., 1993; Motyka, 2003), as well as the rest of the North Atlantic area that is the focus of this series. The time required for isostatic adjustment may thus be less than previously thought, and the Great Ice Age could have occurred much more recently than is commonly believed. Results of these recent isostasy studies could challenge many presently held beliefs among both creationists and evolutionists, and those researchers interested in glaciation and deglaciation, plate tectonics, and the structure of the earth may find these recent results the basis of very fruitful research.