The Little Ice Age in the North Atlantic Region

Part III: Iceland

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Abstract

The first two parts of this series (Klevberg and Oard, 2011a, 2011b) introduced methods of studying past climate change, the historicity of the Medieval Warm Period and Little Ice Age, and the importance of the Little Ice Age in understanding climate change and constraining climatic models. The reasons for concentrating on the North Atlantic region include the richness of the historiography for the period and the utility of the geography in studying climatic constraints on the inferred postdiluvial ice age. Nowhere is the historiography richer or the geographic setting better for this than Iceland. This paper summarizes observations of climate change in Iceland from *Landnám* to the present and the contemporary glacial fluctuations.

Why Iceland Is Special to Paleoclimatology

Iceland is exceptionally sensitive to climate change, being on the edge of the Arctic, and it is also a good indicator of European climate generally (Grove, 1988). "Iceland is ideally located to study the timing of [Little Ice Age] glacier fluctuations due to its position astride the atmospheric convergence zone and its proximity to the oceanic polar front" (McKinzey et al., 2005, p. 171). It is widely believed that effects of climate change are greater with increasing latitude (Ives, 2007).

Iceland has an unparalleled historiography, beginning with the sagas from the time of *Landnám* and extending through medieval times (Fell, 1999). (*Landnám* refers to settlement of a previously uninhabited country. In the case of Iceland, *Landnám* occurred from about AD 870 to 930). "The sensitivity of the economy to climatic fluctuations, together with the extraordinary literary bent of the Icelanders and the emergence of a line of gifted field scientists (Þórarinsson, 1960), mean that the Icelandic records relating to the Little Ice Age are of substantial length and richness" (Grove, 1988, p. 15).

Iceland's climate is greatly influenced by ocean currents and the salinity changes and atmospheric circulation patterns that drive them (Grove, 1988). Its latitude and maritime setting (Figure 1) make it a suitable laboratory for investigation of any postulated previous ice age.

As Iceland plays such a prominent role in studies of the Little Ice Age, this paper (Part III) is devoted solely to this country. Vatnajökull (Figure 2) and other major glaciers of Iceland are shown on Figure 3.

Prehistoric Iceland

Traditional speculations regarding the prehistoric (i.e., pre-*Landnám*) period, which are unrestrained by historical

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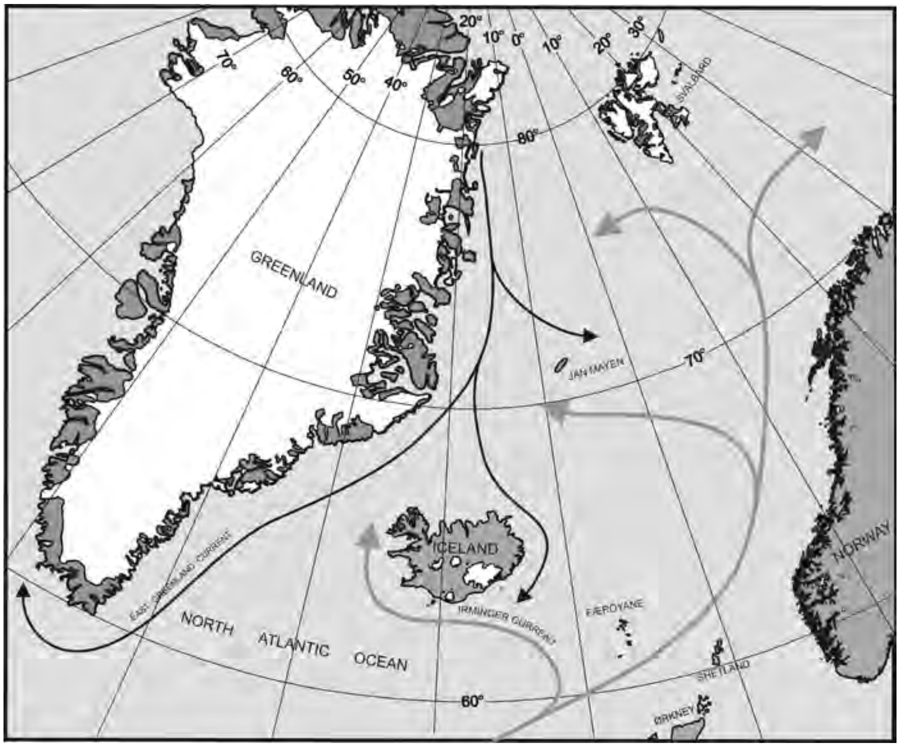

Figure 1. The North Atlantic Region. Relatively warm ocean currents are shown in gray, cold currents in black.

sources, include multiple glaciations and belief that nearly the entire island group was covered with ice during the "Pleistocene" glaciation (Björnsson, 1980; Haberle, 1991; Hjartarson, 1991; Ingólfson, 1991; Norðdahl, 1991; Pétursson, 1991; Stötter, 1991). Traditional ideas are summarized in Table I.

The Saga Age and Medieval Warm Period

Saga age is the term commonly used for Iceland's early history, from *Landnám* to about 1030. During this period, history was conveyed via oral tradition, and was not written down until medieval times. The validity of these sagas as historical references has been greatly debated (see Appendix B), but they contain invaluable insights into contemporary climate. Those sagas that fit the historical genre have generally proven reliable when archaeological and other evidence is available for comparison. We have made use of several of these references as indicated in Table II.

Historical descriptions are corroborated by jökullhlaup evidence from Skeiðarárjökull (Figures 2, 3, and 9); the nature of these glacial outburst floods is indicative of a thinner glacier according to Grove (1988). The existence of good farmland in areas that are now denuded and barren indicates considerable time had elapsed since any previous glaciation for thorough soil development (Table III). During *Landnám*, the southern Vatnajökull outlet glaciers are thought to have been approximately 20 km behind their present margins (Evans and Twigg, 2002). Glacier positions prior to the Little Ice Age argue for a climate at least as warm, and quite possibly warmer, than today (Ives, 2007). The climate prior to about 1200 was evidently warmer than after 1200 (Fell, 1999).

Icelandic Evidence for the Medieval Warm Period

Probably 85 percent of Icelandic land area was forested at *Landnám* (Landnåmsboken, 1997), mostly in scrub

Figure 2. View toward Vatnajökull from Skeiðarársandur. On a volume basis, Vatnajökull is the world's third largest ice cap (or first, if Greenland and Antarctica are capped by ice *sheets*).

Speculative Time (years before present)	Corrected* ^{14}C (median years b.p.)	Vegetation (Principally Pollen)	Inferred Temperature	Remarks	References
ca. 14 Ma	Outside range typically "dated" using ^{14}C.	*Sequoia, Pinus, Juglans, Alnus, Fagus, Ulmus, Tilia, Vitis*		Selúrdalur flora; *Taxodiceæe* give way to *Pinaceæe*	Símonarson
14 - 13 Ma		*Abies, Sequoia, Comptonia, Betula prisca, Acer, Alnus, Magnolia, Sassafras*		Brúnslækur flora; *Pinaceæe* give way to *Toxodiceæe*	Símonarson
13 - 10 Ma		gymnosperms give way to angiosperms		Gerpir flora	Símonarson
10 - 9 Ma		*Polypodiceæe* predominate; *Osmunda, Salix, Juglans, Betula, Acer, Magnolia, Carya*		Húsavikurleif flora, Tröllatunga flora, Hólmatindur flora	Símonarson
9 - 8 Ma		*Alnus, Betula, Acer, Pterocarya, Fagus, Corylus*		Mókollsdalur flora, warm-temperate flora similar to North American Eastern Deciduous Forest	Símonarson
7 Ma		*Betula, Salix,* conifers		Hreðavatn flora	Símonarson
6 - 3 Ma		*Betula, Salix,* shrubs and grasses		Sleggjulækur flora, Tjörnes flora	Símonarson
3.1 - 2 Ma		*Alnus, Betula, Salix,* grasses	Similar to today during interglacials, 5 - 10 °C colder during glacials	Extinction of temperate conifers and deciduous trees during glaciation	Símonarson
2 - 1 Ma		*Alnus, Betula, Salix,* grasses		Bakkabrúnir flora	Símonarson
ca. 1.1 Ma - 700,000		*Alnus?* and *Betula*		*Pinus* becomes extinct; Stöð flora	Símonarson
700,000 - 12,500				Wechselian glacial maximum at ca. 18,000 B.P.	Norðdahl
12,500 - 12,000	5075			Álftanes (Older Dryas); ice remained on western and northern coasts	Björnsson
12,000 - 11,000	5042			Alleröd Interstadial	Björnsson
11,000 - 10,000	4999			Búði, Álftanes? (Younger Dryas), most of Iceland glaciated	Björnsson, Hjartarson
10,000 - 9,000	4946	*Betula* maximum in northern Iceland, no *Betula* in southern Iceland		Búði?; refugia in northern Iceland, rapid near disappearance of ice	Símonarson, Hjartarson, Björnsson

Speculative Time (years before present)	Corrected* ^{14}C (median years b.p.)	Vegetation (Principally Pollen)	Inferred Temperature	Remarks	References
9,000 or 6,700 - 6,000	4807	*Betula* expanded rapidly into southern Iceland; *Betula* maximum	annual mean ca. 2 °C higher than today	Boreal and Lower Atlantic in Europe; final deglaciation ca. 10,500/9,650 B.P.	Simonarson, Wastl et al., Norðdahl, Pétursson
6,500 - 5,000 or ca. 3,300	4312	*Betula* minimum, bogs increased, *Sphagnum* maximum	slightly warmer than today	Wet Atlantic of continental Europe	Simonarson, Wastl et al.
5,000 - 2,500	3640	Second *Betula* maximum (50%+ of country)	annual mean temperature 2 - 3 °C warmer than today	Sub-boreal of continental Europe, somewhat lower precipitation and milder winters, possibly 3m higher sea level	Símonarson
2,500 - ca. 1,500	2000	*Betula* declined, bogs increased		"climatic deterioration," "Subatlantic time," glacial advances only exceeded by Little Ice Age, E.L.A. depressed ca. 5 m	Björnsson, Haberle, Símonarson
ca. 500 - 870 A.D.	1350	*Betula* declined, bogs increased		"climatic improvement"	
870 A.D. ff.	550	Sharp decrease in *Betula*, increase in grasses		cultural indicators, soil erosion commences	Símonarson

*"corrected" using Brown (2006) without examining the many variables (e.g. marine reservoir) of each specific sample; "corrected" years are for initial comparison purposes only.

Table I. Traditional (uniformitarian) inferred paleoclimatology of Iceland (Simonarson, 1980; Norodahl, 1991; Bjornsson, 1980; Haberle, 1991; Hjartarson, 1991; Petursson, 1991).

woodland of dwarf birch (*Betula pubescens tortuosa*). *Dwarf birch* is a common English name for the subspecies of Downy Birch (*Betula pubescens*), which grows in the Arctic and typically reaches only about 5 to 6 m (15 to 20 feet) in mature height (Figure 4). The climate must have been milder than at present for some time for woodland to become so well established, especially trees much larger and straighter than the largest *Betula pubescens* that have survived in Iceland (Landnåmsboken, 1997). Trees are frequently mentioned from all parts of the country (Landnåmsboken, 1997). Even on the north coast, the woods were high enough to completely hide horses and other livestock (Landnåmsboken, 1997).

Plains were much better vegetated a thousand years ago, with more stable rivers (Ives, 2007). At *Landnám*, the *Þjórsá*, a major river in the south of Iceland, was a good anchorage, "much deeper and narrower" than it was two or three centuries later, according to *Egil's Saga* (Lie, 1951—presumably a note added by Snorri Sturlasson in his work of ca. 1250). Other inlets were good anchorages that no longer are, or that have even ceased to exist (e.g., Hjörleifshöfði, mentioned in Landnåmsboken, 1997). Such inlets and deep, stable river channels indicate a much lower rate of erosion, indicative not just of a land yet undisturbed by human activity, but also one with little glacial erosion.

On two occasions, pigs that escaped survived in the wild for one to three years and actually multiplied (Landnåmsboken, 1997). One of these locations was on the west coast, the other on the north.

Source	Modernized Name (in Norwegian)	Approximate Years Covered
Iceland		
Landnámboka	Landnåmboka	870–930
Egils saga	Egils soga	840–995
Brennu-Njáls saga	Njåls soga	975–1015
Kormáks saga	Kormaks soga	875–965
Laxdæla saga	Laksdøla soga	865–1035
Hrafnkels saga Freysgoða	Soga om Ramnkjell Frøysgoda	900–950
þórgills og Havlide	Soga om Torgills og Havlide	ca. 1000's?
Gunnlaugs saga ormstungu	Soga om Gunnlaug Ormstunge	965–1025
þórðar saga hreðu	Soga om Tord den Hardbalne	850–1050
Greenland		
Grænlendinga saga	Grønlendinge soga	985–1025 (1100's ?)
Eiríks saga Rauða	Eiriks soga/Soga om Eirik Raude	985–1025 (1200)
Grönlands Þáttr	Grønlands tåtr	1120–1130

Dates in parentheses may be approximately when sagas recorded in Iceland.

Table II. Historical Sources

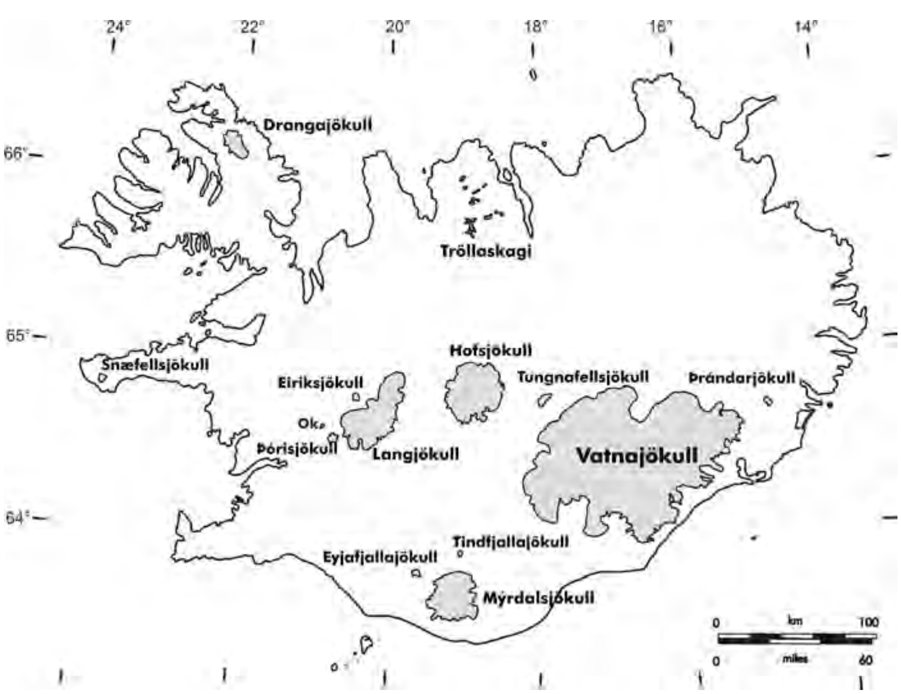

Figure 3. The principal glaciers of Iceland.

While the pigs raised in medieval times were smaller, longer-legged, and hairier than those raised today (Bjørvik, 1994), they could not be expected to survive in the current climate. Icelanders are accustomed to eating considerable lamb and horsemeat rather than beef or pork, since sheep and horses survive better than cattle (and certainly swine!) in the open fields. Cases of sheep and horses escaping and thriving are less problematic and could even be imagined occurring today.

Farms were prosperous at higher elevations than are possible today. For example, *Hrafnkels soga freysgoða* (Saga of Ramnkjell Frøysgoða), while it has its errors and its critics (Pálsson, 2000), clearly indicates the presence of a prosperous farm in eastern Iceland at too high an elevation for today's climate (Figure 5).

Grain is a more precise indicator of climate. Whether Havranes was a place where oats were grown or simply sold or eaten is unclear. However, that grain was not merely imported but was regularly grown from *Landnám* on is clear. Egil Skalligrimsson (Figure 5) grew grain in the Borgarfjörður area on the west coast (Lie, 1951). Reliable grain harvests were known from nearby Rekjahólar on Barðastrand, based on the Saga of Þórgills and Havlide (Pálsson, 2000). Grain (probably barley) was grown in north-central Iceland near Mývatn, since "Glum murdered Torkjell the Lofty in the grainfield" (Landnåmsboken, 1997, p. 130). Grain was grown at Liðarendi, some distance from the coast in southern Iceland (Liestøl and Hagland, 2003). Grove (1988) asserts that grain was grown in northern and eastern Iceland, as well as southern and western parts of the country, prior to the Little Ice Age. As pointed out in Part II of this series (Kleverg and Oard, 2011b), only in recent decades has it become possible to grow grain again in Iceland, and then only in part of its former range.

Figure 4. *Betula pubescens tortuosa* at Reykhólt, western Iceland. These are old trees about 5 m (16 feet) tall.

Figure 5. Locales of some important Icelandic sagas.

Evidence that the Medieval Warm Period Was Only Slightly Warmer than Today

While the evidence is strong that the Medieval Warm Period was at least as warm as today and probably warmer, it is important to also note the evidence that it was not markedly warmer. It is also important to keep in mind that many factors influence climate, and many combinations are possible. For example, development of a more "continental" climate in a particular location could result in a series of years with harsh winters in conjunction with summers that are slightly warmer and longer than normal and thus provide good growing seasons. Cold winters and cold summers could combine with dry conditions that result in negligible growth of glaciers. Climatology is beset by many variables and complexities, and it is important not to emphasize some of the data at the expense of others.

The first recorded visitors to Iceland were Irish monks in AD 765 who, according to their contemporary Dicuil, encountered sea ice one day's sailing north along the coast (Krag, 1994). At the time of its discovery, Iceland was called "Sneland," or "Land of Snow," suggesting the climate was not dramatically warmer than today (Landnåmsboken, 1997). Floke Vilgerðarsson and his group of explorers gave Iceland its name after overwintering on Vatnsfjörður. They found the spring "rather cold" and named the country after Vilgerðarsson observed ice flows in a fjord to the north (Landnåmsboken, 1997). While glaciers did not extend as far as they have since, several are mentioned. Snow and cold ocean breezes are mentioned in accounts from the north coast in the spring of the year. Helge the Gaunt and his entourage on the north coast had "a difficult first winter" (Landnåmsboken, 1997, p. 120), and it should be remembered when reading these contemporary accounts of Icelandic climate that the settlers were largely Norwegians, not people from the countries of the balmy south.

Although most of the Icelandic mainland was forested at *Landnám*, most of this was apparently scrub woodland of dwarf birch (*Betula pubescens toruosa*), or at least such is certainly mentioned from the earliest records (Landnåmsboken, 1997). That the forest was largely scrub woodland of this type is attested to by the need to import timber. Grantrenes ("Spruce Tree

Point"), in Breiðafjörður on the west coast, was not named for native trees but for an enormous (4-m diameter by 40-m long) spruce log that drifted there. Both Furufjörður and Furuvík are on the north coast, though whether any *Pinus* grew there, we do not know (we think not). *Pinus* was apparently native to Greenland before the Great Ice Age (Dahl-Jensen, 2004); at least some evolutionists claim *Pinus* became extinct in Iceland "about one million years ago" (Símonarson, 1980, p.173). Uprooted trees from Siberia provide a source of driftwood in Iceland (Ives, 2007), but these would be primarily *Picea* from Asia, while native species of both flora and fauna in Iceland are unequivocally European! Unequivocal evidence for growth of *Picea* or *Pinus* prior to planting efforts of the past century is not known.

Not all of the farms mentioned in the sagas at relatively high elevations are indicative of warmer conditions. As indicated in *Egil's Saga* (Lie, 1951) and *Gunnlaug Ormstunga's Saga* (Kent, 1928), some of these were *sæter* farms, areas used as summer range for livestock. *Sæterbruk* and abandonment due to soil erosion may explain a significant percentage of the former farms at higher elevations (Sveinbjarnardóttir, 1991).

While *Landnámsboka* (aka *Landnåmsboken*) indicates bears were not common in Iceland and perhaps had never been resident, ice had apparently come to the north coast in adequate size and quantity to transport polar bears (*Ursa maritimus*), since one killed Odd Argeirsson's father and brother in a blizzard on Sletta (he killed the bear) in the tenth century (Landnåmsboken, 1997). The only other account of *Ursa maritimus* we are aware of was a sow and cub captured by Ingemund the Old by Húnavatn, also on the north coast. Polar bears have travelled to the country on ice floes from Greenland during recent centuries.

The saga of Þórðer Hardbalne (Hagland, 2004) mentions winter experiences with plenty of snow and "good ice" on Midtfjörður. Cold years were also reported for Norway in the late 900s and the 1030s (Krag, 1994) from the same latitude as Iceland. However, usable pastureland in Norway during the period AD 800–1100 was two to four times the modern value (Helle, 1994), so these cold years appear to have been the exception rather than the rule in the North Atlantic region. If climatic conditions were significantly different in the two countries, it is certain the difference would have been mentioned in the sagas, but they seem to have been similar. The evidence, taken together, thus seems to indicate conditions that were generally more clement than today during the Medieval Warm Period but did not differ greatly from today and included many of the same variations in weather, including cold winters, which have occurred during the modern instrumental period.

Microclimatic Considerations

At *Landnám*, Iceland was largely forested, "from sea to mountaintop" (Landnåmsboken, 1997). Forest cover would have moderated the climate, though it also suggests the climate had been milder than at present for some time for woodland to become so well established, especially trees much larger than the largest surviving *Betula pubescens tortuosa*. "Deforestation in Iceland combined with climatic deterioration to exacerbate the crisis" (Bjørvik, 1994, p. 35).

The Little Ice Age Commences

Climatic deterioration apparently began in the 1180s (Ogilvie, 1984) or 1200s (Grove, 1988). Cereal grains could no longer be cultivated in northern and eastern Iceland after 1300, and barley was limited to only a few south coast locales, and Flaxifloí on the west coast (Figure 5) in 1350; it was limited to a few spots on the south shore of Flaxifloí thereafter and ceased altogether before 1600 (Grove, 1988).

Ice advanced from all the ice caps and major glaciers in Iceland. While reverse oscillation between Drangajökull and Eiríksjökull in the northwest (Figure 3) and Vatnajökull and Mýrdalsjökull in the southeast is a normal weather pattern (Guðmundsson, 1998), this was not observed during late medieval times. Vatnajökull and Mýrdalsjökull (Figure 6) receive moisture from the relatively warm Irminger Current (Figure 1), in

Figure 6. Mýrdalsjökull from the sea. This ice cap overlies the shield volcano Katla (light gray outline) and surrounding ridges. The relatively warm Irminger Current provides moisture to Mýrdalsjökull and Vatnajökull.

Farm or Settlement	Location	Glacier	Date Overrun
Fjall	Southeast	Breiðamerkurjökull	ca. 1700
Breiðá			1697 - 1700
Kári Sölmundarsson's tomb			pre 1712
Breiðamerkursandur farms			ca. 1350 - 1750
Trimbilsstaðir	Northwest	Drangajökull	ca. 1600
Öldugil			ca. 1400 - 1710
Sviðningsstaðir			ca. 1700?
Þaralátursfjörður valley			ca. 1450 - 1650
Nedra Horn		Reykjafjarðarjökull	pre 1650
Fremra Horn			pre 1650

Sources: Grove, 1988; Evans and Twigg, 2002; Ives, 2007.

Table III. Farm or Settlement Overrun by Ice During Little Ice Age

contrast to the northern glaciers. Overall advance of outlet glaciers from all of these ice caps occurred during the Little Ice Age (Grove, 1988). Small plateau ice caps also appeared on the Gláma Plateau near Drangajökull and Ok near Langajökull (Figure 3) during the Little Ice Age (Björnsson, 1980). Farms known to have been overrun by ice are listed in Table III and include locations in both the northwest and southeast of the country. While some of these farms may have been destroyed prior to the arrival of the ice front by jökulhlaups or similar phenomena, these events were also closely linked with the growth of the glaciers.

In the area of Breiðamerkursandur (Figures 7, 9, and 10), Grove (1988) cites the 1772 record of Ólafsson and Pálsson, who said "many farms" were settled in this area during *Landnám* and the area was "well grassed" until 1100 or later. Breiðamörk was a wooded area on the west side of Breiðamerkurjökull. Breiðá was still prosperous in 1343, and Fjall was still being cultivated in 1387. Breiðá was still in existence in 1525 but possibly abandoned in 1697 (or possibly later). The tomb of Kári Sölmundars-

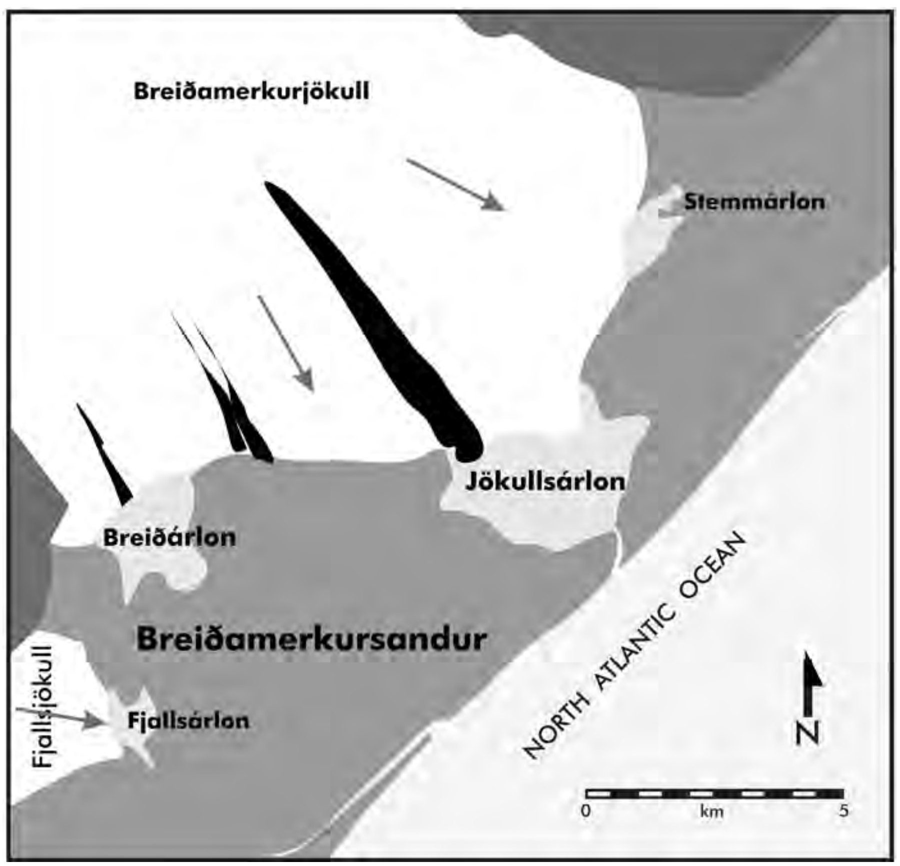

Figure 7. Breiðamerkursandur, a prominent *sandur* (seacoast glacial plain) in southern Iceland. Prominent black ridges in Breiðamerkurjökull are medial moraines. Arrows show general direction of ice flow.

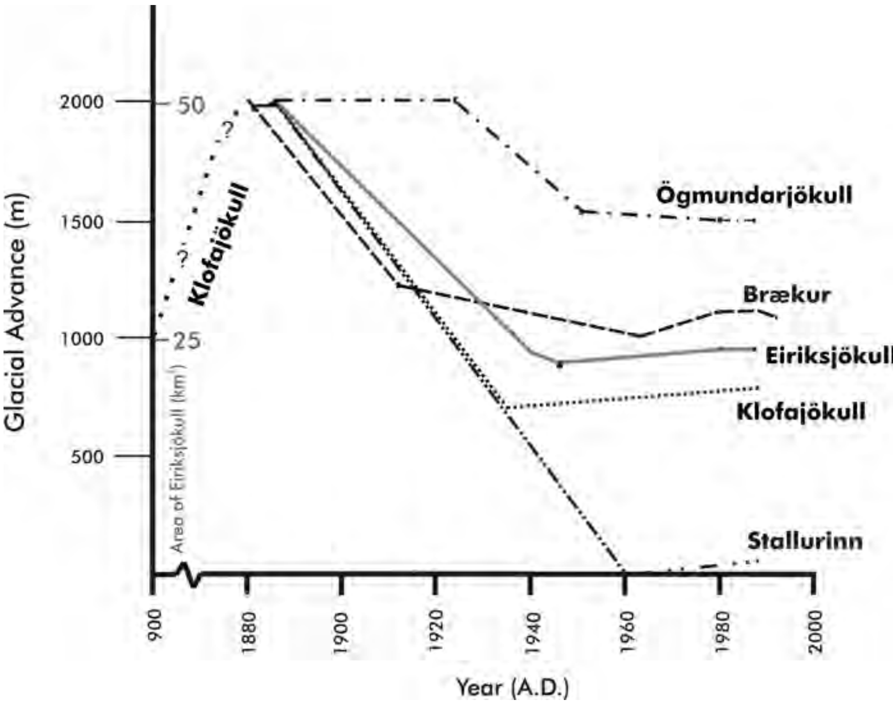

Figure 8. Fluctuations of Eiríksjökull ice cap and outlet glaciers: area of Eiríksjökull in gray, end position of outlet glaciers in black.

Year	Maximum Advance of Glacier (m)				Area of Eirik-sjökull (km²)
	Klofajökull	Brækur	Ögmundar-jökull	Stallurinn	
pre 900	1,000				
1880		2,000			49.4
1885	2,000		2,000	2,000	49.4
1911		1,215			
1923			2,000		
1934	700				
1938					23.3
1945					22.0
1946			1,600		
1960				0	
1962		1,000		0	
1979		1,100	1,500		
1980					23.8
1987		1,100	1,500	50	23.8
1991		1,075			

Table IV.

son (Liestøl and Hagland, 2003) by the Breiðá church was under the ice by 1712.

As Table III shows, glacial advances were not limited to the Vatnajökull outlet glaciers. Eiríksjökull, in west-central Iceland, and Drangajökull, in the northwest (Figure 3), are not favored by the same weather systems that favor Vatnajökull (Grove, 1988; Guðmundsson, 1998), yet their fluctuations show the same basic pattern (Table IV and Figure 8). Thus, the effects of the Little Ice Age were felt throughout the country, and did not result from shifting local weather patterns.

By 1700, Hafrafell west of Öræfi (Figure 9) was inaccessible due to growth of glaciers. "It may be concluded that the Vanajökull glaciers advanced rapidly between 1690 and 1710 and were more extensive than at any time earlier in the historic period" (Grove, 1988, p. 45).

The Little Ice Age Peaks

"The most extensive glacier advance culminated for the steeper glaciers in the 1750's, and in 1850 to 1890 for the broad lobes from the plateau ice caps" (Björnsson, 1980, p. 206). A combination of lichenometry (cf. Klevberg and Oard, 2011b, Appendix B) and tephrochronology on Vatnajökull outlet glaciers yielded a Little Ice Age maximum of 1755–1873 (McKinzey et al., 2005). Grove (1988) concludes the maximum position of Vatnajökull outlet glaciers probably occurred ca. 1760, though several were a century or more later.

Some of the best documentation comes from the Breiðamerkursandur area (Figures 7, 9, and 10). Based on what the Danish land register of 1708–1709 recorded of Fjall (Grove, 1988): "Fourteen years ago tún and ruined buildings were still to be seen, but all that is now in the ice." The 1712 land register said, "Fjall was the name of a farm west of Breiðamörk. It is now surrounded by ice. Twelve years ago ruins could still be seen" (Grove, 1988, p. 43). The farm at Brennhólar on east

Breiðamörk was overrun by the glacier in 1753 (Evans and Twigg, 2002). A 1756 visit to the former Breiðá church site indicated the glacier was still advancing, and Breiðamerkurjökull continued to advance at up to 4–8 m/day, with advances greatly outpacing recessions, until it nearly reached the beach in the 1870s and 1890s (Grove, 1988). In 1865, it finally overtopped a large moraine (apparently from the Great Ice Age) and destroyed the farm at Fell (Evans and Twigg, 2002). The Little Ice Age was a dramatic reality for the Icelanders and brings a sober reality check to bear on popular climate change speculations.

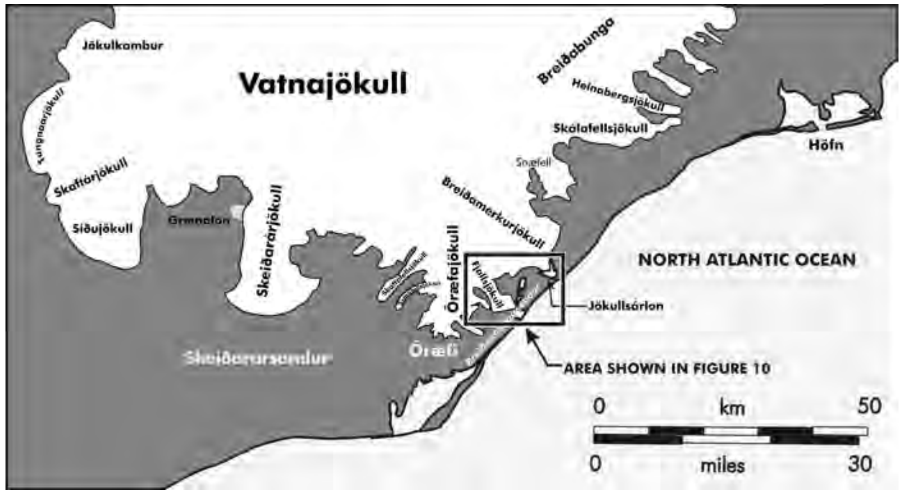

Figure 9. Map of the southern outlet glaciers of the Vatnajökull ice cap.

As explained in Part I (Klevberg and Oard, 2011a, Appendix A), the lag time of glaciers can differ greatly. Several Icelandic glaciers reached their maximum extent in the late 1800s (Grove, 1988), but this does not necessarily point to climatic complexities as lag time differences of several decades may explain this late maximum when other glaciers reached their maximum extent a century earlier. The extent reached by Vatnajökull outlet glaciers (Figure 9) during the Little Ice Age was observed by Þórárinsson to be the maximum extent of moraines on the sandur or coastal outwash plain (Grove, 1988). "The main moraines in front of the glaciers in Iceland date back to the maximum advance in the last centuries. All the proglacial landforms associated with retreating glaciers are found between the present glacier snouts and these moraines. Some of the end moraines from 1890 still have

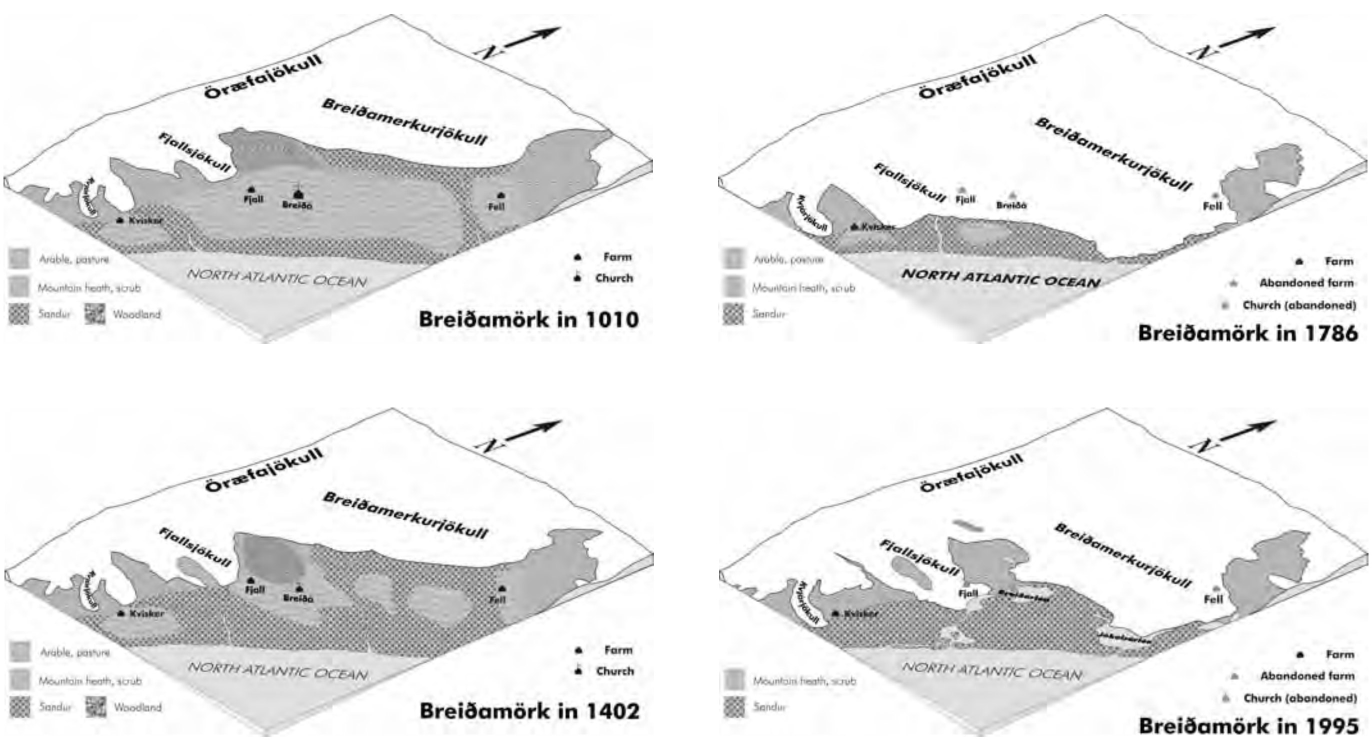

Figure 10. Oblique views (block models) showing historic changes in Breiðamörk, southern Iceland.

Figure 11. Jökulsárlon, proglacial lake at southeastern edge of Breiðamerkursandur. This lake extends approximately 100 m (300 ft.) below sea level and was excavated by advancing glaciers during the Little Ice Age. Photomosaic facing generally northwest.

ice cores" (Björnsson, 1980, p. 209). However, some of the mountain glaciers in northern Iceland apparently did not advance as far, perhaps in response to reduced precipitation with the growth of sea ice (Stötter et al., 1999).

The Little Ice Age Ends

Perhaps partly due to the positive feedback mechanisms of the glaciers or Iceland's location on the edge of the Arctic, the Little Ice Age ended later in Iceland than in central Europe (Grove, 1988). As it began with the irregular advance of glaciers with different lag times, so it ended in an irregular fashion. Farms overrun by Drangajökull and Breiðamerkurjökull during the Little Ice Age are now mostly melted free, and the Gláma and Ok ice caps have disappeared. Recession began in the 1890s, became rapid after 1930, slowed in the 1960s, and has varied since (Björnsson, 1980). Based on the recession of Breiðamerkurjökull (Figures 10 and 11), Sigbjarnarsson estimated the shrinkage of Vatnajökull since its Little Ice Age maximum at somewhere between 268 and 350 km^3 (8 to 10 percent of its total mass), which, if continued at this pace, would result in the complete disappearance of Vatnajökull in 600 years. "Whether melting at a similar rate over a period as long as six centuries would ever be likely to occur is, of course, quite another matter"(Grove, 1988, pp. 55–56).

Analysis and Summary

More than colder temperature is needed to cause glaciers to grow. As pointed out by Stötter et al. (1999), precipitation must keep pace with or outpace the drop in temperature. If sea surface temperature does not drop as much as land surface temperature, significant moisture may encounter a lower equilibrium line altitude (ELA), and the growth of ice will provide a positive local feedback encouraging the precipitation to fall as snow. Lower summer temperature and increased cloudiness help to maintain a lower ELA and reduced summer melting, which will result in a positive mass balance. As shown in Figure 12, an even lower ELA than what occurred in the Little Ice Age must have existed thousands of years ago for Vatnajökull to have formed in the first place; only the ice itself holds the surface of Vatnajökull above the ELA today.

Historic evidence points to a climate at *Landnám* in Iceland as warm as now or slightly warmer than at present, with cooling beginning about AD 1200. The drop in temperature was apparently accompanied by a less significant drop in precipitation (or possibly no drop in precipitation), resulting in a lower ELA. Inferred drops in ELA and temperature for Iceland are shown in Table V. These equate to a roughly 2°C lower Little Ice Age temperature relative to today, and approximately 3 to 4°C relative to the inferred temperature of *clima optima* (Björnsson, 1980). Based on the historical evidence presented above, the drop in temperature and ELA from the pre-*Landnám* optimum to the Little Ice Age

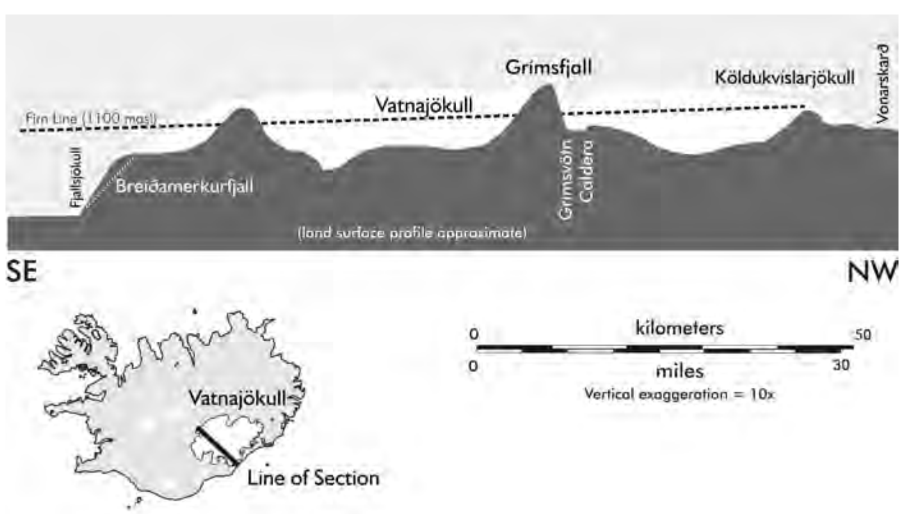

Figure 12. Section through Vatnajökull

	Little Ice Age Inferences			References	
Glacier/Region	Year	Temperature Difference	E.L.A. Difference	Base Year(s)	Author
Sólheimahjájökull	ca. 1800	-1.6 °C		1960–90	McKinzey et al., 2005
Eiríksjökull	ca. 1875	-1.5 °C	-250 m	ca. 1990's	Guðmundsson, 1998
Tröllaskagi	pre-1925		-200 m?	post 1925	Caseldine, 1987; Björnsson, 1980
Tröllaskagi-Hörgárdalur	1800's		-5 m		Häberle, 1991
Tröllaskagi—observed		-2 °C	-50 m	1925–1960	Caseldine & Stötter, 1993
Tröllaskagi—theoretical			-300 m		
Iceland in general	1600–1920	-3 to -4 °C	ca. 200 m/º C	*clima optima*	Björnsson, 1980

Table V. Inferred Little Ice Age equilibrium line altitudes

maximum was probably about 2°C, or slightly more, and 500 m, respectively.

The rise in average temperature and resulting rise of the ELA during the twentieth century to approximately their *Landnám* values did not occur in isolation from the rest of the North Atlantic region or the rest of the world climatically. As will be shown, these changes were contemporary with similar climatic and glacial developments in Norway and Greenland and coincided with "climatic improvement" elsewhere in the world (Grove, 1988). While, as indicated in Figures 2 and 10, present conditions are not as favorable to human occupation as they were a thousand years ago, conditions on Breiðamerkursandur are now improved to the point of inciting legal action by the descendants of those who owned the ravaged farms, land now claimed by the government (Hornafjörður, 2004). Retreat of the ice has also exposed a wide variety of landforms and sedimentary deposits, which will be the focus of the concluding paper in this series. Iceland has become a focal point in the global climate change debate, and for those who hold to the biblical worldview, it has become a laboratory for evaluation of climate models and ideas for the postdiluvian period. Climate change and the Great Ice Age will also be addressed in future parts of this series.

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Glossary

Dicuil—an Irish monk who recorded the discovery of Iceland by Irish monks in the 800s.

diluvialist—one who maintains that the Deluge of Noah's day was the principal global geologic event in earth history since the Creation.

jökullhlaup—a glacial outburst flood; these typically occur in Iceland as a result of subglacial volcanism, but they can also be triggered by buoyancy effects, with periodic release of water as whenever the ice dam floats. Jökullhlaups suddenly release the stored water in great floods that carry ice and sediment to the sea.

Landnám—Old Norse for settlement of a previously uninhabited land.

postdiluvian—the period of earth history after the Deluge (Genesis Flood), probably consisting of a time of residual catastrophism and a great ice age followed by a more stable period of relative climatic equilibrium.

proxy—a phenomenon that is mathematically or causally related to the phenomenon of interest, e.g., length of growing season can be a proxy for average annual temperature.

tún—farm yard, area between the buildings of a farm.

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Stötter, J., M. Wastl, C. Caseldine, and T.

Letter	Pronunciation	Letter	Pronunciation
“Short” Vowels (typically before double consonants)		**“Long” Vowels (typically before single consonants)**	
a	a as in *arm*	a	*a* as in *father*
e	*e* in *red*	e	*e* as in *very*
i	*i* as in *into*	i	*i* as in *believe*
o	*o* as in *not*	o	*o* as in *long*
u	a little softer than *u* in *useless*	u	like *u* in *futile*
y	like second *i* in *intrigue*	y	like *y* in *really*
æ	like *i* in *hi* (or *æ* in Latin)	æ	like *i* in *ivy* (or *æ* in Latin)
u	like *u* in *under*	u	a little more like *u* in *urgent*
Accented Vowels		**Consonants and Diphthongs**	
á	like *ou* in *ouch*	Þ,þ	like *th* in *thing*
é	like *ye* in *yen*	Ð,ð	like *th* in *there*
í	like *e* in *reed*	ei	like *ey* in *hey*
.ó	like *ou* in *soul*	au	slightly longer than *y* in *Færöy*
ú	closed" or "hard" *u*, like *deux*	c, q, w	foreign words only
ý	closed" *y* like Swedish	z	like *z* in *zebra*, but seldom used

Table VI. Guide to Icelandic Pronunciation

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Appendix A: Pronunciation of Icelandic Names

Icelandic is a relatively phonetic language, but many of the letters are likely to be unfamiliar to many English-speaking readers. This brief guide should assist most readers in coming close enough to actual pronunciation to make name recognition possible. Icelandic contains a larger alphabet than English, and the additional letters are included in Table VI.

Appendix B: Veracity of Saga Historiography

Much of our knowledge of Iceland from the end of the previous millennium is necessarily derived from the *sagas*, typically prose compositions of considerable length describing the lives and actions of notable people. Sagas were transmitted orally; many were apparently not written down until two or three centuries later (Sturlasson, 2008; Pálsson, 2000). Associated with sagas were *þáttur* (a shorter literary form) and poetry of various forms known as *kvad*. As in Anglo-American poetry, rhyme and meter are important in a *kvad*, along with alliteration and assonance. As a more highly developed (inflected, intricate, and specific) language than English, however, Old Norse was less syntactical, permitting great freedom in word order. Great weight was placed on the use of metaphor. The resulting poetry was very “tight” and did not lend itself to change. Once a *kvad* was in the public domain, it was not easily corrupted. It might have been lost, in whole or in part, and the metaphors might have ceased from common usage, but it was not likely to be changed.

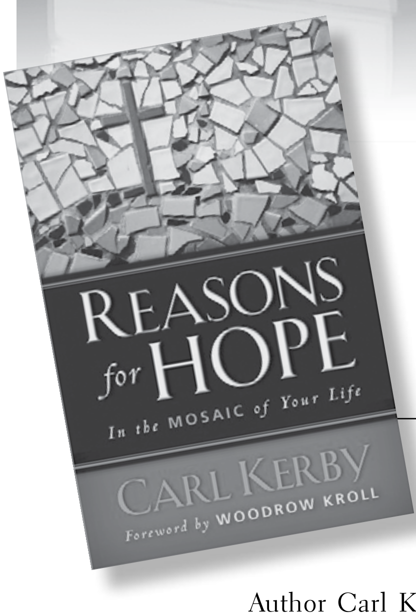
The saga literary form is one of almost minimalist action. Description is scarce and typically tied to the appearance of major personages, not landscapes or climate. This has the obvious disadvantage to this study of providing scant data. It has the less obvious advantage that the saga authors had no motivation to fictionalize any of the descriptions that do appear. There is a wide variation in the types of sagas–some are obviously tall tales (usually mythology or romanticized religious writings) meant to entertain, while others are very different, especially the *islendingesagaer*, which appear as sober history. It is not difficult to tell the difference.

There are two major schools of thought regarding the veracity of *islendingesagaer* (Pálsson, 2000). *Friproseteorien* is the position that these sagas are as they appear: historical accounts. The events they contain are, by and large, historical events honestly reported. The veracity of individual sagas may vary, of course, just as one should not put as much weight on the writings of Michael B. Shermer, Washington Irving, or Sheila Rowbotham as on the writings of Herodotus, James Ussher, or Alexis de Tocqueville. *Bokproseteorien* is the position the sagas contain very little historical truth and should be seen not as a source of historical data, but as great works of literature, of *belles letres*.

We favor *friproseteorien*. Those who recognize the infallibility of the Bible and the wealth of data substantiating its veracity will hear a familiar ring in the lines of *bokproseteorien*. Just what creative greatness lies in such mysterious opening lines as "Gunnlaug was the name of a man," is a little difficult for some of us to grasp. Archaeology and geography have confirmed the historicity of many places mentioned in the sagas.

This is not to deny the need for careful historical research and judgment. For example, there is much overlap between *Eiríks soga rauðe* (Erik the Red's Saga) and *Grönlendingene soga* (Saga of the Greenlanders), but the former contains embellishments and anachronisms, while the latter does not. Nonetheless, *bokproseteorien* held sway with *Grönlendingene soga* until the Ingstads vindicated it by following its account from archaeological site to archaeological site clear to the Vinland settlement in Newfoundland (Ingstad and Ingstad, 1996). Even *Eiríks soga rauðe* is superior to Shermer or Rowbotham, however, and many historic elements may be gleaned from it.

Sagas from which we have obtained information for this paper are indicated on Figure 6. Also indicated are sites cited from *Landnámabok*, a largely genealogical work documenting the settlement of Iceland that dates from at least the late 1200s (i.e. the manuscript used for Kjørsvik Schei's translation) but clearly draws on sources one to two centuries older (Landnåmsboken, 1997).



Reasons for Hope

by Carl Kerby

Genesis Publishing Group,
Bartlesville, OK, 2011,
240 pages $15.00.

Author Carl Kerby tells a fascinating story of his life journey. Some of the negative details include a distant professional-wrestler father, child abuse from a relative, a broken home, dropping out of high school, and a wild lifestyle as a youth. This tough start in life is then transformed by God's grace. There follows military discipline, training in air traffic control, conversion to Christian faith, a wonderful wife Masami, and exposure to the excitement of biblical creation. Following a period of behind-the-scenes service to Answers in Genesis, Carl became an AIG board member, then one of their most in-demand speakers. In 2011 Carl moved on from AIG and launched a