The Little Ice Age in the North Atlantic Region

Part II: Magnitude, Extent, and Importance of the Little Ice Age

Peter Klevberg, Michael J. Oard*

Abstract

Controversy has surrounded the term "Little Ice Age" since its inception in 1939. While some degree of cooling is acknowledged in the Northern Hemisphere in recent centuries, the magnitude, extent, and timing of the Little Ice Age remain controversial. A tendency to downplay both the Little Ice Age and the preceding Medieval Warm Period has accompanied the recent emphasis on climate change in general and global warming in particular. Secular scientists and diluvialists hold different assumptions about natural history, and employ different methodologies in paleoclimatology, resulting in different opinions about future climate change. While inferred past ice ages are entirely speculative, the Little Ice Age is constrained by historical data, providing a unique opportunity to evaluate natural history speculation. Although instrumental records are too brief to allow anything more than calibration of transfer functions for climatic proxy data, these proxy data are particularly good for the North Atlantic region, which also can provide useful geographic conditions for testing predictions of the rapid, postdiluvial ice age model. The first paper in this series provided background for the methods used to study climates of the past. This paper summarizes evidence for past climate change and provides a description of the study area.

Was the Little Ice Age Regional?

Could the Little Ice Age have been just a European phenomenon? The question is an important one, especially in regard to the applicability of the data obtained from the Little Ice Age to testing natural history scenarios on a broader scale.

* Peter Klevberg, B.S., P.E., Great Falls, Montana, grebvelk@yahoo.com
Michael J. Oard, M.S., Bozeman, Montana
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Global Evidences

The best historical data for the Little Ice Age are from the North Atlantic region; although historical accounts are available from China and Japan, proxy data must be relied upon for most of the rest of the world (Grove, 1988). These data do provide a strong case for a period of widespread glacial advance across the earth—a little ice age. In particular, one

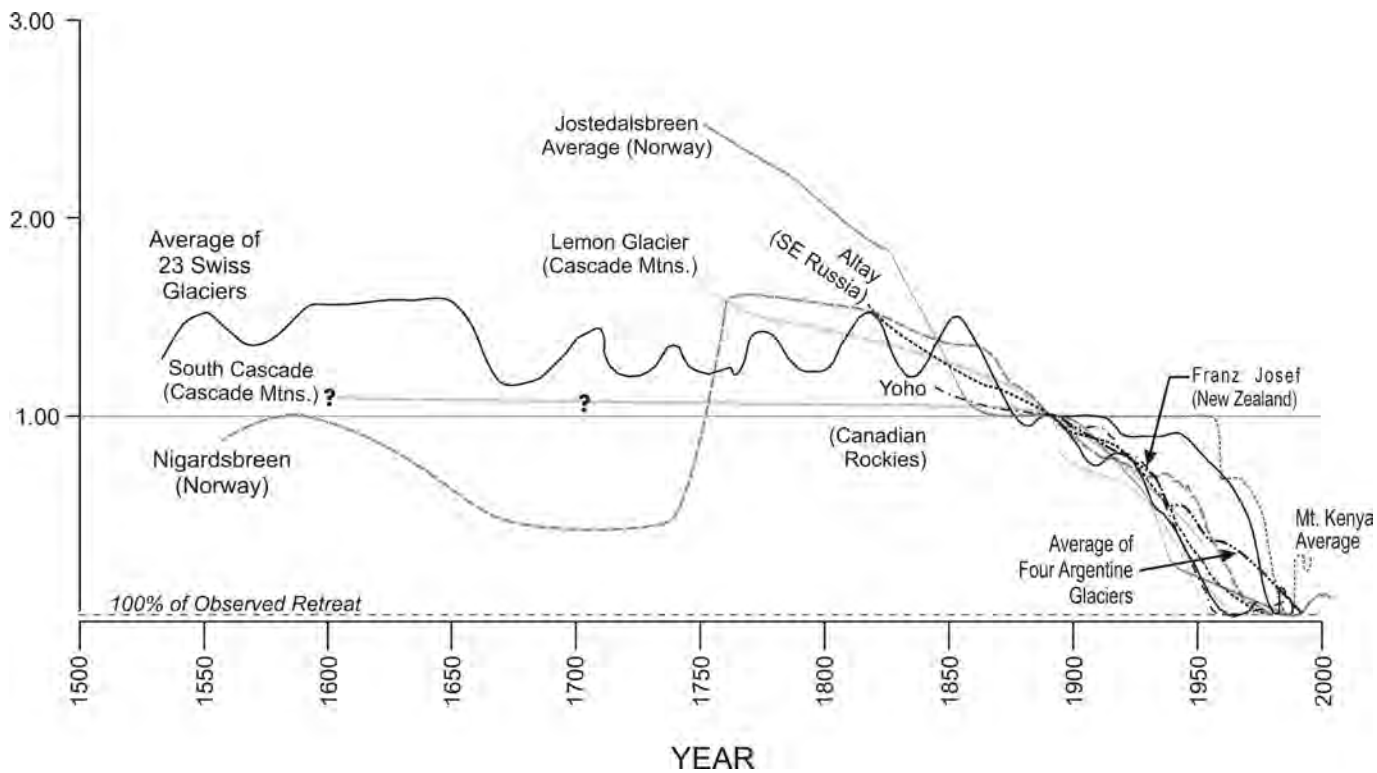

Figure 1. World glacial fluctuations. Frontal positions of representative glaciers from various temperate regions of the world. The reference datum (horizontal line at 1.0) chosen to standardize these data is the frontal position of each in 1890. Data from Grove (1988) and Kjøllmoen (2007).

form of proxy data—measurements of the glaciers themselves—is particularly useful (Oerlemans, 2005). Some important records are presented in the form of Figure 1.

"Glaciers on every continent have expanded in the last few centuries; the Little Ice Age was a global phenomenon" (Grove, 1988, p. 354). Jean Grove's salient work on the Little Ice Age presents data from far beyond the North Atlantic region: Switzerland, Russia, the Himalayas, East Africa, Indonesia, New Zealand, South America, and North America. These show a roughly contemporary fluctuation of glaciers in these distant places (Oerlemans, 2005)—perhaps even more strictly contemporary if we account for some of the uniformitarian biases that may affect proxies. Even areas without glaciers have produced records of climate change that support the conclusion that climate fluctuations driving the Little Ice Age reached far beyond the North Atlantic region (Grove, 2001; Hendy et al., 2002; Pienitz et al., 2000).

Regional Influences

The most prominent regional influence invoked to attempt to explain the Little Ice Age is the North Atlantic Oscillation (Fagan, 2000; Mann, 2002). A "positive index" for the North Atlantic Oscillation (N.A.O.) resembles the situation shown in Figure 2, while a "negative" N.A.O. index has high pressure over Iceland and low pressure near the Azores. A "positive index" is associated with strong westerly flow from the North Atlantic Ocean to Europe, with milder conditions, while a "negative index" produces reduced flow and greater winter-summer contrast, with more of the storms heading south to the Mediterranean. Changes in the N.A.O. produce a "seesaw" effect between Greenland and Europe; for example, a mild winter in Greenland is likely to coincide with a hard winter in Europe. Clearly the N.A.O. cannot explain the Little Ice Age itself, since temperatures fell and glaciers advanced on both sides of the North Atlantic, so variations in the N.A.O. explain only the decadal-scale variations within the Little Ice Age (Barlow, 2001). The global cooling signal was therefore stronger than the regional (Grove, 1988).

When Was the Little Ice Age?

The term "Little Ice Age" was originally coined by F. Matthes for what is generally called today the "neoglacial"

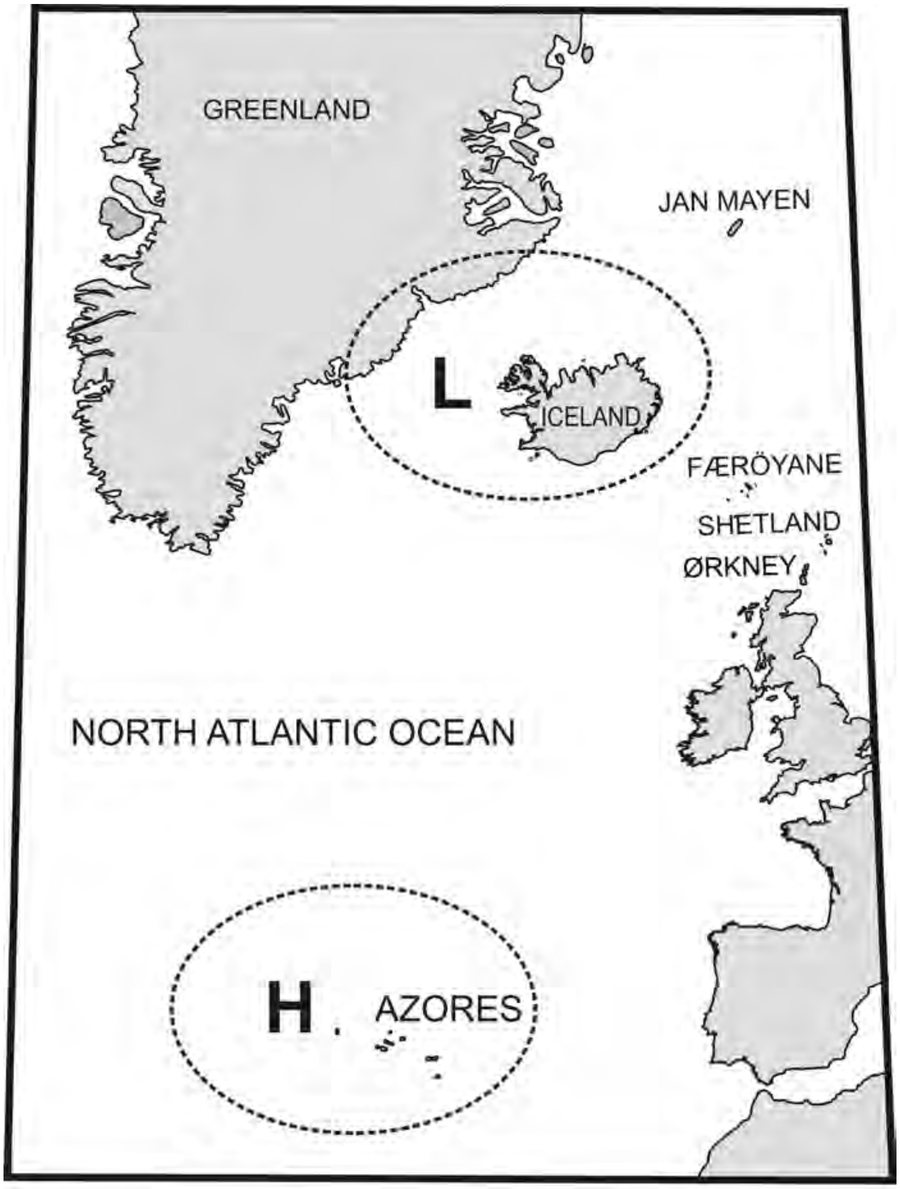

Figure 2. The North Atlantic Oscillation. The N.A.O. is shown in "positive" or normal mode; a "negative" N.A.O. index would have high barometric pressure over Iceland and low over the Azores.

period (Mann, 2002; Ogilvie and Jónsson, 2001). It has now come to be used for an equivocal period in late medieval to early modern times, depending on the definition. The definition may be climate-based, or it may be based on observed glacial response, which is a less used but more objective definition. Regardless of the approach taken, and contrary to naysayers (Mann, 2002), the Little Ice Age was still a phenomenon that is reasonably definable on a global basis.

The beginning of the Little Ice Age in Iceland may be placed at about 1360 or as late as 1500, depending on the climatic changes or glacier positions one chooses to define it (Ives, 2007). Fell (1999) describes a "worsening" of the climate after 1200 but "much worse" in the seventeenth and eighteenth centuries. Onset of the Little Ice Age occurred at a similar time in Norway and Greenland (Grove, 1988). The Little Ice Age peaked in Iceland, Norway, and Greenland about 1750 to 1850 (Grove, 1988; McKinzey et al., 2005). In Norway, the Little Ice Age ended about 1880 according to Nordli (2001), which coincides with the maximum extent of major outlet glaciers in Iceland (Ives, 2007). For Western Europe, the reconstruction of Guiot et al. (2005) provides a marked cold period from AD 1560 to 1930. Oerlemans (2005), in an investigation of glaciers worldwide, placed the peak of the Little Ice Age at about 1800.

"The timing attributed to [the Little Ice Age] has varied considerably from author to author, perhaps reflecting real regional differences. However, this lack of agreement could be due in part to the uneven distribution and character of the evidence available, to the dating techniques used, and their resolution, and possibly to differing degrees of effort devoted to unravelling glacial history" (Grove, 2001, p. 54). Apparent differences in timing sometimes result from uniformitarian bias in dating methods, as described in part I of this series, and sometimes from natural factors. Lichenometry is probably the chief method for Little Ice Age moraine dating (methods and difficulties of lichenometry are described in Appendix B). But differences in timing may also be real. Differences in timing from region to region can be a natural response to climatic forcings (Juckes et al., 2007). In general, the Little Ice Age is considered to start about 1350 and end around 1880.

Did the "Medieval Warm Period" Exist?

The Medieval Warm Period is even more controversial than the Little Ice

Age. This is partly to be expected, since the Medieval Warm Period is even more distant in time from us than the Little Ice Age. The end of the Little Ice Age, in fact, occurred during the instrumental period, the time of photography, and a time with significant expansion of population and technology. Whether the Medieval Warm Period existed is a question entirely dependent on historiography and proxy data.

Arguments against the Existence of the Medieval Warm Period

Many dispute the existence of the Medieval Warm Period, especially strong advocates of the man-caused global warming theory, some of whom also reject the existence of the Little Ice Age itself (Mann, 2002; Ogilvie and Jónsson, 2001). Most of the data marshalled against the existence of a significant period of time warmer than the present are proxy data, not historical data, and are typically tied to varves, radiocarbon dating, or ice cores. In general, they are simply inconclusive data or very dependent on subjective or local factors, not data that refute the Medieval Warm Period (e.g., Clement and Horn, 2001; Cook et al., 2007; Retelle and Johnson, 2007; Stevens et al., 2001). These proxy data have been smoothed and "massaged" and may be variously interpreted (Esper et al., 2005), including to denying the Medieval Warm Period entirely or at least as anything comparable to current conditions (Mann and Jones, 2003; Juckes et al., 2007).

Arguments for the Reality of the Medieval Warm Period

While models such as that promoted by the Intergovernmental Panel on Climate Change (IPCC) tend to downplay (if not deny) the Medieval Warm Period, others support it (Esper et al., 2005; Guiot et al., 2005), and historiography (i.e., the body of contemporary historical accounts) supports them. A considerable number of proxy data are more readily interpreted by a significant Medieval Warm Period (Anderson et al., 2007; Brown et al., 2005; Eiríksson et al., 2000; Fréchette et al., 2006; Heyerdahl and Lillieström, 1999; Keigwin, 1996; Ogilvie and Jónsson, 2001), including in locations outside the North Atlantic region (Brown et al., 2005; Keigwin, 1996). Diluvialists, recognizing the catastrophic and providential nature of history, should be aware of the limitations of climate modeling, particularly when the models are based on uniformitarian assumptions and methods. In the realm of history, natural history or otherwise, the methods and records of history take precedence.

Whether the Medieval Warm Period existed as a global phenomenon is another and more difficult question, though proxy evidence seems to confirm it (Broecker, 2001; Grove, 1988). Further evaluation of the regional or global nature of the Medieval Warm Period is a promising area for future research but is beyond the scope of this paper.

English and German Agriculture

Both England and Germany had well-established wine industries during early medieval times, and both were forced to cease due to climate change (Fagan, 2000). Agricultural changes extended well beyond the wine industry and were not primarily driven by social conditions, disease, or other nonclimatic factors, as both weather records and general historical accounts indicate. Weather records from England are particularly complete.

Swiss Agriculture and Settlement

Switzerland is particularly important in studies of the Little Ice Age. Records are very good, and impacts from growing glaciers were both severe and widespread. Valleys, farms and towns, and mountain passes were overrun by ice. The extent of agricultural development and trade routes indicate conditions in early medieval times as warm as or warmer than today (Grove, 1988).

Icelandic Glaciers

Icelandic glaciers were much subdued relative to today at the time of the country's settlement (*Landnám*). Rivers had deeper, more established courses than today (Landnåmsboken, 1997), and the outwash plains (*sandur*) that are today barren and often ravaged by catastrophic outburst floods were then generally fertile and well vegetated. The much-reduced nature of Icelandic glaciers prior to the thirteenth century will be more fully documented in part III of this series.

Icelandic Crops

As will be described in part III, cereal grains were grown in various parts of Iceland during the Medieval Warm Period. As the climate cooled in the 1200s, the range of grain growing was steadily reduced, and finally ceased altogether (Grove, 1988). It is now possible to grow barley again on the southern coast of the Icelandic mainland (Figure 3) but not on the north or east coasts.

Norwegian Forests

The Medieval Warm Period was not the *clima optimum* in Norway; this occurred much earlier, as indicated by remains of pine forest on Hardangarvidda, far above the present treeline (Lillehammer, 1994). The greater warmth of the Medieval Warm Period is, however, indicated by the extent of pine-oak forest where spruce-birch now predominates and agricultural development at elevations above what can be sustained today (Helle, 1994).

Agriculture in Greenland

As will be described in part V, Norse Greenland was an agricultural society. The population of Greenland was well in excess of what could be supported by the traditional Inuit (Eskimo) lifestyle. As advancing ice covered farms, increasing cold stunted vegetation, and falling water temperatures chased cod from the Davis Strait, Greenland's agriculture collapsed (Fagan, 2000).

Figure 3. Photograph of barley stubble on south coast of Iceland, April, 2002.

Elsewhere

Records from other parts of the world (Western Hemisphere, Southern Hemisphere) tend to be few and relatively recent. They document retreating ice with the end of the Little Ice Age but do not generally extend far enough back to document whether the Medieval Warm Period was global. The few proxies that cover longer periods and low latitudes tend to be more prone to speculation and interpretation, with the predictable controversy resulting (Grove, 1988; Linderholm et al., 2009).

Little Ice Age Was Not Uniformly Cold

Various fluctuations in climate, both regional and more general, occurred throughout the Little Ice Age (Fagan, 2000; Guiot et al., 2005). Phrases such as "the terrible winter of 1678," "the terrible winter of 1684," and "the terrible winter of 1888" (Poirier, 1960) imply that these were in fact unusual years. Uniformly cold conditions would cease to be mentioned after approximately one generation, since observers would then be accustomed to the conditions. "Climatic research from more recent times has pointed to the 1400s as the period in Europe's history when the climate was the worst, and especially the 1430s and 1450s" (Bjørvik, 1994, p. 35). The Little Ice Age appears to have peaked earlier and ended earlier in Switzerland and southeastern Europe than in the North Atlantic region, which is the subject of this paper (Grove, 1988). Thus, the Little Ice Age was a period of significant variability, but it was also a time during which cold, especially hard winters, clearly predominated (Eiríksson et al., 2000; Fagan, 2000).

The Little Ice Age—What Difference Does it Make?

The Little Ice Age holds a special potential for the application of science to the study of natural history—it is historically constrained. Natural history scenarios are often rendered believable by their remoteness from observation, which the Little Ice Age was not. Research into the Little Ice Age may be a good means of discrediting some of these speculative models and, beyond that, illuminating the worldview struggle that underlies disagreements in beliefs about Earth history.

Good Science versus Political Manipulation

Whenever you hear, "The science is in," you know that science is out. Science deals in probabilities, not certainties. Certainties require divine revelation, and true science is always subject to revision as new data are acquired and old ideas are disproved. No doubt the domination of empiricism and evolutionism in Western culture over the past couple of centuries has conditioned the masses to accept such oxymorons as "scientific certainty" and "scientific consensus." A dose of good science may inject an element of healthy debate into this arena, perhaps even helping to free science from the clutches of a disingenuous and manipulative political elite.

Good History versus Political Manipulation?

Those enlightened by divine revelation understand the personal nature of evil in the world and the purposive corruption of what God has created (2 Cor. 2:11). The Bible is a book of history, and it is no coincidence that so-called "postmodernism" (or "nonreason" per Schaeffer, 1982) rejects the value of history with a skepticism ad absurdum and often rationalizes falsehoods based on desired social or political outcomes (Grenz, 1996; Veith, 1994). The threat this poses to science has been pointed out (Anderson, 2007, 2008; Klevberg, 1999, 2008). That this is behind at least some of the junk science (e.g., Gore, 2006) at the surface of the global climate change question is clear. Regardless of postmodern denials, one's view of history determines one's view of the present and future, and it is for this reason that the forces of evil have so virulently attacked not just the verac-

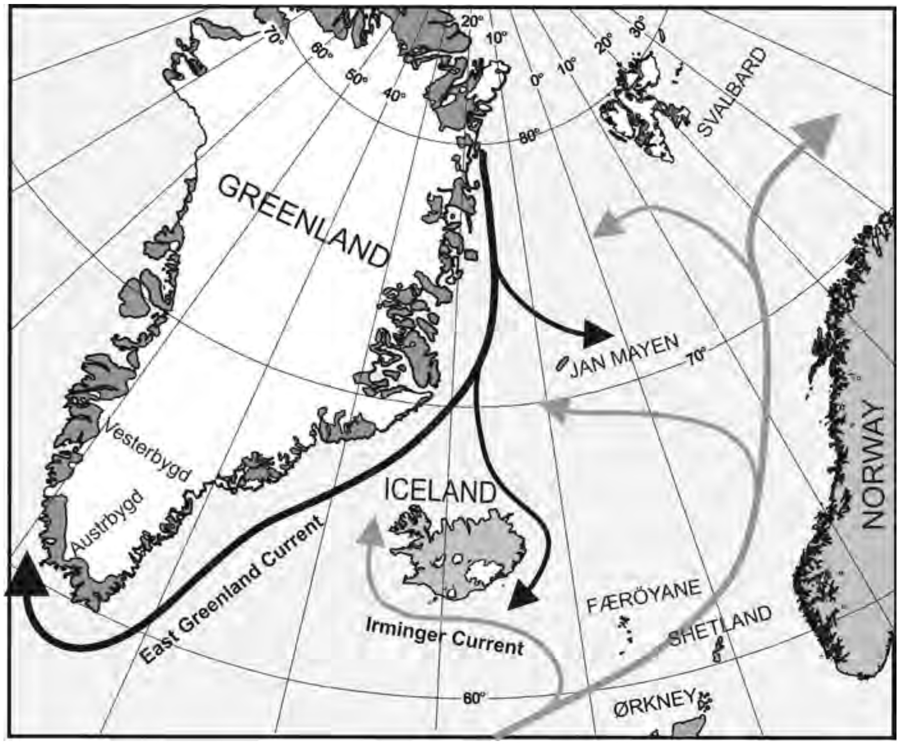

Figure 4. Map of North Atlantic region. Gray arrows indicate comparatively warm ocean currents; black arrows indicate cold currents.

ity of the Bible in general, but also the account of natural history it provides us. The good historiography of the Little Ice Age, especially from Europe, is helpful in this struggle over the nature of history.

Good Research versus Evolutionism

Many evolutionists have contributed good research for our understanding of the Little Ice Age, and we will cite them throughout this series. We contend that their research is conducted despite their worldview, not because of it, and actually rests on principles of honesty, the objective nature of reality, the uniformity of natural processes, and allied concepts derived from the Biblical worldview (Morris, 1984; Schaeffer, 1982; Reed, 2001; Reed et al., 2004).

Evaluating the Great Ice Age

We have no historical proof of a great ice age. Most creationists accept the idea of a single, significant ice age in the early postdiluvian period. This position has been well developed and its plausibility well established (Oard, 1990, 2004). Evolutionists, loath to accept the idea of unique geologic events, speak of "ice ages" during the "Pleistocene" and other times in Earth history, clear back over 2 billion years ago (Oard, 1997). Since climate models are simply sophisticated and mathematically refined guesswork, there is no means of constraining speculation regarding a great ice age. However, this is not true for the Little Ice Age.

Quantifying "Quaternary" Geology

"Pleistocene" or "quaternary" geology in much of the Northern Hemisphere deals largely with deposits believed to result from continental glaciation. Like paleoclimatology, historical geology is a branch of history that can roam unfettered to the realms of absurdia without scientific constraint. The Little Ice Age provides significant constraint and opens avenues for quantitative evaluation of likely glacial deposits. This provides a new level of insight into geologic processes and deposits.

The North Atlantic Study Area

As shown above, the Medieval Warm Period and Little Ice Age impacted far more than just the North Atlantic region (Figure 4). However, we have chosen to focus on the North Atlantic due to its good historical data, variety of climates (temperate to polar), degree of glaciation both before and during the Little Ice Age, and to scale back our task in the face of the enormity of the subject. We employ the definition of Jean Grove (Ogilvie and Jónsson, 2001): the Little Ice Age was a period of widespread glacial advance on a global scale during the past millennium. Much of Europe that shows evidence of past glaciation (e.g., Great Britain, Germany) was not affected by glaciation during the Little Ice Age and is therefore excluded from our study. We also excluded the Alps, since Switzerland is in a continental setting less suitable to our desired application to a postulated postdiluvial ice age.

One might also argue the choice of the study area may be partly due to the ethnic heritage of the lead author. For various reasons, an abundance of pertinent literature has not gained the attention of the English-speaking audience. Unless otherwise noted, translations from Norwegian and Danish in this series and efforts at deciphering Icelandic and Old Norse are those of the lead author.

Summary

The complexities of paleoclimatology belie efforts at simplistic affirmation or denial of the Little Ice Age, but evidence is significant that terrestrial climate was cooler for a period of several centuries worldwide compared with today's average temperatures and the averages of the early second millennium (the Medieval Warm Period). With the definition of the Little Ice Age as a period of roughly contemporary advance of glaciers worldwide, we affirm the existence of the Little Ice Age and find the term useful in describing the period of roughly1350 to 1880. Because good historiography and even some instrumental records exist for this period in key locations of the North Atlantic region, the Little Ice Age provides a key to understanding climate change in the postdiluvian period, tempering political rhetoric and naturalistic speculations and offering hope for insights into the much more substantial Great Ice Age and glacial geologic processes in general.

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Glossary

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

Historiography – the body of historical records on a particular topic; also, the manner in which historical research is conducted, particularly in reference to a particular topic.

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.

Paleolimnology – the study of earth history using samples of lake sediments.

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.

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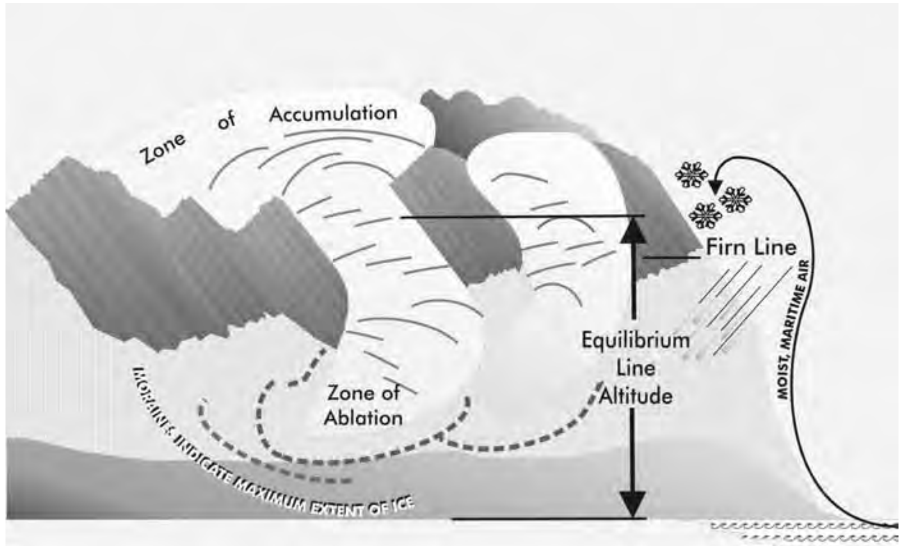

Figure 5. Glacier schematic.

Appendix A: Glaciology Primer

Glaciers have the following components.

- A zone of accumulation, where snowfall exceeds snowmelt and ice is produced.
- A zone of ablation, where annual melting of ice exceeds the formation of ice from snow.
- A firn line, an elevation above which precipitation falls as snow.
- An equilibrium line altitude, the elevation that separates the zone of accumulation from the zone of ablation (usually very close to the firn line).

These components are illustrated in Figure 5.

Geography significantly impacts the response of glaciers to climate. If the glacier is steep, with a large zone of accumulation, much ice can move far below the equilibrium line altitude (ELA), even to sea level. Such a glacier may respond quickly to changes in precipitation. If the glacier follows a low gradient, a slight change in ELA may produce a very large response by greatly increasing or decreasing the ratio of accumulation area to ablation area, but the movement of ice over the low gradient is likely to be slow. Glaciers that respond

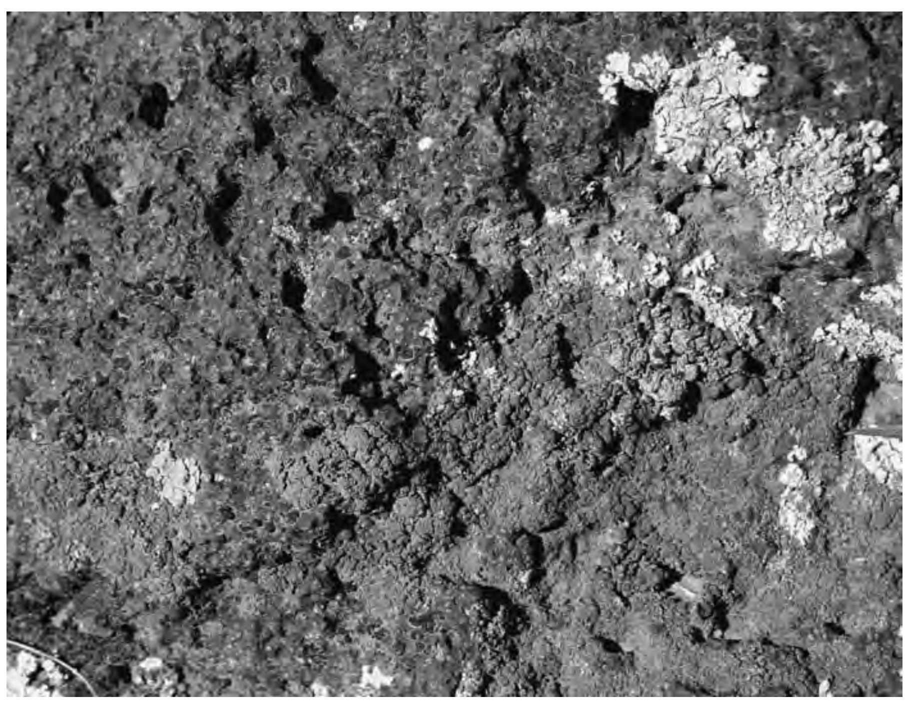

Figure 6. Photograph of lichens on basalt rock. For lichenometry, *Rhizocarpon geographicum* is preferred. Photograph by Mark Armitage.

slowly to changes have large lag times. For example, if a particularly warm and dry decade were to interrupt otherwise normal years, a glacier with a long lag time could be stable or actually advance throughout that dry and warm decade, and begin receding during subsequent years that are wetter and colder again. In Iceland, differences in lag times between some of the steeper, smaller glaciers and large outlet glaciers may have exceeded a century (Kirkbride and Dugmore, 2001). With differences in lag times, inferring climate from glacial response can be tricky.

Appendix B: Lichenometry

Lichenometry is a commonly used means of dating moraines. When the ice withdraws, rocks are colonized by lichens (Figure 6). The method is simple: find the largest lichen, measure it, and figure out how old the moraine is by the rate of growth of the lichen. In practice, it is not very exact, with lots of potential problems (Grove, 1988; Kirkbride and Dugmore, 2001; Thompson and Jones, 1986). A better statistical basis is needed for the "largest" lichen (Caseldine, 1991; McKinzey et al., 2005), a measurement method must be defined (Kirkbride and Dugmore, 2001), local curves linked to known dates (e.g., gravestones, buildings) are needed (Grove, 1988; Kirkbride and Dugmore, 2001; Kugelmann, 1991), and growth rates may be nonlinear. In some cases, lichenometric dates have been disproven by tephrochronology or other methods (Kirkbride and Dugmore, 2001; McKinzey at al., 2005). Nonetheless, it can provide an educated guess for features from the Little Ice Age (Thompson and Jones, 1986).