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New World with a New Sky: Climatic Variability, Environmental Expectations, and the Historical Period Colonization of Eastern North America

ABSTRACT

Colonists arriving in eastern North America at the start of the historical period faced not only new topographies and new plant and animal communities, but also new climatic regimes. The transition from the Medieval Warm Period to the Little Ice Age several centuries earlier presented Viking settlers in the North Atlantic region with the task of learning that their new environments were more fragile and changed more rapidly than the familiar forms of those environments suggested at the outset of colonization. North American colonists arriving from England expected different environments, but also expected them to vary consistently according to latitude. Examination of these two examples of colonization using the landscape learning model, particularly the concept of limitational knowledge, shows clear time gaps between practical and archaeologically identifiable adjustments to local climatic conditions and updating of the wider social understanding of the regional environments.

Introduction

"Now although there be Deere in the woods, Fish in the rivers, and Fowles in abundance in their seasons; yet the woods are so wide, the rivers so broad, and the beasts so wild, and wee so unskilfull to catch them, wee little troubled them nor they us" (Kupperman 1988; Blanton 2003). So reported Captain John Smith on the early days of the Jamestown colony of Virginia. His statement captures well what has long been considered a source of many of the problems at Jamestown: "unskilfullness" combined with a lack of intent and careful planning for subsistence tasks.

The apparent shortcomings and unhappiness of the early settlement at Jamestown is set here as a framework for considering the roles of perception, expectation, and environmental change in the historical period English colonization of eastern North America, using the archaeological model of landscape learning (Rockman 2003a, 2003b). Documentary analysis of the writings of early North American exploration and settlement is extensive; sources reviewed here include the work of Kupperman (1979, 1982, 1984, 1988), Kelso (2006), and Noël Hume (1994), among others. The contribution this paper seeks to make is the application of the landscape learning model to the example of the establishment of Jamestown and contemporary settlements, and the demonstration of how intangibles such as thought, memory, experience, and expectations can be applied to the practice of environmental archaeology.

The Landscape Learning Model

Landscape learning is the process by which human individuals and groups gather, share, and use environmental information in such a way that it can be communicated to others and subsequent generations as an established sense of "this is how we live here." Landscape learning is necessary in any situation in which there is difference between the currently occupied environment and a previous environment. Such situations are most likely in the context of colonizations or migrations, particularly initial colonizations, although presence of a previously established population does not guarantee availability of relevant environmental information. Landscape learning may also be necessary in situations of environmental change.

The core of the landscape learning process model is a set of three types of knowledge gathered from different sources over different time frames (Rockman 2003a, 2003b). These knowledge types are locational knowledge, limitational knowledge, and social knowledge.

Locational knowledge consists of information relating to the spatial and physical characteristics of particular resources, such as the location of a spring or a certain type of plant along a stream, an outcrop of a particular kind of metal ore, or the geographical coordinates of an island intended for settlement, such as Roanoke Island or Jamestown Island. Locational knowledge is the easiest form of environmental information to collect, and in many instances can probably be gathered in the space of hours, days, weeks, or months of

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arriving in a new place. This should not be taken to mean that all resource locations are identified effectively and instantaneously. Rather, at least some examples of a resource type will likely be found relatively quickly once they are sought, provided they exist in the given environment.

This author recently completed an extensive investigation of the development of locational knowledge by hunter gatherers during the late glacial recolonization of the British Isles, which took place approximately 13,000 to 10,000 years ago (Rockman 2003b). Specifically, this investigation looked at how the hunter gatherers of that time located and went about using sources of flint. Results of this study suggest that their previous experience with the topography of flint-bearing chalk on the European mainland—particularly in the vicinity of the Paris Basin—had a substantially greater influence for at least several hundred years on the development of flint-procurement practices than did proximity of flint deposits to probable colonization routes.

Limitational knowledge includes information about the usefulness and reliability of various resources, and their ranges of variation within the overall environment. For example, how many types of animals live in the area and how stable are their populations? Are the rocks, such as mineral ores and building stones, of good quality? How fertile is the soil and how predictable is the rainfall? Also, particularly key for the following discussion of historical North American environmental adaptation, how extreme are the temperatures in winter and summer?

Limitational knowledge cannot be gathered instantly. It can only be gathered through experience, and the lengths of time for learning can differ dramatically for different aspects of the environment depending on the frequency of use of the resource or the nature of the cycle being learned. For instance, it may take only a few winters and summers to get a sense of seasonal variation, such as when it rains and when it is likely to snow, but much longer to recognize and accommodate cycles and extremes in seasonal fluctuations.

Social knowledge comes from the attribution of names (Fowler 2004) and meanings (Basso 1996) to natural features, and the storage of locational and limitational knowledge in a form that is remembered and transmitted by the group to succeeding generations (Boyd and Richerson 1985; Richerson and Boyd 2005). It is not yet clear how much time is needed to develop social knowledge. The major initial colonizations of the world took place long before the experiences documented by ethnography and history, so there is little direct information to go by (Kelly 2003; Meltzer 2003). Studies of the folklore of smaller, more recent colonizations, such as the movement of escaped slaves, known as maroons, into the backcountry of Surinam in the 18th century (Price 1983) suggest that creation stories may form in the range of 400 to 500 years.

Once created, available information suggests that social knowledge can persist for up to about 1,000 years in oral cultures. For example, studies of Viking sagas indicate that crucial pieces of information—such as sailing times and topographic landmarks across the North Atlantic (Mowat 1965; Ingstad 1969)—can be remembered and remain accurate over a couple of hundred years, even while other aspects of the stories may change. After a maximum of 1,000 years without direct experience with a remembered landscape, it is likely that too much detail has been lost and remaining knowledge is no longer adequate for direct use (Strong 1934; Vansina 1985; Echo-Hawk 2000). In some circumstances information may degrade over much shorter timeframes.

For the sake of modeling, the three types of environmental knowledge are considered to develop sequentially; some locational knowledge must be established before limitations can be determined. Likewise, at least some limitations must be known before they can be incorporated into social knowledge. There is feedback within the set of knowledge types or knowledge structure, and any part of the knowledge structure for any given resource may be updated at any time. For the purposes of analysis, development of knowledge for different resources should be considered independently. In other words, a group may have detailed social knowledge for some aspects of the environment, yet still be gathering locational and limitational knowledge for other resources.

The landscape learning model is a new approach in environmental archaeology. The idea that unfamiliarity with an environment may have affected the progress and outcome of colonization has been recognized for some time (Bogucki 1979; Fedele 1984; Kelly and Todd 1988;

Whittaker 1989; Beaton 1991), but the landscape learning model is the first effort to describe environmental familiarization as a consistent process that can then be compared across the archaeological records of colonizations separated in space and time. Recent collected papers in Rockman and Steele (2003) demonstrate the wide applicability of the landscape learning concept. To date, however, direct testing and exploration of the landscape learning model has been limited. The study of late-glacial British flint (Rockman 2003b) noted earlier was the first direct test of the landscape learning model, with emphasis on the development of locational knowledge.

The research presented here is an initial investigation into the development of limitational knowledge. Climate is an important example of limitational knowledge, and as will be amply demonstrated by the case study of Jamestown and other colonization attempts, climate played an important role in the experience of setting up colonies and plantations, hence its place in this volume. The objective of this paper is to present a general comparative landscape learning framework for studies of climatic variability, environmental expectations, and their roles in the historical period colonization of eastern North America, and consider from a modeling perspective how the development of limitational knowledge interacts with previously developed social knowledge in an historical period context. The features of historical period contexts that distinguish their landscape learning from prehistoric (considered here to be generally prior to the development of writing and technologically aided transport such as wheeled vehicles and seaworthy vessels) is the capacity to move rapidly (within the space of one annual seasonal cycle) from one ecozone to another, and to spread information about local environments widely. Landscape learning in prehistoric, and generally in completely oral societies presents another interesting set of considerations too extensive to consider here. For further discussion see Beaton (1991), Kelly (2003), and Meltzer (2003).

Climate in Early Jamestown

Recent work with dendrochronological sequences of bald cypress trees in the southeastern United States has provided dramatic evidence of the climate in early Jamestown. The most severe seven-year regional drought in the Virginia Tidewater region in 770 years occurred between 1606 and 1612 (Stahle et al. 1998; Blanton 2000). This range brackets the crucial initial settlement years of 1607 and 1608, which saw mortality rates well over 50%, and a great deal of general misery for the colony (Kupperman 1979; Noël Hume 1994; Kelso 2006).

Tree-ring data indicate other prolonged and severe droughts during the last three decades of the 16th century that appear to have affected earlier European attempts at colonization. An extended period of low growing-season rainfall occurred between 1562 and 1571, and was noted by a Spanish mission in the area that may have been on the York River just six miles north of Jamestown (Blanton 2000). The driest three-year cluster of growing seasons in the dendrochronological sequence occurred from 1587 to 1589, a timeframe that coincides with the disappearance of the "Lost Colony" at Roanoke Island (Stahle et al. 1998). Clearly, in addition to all of its other attributes, early European colonization in the Middle Atlantic states suffered an astounding case of climatological bad luck.

European colonists were not the only ones to feel the effects of the droughts. In 1570, Father Segura of the Spanish mission in Virginia wrote with respect to the conditions of the local Native Americans (Blanton 2000):

> We find the land of Don Luis [a local native] in quite another condition than expected, not because he was at fault in his description of it, but because our Lord has chastised it with six years of famine and death, which has brought it about that there is much less population than usual. Since many have died and many also have moved to other regions to ease their hunger, there remain but few of the tribe ... they have no maize, and have not found wild fruit, which they are accustomed to eat. Neither roots nor anything else can be had, save for a small amount obtained with great labor from the soil, which is very parched.

Captain Smith recorded a similar level of distress with a request for aid from a native leader near Jamestown in the early 1600s. This leader "did beleeve that our God as much exceeded theirs, as our Gunnes did their Bowes and Arrowes, and many times did send to me to James Towne, intreating me to pray to my God for raine, for their Gods would not send any" (Blanton 2000).

Dennis Blanton (2000), in his thorough presentation and consideration of the tree-ring and historical data (this study is indebted to him for identification of the quotes above), summarized the effects of the Jamestown droughts in terms of its effects on food supply, water quality, mortality, and intercultural hostility. He concluded that the initial favorable descriptions of Virginia's environment must be interpreted with caution, that the native reports of food shortages were not deceptive strategies but real indications of stress, and that the near-complete silence of early Jamestown accounts on the subject of drought for nearly a decade following settlement is a clear signal of the unfamiliarity of the colonists with the climate of their new home. David Stahle, along with Dennis Blanton and the other researchers involved in the Jamestown tree-ring research project, concluded that, while the Jamestown colonizers have been criticized for "poor planning, poor support, and a startling indifference to their own subsistence" (Stahle et al. 1998), the tree-ring data suggest that even the most well-planned and supported colony would have been highly challenged by the climatic conditions of the early 1600s.

Determining Climatic Expectations

Returning to the concept of limitational knowledge development, and following on the results of Paleolithic British locational-knowledge flint study noted previously (Rockman 2003b), and the relative importance of previous environmental experience that it showed, it is appropriate to begin with the question of what sort of climate the early historical period colonists in North America might have expected to find. Because we know that climate is variable, this question should be phrased with respect to time: from how far back in time, prior to colonization, does the baseline climate that underlies such expectations derive? Or, in the terminology of landscape learning, how can the climate included in colonists' social knowledge be identified and characterized?

Recent detailed research into the Viking colonization of the North Atlantic region (McGovern and Perdikaris 2000; Simpson et al. 2001; Dugmore et al. 2007; McGovern et al. 2007) provides an important case example on the time depth of climatic understandings and their temporal, geographic, and social factors. For example, similar plant communities extend across the North Atlantic from Norway to southern Greenland. At the outset of Viking colonization of the central North Atlantic region, evidence indicates that the Icelandic environment appeared similar to that of Scandinavia (Smith 1995). Early medieval Scandinavian farmsteads consisted of barley fields along with herds of dairy cattle, pigs, sheep, and goats, as well as horses. In accordance with this apparent similarity, the Vikings transplanted this way of life to Iceland in the last quarter of the 9th century A.D. Although Iceland lies several hundred miles to the south of Scandinavia, its location with respect to Atlantic currents and soil conditions make it a more marginal environment (McGovern et al. 2007). Studies of soil accumulation and erosion rates using a combination of micromorphology, tephrochronology, aerial photography (Simpson et al. 2003; Simpson et al. 2004), and pollen analysis (Smith 1995) have indicated rapid erosion of soil following initial colonization that appears to have been due to the combined effects of deforestation and introduction of the grazing animals to Iceland's friable volcanic soils.

Recent studies have concluded that the Viking colonists were not unresponsive to their new environment. By the early-to-mid-11th century, the number of pigs, goats, and cattle in Iceland was reduced in proportion to the number of sheep, likely due to the realization that to produce a similar quantity of milk and other products, the former animals required more forage than sheep (Smith 1995; McGovern and Perdikaris 2000). The timing and extent of erosion was not uniform across Iceland either. Erosion appears to have occurred unevenly (McGovern et al. 2007), which may indicate variations not only in local environmental conditions, but also in individual farmstead practices. Faunal analysis of remains from an area in northern Iceland has identified egg-harvesting practices that appear to have successfully managed local bird populations from the time of colonization to the present (McGovern et al. 2006). Despite these efforts, a farmstead economy did not flourish in Iceland, and the colony endured severe privation which continued through development of the northern European fishing industry in the Icelandic area from the 13th and 14th centuries onward (McGovern and Perdikaris 2000; Pope 2004).

In light of the early settlement history of Iceland, the transfer of Viking settlement to Greenland is particularly interesting with respect to the development and transmission of environmental knowledge. A group under the leadership of Erik the Red left Iceland for Greenland in the late 10th century, more than 100 years after the *landnám*, or initial settlement of Iceland. The colonists took with them supplies and animals sufficient to set up not just the Icelandic sheep-based farmstead but also the original Scandinavian farmstead rich in pigs and cattle (McGovern, et al. 2007). For a range of reasons, political, social, as well as climatic, the Greenland colonies did not last beyond the Middle Ages (McGovern 1994). Whether a different Iceland-based origin for the colonists would have altered the fate of the Greenland settlement is difficult to determine here. It is interesting to note, however, that the leader Erik the Red himself was not a native of Iceland. Rather, he arrived there from western Norway following a killing, therefore presumably as an adult or later adolescent. He settled first in the north of Iceland and then moved south where he began a family. Following further conflicts he was outlawed from Iceland, and following several years of exploration organized the expedition to Greenland (Ingstad and Ingstad 2001).

The environmental preparations and expectations of the Greenland-bound Vikings, including that of their leader, therefore, cannot be seen as having derived entirely from Iceland, which was the setting-off point and had been a home for multiple families for more than a century. Environmental background knowledge also came from Scandinavia. The key point of this example for this paper is that environmental expectations can draw from community experiences more than a hundred years in the past, and may derive from places lived in prior to the most recent departure point.

Describing Climate and Climatic Change

The Viking spread across the North Atlantic region took place during the climatic phase known as the Medieval Warm Period. The Medieval Warm Period extended from approximately A.D. 900 to 1300. In Europe it was characterized by relatively stable and warm conditions during summer months and through the agricultural harvest. Comparison of climate proxies worldwide has identified three periods of approximately 30 years each of notably warmer atmospheric conditions, A.D. 1010 to 1040, 1070 to 1105, and 1155 to 1190 (Crowley and Lowery 2000). Generally, temperatures ranged from 1 to 2° C above mid-20th century temperatures, with higher averages at higher latitudes and lower variations at lower latitudes (below approximately 40° north) (Lamb 1965; Crowley and Lowery 2000).

The climatic phase known as the Little Ice Age began ca. A.D. 1300 and lasted until approximately 1850 (Grove 1988). Its contrast with the Medieval Warm Period lay not only in the general drops in temperature implied by the name, but in changes in the temperatures by season and the timing of precipitation (Ladurie 1971; Ladurie and Baulant 1980; Pfister 1980; Grove 1988). Periods of identifiably colder and wetter weather based on agricultural documentary records from central Europe included 1488 to 1493, 1527 to 1529, 1541 to 1544, 1563 to 1600, 1616 to 1635, 1640 to 1643, 1648 to 1650, 1672 to 1675, 1687 to 1703, 1713 to 1716, and 1767 to 1777, following analysis in Bell (1980). The fluctuations of the Little Ice Age were also felt in the New World, but often in the form of drought rather than additional rain and cold (Lyon 1936; Stahle et al. 1985; Stahle et al. 1998; Fagan 2004).

Current consensus among recent archaeological and paleoenvironmental studies of the Viking expansion (Bell 1980; Simpson et al. 2001; Simpson et al. 2003; Dugmore et al. 2007; McGovern et al. 2007) is that while unfamiliarity with the natural environment of the North Atlantic played a role in both the degradation of the Icelandic landscape and ultimate failure of the settlements in Greenland, changes in the predictability of environmental conditions due to climatic instability were a major factor in reducing the effectiveness of human responses. The nature of variability in the early Little Ice Age climate essentially created two moving targets: discovery of the nature of new environments and different rates of change, which together created a situation in which landscape learning was difficult indeed.

How then to characterize the climatic learning of the colonization of North America at about the time of Jamestown? While the Vikings had the misfortune of watching relatively stable climates of the Medieval Warm Period recede, what was the climatic background for colonization undertaken several hundred years later from England near the temporal middle of the more variable Little Ice Age?

The work of Jeffrey Dean (1988) is a useful starting point. Based on his work in the late prehistoric American Southwest, Dean has proposed that humans interact with two levels of environmental change: high frequency processes (HFPs) and low frequency processes (LFPs). HFPs are processes that change within the timeframe of a single generation, which Dean estimates at 25 years in length. HFPs include such environmental characteristics as annual variations in rainfall, temperature, and wildlife abundance. LFPs are processes that change in cycles of longer than 25 years, such as erosional cycles and fluctuations in water tables. Dean suggests that from a human perspective LFPs are perceived as environmentally stable conditions. As a result, most human environmentally related behavior responds to HFPs.

From this perspective, the approximately 30-year fluctuations of the Medieval Warm Period can be seen to support the interpretation of this phase as relatively climatically stable. In turn, the transitions between colder and wetter periods of the Little Ice Age can be generally characterized as high frequency changes, with the exception of the somewhat longer colder and wetter period in Europe from 1563 to 1600.

What do such changes mean in terms of human experience? Two researchers looking at different aspects of the Little Ice Age have applied the statistical technique of cumulative deviation to climatic (Dugmore et al. 2007) and agricultural data sets (Bell 1980), and developed means for describing and comparing how individuals and groups of that time may have identified the ongoing changes. Cumulative deviation is developed by first calculating the mean of the chronological data set and then summing the difference of each data point from the mean beginning with the oldest data point (Dugmore et al. 2007). A graph of cumulative deviation can be used as an illustration of memory; strong changes in the direction of the graph indicate points at which previously gathered data no longer predict the future. For example, using measurements of sodium (Na+) and chloride (Cl-) from the GISP2 ice core, Dugmore et al. (2007) developed a cumulative deviation plot of relative storminess in the North Atlantic (Figure 1). Nick points in the plot show major changes in storm regimes in A.D. 975, 1025, 1425, and 1525, with an overall trend of decreasing storminess to 1425 and increasing storminess from 1425 onward. Storms therefore may be seen as a relatively stable climatic trend from the early Little Ice Age onward.

Bell (1980) in turn analyzed wine-harvest dates from central Europe (Ladurie and Baulant 1980)—the predictability of which would have been of immediate and very tangible concern to the economy of the time, and which can be related to the predictability of other agricultural dates and crop successes (Pfister 1980). Earlier work by Ladurie (1971) identified comparable patterns between fluctuations in wine-harvest dates and changes in mean temperature (Figure 2*A*). For example, the 25-year period including the establishment of the Jamestown colony, 1600 to 1625, shows a maximum range of 26 days for the date of the start of the wine harvest, with few adjacent years in this time span appearing even generally similar to each other. Bell's work places these changes into a different perspective, showing a discernible trend toward earlier harvests between 1500 and 1560, a trend toward later harvests between 1560 and 1600, and relatively stable harvest dates between 1600 and 1620 (Figure 2*B*).

Interactions between measured climatic variability, identified trends, and human responses are not easily resolved. The ecological concept of the *holon,* however, does provide a useful approach. A *holon* is a set of interacting variables whose combination can be described as a single signal. Terry Hopkinson (2001, 2007), who has developed the *holon* concept in his study of the European Middle Paleolithic, has provided an example of temperature—effectively a combination of dew point, humidity, solar radiation, and so forth, taken together over a defined period of time, such as a minute, hour, or day. Climate itself may be considered another *holon*, with an even wider range of contributing factors. From the perspective of landscape learning, human behavior may also be considered a *holon* (Rockman 2009). For instance, a given set of behaviors or activities can generate an overall "signal" or level of adaptedness to a given environment. This adaptedness signal can then interact with other groupings of behaviors of the given group, population, or species, and with external *holons* found in the environment.

For this discussion, the key point of behavioral *holons* is that they are a collection of individual

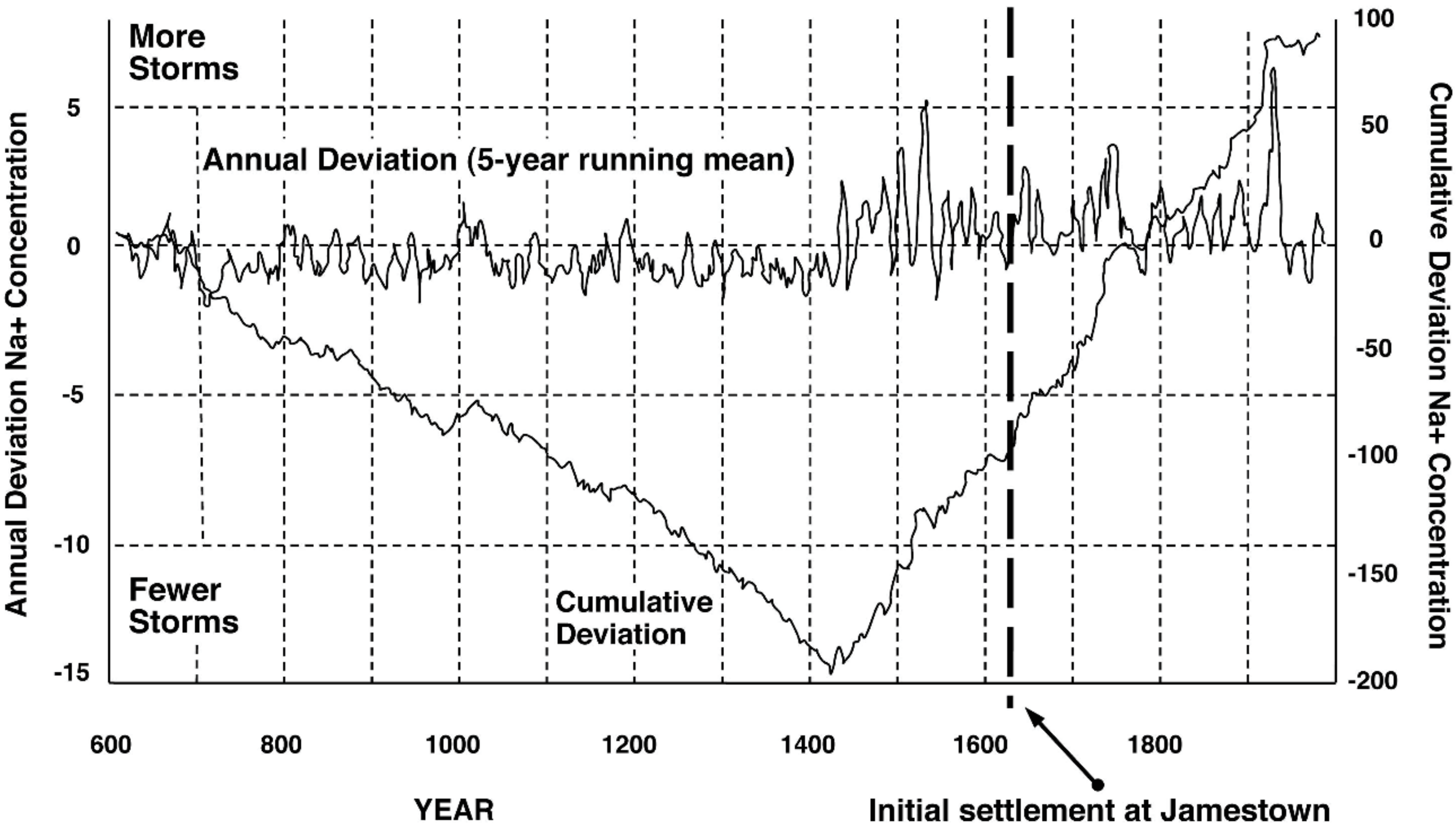

FIGURE 1. Annual deviation and cumulative deviation curves showing trends in North Atlantic storminess from the Medieval Warm Period through the Little Ice Age based on Na^+ concentrations in the GISP2 ice core (Dugmore et al. 2007:figure 2). (Major labels redrafted by author, 2009.)

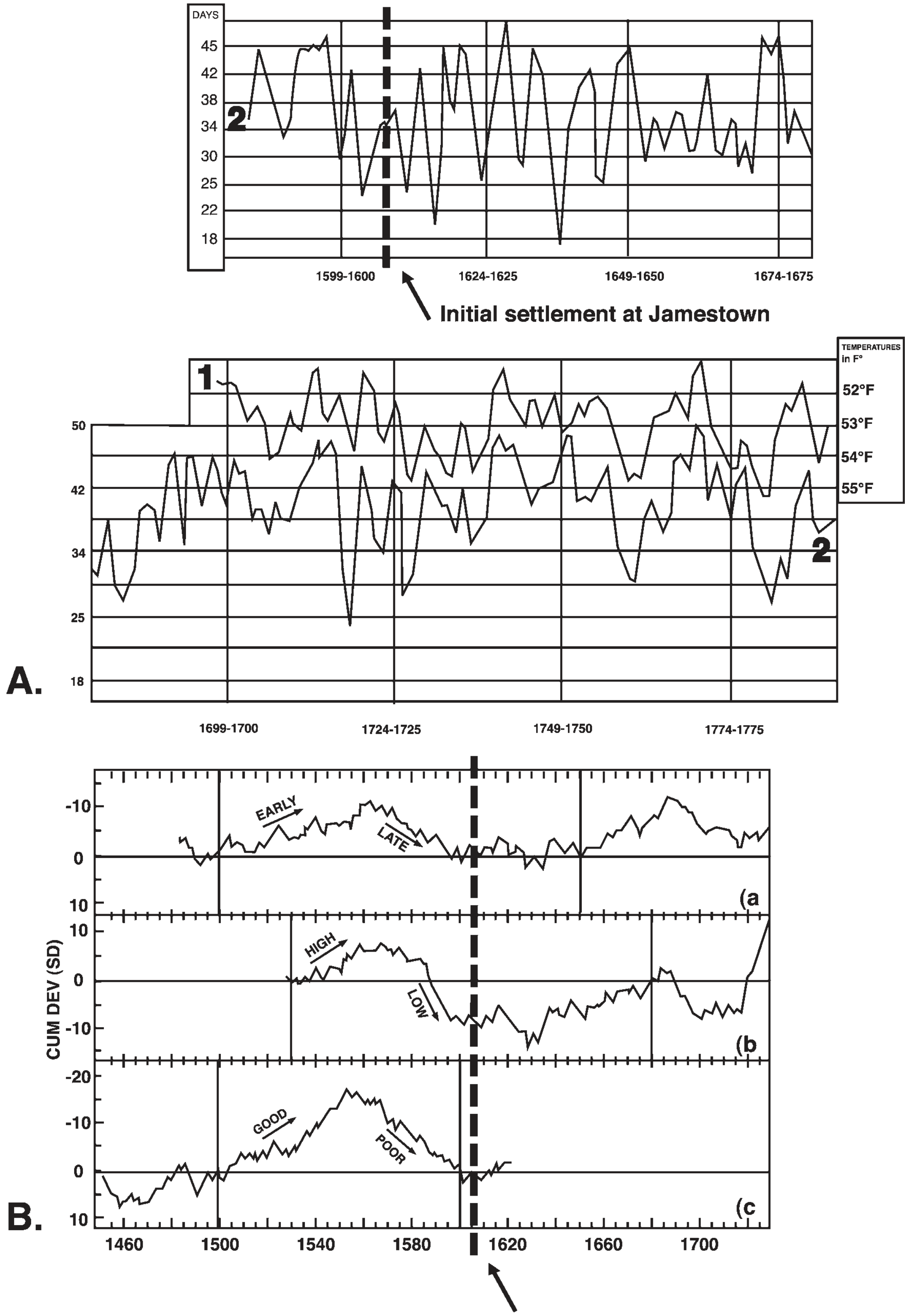

FIGURE 2. Variations in wine harvest data during the Little Ice Age. Chart *A* (*top*) shows variation in mean spring and summer temperatures in England (line *1*, 2-year running mean, scale inverted) and its correlation with the date of the wine harvest in number of days after 1 September (line *2*) (Ladurie 1971:figure 5). Chart *B* (*bottom*) shows cumulative deviation curves of wine harvest dates (*a*), vine yield (*b*), and wine quality (*c*) (Bell 1980:figure 1).

practices. Within a given collection of behaviors, ideas, or perceptions, some previously established adaptations may work for some time in relatively similar environments. Problems develop when the product or "signal" of the combined practices is no longer adapted to the new local conditions. In such a situation it may be difficult to determine which of the combined practices, if not all, is contributing to the unadapted signal, and therefore in need of change. In such instances, not only will the updating of limitational knowledge be delayed, but also the social knowledge to which the limitational knowledge contributes.

This appears to have been the case during the historical period colonization of North America. Historical research by Kupperman (1982, 1984) indicates that colonists and the financial backers of colonization expected environmental stability. Unlike the Viking colonization of the North Atlantic, they did not look for the same environment known at home. Rather, they anticipated environmental characteristics based on stable geographic coordinates. Climatic knowledge in place at the time of early historical period exploration and colonization in North America included the idea that climate was constant by latitude. Hence, all points of intended settlement in North America south of the latitude of London were expected be warmer, and in some places much warmer, than England. Correspondingly, settlement areas were expected to provide appropriately tropical products, such as silk and wine in Virginia (Kupperman 1982). This simply was not, and could not be the case. Due to the influence of the eastward-trending Gulf Stream, oceanic western Europe generally has a smaller range of seasonal and daily temperature fluctuations than the continental climate of North America. Colonists faced their own set of double moving targets: climates that differed from the climatic difference that was expected, and an overarching climatic regime that included strong individual variations within relatively short LFP trends. These multiple sets of variation, noted in several settlement regions across North America, were not easily reconciled with the climate-by-latitude model. Changes in climatic understanding were quicker and more extensive where the contrasts between expectation and experience were strongest. Social knowledge was revised to include the North American experience. Due in part to the lack of understanding of the source of climatic difference between North America and western Europe, however, the changes to social knowledge during the early colonization period included a wait-and-see approach, maintaining a hope that in the future climate in North America might more closely approximate expectations.

Climatic Learning in Early Historical period Eastern North America

The majority of the first colonists of Jamestown came from counties in the southeast and eastern portions of England (Kelso 2006). Family history information for many of the early Jamestown leaders indicates long occupation in England (Kelso 2006), so the previous-homeland effect described with respect to the Viking colonization of the North Atlantic region is less of a concern with respect to North America. Life histories of several of the major early North American explorers, including John Smith and Martin Frobisher, include travels across Europe, the Middle East, and Africa; northern Europe and England particularly, however, appear to have remained the explorers' primary climatic reference (Kupperman 2007).

Detailed climatic data for England covering time periods prior to the settlement of Jamestown are few. For instance, temperature records compiled by Manley (1946, 1953) begin only in the late 17th century. Lamb (1968) developed high summer wetness/dryness indices for Britain from multiple sources, referenced to the prime meridian (0° longitude) by decade between 1100 and the 1950s. A cumulative deviation plot of these indices is shown in Figure 3. The plot indicates a trend of increasing dryness from approximately 1130 to 1300. The period between the 1300s and 1550s was characterized by, as described previously, relatively short-term changes between dryness and wetness trends. A long trend of increasing wetness began in the 1550s and characterized the years in which preparations were made for colonization in the Carolina Outer Banks, Jamestown, and by extension settlements in New England. As will be described here further, contact with Newfoundland began earlier, due in large part to the fishing trade (Pope 2004).

Experience with such previous climatic trends appears to have been less important to the climatic expectations of North American colonists than in the cases of Iceland and Greenland,

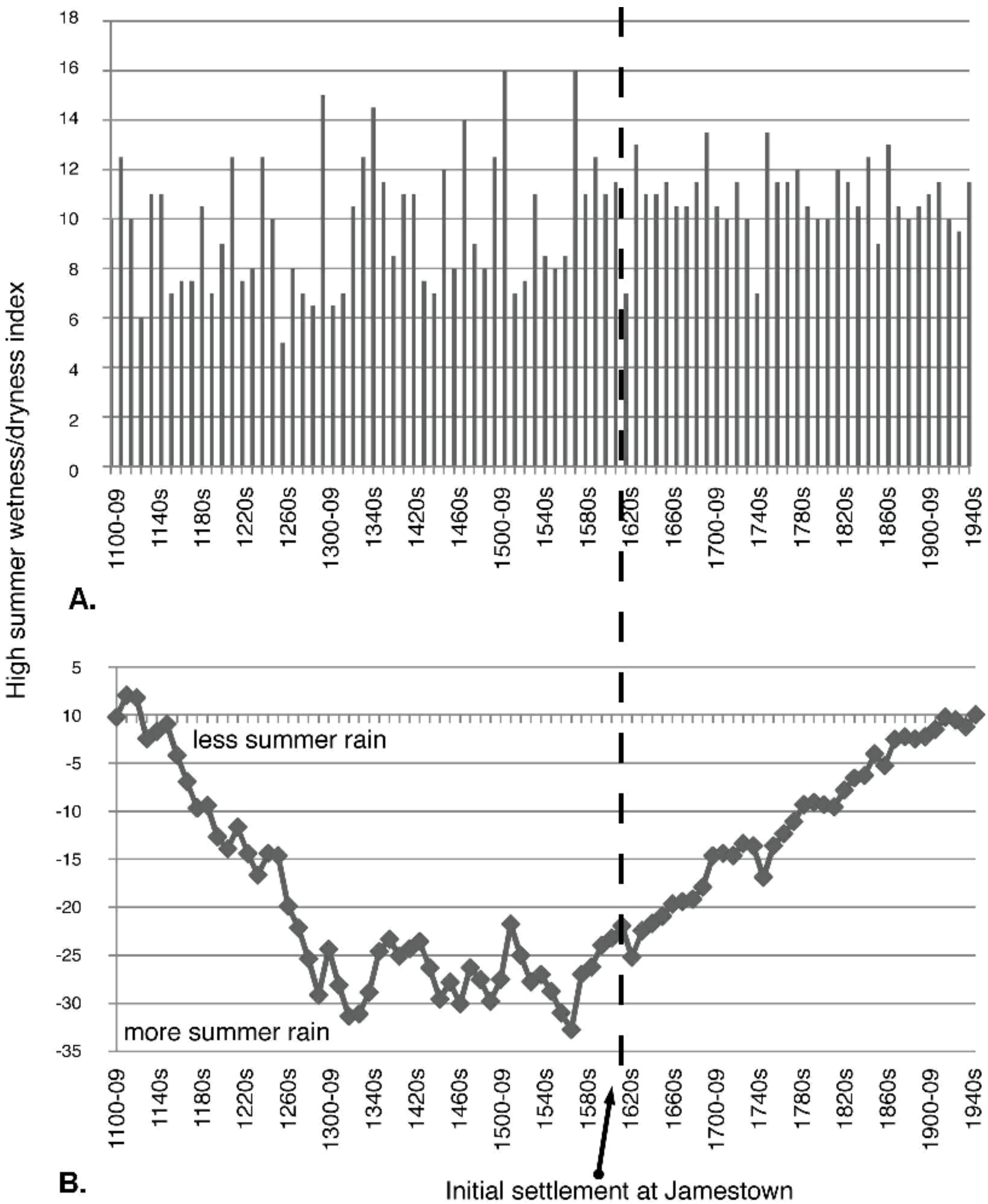

FIGURE 3. High summer wetness/dryness indices for Britain by decade A.D. 1100 to 1950. Chart *A* plots index values. Chart *B* shows a cumulative deviation curve of the index values. Indices are calculated as decade totals, with each July or August with unmistakable evidence of frequent rain counted as 1, each unremarkable July or August counted as 0.5, and clearly dry July or August months counted as 0. Data from Lamb (1968:appendix 2). (Graphs by author, 2009.)

because as noted earlier, North America was expected to have a different climate and thereby support production of different ranges of materials. This does not rule out the influence of climate in the motivations for pursuing the settlement in North America. In the late 16th and early 17th centuries, the economy of the great majority of Europe was still subsistence level farming, with small buffers against hunger in the best years and highly susceptible to environmental stress (Brandon 1971; Ladurie 1971). Many archaeological, historical, and modern examples have shown that one of the primary responses to environmental stress is migration, and so the effects of the Little Ice Age as a "push" factor in the emigrations to the New World should not be disregarded (Bailyn 1986; Anthony 1990, 1997).

The pre-existing knowledge with which early settlers arrived was a combination of the model of climatic consistency by latitude overlain with the economic expectations that such consistency would support. Further, a change in the understanding of climate would have real consequences to the profits of the backers of settlement efforts and the support provided to the colonists. Therefore, analysis of documentary evidence of climatic thought must take into account not only the position of the author and the nature of the author's experience with the North American environment, but also the intended audience. Sources of information about climate included writings by colonists themselves, men known as "intelligencers" (a position akin to today's journalist, responsible for collecting information and disseminating it in newsletters to interested parties for planning purposes; one example was John Pory of the Jamestown colonists) (Kupperman 2007), as well as writings by those with less-direct experience (Kupperman 1982). Kupperman (1982) noted that John Smith can be seen to have added to some of his writings rhetorical flourishes that belie his own extensive experience in exploration of North America and with the regional variations in climate, perhaps to promote investments in the colonization efforts.

In addition to the positions of authors, there were many practical limitations on the gathering of climatic information in the early periods of colonization. Foremost among these was the initial short timeframes of exploration visits and the absence of accurate instruments for measuring temperature. These conditions resulted in reports of new areas being taken as comprehensive when in fact they were not, as the reports were based on climatic experience of, in some cases, only a few months, and relied on subjective comparisons of climates between one place and another (Kupperman 1982). Other limitations included the very broad condition of English trepidation toward warm temperatures and related concerns for health (Kupperman 1984), and very specific problems of linking climatic cause and effect, such as with failure of transported plant samples to thrive in new North American locales, some samples of which were reported as damaged in transit (Kupperman 1982). With respect to study of these topics, there are also limitations on determining the precise timeframe of climatic learning, due to different exploration histories of different areas. Following Kupperman (1982), time estimates used in the following discussion are based on publication dates of reports.

The following brief discussion of climatic expectations and timeframes of North American climatic experience, and some of the ways in which English colonization incorporated and updated the contemporary knowledge structures of both emigration and climate, draws almost exclusively on the work of Kupperman (1982, 1984, 2007). Kupperman's work with primary documentary sources is of such detail that it was not possible to replicate it in a paper of this length and objective. As noted above, the purpose of this paper is to demonstrate how the historical colonization of North America can be studied as an example of the limitational aspect of landscape learning. Further testing of suggested patterns and timeframes among additional primary sources is recommended as the next stage of research.

With all of these considerations in mind, explorations and writings about the northern reaches of North America provide a useful illustration of the relationships between type of climatic contact, the timeframe of acknowledgement of the actual nature of the northern climate, and the resilience of previously established climatic thought. For instance, Jacques Cartier explored the St. Lawrence River in the 1530s and noted thick ice into mid-April, but more heat than Spain in July. This report can be classified as based on experience (Kupperman 1982). Edward Hayes, a traveling companion of Sir Humphrey Gilbert, explorer and older half brother of Sir Walter Raleigh, made an argument in 1592 that New England was more suitable than Newfoundland based not on any winter experience there, but from the reasoning of latitude alone—referring to the pre-established climatic model (Kupperman 1982). In turn, Samuel de Champlain experienced a very cold winter in Maine in 1604, but his next two winters spent in Nova Scotia were relatively mild, suggesting to him that the first bitter winter had been anomalous or a local phenomenon—a report that can be classed as experience (Kupperman 1982). Bartholomew Gosnold wrote general statements about climate after visits to northern North America of only a few months—a report based on short experience combined with the climatic model (Kupperman 1982). His settlement of Sagadahoc in Maine was founded the same year as Jamestown, but lasted less than a year due in large part to a very extreme winter. John Smith promoted New England as "golden mean" after a three-month voyage in 1614, however, and Sir Fernando Gorges promoted New England as "temperate, delicate, and healthful" both by "reason and experience" in 1622. Both of these reports emphasized the climatic model, some experience, and—probably—some marketing as well. Reports from the Plymouth colonists at about this time noted, however, that winters were colder than England, although they did not know why—again showing the prevalence of the climatic model (Kupperman 1982). Kupperman (1982) noted that by about 1631 there was some recognition that winters in the New England area were colder and summers hotter than in England—recognition of experience—but as late as the 1640s, more than 100 years after the Cartier reports of the area, the promotion was still being made by persons as prominent as Thomas Gorges, a relation of Sir Fernando Gorges, that both winters and summers should be hotter in Maine than in England because Maine is closer to the equator, a final emphasis on the climatic model (Kupperman 1982).

The learning curve was abbreviated in the portions of North America north of New England. It took only about 10 years, 1583 to 1592, to recognize Newfoundland as less pleasant than expected for settlement, even though it lies on the latitude of southern France and was expected to be comparably temperate (Kupperman 1982). These dates indicate a learning timeframe approximately 50 years in length, less than half of that indicated by the conflicting reports of the New England climate. It is also noted that discussion of weather and climatic variation appears to have been more extensive for areas in which the effects of severe weather were most pronounced, notably Newfoundland and New England (Kupperman 1982). With respect to Newfoundland, such discussion may have been due in part to the economic situation. The extent of the fishing industry there indicated potential for substantial future profits (Pope 2004) if the region could be reliably settled. The contrast between expectations and the harsh winters that were encountered challenged both financial hopes and the prevailing climate model. Following available data, the exploration and analysis of Jamestown climate was both sparser and more condensed than that of the northern areas. Perhaps because of the relatively milder climate there also appear to be fewer statements of recognition of variation from the climatic model.

For example, both Richard Hakluyt, author of *Divers Voyages Touching the Discovery of America and the Islands Adjacent* (1582), and his elder cousin of the same name were instrumental in developing the early Virginia voyages and referred many times in the 1570s to the links between latitude and climate as surety that the Virginia region would supply many needed products previously purchased from southern European countries (Kupperman 1982). Thomas Hariot argued in the 1580s that the latitude of Roanoke would support oranges, lemons, and sugar cane (Kupperman 1982). In 1610, William Crashaw continued to apply the climate model when he noted that Virginia was not as hot as corresponding European countries along the same latitude, although he could not explain why (Kupperman 1982). As late as 1620, the Virginia Company persisted in efforts to import olive trees, which could not survive in the relatively severe, non-Mediterranean Virginia winters (Kupperman 1982), which suggests continued support of the climatic model rather than local experience. The winter of 1607 was noted to be particularly severe, although as this winter was also bitter in New England and Europe, this observation does not appear to have been linked to variation in the Virginia climate specifically.

Climatic thought at the time of early North American colonization then, was a mix of experience and similar evidence alongside the previously established model of climatic symmetry. Kupperman (1982) noted that by the 1630s, "thoughtful" people understood that North American winters were genuinely colder than those of northern Europe, although they remained at a loss to explain why. Part of the problem was how to incorporate climatic experience in the New World with long-standing classical teachings. For example, the climatic model received from classical thinkers, particularly Aristotle, held that only the temperate zones were habitable. The far north and the equatorial zones were held to be frozen and burning, respectively. Discoveries by explorers such as Martin Frobisher in his late-16th-century voyages to Canada's Baffin Island, which revealed that northern reaches were not completely frozen over and uninhabitable set the ancient classical wisdom on edge, and in turn placed emphasis on more modern thought, and potentially, experience (Kupperman 1982).

The mechanisms that brought about the contradictory climatic evidence remained unknown, however. Kupperman (1982) noted that from early on in the colonization effort "even the proponents of experience over inherited wisdom were not clear how reason from experience alone or about how hypotheses should be tested." George Best in 1578 amended the ancient model such that it was not only the angle of the sun that determined climate, but also the duration of the day. He concluded from this approach that icebergs in the vicinity of Newfoundland were not indications of local cold, but rather indications of summer warming in northern regions, and that the icebergs had been detached through melting in the summer sun (Kupperman 1982). The icebergs in Newfoundland, therefore, caused the cold, and were not the result of it. This idea is not completely wrong, since sea ice can change local terrestrial climates. But larger global trends were also at work; the amount of sea ice in the North Atlantic in the early colonization period was much larger than has been observed during the modern warm period, due to the temperature fluctuations and downturns of the Little Ice Age (Kupperman 1982). The point for archaeological analysis of limitational knowledge and landscape learning is that colonists are likely to approach colonization differently if neighborhood ice is seen as an indication of warmth rather than cold.

The disconnect between the expected climate and the climate encountered may have been responsible for the apparent time gap between the development of some forms of limitational knowledge and adapted practice, and evidence of the updating of climatic social knowledge (Kupperman 1982). For instance, on the one hand there was relatively rapid adjustment of some agricultural products, such as the adoption of tobacco as a primary crop in Jamestown by the early 1610s (Noël Hume 1994; Blanton 2003). On the other hand there was great reluctance to accept North American climatic limitations with respect to the growing of crops, and promotion of tropical products continued into the 1630s (Kupperman 1982).

Some updating of social knowledge can be seen in documentary records by approximately 1625. For example, responsibility for climatic problems shifted from the country to the people (Kupperman 1982). Early views that North America could provide sustenance with little effort came to be seen as morally repulsive amongst the Puritans of New England, who began to put forth the idea that the New World had raw ingredients, but required honest sweat and labor to be fully realized (Kupperman 1982).

There were also changes in what the colonists were expected to send back to England to satisfy investors. These were not only practical adjustments, but were proposed as representing English morals: the Spanish might be content to gain gold and silver without effort, but Englishmen valued honest labor (Kupperman 1982). Recognition also came later of the seasonal appropriateness of expectations (for example, it is not possible to grow wheat in January in England, but that does not mean one cannot grow wheat in England), and that simply put, as in England there were some parts of the New World more desirable than others (Kupperman 1982).

The effects of these changes on social knowledge were such that original climatic expectations were displaced or postponed, rather than revised entirely. In particular, ideas were put forth that the interior of the North American continent would be better than the coastal regions. Proposals were also made suggesting that increased cultivation would get rid of mosquitoes (Kupperman 1982) and generally improve the climate: clearing forests would raise temperatures, as would the collective heat from the fires of towns and cities (Kupperman 1982). This concept of improvement through civilization and the direction of environmental hopes and expectations westward was the seed of American frontier thought that continued and expanded through the major westward emigrations of the 18th and 19th centuries (Limerick 1987; Worster 1991; White 1994), and which can be seen as characterizing significant portions of the Western outlook on natural resources to the present day (Nash 1983; Rockman 2003a). In this regard, writers at the time were noting that their limitational knowledge was not yet complete, as the full potential range of the North American climate was not yet known.

Conclusions

How does all of this relate to the practice of environmental archaeology? What does the example of Jamestown and the early historical colonization of North America contribute to our understanding of limitational knowledge and the landscape learning process, and vice versa?

One final example addresses these questions. Dennis Blanton (2003) proposed a three-part sequence of archaeological correlates for landscape learning in colonial Virginia. The periods he defined on the basis of their material characteristics and place in the landscape learning curve include: (1) Exploration and Hardship (1607–1618), with correlates such as nucleated fortified settlements, military gear, impermanent architecture, and anomalous subsistence evidence; (2) Initial Expansion (1618–1680), with correlates such as agricultural success, introduced plants and animals, and environmental degradation and impact; and (3) Emergent Chesapeake Society (1680–1750), with correlates such as unique architectural styles, subsistence, and forms of landscape modification, as well as additional environmental degradation. Review of the historical data compiled and analyzed by Kupperman (1982) indicates that the struggle to fit new climatic evidence to the old paradigm continued into the 1650s. This was nearly 80 years after initial British encounters with North America, particularly northern North America, and important with respect to comparison with Blanton's model, with few internal divisions. Climatic reports throughout the Exploration and Hardship period and first half of the Initial Expansion period continued to flip-flop between assessment of climatic experience and reference to the previously established climate-by-latitude models. This disparity illustrates that there can be disconnects between material traces and practice, and widely held ideas in the broader social context.

In summary, this review demonstrates that there were real time gaps between contact with unfamiliar environments and adjustment of both practices and thought to those environments. Further, there appear to have been time gaps between changes in practice and the social context that acknowledged, accepted, and supported those practical changes. Current paleoenvironmental techniques, such as tree-ring analysis that identified the Jamestown drought (Stahle et al. 1985; Stahle et al. 1998), have the ability to identify and quantify past environmental variability. There is not, however, a one-to-one correlation between environmental change and concurrent or subsequent social change. Social response to environmental difference is complex, and sufficient responses may require changes in many lifeways and activities that at first glance are not directly related to the environment at hand. Conversely, some of the most profound social adaptations may be linked to material traces only at a general level, such as the realization that the climate of coastal North America was different from that of Europe and that hard work would be required to settle in it.

The modern age has its own climatic irony—available evidence indicates that indeed, settlement and development have the capacity to change the North American climate. The next steps for research in climatic knowledge are to examine the development of climate perspectives in more recent, post-colonial times. For instance, have populations overcome or updated previous expectations of stability and predictability in the climate? Examples of the stress experienced by the Native Americans at the end of the 16th century and in the early 17th show that even longtime residents can be severely stressed by climatic variability. The extent to which long-term climatic adaptation is possible is another topic worthy of greater consideration. Examples given here, addressing how people considered and responded to climate and climate change in the early historical period, show that how societies think about the weather can influence the form and expectations of colonization. This topic has important place in the environmental study of colonies and plantations.

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