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ASPECTS OF SOME PREHISTORIC CULTURES IN RELATION TO CLIMATE IN SOUTHWESTERN FINLAND

ABSTRACT

The cooling of the Finnish climate since 2800 BC after the Holocene optimum may have caused the retreat southwestwards of the Corded Ware and subsequent west-Finnish cultures, so that 3000 years later their settlement was to be found only on the southwestern coast. Indications of the cooling main of winters in just this period are given by the study of lake sediments cited and by the movement of the limit of occurrence of spruce. At each stage of retreat, the 'cold limit' of settlement lay along the isopleths of the duration of permanent snow cover in the present climate. The problem for those cultures was the collecting of winter hay fodder for cattle without metal tools. The retreat was slower at the beginning of the Bronze Age, perhaps due to the introduction of flint-edged sickles. Assuming that each limit of the settlement during the retreat corresponded to the change of climate that also continued during the Bronze Age, it was found that the mean winter temperature fell by 4 to 5 °C. This temperature fall in Finland involves a contribution caused by the appreciable decrease in the volume and mean depth of the Gulf of Finland and the Gulf of Bothnia due to land uplift.

Keywords: Ancient Fennoscandian cultures, Holocene climate, *Trapa natans*, spreading of Norway spruce, Litorina Sea and climate, traveling and climate

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INTRODUCTION

In this study, the archaeological evidence of the cultures in southern and western Finland from the beginning of the Corded Ware period to the late Roman Iron Age, and particularly their temporal and regional changes, are considered in connection with the estimated regional distribution and temporal changes of climate. Climate and its change are considered not only on the basis of the evidence of pollen, accumulation of matter on lake bottoms and bog morphology, but also as connected with the decrease in the volume and depth of the Gulf of Bothnia and the Gulf of Finland. Further, the regional features of climatic variables in the present climate were applied, because these features are rather conservative, being determined by geography. This means that the isopleths of these variables are conservative, albeit their labelled values change with changing climate. Further, there is ground to assume that the spatial distribution of each culture and its changes resemble the distribution of the climatic variable crucial for the culture considered. Particular attention is paid to the winter climate, for which new knowledge based on research of lake sediments is available. In order to overcome the inexactitude and consequent risks of false conclusions related to each kind of proxy data available, the problematics were handled from several different aspects to see in what way the results obtained by various methods mutually complemented each other.

INDICES OF CLIMATIC CHANGE FROM 3000 TO 1 BC IN FINLAND

Evidence of the change in the winter climate

In Nordic countries, pollen data bear evidence to the cooling of the climate after the climatic optimum in about 3000 BC, but these data refer mainly to the vegetation period. However, some proxy data indicating a warming of winters in northern areas is also available; each kind of such evidence is somewhat inexact and insecure, waiting for future progress of research. One kind of proxy data concerning the climate of Finland during the period considered, and, most importantly, observed particularly in Finland, is the accumulation of mineral matter (during winter) and organic matter (during summer) in the sediments of Lake Nautajärvi (61.8 ºN, 24.7 ºE). Ojala et al. (2003), analyzing this material, connected the variation in the accumulation of mineral matter to the variation in winter temperatures. They based this relationship on three assumptions: The accumulation of the mineral matter increases with the volume of spring flood, which in turn increases with the water equivalence of the snow cover; the correlation between the water equivalent of the snow cover and the mean winter temperature is negative.

Concerning the first assumption, I must rely on geological expertise. The second assumption is obvious, while the third assumption needs critical examination. In the present climate, the water equivalence of the snow cover in late winter in the regions around L. Nautajärvi explains only 5 to 10 % of the variation of the mean temperature in winter, while in south-western Finland it explains 25 to 30 % of it (Solantie & Drebs 2001). The accuracy of the geological evidence thus increases with the mean temperature of the winter, which, in the early part of the cooling period, was about the same at Nautajärvi as it is in south-western Finland at present. From the end of the cooling period onwards only major changes over long periods can be detected. According to the proxy data from L. Nautajärvi and the assumed relationship between accumulated material and climate, particularly mild winters prevailed during the period ca. 4000 to 3200 BC. A period of variable winter climate then followed till 2 300 BC. The temperatures in winter had minima around 3100 and 2500 BC, and very favourable maxima around 2800 and 2300 BC. After the latter maximum, the temperature fell rather steadily during the period 2300 BC to 500 BC. After a short, slightly milder, period (its existence is less secure than that of the two earlier), the lowest point for winter temperatures was attained around 100 BC. In summer, a climatic optimum was observed around 4000 BC, and minimum around 300 BC. Thereafter, summers got warmer till a secondary maximum around AD 400 to 600, followed by a rapid cooling. This kind of conclusion is, however, not without risk because the properties of clastic-organic varves in Fennoscandia reflect the annual flux of mineral matter to the sedimentary basins via a multitude of interacting factors (Ojala et al. 2003).

The history of the spread of Norway spruce (*Picea abies (L.) Karst.*) to Finland and adjacent regions on the basis of pollen analysis (Tolonen & Ruuhijärvi 1976; Giesecke & Bennet 2004) carries indications of changes in winter climate because this is doubtless a crucial factor for the actual western limit of this species. Solantie (1983, 1991) concluded, on the basis of the spread of Norway spruce as given by Tolonen and Ruuhijärvi (1976), that the mean January temperature fell by about 5 °C between 3000 BC and 1 BC. The climatic western limit of Norway spruce can be given in terms of climatic variables (Lähde et al. 1996) as

$$T(Jan) = 1 – 0.19 \times A$$

where T(Jan) = the January mean temperature (°C) and A = the annual temperature amplitude (°C) as the difference between the July and January mean temperatures. At the limit in western Norway A = 16 °C and T(Jan) = –2 °C while at the Vistula A = 21.5 °C and T(Jan) = –3 °C, respectively. The limit corresponds well to the limit of the region of regular permanent snow cover. This is in accordance with the ecological demands of Norway spruce. Norway spruce needs amply winter frosts to fall into dormancy, in order to avoid excess respiration in winter. Its radial growth in Fennoscandia is negatively correlated with the NAO (North-Atlantic oscillation) index (Mäkinen et al. 2003) (a high NAO-index indicates strong prevailing south-westerly winds and mild winters). High soil moisture in early summer is also crucial for welfare and good growth for Norway spruce, and this demand is met best by release of snow melt water. In Europe, the correlation between May and July precipitation and the radial growth of Norway spruce is clearly positive in regions with a rather mild climate, including high evapotranspiration and lack of snow melt water, slightly positive in average conditions but negative in the coldest regions of the occurrence of this species (Mäkinen et al. 2003). Even in southern Finland drought may cause damage to spruce (Mäkinen et al. 2001). Good vitality is important for spruce in competition with hardwoods, because in natural conditions it starts growing on open places later than hardwoods, pioneers that appear first but also shelter young spruces from frost damage in early summer. On the other hand, Norway spruce has a particular advantageous feedback effect on climate just in the regions of regular permanent snow cover: during the snow melt period, snow reflects most of the global radiation back to sky, but a spruce forest only about 20 % (Solantie 1988a). Thus, the appearance of Norway spruce appreciably raises temperatures in early spring and hastens the onset of the thermal growing season.

Looking at the map by Giesecke & Bennet (2004) of the settling date of spruce with a critical pollen frequency of 5 % of the total pollen, we recognize that during the summit of the climatic optimum, 5000 to 3000 BC, the western limit of Norway spruce from Byelorussia through the easternmost corner of Finland to the southwestern coast of White Sea proceeded westwards appreciably slower than before or after. In western Byelorussia and the Baltic countries, the movement of the limit practically ceased, while farther north it still moved somewhat westwards during the climatic optimum. This fact indicates that climate was a hindrance to the further spreading of Norway spruce in the southern segment of the limit, while in the northern segment Norway spruce had not reached its climatic western limit; this is because its natural spreading speed in the north is rather low due to its rather long rotation period of generation. The stagnation or slow progress of the western limit for Norway spruce ended just after the climatic cooling of winters, according to the evidence of lake sediments, began, i.e. at the end of the period 4000 to 3000 BC. After that the limit moved rapidly: the Baltic countries were occupied by 2000 BC, Finland by 1000 BC and Sweden down to the 60th latitude by the time of the birth of Christ, with exception of the northern edge the boreal forest. With a high probability these facts indicate an appreciable hardening of winters during the period 3000 to 1 BC and the withdrawal of the –2 and –3 °C January isotherms towards west-southwest. In central and southern Finland, the 5 % isoline of spruce pollen proceeds gradually westwards in time with the cooling of climate, but in northern Finland the westward progress is lower, leading to an orientation of the 5 % isoline that is SW–NE, almost at right angles to the January isotherms. This may simply be caused by the fact that the rotation period of tree generation gets longer northwards, which reduces the speed of advance of the limit westwards. The fact that the volume of the water body in the Gulf of Bothnia during the considered period was appreciably greater than at present, while that of Baltic Proper was not, also explains this difference. If the spread of spruce westwards during the period 3000 to 1 BC is assumed correspond to the cooling of the winter climate, then the January mean temperature in western and southern Finland fell by about 4 to 5 °C and the annual amplitude by 5 to 6 °C.

Peat also bears evidence of the Holocene permafrost dynamics. Macrofossil evidence in the East-European Russian Arctic shows that permafrost appeared in some places in ca. 3000 to 2500 BC, and aggregated intensively from 1500 to 1000 BC, 500 to 1 BC, and from AD 1400 to 2000 (Kuhry et al. 2001); despite that climate there is more continental than in Finland, both areas are under the influence of the Northern Atlantic and experience the climatic trends in its vicinity. Therefore, it is not surprising that the results of Kuhry et al. (2001) broadly agree with those by Ojala et al (2003).

The decrease in the mean volume and depth of the Gulf of Bothnia and the Gulf of Finland with reference to climate

The fall in the mean temperature in winter during the period 2800 to 100 BC in Finland was contributed to by the fact that the volume and depth of the Gulf of Bothnia and the Gulf of Finland decreased appreciably during the period considered due to land uplift, totally independent of the general trend of mean temperature in winter in high latitudes. Let us examine this effect in detail. The amount of sensible heat included in any water body is proportional to the product of its volume and mean temperature, and the deeper the water body is, the later is the date of freezing-over. The changes in area and volume of the seas surrounding the Finnish peninsula, as calculated using the map of land uplift by Eronen (1974), have been significant indeed. The newer study on this subject by Vermeer et al. (1988) hardly effects these estimates of the changes in area and surface of these seas at all. The rate of land uplift during the 7000 last years has been slightly decreasing. The mean rate during the period from 3000 to 1 BC has been at least the same as the average during the 7000 years' period back from the present, i.e., 0.98 cm/year for the Gulf of Bothnia and 0.22 cm/year for the Gulf of Finland. In addition to the land uplift, the eustatic changes in the surface level of the world's seas must be also taken into account. According to Eronen (1974), this level increased by 18 m during the period 6500 to 4000 BC; since the latter time, the rate of rise of the mean sea level decreased with the level being at its highest 3300 to 2700 BC. Since then, the level has decreased at the small rate of 0.07 to 0.08 cm/year, i.e., by 3.5 m to the present time, of which 2.7 m occurred before 1 BC; this indicates global climatic cooling. Thus, due to the combined effect of land uplift and lowering of the world sea water level, the volumes of the Gulf of Finland and the Gulf of Bothnia decreased most rapidly during the period 3000 to 1 BC, the latter by 35 %. Even during the period from AD 1 to 2000, the Gulf of Bothnia has lost 16 % of its volume in 3000 BC (which means that in 3000 BC its volume was over twice as large as today). The relative decreases in the mean depth of the area under water at the end of the periods 3000 to 1 BC and AD 1 to 2000 are 30 % and 17 %, respectively. For the Archipelago Sea, the relative decreases are about the same, while for the Gulf of Finland they are somewhat smaller but in any case notable, for volume 20 % and 9 %, and for depth about 19 % and 8 %, respectively.

The huge decrease in the volume and mean depth of the sea areas surrounding the Finnish peninsula must have had a powerful effect on air temperature in both summer and winter. We may suppose that due to a successively more frequent freezing over of the seas and later break-up of their ice cover, the effect of the decreasing volume of the water body on air temperature was negative in spring, but due to the decreasing ability of the sea to restrain the temperature rise in early summer and its fall in late summer, the influence was indifferent in June, positive in July, indifferent in August and increasingly negative during autumn and winter. Due to this particular behavior of the Baltic Sea, the mean temperature in winter in Finland has most probably fallen obviously faster than on average in northern areas, and much faster than in summer. On the other hand, although the shore line has moved, the form of the Finnish peninsula, the relative height relief, the location of the Scandinavian peninsula and the Norwegian coast, as well as latitude, all of which determine the relative differences in winter temperatures and snow cover between regions, have remained practically or exactly the same. Therefore, the regional distribution of the duration of snow cover in Finland as observed at present, as well as its spatial and temporal changes as a function of mean temperature, can also be applied to earlier periods. Consequently, the circumstances nowadays attached to a certain isopleth of a climatic variable, corresponded in another time to another actual isopleth of this variable

Fossilized concentric raised bogs as indicators of the passing of the climatic optimum

In boreal northern Europe, there are a variety of regional bog formation types, each of them having developed under certain climatic conditions (Ruuhijärvi 1960; Eurola 1962). The inland area of southwestern Finland, at the western coast up to the 62nd latitude, is at present a region where climate favours the formation and existence of concentric raised bogs. The climatic feature creating such a morphology is the occurrence of a long period in early winter with a mean temperature between 0 and –5 °C and abundant precipitation during this period, which causes alternation between the freezing and melting of the snow and ice crust lying on the bog (Solantie 1986). North of the area where the present climate favors such bogs, there is however a region where raised bogs with an emphasized morphology of steep-edged and high hummocks and deep hollows prevail.

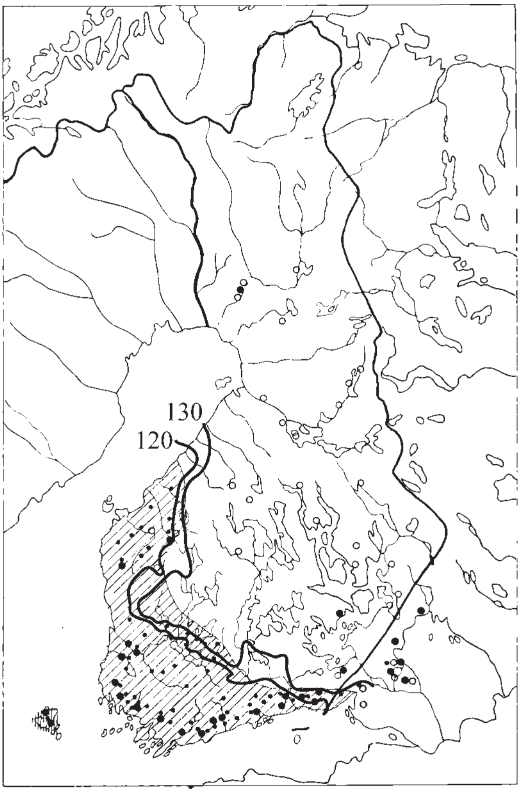

Fig. 1. The settlement in Finland of the Corded Ware culture (3200–2000 BC), denoted by small dots and diagonal ruling, according to Huurre (1995), shown with the mean duration of permanent snow cover in the present climate (days); the corresponding values in 2800 BC are about 50 days less.

This morphology, however, is at present fossilized without any changes in time. This region is located between the 62nd and 63rd parallels of latitudes, 20–70 km distant from the coast, where the terrain rises steeply inland; this triggers abundant orographical precipitation during onshore winds in autumn and winter. On the basis of the climatic change since the Holocene optimum, we note that favourable conditions for such development prevailed there in about 1000 BC, with a duration of vegetation period of 170 d and a December–March mean temperature of –5.5 ºC. Vegetation periods were somewhat cooler, but as long then as in inland areas of southwestern Finland at present. The mean winter temperature and the duration of the season with alternation between periods with increasing and melting snow covers, conditions favourable for the formation of raised bogs, were about the same as in south-western inland areas at present. Additionally, these highlands get abundant precipitation due to the uplift of air moistened by the open sea just west of the region. The conditions in this region around 1000 BC were thus ideal for an effective development for hummocks and hollows.

SETTLEMENT OBEYING CLIMATE

The retreat of the Corded Ware and subsequent western cultures in Finland in relation to their main livelihoods and the cooling of the climate

According to Huurre (1995), people of the Corded Ware culture, having small livestock, i.e., sheep, pigs and goats, arrived in Finland in about 3200 BC, and their settlement occupied wide regions of southern and western Finland during the period 2500 to 2000 BC, in coastal regions as far north as to the 64th latitude. Thereafter, this settlement withdrew to the coastal areas, obviously due to worsening climate. Move Huurre's dating 200 years earlier, and it fits well the proxy data on climate by Ojala et al. (2003). During this retreat, the Corded Ware culture became melded with the late Comb Ware foraging culture. This resulted in the Kiukainen culture (e.g. Huurre 1995). There is various archaeological evidence for the ways in which the Corded Ware people reacted and adapted to the deterioration in the climate. They adopted foraging as a more important part of the livelihood, while, on the other hand, Comb Ware people may have learned from the Corded Ware people more effective methods of hunting wild boars. The Kiukainen culture lasted from 2400 to 1200 BC (Huurre 1995); on the basis of the climatic proxy, the timing of the period is perhaps somewhat earlier. During the Bronze Age, this culture continued in these coastal regions. Already during the Kiukainen period, and even more so during the Bronze Age, contacts with Estonia and particularly to Sweden intensified even so that Finnish artefacts appeared there, indicating settlement and contacts overseas towards the southwest and south. During the Pre-Roman Iron Age, too, the coastal settlement declined, attaining its minimum around the Early

Roman Iron Age. Note that there was also coastal settlement north of the 64th latitude; this settlement is treated in the next section.

The outer limit of the settlement of the Corded Ware people was perhaps determined by the impact of winter climate (Solantie 1991). Archaeological remains**,** as well as the choice of dwelling sites, show that animal husbandry was their most important source of nutrition. Considering that they did not have any metals available, the gathering of hay fodder for long winter periods was too troublesome. On the other hand, leaf fodder was easier to collect manually. The availability of winter fodder was not the only significant factor for the viability of the households of Corded Ware people. Wild boar, that obviously constituted an important part of their nourishment, suffers seriously from snow-covers that are thick and of long duration. The mean temperature of winter during the climatic optimum was about 4 to 5 °C higher than at present (Solantie 1983, 1991); in southwestern Finland the climate during the climatic optimum (4000 to 3200 and around 2800 BC) was about the same as that prevailing in southwestern Sweden nowadays. Considering the high specific heat of water, the month of July was probably not warmer than at present, while the thermal vegetation period was appreciably longer. By 100 BC the mean winter temperature had fallen to about the present level.

Snow cover was obviously a crucial climatic factor. Let us introduce the concept of ‘permanent snow cover’ which here means the snow cover having the longest duration during each winter, and denote this duration by D. In the present climate, the location of the average 130 days’ isopleth of D (Solantie et al. 1996) matches fairly well the outer limit of the widest occurrence of Corded Ware settlements (Fig. 1); out of the 59 artefact sites, 51 are found in regions where D = 120 d, 6 in a narrow frontier belt where 121 = D = 130 days, and only 2 where 131 = D = 140 days. At the 130 days’ isopleth, the snow cover lasts longer than half a year on average once in three decades. We may note that, after its peak in coverage, the west Finnish settlement retreated towards southwest in such a way that the limit of the settlement was continuously situated along one of the isopleths of D of the present-day climate. This can be seen from a comparison of maps for the settlements of subsequent cultural periods

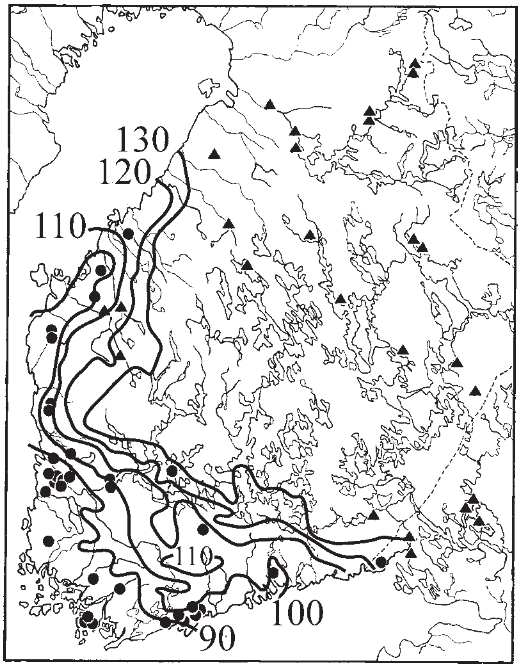

Fig. 2. The settlement in Finland of the Kiukainen culture 2400–1200 BC, denoted by circles, according to Salo (2003), shown with the mean duration of permanent snow cover in the present climate (days). The corresponding values in 2600 BC were about 45 days less than and 1400 BC about 25 days less than these. Triangles denote artefacts of asbestos ceramics hunting-fishing Pöljä group.

and those of D. The settlement area occupied by each culture corresponds to its distribution at the beginning of the given period, and its limit the line to which the settlement had retreated during the previous cultural period. Let us first consider the settlement of the Kiukainen culture (2200–1000 BC), brought about by the coalescence of the Corded and Comb Ware cultures (Fig. 2). Of the 34 dwelling sites found (Salo 2003), 30 are situated in regions where D = 100 days in the presently climate (Fig. 2); of these, 17 are found in regions where 91 = D = 100 days. Only 3 of the dwelling sites are located in regions where 101 = D = 120 days, and only one in the regions where 121 = D = 130 days. Of the 61 artefact finds of coastal western Bronze Age culture during the period 1500 to 500 BC (Salo 2003), 44 are located in regions where D = 90 days in the present

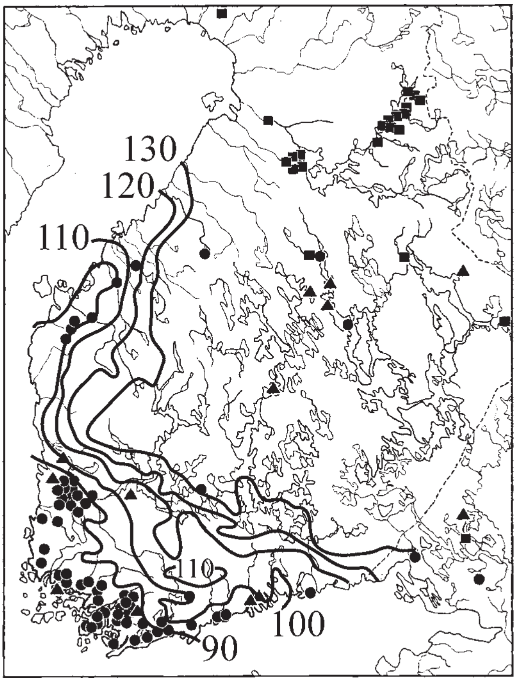

Fig. 3. The artefact finds of the western Bronze Age culture (1500–500 BC), denoted by circles, according to Salo (2003), shown with the mean duration of permanent snow cover in the present climate (days). The corresponding values in 1500 BC were about 25 days less, and those in 500 BC about 10 days less. Triangles denote eastern-type Bronze artefacts and squares their casting moulds.

climate, 10 in regions where 91 = D = 100 days, and only 7 in regions where D > 100 days (Fig. 3). The area of numerous Bronze Age cairns (Salo 2003) consists of a coastal belt extending inland in the southwest to about the D = 90 d isopleth, and elsewhere to the D = 100 d isopleth. During the Pre-Roman Iron Age 500 BC to AD 50 (Fig. 4), 27 of the 28 dwelling sites of the Morby culture (Salo 2003) are situated in a region where D = 90 days and only one site in the region where D ~ 95 days. Finally, during the Early Roman Iron Age AD 50 to 200, there were only 22 dwelling sites (Kivikoski 1961), of which as many as 16 were situated in an area where D = 80 days. Thus, most of the people had withdrawn to the southwestern coast. Only one exception is revealed by the latest archaeological research. In conclusion, the values of D, corresponding to the outer limit of the west-Finnish settlement (7/8 of sites), was during the period 3200 to 2800 BC 125 days, between 2200 and 1500 BC 100 days, in 500 BC 90 days and finally, during the period AD 1 to 200 85 days.

A fall in the mean winter temperature of 4 to 5 °C during the period 3000 to 1 BC close to the present level occurred at an average rate of ca. 0.15 °C per century. This cooling causes, on the basis of Finnish climate at present, an increase in D of 60 days. This, in turn, corresponds to the withdrawal of settlement with its outer limit in unchanged climatic conditions. Assuming that at the end of the cooling period the duration of permanent snow cover and its temporal variation were equal to those at present, it can be found that the outer limit of the Corded ware culture were about 60 days during average winters, and 110 days or more only once in 30 years.

Note that there are indications that the retreat of the settlements slowed down during the Bronze Age for 1000 years. The introduction of flint-edged sickles (Huurre 1995), which made it possible to collect hay for winter fodder, may have contributed to this stagnation. The start of the second period of retreat occurred contemporarily with a stage of abrupt cooling in European climate in about 700 to 600 BC, according to palaeological and archaeological indicators in various regions of Europe (Van Geel et al. 1996). During the two periods on each side of the Bronze Age, well over 2000 years in total duration, the values of D at the outer limit of the settlements decreased on average by 20 days per 1000 years; during the first one of somewhat less than 1000 years the decrease in D was 25 days while during the latter age of 1500 years it was only 15 days. The decreasing rate of retreat may have been caused either by a decrease in the rate of cooling of winters or by the increasing efficiency of fodder harvesting caused by the further replacement of flint-edged sickles by iron-edged. In any case, applying the average decrease rate of D to the Bronze Age, the total decrease in D over the three thousand years considered was in excess of 60 days.

Considering that the climatic change during periods of a few generations was not significant enough to trigger radical changes in livelihoods, the main reaction to such a creeping hardening of the winters was, however, to abandon the outermost posts of settlement without noting the basic reason causing their slow retreat. This retreat to the coast and later settlement in Sweden, which brought about increasing relations and traveling in both directions over the Archipelago and the Åland Sea, as well as fishing and hunting seals at sea, enhanced the role of the sea in culture, and made people constantly aware of the water, watching the weather and the state of the sea. This may also give a natural explanation for the new way to bury their dead in high burial cairns on elevated rocks with views of the open sea.

Coastal settlement north of the 64th latitude in relation to the winter climate

Going northwards across the 64th latitude along the coast of the Gulf of Bothnia on both sides, the population of the Corded Ware culture changed to another that occupied the coasts all around the northern end of the Bay. The area occupied by these people and its variation in time has been recently studied thoroughly by Okkonen (2003) mainly on the basis of cairns and their situation with respect to the coast. The evidence of this culture consists of sites containing dwelling depressions and cairns, large rectangular enclosures (Giants' Churches) and sites with many kinds of stone structures. Living on the shore, they were accordingly devoted to fishing and seal hunting, as bone remains prove. Considering that the skull of a Greenland seal was found there (Huurre 1995), this was probably the last haven of this species. The dwelling sites were moved with the movement of the shoreline. Most people lived on convex segments of the shoreline. The dwelling places were most numerous and continuous along the shore during the period 2500 to 2000 BC. After that, the number of dwellings declined, and finally vanished around AD 500. However, a secondary maximum occurred during the period 1000 to 500 BC. The decline of this population may also be caused by the cooling of the winter climate. The particular factor in this case is the annual duration of the sea ice cover in coastal waters. During the climatic optimum, the shores were free of ice during most of the winters, with the exception of shallow or concave segments. This enabled open-water fishing practically the whole year around. With the increasing occurrence of hard winters, the main livelihood met increasing difficulties. Already during the Bronze Age, the continuous line of dwelling sites ended at latitude 64.5 ºN latitude. This is noteworthy, because just north of this latitude the distance from the shore to deep waters (deeper than 80 m) increases rapidly with increasing latitude.

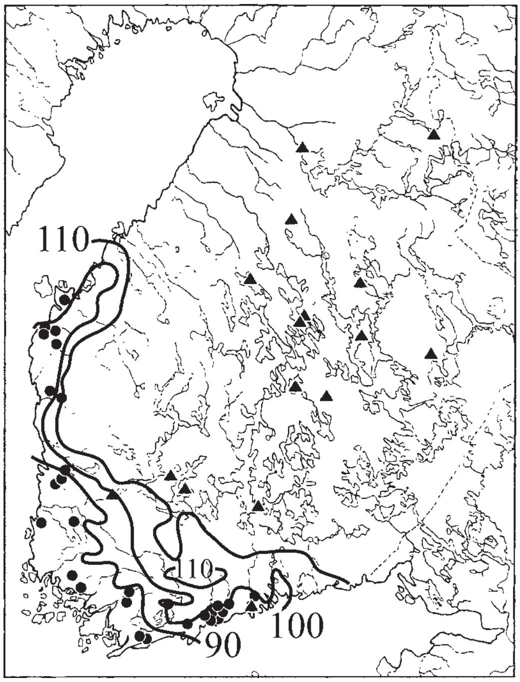

Fig. 3. The artefact finds of the western Bronze Age culture (1500–500 BC), denoted by circles, according to Salo (2003), shown with the mean duration of permanent snow cover in the present climate (days). The corresponding values in 1500 BC were about 25 days less, and those in 500 BC about 10 days less. Triangles denote eastern-type Bronze artefacts and squares their casting moulds.

Traveling and transportation in relation to remains and climate

Finds of the means of transportation tell us something about climatic conditions during their use. Let us study the structure of the wooden runners of the so-called central-grooved type found in bog peat and dated from the period from 3100 to 2500 BC, i.e., during the Corded Ware and late

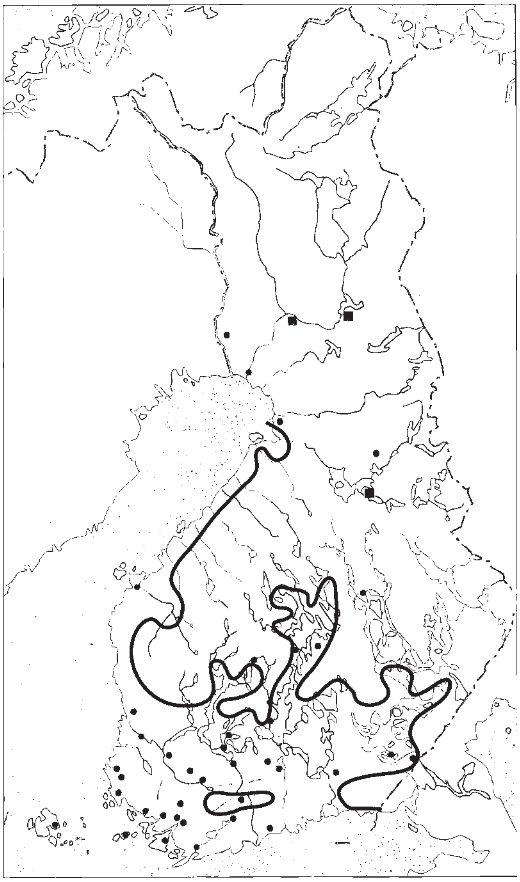

Fig. 5. Detected sites of crop cultivation before the birth of Christ as collected by Huurre (1995) shown with of a climatic limit at which the combined risk for crops failure for arable rye due both to summer frosts and failed wintering is 25 % (Solantie 1988b).

Comb Ware cultures, as described and reconstructed by Kuokkanen (2000). In Finland, four finds exist having sledge runners with clear-cut, deep, and vertical holes where stout posts could be firmly fastened. These runners are obviously for twin-runner sledges and rather broad, suitable for moving in deep snow. These runners were found only in regions where the permanent snow cover at the present time is 130 days or more (during the period of their use, 70 days or more). On the other hand, other types of runners have been found, having more holes for lashing than for posts; additionally, the post-holes are sloping, and often so shallow that the firm fixing of posts would not be possible. Kopisto (1964) proposed that such a structure is meant for a single-runner sledge. Following this idea, Kuokkanen (2000) constructed and experimented with such a sledge. The difficulty was that, due to the lack of a cross-beam in the rear on which to stand, the driver must walk, and the draught animals could not proceed faster than the driver. Further, another severe problem arose in the experiments: how to keep such a single-runner sledge upright when loaded. This unwieldiness is strange, indeed. Note also that the fore part of the runners had recesses, suitable for gripping by hand. Additionally, the end part of one runner became curved while drying. Finally, such runners are found all over Finland, also in western and southern Finland where the snow cover was thin and irregular. These facts tempt us to suggest that these runners are not for a sledge but are single thills having their front parts off the ground while the rear trailed on the ground; the load was firmly bound with lashes to one or two such poles fastened to each other; this is accordance with the fact that, according to Kuokkanen (2000), some boards, about 50 cm in length and with a pair of holes at both ends, were found next to the runners. A single-runner construction could proceed in thick vegetation, while a two-pole system prevented the load from swinging, if needed; note that a load bound to one pole, can hang down without touching the ground or getting torn or broken. The grooves on the poles were not only needed to make the hole-making easier, but they also added friction on the upper side of the pole, hindering the sliding of the load. In a terrain with thin snow cover or none at all, such so-called travois sleds, were practical. First, they had only small area touching ground and causing friction. Secondly, the rear slid easily over stones and roots. Thirdly, a narrow load could pass easily through vegetation without catching or tearing. In this case, too, mires were easier to proceed through than forests.

The fact that both types were found in regions of good snow conditions, but the latter type all over the country, indicates the use of the latter for transportation also in summer. The general note by Kuokkanen (2000) that the former type got more common with time is also accordance with the temporal expansion of good snow conditions. In Finland, not only were snow conditions important for transportation in winter, but ice conditions on lakes were too. *In conditions of winters 4 to 5 °C warmer than at present, transportation over lake ice in southern and western Finland would be far more problematic than in present conditions* because the duration of the period with a dangerous ice cover somewhere along the route is then much longer. In such a winter climate, the period in which it would be impossible both for either boat or sledge/travois transportation, would be several months long, in mild winters for the whole season. Thus, *as winters got colder, winter transportation got more popular and important; this appreciably changed conditions for the commercial use of furs.* Even later on, deep and wide lakes in the Southern Finland remained dangerous long into winter. Rows of small lakes were therefore preferred. Dangerous, deep waters were preferably avoided. As a warning, such lakes were named informatively, like lake Kuolimo, meaning a place of death, at the end of a long safe route.

Climate as a critical factor for agriculture as a main livelihood during the prehistorical era in Finland

During the deterioration of climate lasting 2500 years no attempt was made to begin agriculture in Boreal northern Europe (e.g. Moberg 1966). However, the climate around the time of the birth of Christ, also prevailing at present, was not too severe for crop cultivation as a main livelihood. In fact, as compiled by Huurre (1995) and shown in Fig. 5, sites of crop cultivation predating the birth of Christ have been found; these sites were in connection with a climatic limit for which the combined risk for crops failure for arable rye both due to summer frosts and failed wintering is 25 % (Solantie 1988b). As many as 35 of the 39 cultivation sites found are situated south of or on this climatic limit. This fact proves that the limit of cultivation, practiced with a tolerable total risk of crops failure, was found through trial and error. The tolerable risk, however, was still rather great, showing that the cultivation of crops was only a very secondary livelihood till the end of the early Roman Iron Age. Note also that crops were cultivated in this way both by the coastal population and the Luukonsaari people inland.

Iron tool production made basic improvements in the technology of agriculture possible, albeit in the Nemoral Zone agriculture as the main livelihood was already practiced during the Bronze Age (e.g. Zvelebil 1985). In my opinion, agriculture as the main livelihood was not possible in Finnish winter conditions before iron tools were available, even though winters were milder than today. Stone axes were naturally less effective than those of metal. The problem with bronze axes as the most important tool was not so much the quality of the material; the experiments with bronze axes made by Kuokkanen (pers. comm.) proved that the felling of trees was rather efficient and easy. The difficulty was that bronze was only available as an imported material, while iron ore could be found, and the metal could be separated, by almost any local craftsman (e.g. Huurre 1995; Kuokkanen, pers. comm.). In the reclamation of clearings to be sown, fire and axes were the main means, but the felling of trees with metal-edged axes was less troublesome than with stone-edged. Crops cultivation not only demanded sickles for harvesting, but additionally, scythes for harvesting hay as winter fodder for cattle; cattle were necessary for manure production. *The collecting of hay for winter fodder and the keeping cattle inside were not necessary in the Nemoral climate, where grazing was possible almost throughout the year, but in the Boreal zone these were indeed essential.* Note that in the lowlands of Central Sweden agriculture as the main livelihood became established as early as 1800–1300 BC (Zvelebil & Rowley Conwy 1986), but this region still had a Nemoral climate and green grass throughout the year well into the period of cooling. *The need for nutrition determined the number of cows, and the number of cows and the duration of winter determined the area needed to supply cattle with fodder to keep them alive till spring.* To maintain such a system under Finnish climatic conditions, treble the area of cultivated fields were needed as hay fields for winter fodder (Soininen 1974). That alone is not enough to keep cattle alive over the winter: *A cow shed was also necessary, for which timber was needed. For these reasons, crop cultivation before the Iron Age could only be of secondary importance.* This also holds for the Pre-Roman and Early Roman Iron Ages, because agriculture as the main livelihood not only demanded iron sickles and scythes, but also a great combination of tasks to be carried out at the right time and in optimal amounts as described above.

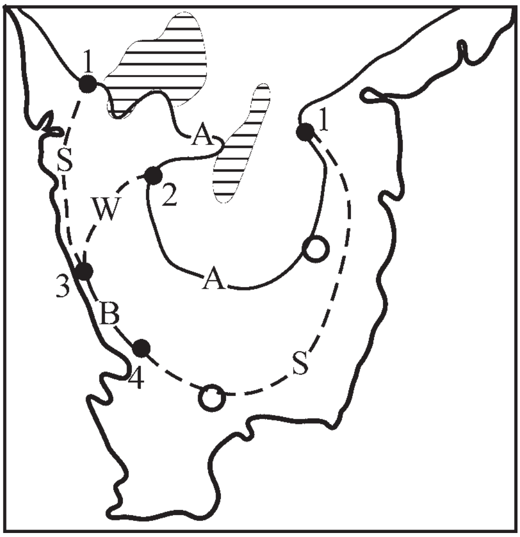

Fig. 6. The present-Swedish counterparts of the climatic limits in Finland in 2800 BC. On the solid line labelled A the mean temperature of the period December–May (1961–1990) is –2.3 ºC while on line B it is –0.5 ºC. The segment of B between 3 and 4 represents the climate on the south-western coast of Finland, while the segments on A between 1 and 2 represent the climate at the outermost inland limit of the Corded Ware settlement. The segments S on the broken lines between 1 and 3, and 1 and 4, represent the climate on the southern coast, while the segment W between 3 and 2 represents the climate on the western coast.

Considering that agriculture as the main livelihood was imported from regions where winter is shorter than in Finland, the threshold for relying on agriculture as a livelihood in more difficult conditions than in those in the region of origin was high. It thus took a lot of time and many discouraging failures before new settlers, who had originally been used to agriculture as their main livelihood could make it work properly in Finland. They were compelled to develop their practices into those suitable for Finnish conditions if they really wanted adopt agriculture as their main source of livelihood (in any case, supported too by fishing and hunting). At last, during the Late Roman Iron Age, the agricultural settlement began to succeed. *The agricultural settlement occupied new regions, but only those where the risk of crop failure in combined cultivation was tolerable. With agriculture as the main livelihood, the tolerable risk of crop failure must be brought appreciably lower than in secondary cultivation. For these reasons, the agricultural settlements in the Late Roman Iron Age period redistributed themselves regionally in a new way that can be precisely explained by the climatic conditions for cultivation* (Solantie 1988b).

In the ‘new climate’, winter conditions were appreciably easier for travel and transport than before, and new excellent continuous routes became available. Former troubles and dangers met along traveling routes in winter, including continuous temporal and spatial variation between firm ice, breaking ice and open water, had became appreciably fewer. This fact allured people to increase hunting of fur animals that also grew denser furs than before due to harder winters. The commercial utilization of wilderness became thus an important subsidiary livelihood for the population of the agricultural settlements till the end of the Middle Ages. People living outside of the agricultural settlements continued to maintain crops growing as a secondary business only till root rye was introduced. This new variety of rye, demanding unfrozen ground under snow cover, made agriculture possible as main livelihood in regions where agricultural settlement was avoided due to damage for rye caused by snow mold fungi; this variety came from Carelia around the 11th century; it came there possibly from the Black Sea region along the western side of the middle Russian highlands where snow and soil frost conditions are much alike to those in southeastern Finland (Solantie 1998).

RECONSTRUCTION OF THE MAIN FEATURES OF THE THERMAL CLIMATE IN 2800 BC IN FINLAND AND THE PRESENT COUNTERPARTS OF SUCH A CLIMATE IN ADJACENT REGIONS

Let us relocate the supposed climate, as it was during the climate optimum in Finland, in present-day northern Europe. The climatic conditions supposed to exist at outer limit of the Corded Ware culture during it greatest extent (limit A), involving a January mean temperature of about –3.5 to –4.0 °C, and annual temperature amplitudes from 18 °C (northwest) to 19 °C

	Annual temperature amplitude (°C)	Sum of effective temperature (°Cd)	Duration of the vegetation period (d)	Mean temperature June to August (°C)	Mean temperature December to March (°C)
Limit A in 2800 BC	18.2	1227	188	14.3	-2.2
Limit A 1961–1990	24.6	1123	162	14.5	-6.9
Limit B in 2800 BC	17.5	1478	207	15.3	-0.5
Limit B 1961–1990	22.7	1300	178	15.4	-4.6

Table 1. Comparison between average climatic variables in 2800 BC and at present at the outer limit of the Corded Ware settlement (limit A) and on the Finnish southwestern coast (limit B). The actual accuracy of the values is less than the numerical values imply.

(southeast), and just about tolerable for spruce, are found at present at the edge of the Småland highlands of Sweden. The climate on the southwestern coast of Finland during the climate optimum (Limit B), involving January mean temperatures of about –2 °C, and annual temperature amplitudes of about 17.5 °C, just west of the climatic spruce area, are respectively found correspondingly in Halland. In those regions, in the vicinity of open waters in winter, the impact of the sea on climate is at present greater than nowadays in Finland, but about the same as during the climatic optimum.

The average conditions at both limits in 2800 BC and on average during the period 1961–1990 (Climatological statistics in Finland 1961–1990; Temperaturen and nederbörden i Sverige 1961–1990) at these limits were approximated as follows.

Limit A at present: Approximated by the means of values at Valkeala (60.9 ºN, 26.9 ºE, 99 m a.s.l.), Pälkäne (61.3 ºN, 24.2 ºE, 103 m a.s.l.), Lammi Vestola (61.1 ºN, 25.2 ºE, 147 m a.s.l.), Kankaanpää (61.9 ºN, 22.5 ºE, 134 m a.s.l.,), Kauhava (63.1 ºN, 23.0 ºE, 42 m a.s.l.), and Alajärvi (63.1 ºN, 24.3 ºE, 171 m a.s.l.).

Limit A in 2800 BC, approximated by values at Gislaved (57.3 ºN, 13.5 ºE, 165 m a.s.l.)
Limit B at present: Approximated by values at Piikkiö (60.4 ºN, 22.5 ºE, 6 m a.s.l.)
Limit A in 2800 BC, approximated by values at Jonstorp (56.9 ºN, 12.6 ºE, 25 m a.s.l.).
The values for the various climatic variables are given in Table 1.

According to this approximation, the annual temperature amplitude in 2800 BC (considering monthly means) was about 6 ºC smaller. The vegetation period was four weeks longer while summers were equally warm or even slightly cooler than at present because the impact of the sea was greater. The effective temperature sum at limit A was 100 ºC d higher, at limit B 150 to 200 ºC d higher. The difference in the latter comparison is greater because in the vicinity of the sea the period with a mean temperature between 10 and 5 ºC is appreciably longer than inland. Note that at limit A the values are averaged along the limiting line, along which the vegetational period gets cooler and shorter northwestwards and warmer and longer southeastwards. For example, Vimmerby (57.7 ºN, 15.8 ºE, 110 m a.s.l.) at the eastern edge of Småland with values of 19.4 ºC, 1357 ºC d, 191 d, 15.3 ºC, and –2.2 ºC, respectively, serves as an example of the climate in the southeastern corner of Finland at limit A in 2800 BC, while those at Tinghalla (58.0 ºN, 13.8 ºE, 278 m a.s.l.), i.e., 18.4 ºC, 1144 ºC d, 181 d, 14.0 ºC, and –2.4 ºC, respectively, apply to the north-western end of limit A in 2800 BC. The present Swedish climatic counterparts of limits A and B, and at the coasts between their ends, are given in Fig. 6.

THE REGIONAL DISTRIBUTION OF WATER

CHESTNUT (*TRAPA NATANS*) DURING THE CLIMATIC OPTIMUM AND RECENTLY, IN RELATION TO THE CORDED WARE CULTURE AND CLIMATE

Interesting evidence of the climate in Finland 5000 years ago is furnished by finds of water chestnut (*Trapa natans*), and its occurrence in Scandinavia during the 18th and 19th centuries. The water chestnut grows in lakes. It was used for nutrition by people in Fennoscandia during the climatic optimum. People may have moved water chestnut to lakes close to their dwelling sites, but in any case the climate in those regions must have been advantageous enough for producing nuts. Therefore, the fact that the northern limit of the occurrence of this species has later retreated appreciably, is good evidence for a hardening of the climate. A map of chestnut finds has been created by the Naturhistoriska riksmuseet, Stockholm, available at http://linnaeus.nrm.se/flora. On this map, 21 out of the 23 finds from the post-glacial period in Finland are situated in the region of the widest distribution of Corded Ware people, up to Evijärvi in the north (Valovirta 1960), while the remaining two are quite close to the limit of the settlements. The northernmost growing sites of *Trapa natans* in the last three centuries in Sweden are given by Lindman (1917–1926). In the 20th century, it last occurred in 1913 in Lake Immeln (56.2 ºN, 14.2 ºE, 81 m a.s.l.) where the December–March mean temperature (1961–1990) is –1.0 ºC, but during the 18th century botanists reported on occurrences farther north, the farthest being in lake Kaksmala (57.4 ºN, 15.8 ºE, 90 m a.s.l.) where the corresponding mean temperature is –2.0 ºC and, according to Linné (1745) in Lake Hökesjö (57.4 ºN, 15.5 ºE, about 170 m a.s.l.) where the corresponding mean temperature is –2.2 ºC, i.e., exactly the same as that of Gislaved in Table 1. As the water chestnut is an annual plant that renews itself by growing a stem in spring from a chestnut that sunk to the bottom in the previous autumn, the crucial factor for its survival is obviously that the effective temperature sum of the lake water is high enough. In this respect, the timing of the break-up of ice is crucial. Thus, the frost sum during the winter is crucial, as well. For the two northernmost populations of *Trapa natans*, the particularly hard and long winter of 1808–1809, experiencing probably the longest ice-cover period in southern Sweden since 1722, on the basis of temperature observations at Uppsala, was perhaps fateful. On the other hand, the reason for its disappearance from Lake Immeln was excessive collection. Note also that *Trapa natans* still occurs in three lakes in Latvia between latitudes 56.5 ºN to 56.7 ºN (Iveta Zvagina, pers. comm.), which proves that this species may survive somewhat longer ice-cover periods than at Hökesjö and Kaksmala if that disadvantage is compensated by slightly warmer summers.

We may further note that the forest vegetation in 2800 BC, according to the present counterparts in Sweden, at the limit B was temperate on the edge of hemiboreal, while at present it is hemiboreal on the edge of boreal (Ahti et al. 1968, Tuhkanen 1984). The climate on the southwestern coast of Finland then was even suitable for beech, although it could not establish itself on this isolated island of favorable conditions. In the southern part of limit A the vegetation was hemiboreal (at present southern boreal), and in its northern part southern boreal (at present middle boreal). The occurrence of spruce pollen in the pollen diagram at the site of finds of *Trapa natans* at Evijärvi (Valovirta 1960) was slight and fragmentary during the warm period, and even completely lacking during the 500 years' period of *Trapa natans*, as evidence of the climatic boundary conditions for spruce, such as around the western limit of the natural occurrence of spruce in southwestern Sweden in the present climate. During the falling winter temperatures spruce became as abundant as pine, as is the case in the southern boreal zone at present. Approaching the end of the cooling period, spruce became less frequent while pine became distinctly dominant, indicating the beginning of middle boreal conditions.

CONCLUSIONS

The deterioration in the climate after the Holocene climatic optimum and the duration of the period of the principal fall in temperatures, long familiar mainly on the basis of pollen analysis, has been known more accurately for the vegetation period than for winter. There is evidence, however, that the climate changed more in winter than in summer. Particularly in Finland, the rapid decrease in the mean volume and depth of the surrounding seas due to strong land uplift has been an effective factor lowering the mean temperature in winter. New proxy data are now available, particularly regarding the timing of the changes in the winter climate. All of these proxy data fit mutually together, and give a satisfactory picture of the winter climate and its changes that can be applied to explain the cultures during the period considered. A very interesting part of the study was that explaining the regional features of the retreat of the Corded Ware people and some later cultures towards regions of milder winters; it was shown that the retreat occurred in a way that was precisely determined by the worsening of the winter climate; this means that at all stages of the retreat the outer limit of the settlements coincided exactly with one of the isopleths for the duration of permanent snow cover in the present climate. Assuming further that the moving settlement limit continuously corresponded to the same duration of the permanent snow cover as determined by their culture, and considering that one days' shortening in this duration corresponds to a decrease of 0.07 ^{o}C in the mean winter temperature, a total fall of 4 to 5 ^{o}C can be found. This amount of fall, again, is the same as that found from the spread of Norway spruce over Finland. Thus, although each of the climatic or cultural changes or regional distributions is in one way or another somewhat uncertain, the almost complete fitting-together of the various components both in time and space cannot be random but confirms the validity of each separate component and the conclusions about their mutual relationships.

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