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Some aspects of late-glacial climate in eastern United States

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Late-glacial localities in eastern United States that lie close to the southern limit of late-glacial ice (of Valders age) yield pollen diagrams that record severe temperature oscillations; fossil localities lying 300—400 miles south of the late-glacial drift border, record less pronounced temperature oscillations. A locality that lies 1000 miles south of this drift border was unaffected by the advance of late-glacial (Valders age) ice.

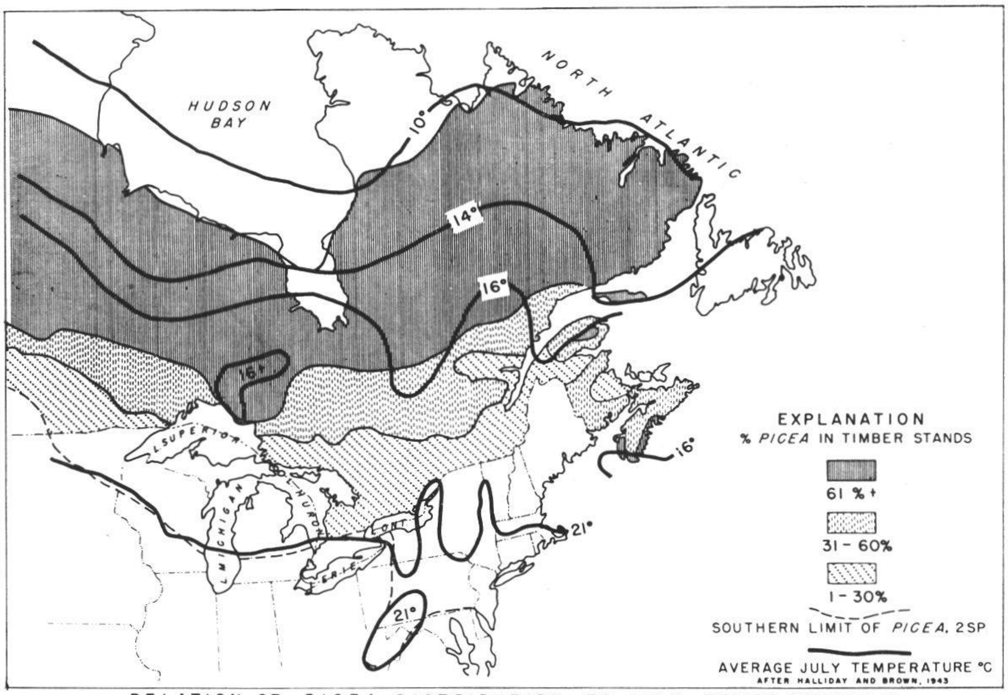
Before discussing the climatic implications of late-glacial pollen assemblages, I will first describe modern pollen data which will be the basis of interpretation for part of the fossil material. Data in the modern pollen map (fig. 2) are presented as percentages of arboreal pollen counts (%₀ AP) because this type of data is the only one currently available for the eastern United States. The fossil pollen maps (figs. 3 and 4) refer to % AP in order to compare with the modern pollen map; they are used here primarily as a basis for estimates of paleoclimate for fossil assemblages in which tree pollen predominates.

Particularly useful for the present purposes is the genus *Picea* which has a modern geographic range that is closely related to temperature. As in Europe (Hultén, 1950), the northern limit of the genus (at tree line) follows the 10° C. average July isotherm (Halliday and Brown, 1943); the southern limit of two American species *(P. mariana* and *P. glanca)* follows the 21° C. average July isotherm (fig. 1). A third species, *P. rubens* (not shown in fig. 1) grows as far south as the 23° C. average July isotherm, and as far north as the Maritime Provinces.

In the first figure, the shaded areas show the numerical importance of *Picea* trees in the standing timber of eastern Canada (Halliday and Brown, 1943). Superimposed on this map are black lines indicating average July isotherms. These data indicate that amounts of *Picea* in forest vegetation increase toward the north in a manner that is more or less inverse to the northward decrease of average July temperature.

In the second figure I have attempted to show the relation of *Picea* forest distribution to numerical representation of *Picea* pollen in modern peat samples. As in figure 1, *Picea* forest is shown by the shaded areas. Superimposed on this map are circles representing localities from which modern peat samples have been analysed (by various authors) for tree pollen content. The percent of tree pollen represented by *Picea* is shown for each locality by the blackened area of the circles.

Picea pollen shows a rough quantitative relation to the northward increase in the number of *Picea* trees. In northern Canada, as an example, where *Picea* trees represent more than 60% of the forest, *Picea* pollen composes 50—75% of the tree pollen count. Where *Picea*



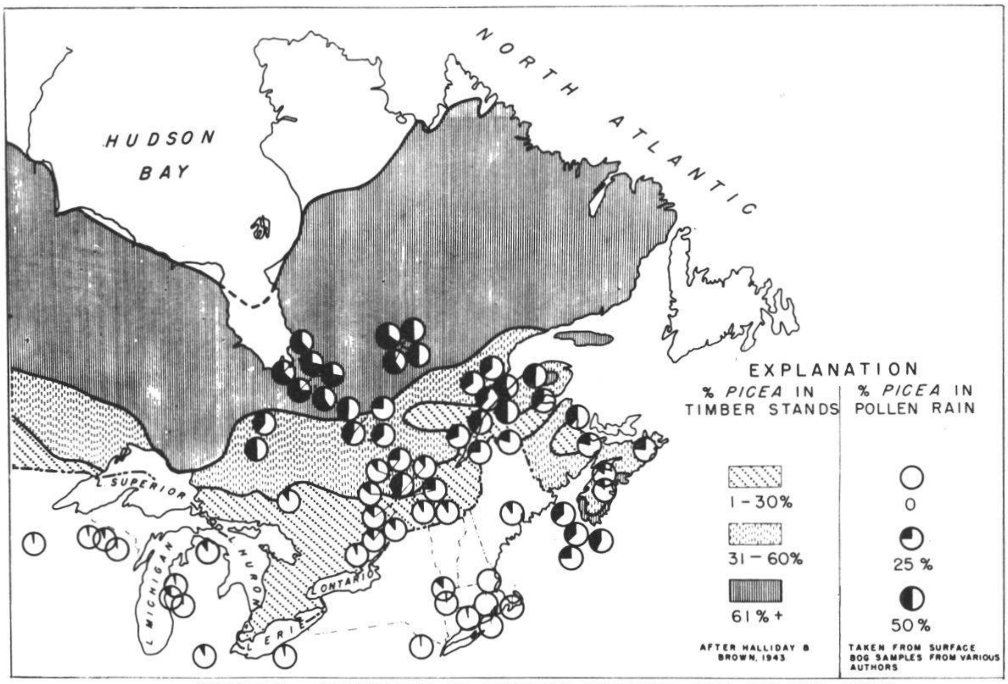
RELATION OF *PICEA* DISTRIBUTION TO JULY TEMPERATURE °C

Fig. 1. Southern limit of *Picea* (2 sp.) shown by dashed line.

forest is only moderately dense (30—60%, fig. 2), pollen counts show that *Picea* pollen composes from 10—50% AP, etc. The balance of the AP counts from the northern localities represents the pollen of pine, and in localities from central Quebec, small amounts of deciduous tree pollen are present. At middle western and southern New England localities, pollen of hardwood trees dominate the counts and *Picea* pollen is only a minor element.

The data presented in figure 1 indicate that the population density of *Picea* trees bears a crude inverse relation to average July temperature. Data of figure 2 suggest a more or less direct relation between population density of *Picea* trees and amounts of *Picea* pollen in the AP count of modern peats. It follows that amounts of *Picea* pollen in fossil samples from this area can be used to estimate approximate temperature characteristics of depositional intervals.

A fossil pollen map, presented as figure 3, refers to pollen content of sediments that are thought to be of interstadial age, contemporaneous with the Two Creeks forest bed of Wisconsin and of the same absolute age as sediments of the middle Alleröd (pollen zone II) of central Europe.



SPRUCE: INTENSITY IN FOREST STANDS AND POLLEN RAIN

Fig. 2

The New England fossil localities shown in figure 3 all show a strong representation of *Picea* pollen (with more *Picea* at northern than at southern stations), and the balance of the tree pollen is mainly pine. Non-arboreal pollen is less numerous than tree pollen in these samples.

Localities in the Great Lakes area show very large amounts of *Picea*. At George Reserve, Michigan, *Picea* represents up to 75% of the tree count if one excludes the large amount of redeposited tree pollen discovered in those samples (ANDERSEN, 1954). Non-tree pollen forms less than 30% of the total pollen in these materials.

The southernmost fossil pollen locality in figure 3 (North Carolina) records mostly hardwood tree pollen with only minor amounts of *Picea* pollen, suggesting a vegetation much like the modern one.

From this information I infer that during the Two Creeks interstadial *Picea* was a fairly important tree in forests of Wisconsin, Michigan, and southern New England — areas where *Picea* is not important today. The nearest modern counterpart of the fossil *Picea* pollen values recorded in southern New England can now be found in modern peats from southern Canada and the Maritime coprovinces where the July temperature is between 16° and 18° C. The present average July temperature of southern New England is 21° C. Hence, during the Two

Creeks interval, the July temperature at these stations was presumably at least 3°—5° C. cooler than present. This figure is comparable to IVERSEN's estimate for the Alleröd climate of Denmark (3°—4° C. cooler than present in July).

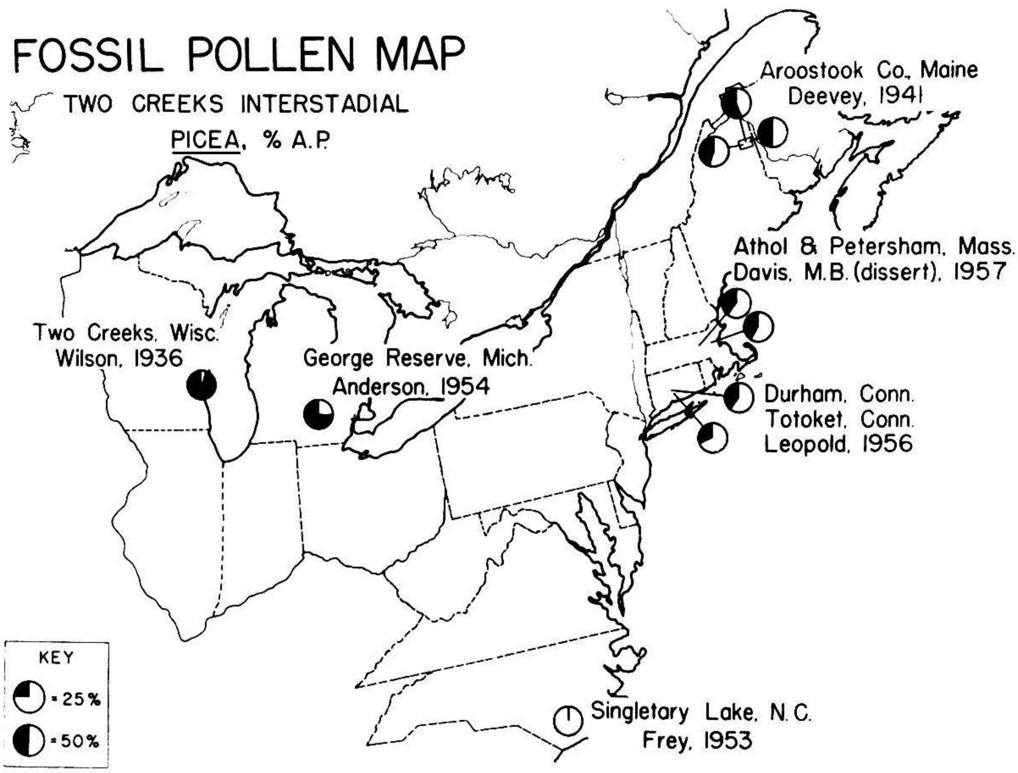


Fig. 3

A second fossil pollen map, presented as figure 4, refers to the pollen content of sediments that are of established late-glacial age; these sediments are thought to be contemporaneous with the maximum of the Valders substage in Wisconsin and are of the same absolute age as sediments of the Younger Dryas (pollen zone III) of central Europe.

Glacial ice of Valders age covered Two Creeks, Wisconsin, and probably lay along the international boundary northeast of that locality. The dominant pollen types at George Reserve, Michigan, and Aroostook Co., Maine, localities are non-arboreal. DEEVEY (1951) and ANDERSEN (1954) conclude respectively that these localities had only weakly developed tree vegetation at this time, probably as a result of the nearness of glacial ice.

The largest amounts of *Picea* pollen in late-glacial samples are recorded in localities from southern New England (fig. 4: up to 70% AP in Massachusetts) suggesting that dense *Picea* forest occupied that region during the Valders advance. Average July temperature at those localities was probably cooler than today's by 4°—5° C.

The most southern locality entered in figure 4 (North Carolina) records a predominance of hardwood trees, and represents a locality that lay far south of the coniferous forest areas during this interval. Evidence from pollen stratigraphy of sections referred to in figures 3 and 4, leads me to conclude the following:

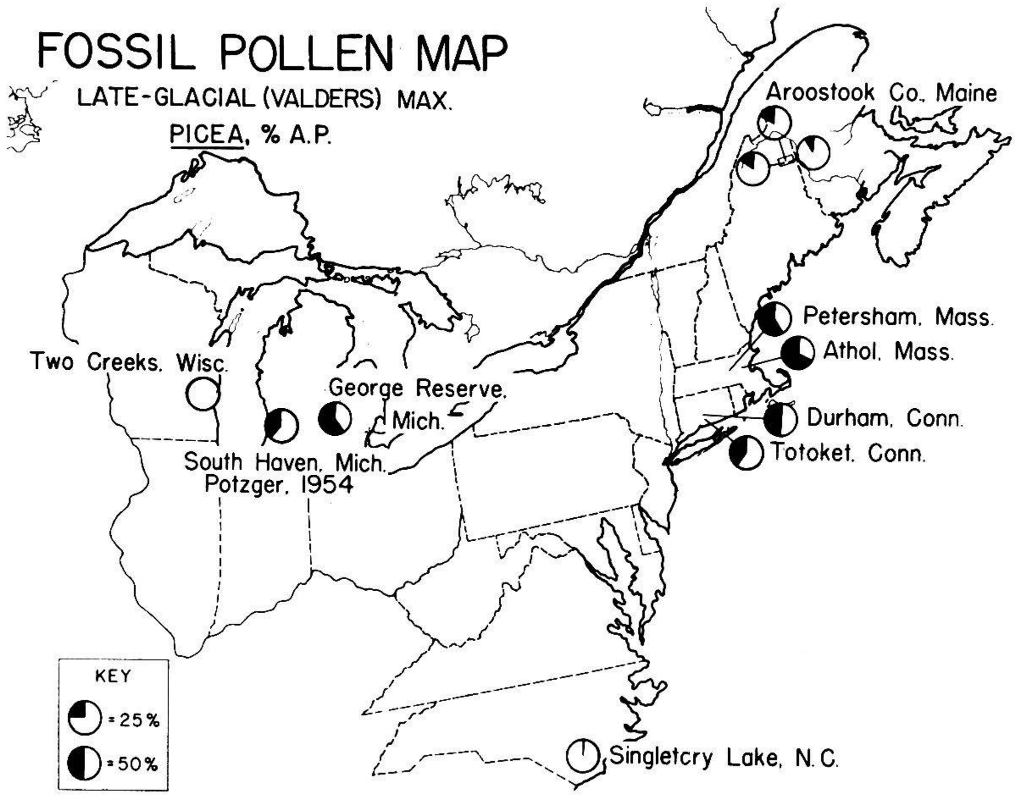


Fig. 4

1) At American localities that lie near the Canadian border, the climatic warming that marked the arrival of the interstadial, was followed by a cooling so effective that forest vegetation reverted to park-tundra conditions. At these localities, the late-glacial temperature oscillation probably followed a pattern like the one characteristic of northern Europe, changing from severely cold, to cool, to cold conditions.

2) At American localities in the mid-seaboard region (southern New England) the climatic oscillation began like the Alleröd of northern Europe; it included a warming comparable to the one that occurred during the Alleröd of Denmark, but finished with a climatic cooling (of Valders age) so slight, that the forest composition changed only slightly. The completion of this temperature oscillation in southern New England is comparable to the climatic record provided by diagrams from southern Germany (Firbas), Switzerland (Lüdi), Welten) and northeastern Spain (Florschütz and Mendenez, 1957). As in southern

Europe, forest vegetation established here during the interstadial interval, underwent only minor compositional changes during the advance of late-glacial ice.

Temperature isotherms during the late-glacial period in the eastern states, probably were arranged in a southwest-northeast pattern in the same manner as today, except they occupied a more southerly position than now perhaps lying farther south by 500—500 miles during the interstadial, and 500—600 miles during the Valders advance.

The data indicate that a north-south temperature gradient along the eastern seaboard was steep, like today's. This pattern is somewhat comparable to the north-south arrangement of isotherms that must have existed in Europe during the Fendoscandian maximum.

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Diskussion. S. Th. Andersen: It was pointed out that the frequency maps for *Picea* in Alleröd and Younger Dryas presented by Dr. Leopold would have been more informative about climatic conditions if the herb pollen had been included in the pollen sum. In their present state they illustrate primarily the proportion within the tree vegetation of *Picea* and *Pinus* emphasizing the remarkable fact that during these periods Pinus was quite common in Eeastern North America while it was absent in Central North America, a fact also shown by the existing pollen diagrams. Referring to the present day state, where *Pinus* in North America reaches closer to the forest border in Quebec-Labrador than further West, this may be explained by a more oceanic climate in Eastern North America during the late glacial.