**Zeitschrift:** Veröffentlichungen des Geobotanischen Institutes Rübel in Zürich
**Herausgeber:** Geobotanisches Institut Rübel (Zürich)
**Band:** 34 (1958)

**Artikel:** Radiocarbon-dated pollen sequences in eastern North America
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**DOI:** https://doi.org/10.5169/seals-308072

# Radiocarbon-dated pollen sequences in eastern North America

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The main outlines of the vegetational history of western Europe are now quite clear, thanks mainly to the extensive and detailed work of pollen stratigraphers. Radiocarbon dating (BARENDSEN et al., 1957; GODWIN et al., 1957) tends to confirm what was already known in its broader features, and its principal value for European pollen stratigraphy is in strengthening regional correlation of pollen dates — for absolute synchrony can never be assumed in a chronology that is ultimately based on migration of plants. By contrast, the pollen chronology of northeastern North America is not only less well known but is harder to study. Postglacial time probably began 10 000 years earlier in southern New England than in the Lake Mistassini district of central Quebec, 1000 km to the north, and throughout this distance the invasion of plants, though it may have been zonally regular, obviously can not have been synchronous. Before the advent of radiocarbon dating little progress could be made in establishing regional correlation of pollen zones, and transatlantic correlations, with their important implications for the earth's climatic history, were entirely speculative.

Despite the difficulties, it has been evident since 1939 or earlier (SEARS 1932, 1948; DEEVEY 1939, 1943) that postglacial forests on both sides of the Atlantic underwent strikingly parallel changes; a BLYTT-SERNANDER-sequence, including Pre-Boreal, Boreal, Atlantic, and Sub-Atlantic climatic phases, can be discerned in most American pollen diagrams, and DEEVEY and FLINT (1957) have urged the use of CHIARUGI's term h y p s i t h e r m a l for the Boreal-through-Atlantic time of maximum warmth. Closer attention to nonarboreal pollen and to pre-Boreal deposits, inspired by the leadership of IVERSEN and FIRBAS, began in northern Maine (DEEVEY 1951), and it was immediately clear that North America's late-glacial history was also closely similar to Europe's. The sections near Presque Isle, Aroostook County, Maine, gave the first clear evidence of dominantly nonarboreal vegetation, and the tripartite or Alleröd sequence that they also showed, though not wholly convincing at the time, seems now to have been firmly established. Evidence of open-country vegetation, doubtfully identical to tundra because of the low latitude and the proximity to unbroken forest, but certainly different from taiga, has since been found at all of the few places where it has been looked for by modern methods; hence it is not true, as has been maintained by several workers, that forests grew so close to the margin of the North American ice sheet that they left no room for tundra.

Substages of the Wisconsin glacial stage are recognized with difficulty in the New England sector of the glaciated territory, and their correlation with substages in the Middle West is uncertain, owing to absence or discontinuity of end moraines in this relatively rugged country of resistant rocks. The outer limits reached by Wisconsin ice are believed to be marked by the complex of moraines on Long Island and on Cape Cod and its offshore islands (FLINT 1953; see Fig. 1). If this complex is a correlative of the outermost Wisconsin (Farmdale — Iowan — Tazewell) complex in Ohio, Indiana, and Illinois, as Flint believed, it should have been deposited between about 21 000 and about 18 000 years ago (FLINT 1955; FLINT and RUBIN 1955). No important readvance is known north of Cape Cod, but in the long retreat across New England the ice margin paused for appreciable lengths of time at several places. One pause, in the vicinity of Middletown, Connecticut, corresponds to pollen zone T-3 (LEOPOLD 1956) and is dated by radiocarbon at about 12 800 B. P.; it is correlated with the Port Huron moraine in the Lake Michigan basin, which in turn is correlated with the Mankato maximum south of Lake Superior (WRIGHT and RUBIN 1956; FLINT 1956). Farther north in the Connecticut valley another pause is known near St. Johnsbury, Vermont; from the pollen stratigraphy at several sites in Aroostook County, Maine (DEEVEY 1951), it is inferred that this pause corresponds to zone L-3, and occurred about 10 600 B. P., the time of the Valders maximum (formerly correlated with Mankato; see LEIGHTON 1957a, 1957b; ELSON 1957; and WRIGHT 1955, 1957) in the Lake Michigan basin.

The evidence on which these New England correlations rest is scanty, consisting as it does in pollen-stratigraphic sections from about ten localities, only six of which are actually in New England. Radiocarbon dates, though also few in number, are remarkably helpful in clarifying points that otherwise would be ambiguous. Many ambiguities remain, and the correlation chart of Figure 2, which attempts to cover an area 1200 miles wide and 700 miles from north to south, for postglacial as well as for late-glacial time, contains as much of hope and prophecy as it does of factual basis. Two important conclusions that emerge from it seem likely to be firm; both are to be credited to Miss LEOPOLD: (1) southern and central New England were forested before, during, and since Two Creeks (= Alleröd) time, and the tundra-like vegetation of Valders (= Younger Dryas) time was confined to a belt a few miles wide; (2) at least one climatic oscillation, comparable both in character and in age to Bölling, occurred in southern New England and was recorded outside the line of the Middletown pause. These conclusions are documented and amplified below.

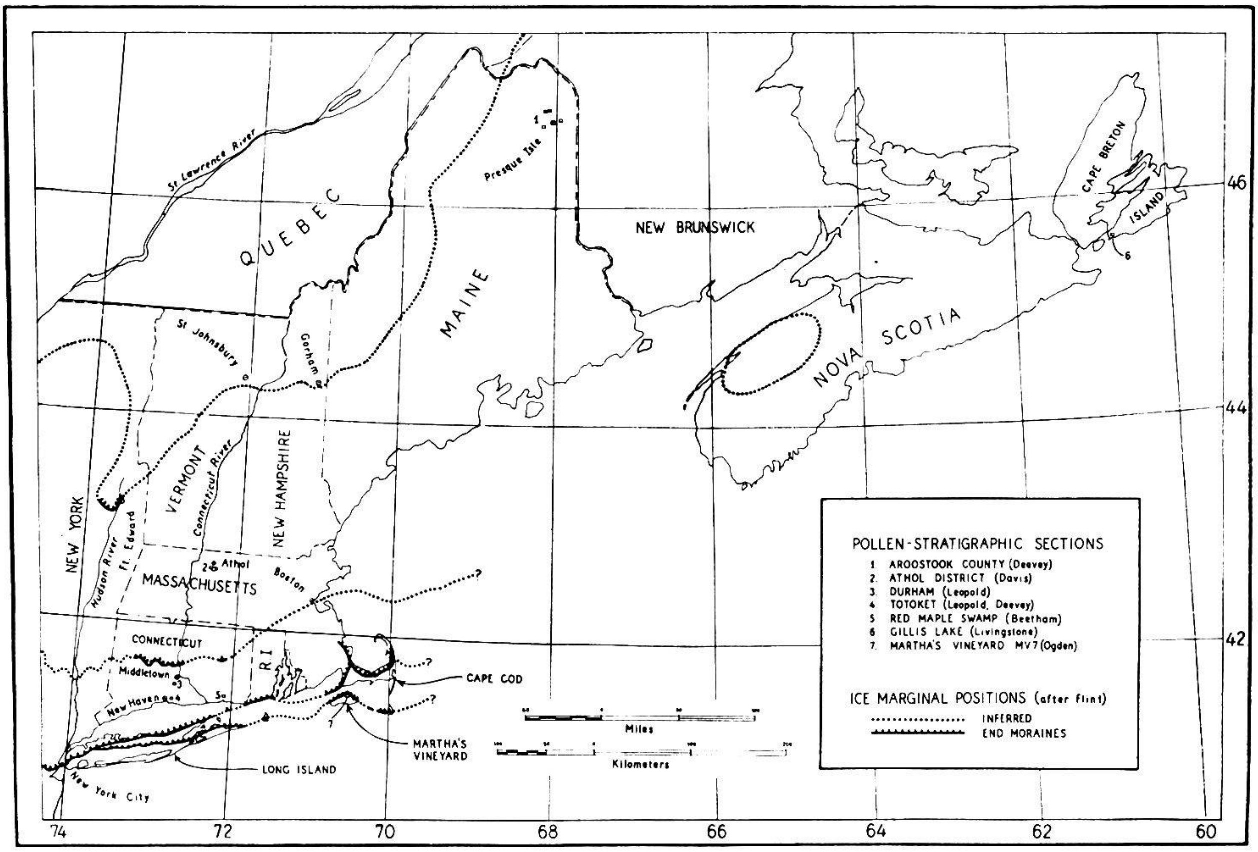


Fig. 1. Sketch map of New England and adjacent Canada, showing location of pollen-stratigraphic sections outside the inferred drift border of Valders time; ice-marginal positions according to FLINT (1953).

The suggestion that the Aroostook County climatic oscillation corresponded to that of Alleröd was made in 1951, and the zone designations (L-1, L-2, L-3) were given in the belief that these zones are late-glacial in the European sense. Just as the Younger Dryas zone represents the Fennoscandian glaciation at localities near but outside the Fennoscandian ice-margin, the younger park-tundra zone in Aroostook County is believed to represent the nearby Valders glaciation (thought of as Mankato in 1951). This correlation (implying L-2 = Two Creeks = Alleröd zone II) rested and still rests on inference from the pollen stratigraphy, not on detailed mapping or on radiocarbon dates, for there are no end-moraines in the vicinity that can be correlated with Valders, and the older sediments of the Aroostook County lakes are poor in organic carbon. The inference is supported, however, by the pollen diagram from Gillis Lake, Cape Breton Island, Nova Scotia (D. and B. LIVINGSTONE 1958). The Livingstones' section agrees with the sequence in northern Maine, approximately on the same latitude, but is more convincing in its demonstration of park-tundra; moreover, it has yielded a radiocarbon date (Y-524, 10 160 ± 160) that shows the upper part of zone L-3 to be of Valders age.

If the Valders ice sheet approached but did not override the Maine and Nova Scotia localities, one would not expect it to have had much influence on the climate of southern Connecticut, 450 miles from Presque Isle and 120 miles from the nearest place (Fort Edward, New York) where Valders ice is supposed to have lingered or readvanced. Miss LEOPOLD's work at Durham Meadows and Totoket Bog, in the vicinity of New Haven, Connecticut, confirmed this deduction and broke entirely new ground (LEOPOLD 1956, 1958 in press). At Durham, on outwash related to the Middletown pause, her diagrams show a brief tundra phase (T-3), followed by a long spruceforest period with two maxima of spruce pollen. The two maxima (A-2 and A-4 in the Durham spruce zone) bracket a zone (A-3) containing much pine and some oak pollen; low values of NAP were found above zone T-3. The sequence implies early postglacial afforestation and development of deciduous forest throughout Two Creeks time, interrupted by a climatic deterioration that brought a resurgence of spruce but not a reversion to tundra during Valders time. That zone A-2 was older than Two Creeks was shown by the date of W-46, 12 700 ± 280 years. The Durham stratigraphy was encountered at three localities in northern Massachusetts (DAVIS 1958 in press), where Mrs. DAVIS' beautiful diagrams show characteristic differences related to the more northerly location — zone A-4 is relatively richer in spruce in Massachusetts than in Connecticut — but establish the essential correctness of Miss LEOPOLD's interpretation. Radiocarbon dates for a log in her zone A-3 at Pleasant Street Bog, Athol (W-361, 10 800 ± 250; M-413, 10 700 ± 800), support the inferred Valders age of the resurgence of spruce. Despite the differences in detail and the probable slight differences in age, the Durham stratigraphy has been combined with that of the Athol district to represent central New England in Figure 2.

At Totoket Bog, 10 miles south of Durham, Miss LEOPOLD also found the Durham sequence, but underneath were two older zones, the oldest (T-1) having much more abundant NAP, whereas the next-oldest (T-2) contained a «pre-Durham» spruce maximum and less NAP than the zones above and below. Evidently the pause of the ice margin at Middletown was represented by the younger NAP zone (T-3), which was complete at Totoket beyond the ice, but incomplete downward at Durham where the outwash was spread. Radiocarbon date Y-285 (13 550 ± 460), though it now seems slightly too old, verified the correlation of zone A-2 at Totoket with that at Durham; two attempts have been made since 1955 to date the older zones. The 1956 studies (Barendsen et al., 1957) gave results which are systematically too old, probably because of inexperience with a new boring instrument, with resulting disturbance of the stratification. More careful studies in 1957 (Deevey, unpublished) give acceptable ages for zones T-2 (Y-502, 13 280 ± 420) and T-3 (Y-505, 12 350 ± 400), as well as confirmatory dates, listed below, for zones A-2 and A-4.

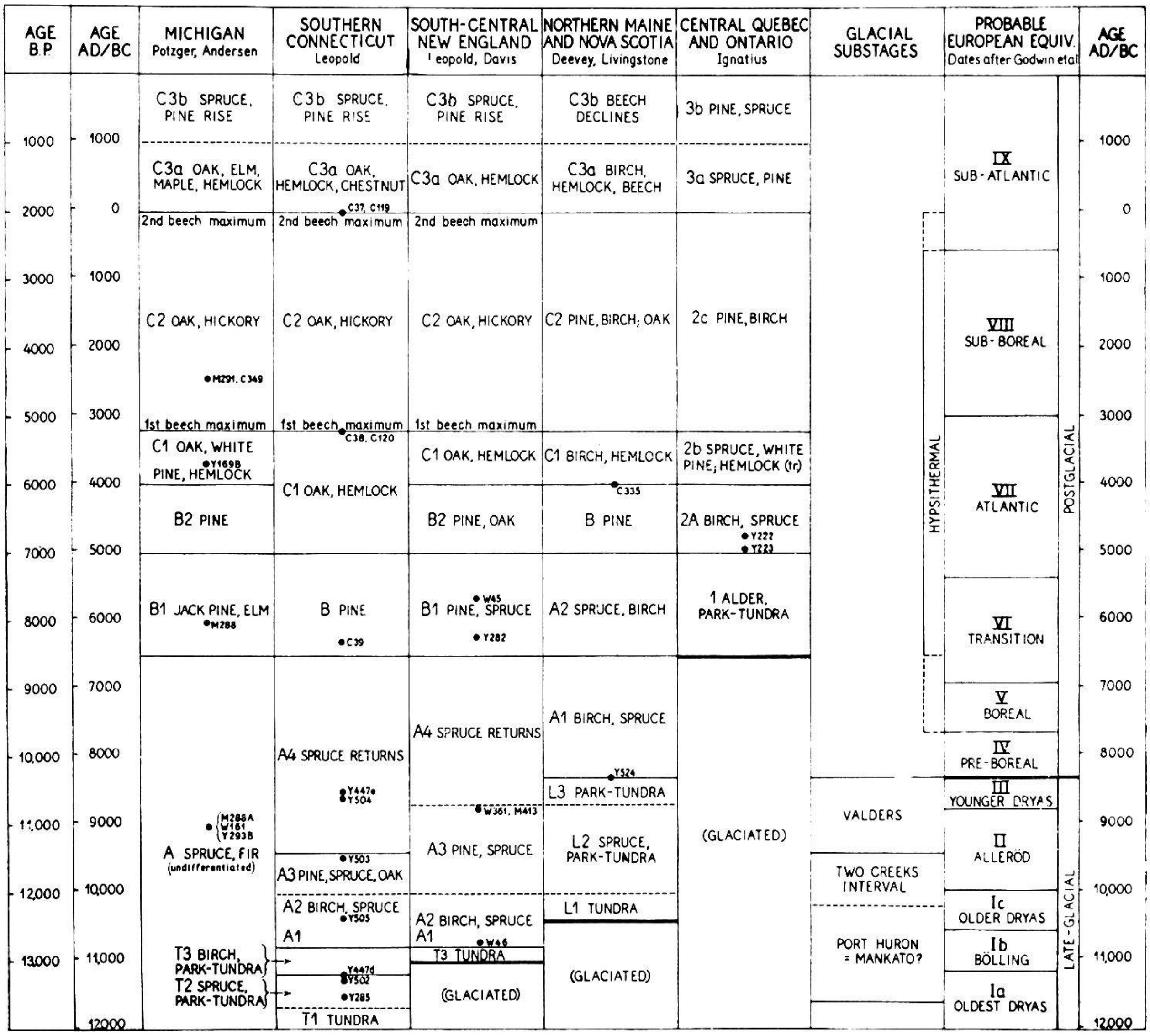


Fig. 2. Correlation of pollen zones in eastern North America, with time scale provided by radiocarbon dates. The zone boundaries are drawn on the basis of averages and estimates, hence the radiocarbon-dated samples do not necessarily fall in their proper zones, but are plotted at their correct chronologic positions as published.

Totoket Bog thus provides the clearest evidence for the present view, that zone T-3 records a time of glacial pause or readvance of Port Huron age, following a period of ameliorating climate — represented in the Lake Huron basin by the Arkona retreat — that is similar to that of Bölling. Because of the large standard errors of single radiocarbon dates, and perhaps because the carbon in a late-glacial clay-gyttja sample is not invariably contemporary with the pollen grains, this evidence is not decisive. It is supported by other stratigraphic data, however:

1. At Red Maple Swamp, near New London, Connecticut, on the latitude of Totoket, an unpublished pollen diagram by Nellie BEETHAM shows the Totoket sequence, beginning in zone T-2. Radiocarbon dates for zones A-2 and A-4 substantiate the correlation, but the older zones are poor in carbon.

2. On Martha's Vineyard, off Cape Cod, unpublished work by J. G. OGDEN strongly suggests that the late-glacial sequence there belongs to an older cycle of amelioration and glacial readvance than the one at Totoket — as it should if the ice-marginal correlations shown in Figure 1 are correct. The Martha's Vineyard data are too new to have been included in Figure 2.

3. Southern Michigan, like southern and central Connecticut, seems to have been forested during Two Creeks time, and climatic changes during Valders time disturbed but did not destroy the forest. This inference was made by S. T. ANDERSEN (1954), but the sequence at South Haven, Michigan (ZUMBERGE and POTZGER 1956), included in Figure 2 because it yielded several radiocarbon dates, is more problematical in its late-glacial portion than is ANDERSEN's sequence from the George Reserve pond.

Little can be said as yet about glacial events subsequent to the Valders maximum; the problem of a Cochrane substage (KARLSTROM 1956) is still unresolved. Unpublished work by Heikki IGNATIUS in the Lake Mistassini and Chibougamau districts of central Quebec, and in the region of Cochrane, Ontario, shows that the pollen sequences began some time after the Valders maximum and before about 7000 B. P.; the date of W-36 (RUBIN and SUESS 1955) is relevant here, as are those of Y-222 (6730 ± 200) and Y-223 (6960 ± 90), which came from IGNATIUS' sections. It is a reasonable guess that the Cochrane readvance is correlated with the Boreal-Atlantic transition, and is recorded far to the south in the United States by the mesic conditions of zone C-1.

In summary, Figure 2 reports a number of local sequences and their probable correlations, made by the classic methods of pollen stratigraphy, Its absolute time scale is only approximate, and is arrived at by considering (but not by blindly relying on) the following radiocarbon dates and their means:

| Zone | Locality | Sample | Date | Average |
|---|---|---|---|---|
| C—3 (bottom) | Upper Linsley, Conn. | C—37, C—110 | 1970 ± 360 | 1970 |
| C—2 (bottom) | Upper Linsley, Conn. | C—38, C—120 | 5230 ± 180 | 5230 |
| B (top) | Plissey Pond, Maine | C—335 | 5960 ± 320 | 5960 |
| B (middle?) | Upper Linsley, Conn. | C—39 | 8320 ± 400 | |
| | Durham, Conn. | W—45 | 7570 ± 250 | |
| | Durham, Conn. | Y—282 | 8155 ± 410 | c. 8020 |
| | [Totoket, Conn., 1956] | [Y—446g] | [9650 ± 90] | |
| | (cf. So. Haven, Mich.) | (M—288) | (7925 ± 400) | |
| L—3 (top) | Gillis Lake, N. S. | Y—524 | 10,160 ± 160 | 10,160 |
| A—4 (middle?) | Red Maple Swamp, Conn. | Y—447e | 10,480 ± 140 | |
| | Totoket, Conn., 1957 | Y—504 | 10,440 ± 200 | 10,460 |
| | [Totoket, Conn., 1956] | [Y—446f] | [12,080 ± 300] | |
| A—3 (middle?) | Athol, Mass. | W—361 (M—413) | 10,800 ± 250 | 10,800 |
| A—2 (middle?) | Durham, Conn. | W—46 | 12,700 ± 280 | |
| | Red Maple Swamp, Conn. | Y—447d | 13,290 ± 120 | |
| | Totoket, Conn., 1955 | Y—285 | 13,550 ± 460 | |
| | Totoket, Conn., 1957 | Y—503 | 11,590 ± 200 | c. 12,780 |
| | [Totoket, Conn., 1956] | [Y—446d] | [14,790 ± 160] | |
| T—3 | Totoket, Conn., 1957 | Y—505 | 12,350 ± 400 | c. 12,800 |
| T—2 | Totoket, Conn., 1957 | Y—502 | 13,280 ± 420 | c. 13,500 |

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