ANALYSES AND CORRELATION OF FOUR NEW HAMPSHIRE BOGS

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The understanding of recent paleoecology by means of the pollen analyses of strata in post-glacial bogs has developed to the point where most ecologists, and even many laymen, are familiar with the usual methods involved. Although large numbers of bogs have been analyzed and discussed with regard to the immediate locality to which they belong, there is still considerable dispute concerning the paleoecology inferred from correlations of these analyses. It is only fair to admit that much of the confusion is due to many missing links in our chain of evidence. The fact of missing links, however, is characteristic of all history, whether natural or human. This paper therefore presents another link in the chain and attempts to point out not only the implications immediately involved in the analysis of four New England bogs, but the inferences drawn from a correlation of a number of other bogs along the Atlantic Coast.

The bogs analyzed by the writer are located in the southeastern part of New Hampshire within the drainage basin of the Merrimac River. The first, Perkins bog, is one-half mile southeast of Center Barnstead in the valley of the Big River. This bog covers several acres of kettle holes and is the most northerly of those considered. Ponemah Bog lies one mile southeast of Ponemah and three miles east-southeast of Milford and consists of about 100 acres in a depression of the Souhegan outwash plain. Spruce Bog is one to two miles north-northeast of Fremont Station and consists of about 200 acres. Welsh Bog, one mile east of Raymond near the Lamprey River, rests in a kettle hole of about seven acres. The bogs are grouped closely enough to indicate a close concurrence of the analyses. The entire area was covered by the Wisconsin Ice Sheet which extended south as far as New Jersey. The bogs do differ, however, in that those of Fremont and Raymond were under salt water during the brief marine submergence of the lower Merrimac Basin as shown by Antevs (1922). Therefore since the date of retreat of the ice (probably from ten to fifteen thousand years ago) and since the retreat of the sea from the area occupied by the two bogs above mentioned, the region has been open to the stages of succession governed by climate to the present time. Apparently the record in each bog is complete from the beginning of peat formation to the present, as the upper levels have remained intact.

The methods of boring and pollen extraction are, as a whole, familiar. The borings were taken at one-foot intervals with a Davis Borer. The deepest boring was taken at the end of actual peat on the bottom of the bogs. It would have been more desirable if some penetration into the sand and clay bottoms below the peat could have been made. Significant additions to the profiles were secured in this manner by Deevey (1939). The samples of peat (about ten c.c.) were placed in 50 c.c. vials of alcoholic potash and sent to the Oberlin Botanical Laboratory. From each vial, from .5 to 1 c.c. of material was removed—by tweezers or by pipette if well digested—and placed in a centrifuge tube to be boiled for a short time with 10 per cent KOH to complete the digestion of the peat.

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[1]Material was collected by the junior author, now with the armed forces. The analyses and all correlation were done by the senior author who also prepared the manuscript. He wishes to express his thanks to Dr. Paul B. Sears for liberal instruction and for the use of his splendid library. Dr. George T. Jones, of Oberlin, has read the manuscript and offered many helpful suggestions.

The digesting action of the alcoholic potash alone was not sufficient for best results in spite of the fact that it had been present for some time.

It may be remarked that many methods were applied to the peat in an effort to make a selection of the most satisfactory system. The new Erdtman Technique (1933) and that of Barghoorn and Bailey (1940) were applied with a number of supplementary modifications. The time required by these new techniques, however, did not seem warranted by results with this material. It is not to be assumed from this that the writer considers the above-mentioned methods generally useless. Undoubtedly under other circumstances they are of value.

After boiling and staining with one drop of safranin per tube, the mixture was centrifuged and the pollen removed from the layer at the top of the peat. Enough of the coarser material from the bottom was added to the pollen layer to allow both for the inclusion of heavier pollen and the stabilization of the film when

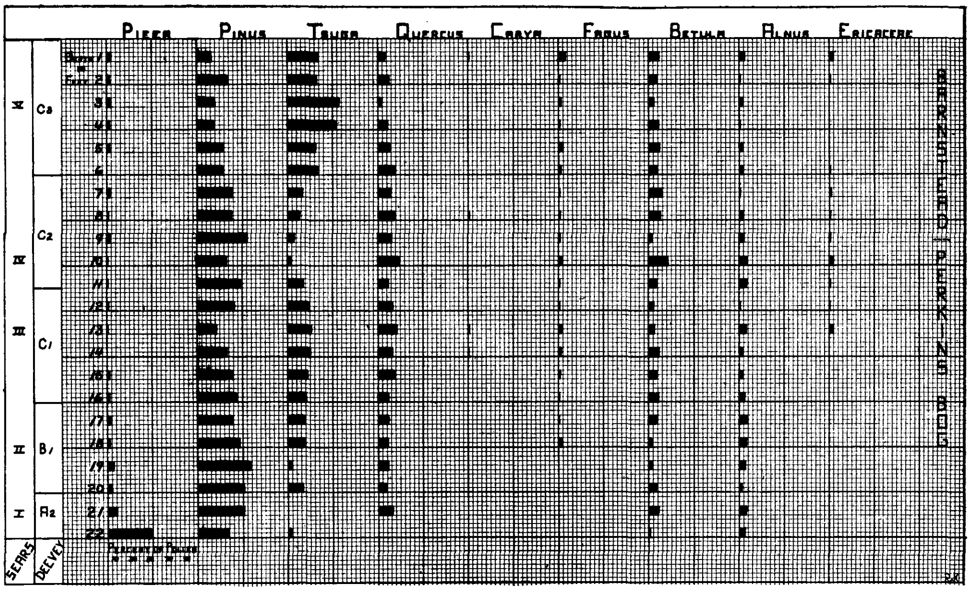


FIG. 1. Analysis of Perkins (Barnstead) Bog.

placed on the slides to dry. Drying completed, the slides were mounted with glycerine jelly. The resulting mounts were excellent in both the number and condition of the pollen grains present. These slides were then counted for 100 grains per level. In certain cases duplicate slides were made in order to check the counts.

As an aid to the discussion of results, the writer will use one bog as a key to which the others will afterward be referred. The bog at Barnstead being the deepest, it is the most logical starting point for this correlation (fig. 1). Beginning the examination with the bottom layer, Spruce is obvious as the dominant. This dominance is characteristic of a cold climate. It is true, of course, that Spruce can be expected in bogs in fairly warm regions, but further investigation of Spruce decline shows that Spruce disappeared from the region except in the bog itself. Deevey (1939) considers a like Spruce maximum in Connecticut the result of the deterioration of climate which had warmed but cooled at this point, due, perhaps, to some readvance of the ice sheet. At all odds, it seems that this period of Spruce dominance can best be placed near the second phase of Deevey's earliest period, lettered A_2. It is the same period which Sears (1942) finds in his discussion of profiles in the Central States and is lettered I. This of course is the cold period which we know must have been represented by the same species of trees as those found in the Northern Coniferous Association today. How long after the retreat of ice it was before arborescent forms began to appear is not yet certain and the writer will therefore make no attempt to date this period. For those interested, however, the dates as set by De Geer (1910) for the early cold period are from 10,000 to about 8,000 years ago. It is apparently near the end of this cold period that the Barnstead Bog began its formation. Whether this Spruce maximum is the first forest community, or if, as indicated by the work of Deevey, it is the second stage of the first community, I am at this point unable to say.

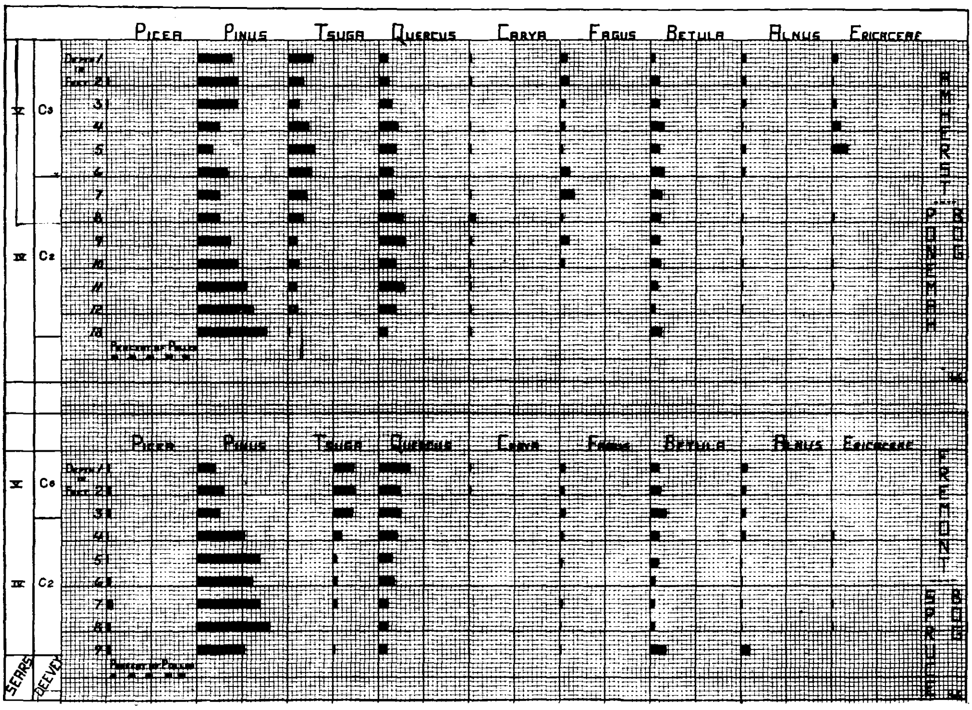


FIG. 2. Analyses of Ponemah (Amherst) Bog (above) and Spruce (Fremont) Bog (below).

Moving on up the profile, there is a quick end of the Spruce dominance. It is replaced mainly by Pine which correlates beautifully with the period marked II by Sears (1942) and B_1 by Deevey (1939). This period shows erratic increase of Hemlock and an increase in Oak. Though the species of Pine and Oak cannot be differentiated, there is considerable indication that this period may have been both cold and dry.

In the next period, letter III or C_1, the Hemlock attains significance and its first maximum appears. Immediately thereafter a deep drop in Hemlock occurs, succeeded again by a maximum near the top. The period of Hemlock minimum (apparently a dry or dry warm one) is paralleled by an Oak maximum (dry) and a Pine maximum (probably Jack Pine) as well. It is extremely unfortunate that we are unable to differentiate between species of Pine. We can only surmize that in view of the spectra the Pine is a xeric species. To show that this species is a xeric one would clinch the supposition that the cool moist period (No. III) was followed by a dry warm one. With this generalization, the spectra seem to be consistent. Beech, with the exception of an increase at level 10, also shows a decline during the warm dry period.

The increase in Beech at the top layer accompanied by a decline in Pine and Hemlock and an increase in Oak and Birch indicates a balanced Beech-Hemlock forest with large numbers of Pine, Oak, and Birch in preclimax stands. This agrees well with the present forest associations.

With periods of the Barnstead Bog pointed out, the other profiles may be examined for correlations. Taking first the bog at Amherst, it is found to be of later inception than the one at Barnstead. The lower levels showing the Spruce dominance are not found here. On the other hand, the Hemlock minimum is found at the bottom, identifying the beginning of peat formation to be in the period marked IV in the Barnstead profile. The same correlation with Pine and Oak may be made here. Beech alone seems a bit out of line which may be in part due to the average low incidence of Beech pollen—a point of difficulty in all genera of lesser representation.

The remaining two bogs are much shallower than the rest. It is to be remembered that these were under salt water during the submergence of the lower

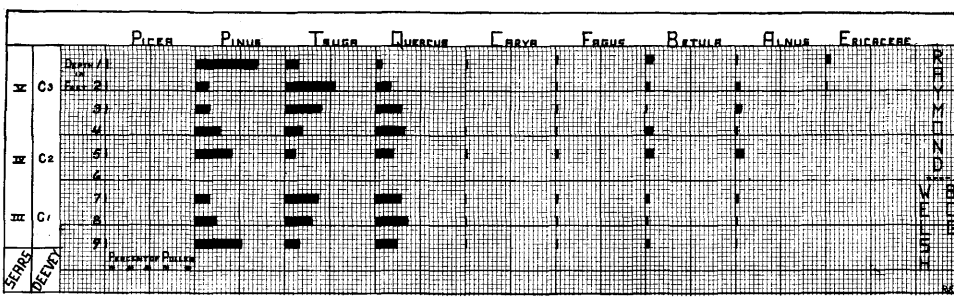
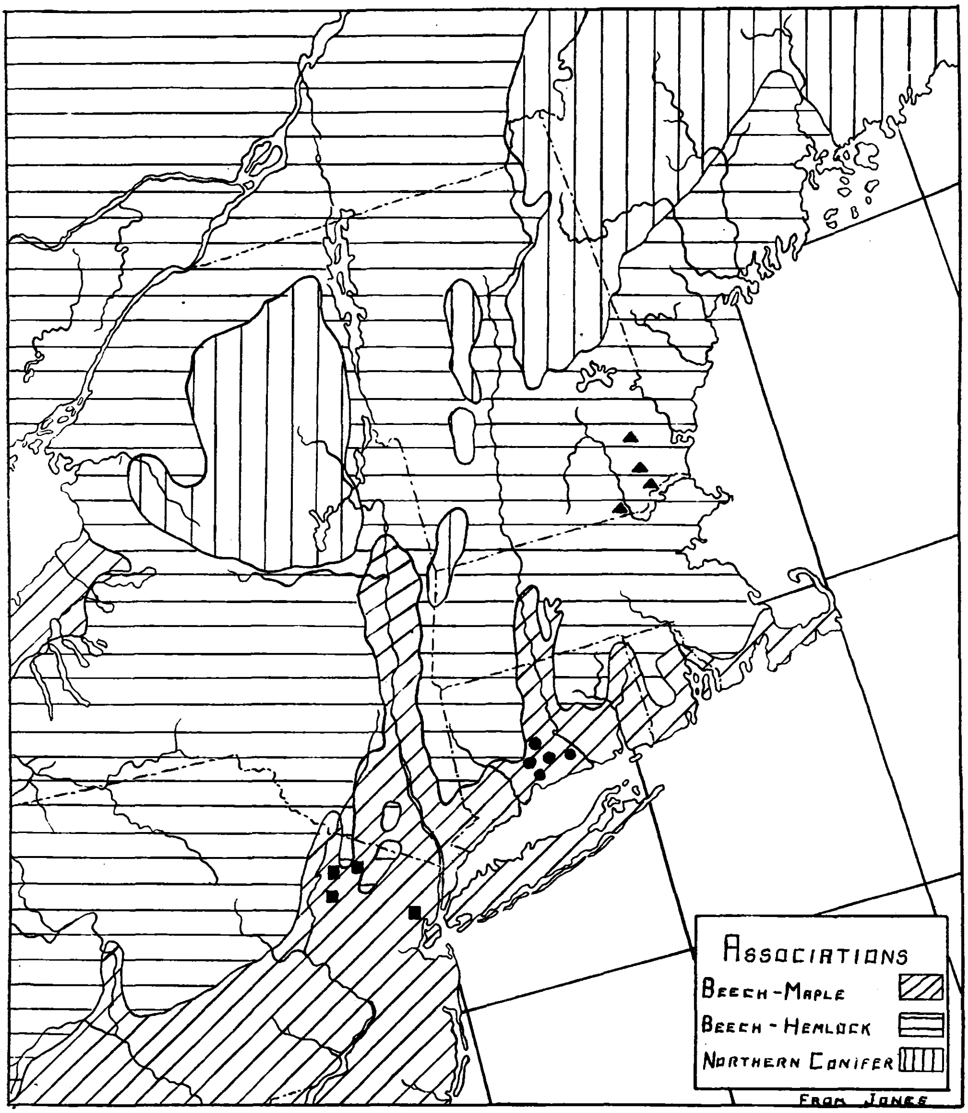


FIG. 3. Analysis of Welsh (Raymond) Bog.

Merrimac Basin. Recovery from this submergence could not have been accomplished soon. Therefore the latter two, Fremont and Raymond, correspond to the upper portions of the former two.

The Hemlock minimum in the Fremont bog is again as is to be expected; and the Beech increase is steadier than elsewhere. The Oak increase at the top, however, is worthy of remark. Possibly the Oak found here is of the mesic Red Oak group, common successionally in the typical Beech-Hemlock forest. Again may we stress the point that a differentiation of the species of Oak is at present impossible and that it would be necessary to clinch our arguments. We have much data for fairly accurate substantiation of our own hypothesis if only these species differentiations were clear. This circumstance limits us to broader generalizations, for no matter how many analyses are made, precision will be impossible unless we can know the species of Oak and Pine in particular. The protests of Potzger (1942) and others against making any generalizations as to climate seem to us, however, scarcely warranted in view of the evident broad correlations between our results and those of Potzger (1943) and Deevey (1939).

Going on to the Raymond Bog two difficulties are met—although as a whole the bog agrees with the other three. The first problem is the recent increase of Pine not shown in the others. This may be due to the interference of man by lumbering or fire. At all odds, it is naturally unexpected and may be open to speculation. The other is that in this shallow profile we have two Hemlock minima. This would indicate a slow filling over a longer period than that of the Amherst Bog. This, though possible, is difficult to explain. The very small size of the bog may have much to do with a slow rate of filling or the local vegetation



Bogs analysed by Potzger ■ ; Deevey ● ; Krauss ▲.

FIG. 4. Location of Coastal Bogs referred to in text.

may have disturbed the profile. The erratic formation of kettle holes and resulting deposition of peat is mentioned by Deevey (1939) and is a problem in any correlation.

What inferences may now be drawn from these results? First, it is obvious that these profiles indicate clearly the presence of a cool dry period after the close of the Spruce maximum. After this dry period, the Hemlock swings up to a maximum and a mesic forest community is indicated by the presence of the typical trees of the present Beech-Hemlock association. A dry and warm period follows, as shown by the marked decrease in Hemlock in agreement in all bogs. Oak and Pine species which we assume to be xerophytic occupy a dominant place in this period after which the Hemlock increases as Pine and Oak decrease and Beech increases to make up the present Beech-Hemlock-Pine forest. In the top layers there is evidence of the work of man as well.

In searching for meteorological corroboration for these shifts of climate, the writer was for a time disturbed by the fact that in order to have the xerotherm pointed out by Sears, Deevey, *et al.* (at Hemlock minimum), the cyclonic-anticyclonic fronts which now occur in the middle New England region would, of necessity, be found further north. This being true, there seemed every reason to suspect that the recession of the cold dry polar air, which had kept out the warm moist air from the Atlantic, would allow this warm moist layer to sweep over the area producing not a warm dry period but a warm moist one. This would have brought about a displacement of the coniferous forest by a Beech-Maple forest, apparent in a bog profile by a great increase in Beech. Such an effect is not shown in any of our profiles nor in those of other workers in the region.

With the possibility of this oceanic influence ruled out, it is clear that a great air movement from the West must have carried dry hot winds far enough east to alter the expected climate of the Northeastern seaboard. Meteorologically this is sound, for any movement of the fronts northward would carry the air from the Mississippi Valley in a swing east which would not be halted by either the low New England Mountain Ranges or the easterly oceanic winds. Therefore a warming at this time would allow the New England States to be influenced by mid-continent climate more than at present. The fact that these easterly bogs were affected by a dry warm period shows definitely that this period, long suspected in the mid-continent, must have been truly a far-reaching one. It is substantiated by the presence of the prairies much farther to the east than at present and by the analyses of Auer (1930), Deevey (1939), and Potzger and Otto (1943). (The latter, however, ignore the Hemlock minimum in their own paper.) The fact of apparent movement of the forests north and then again south should be of great interest to those tracing movements of the polar ice.

There is one other point raised by this analysis, when correlated with the others in the region. In New Jersey, Connecticut, New Hampshire, New Brunswick, and Nova Scotia there is a uniform decline in the abundance of Hemlock at about the same relative levels. In this period of decline there is a variation in the species of trees which take the dominance from Hemlock. In New Jersey, in the dry period, Hemlock is replaced by Oak to a great extent. In Connecticut, the Oak is as active in replacing Hemlock as in New Jersey. We do find a tendency for Pine to press into the gap. We may safely say, however, that Oak is the main representative of the dry period in these two states. In New Hampshire the Pine is the important dominant at the Hemlock minimum. Still farther north in Nova Scotia and New Brunswick (see Auer, 1930) Oak is barely present and certainly Pine is the unequivocal dominant in the dry period.

What then does this dominance of Pine in the north instead of Oak, as in the south, suggest? A clue may be noted in that there is a tension zone of climate in the New England states. Here the cyclonic fronts caused by the conflict of cold polar air with the warm southern air rule the weather. As could be expected, it is through this area that the general line separating the Beech-Maple association from the Beech-Hemlock is found. (Clements and Weaver, 1938; Jones, 1940.)

In figure 4, the bogs in New Jersey and Connecticut are seen to be in what today is Beech-Maple. Those in New Hampshire, Nova Scotia, and New Brunswick, on the other hand, are in the Beech-Hemlock Association. It appears, then, that the warm dry period produced not a northward movement of the Beech-Maple association nor any real shift of boundary at all but rather that the xeric types found in this period represent the xeric series *in their own respective associations.*

It is notable that there is such a pronounced difference in the xerotherm forests of New Hampshire and that of the same period in Connecticut only one hundred miles to the south. It is as though the climax association of today were reduced to the xeroseres peculiar to each. Is not this just what we would expect when we realize that a climax condition had been reached and well established before the beginning of the xerotherm? Nevertheless it is surprising that the line today should correspond so closely to what it was perhaps three or four thousand years ago. It indicates a stability of forest associations and their seres not previously pointed out and certainly calls for further ecological investigations.

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