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Pollen Spectra from Four Bogs on the Gillen Nature Reserve, along the Michigan-Wisconsin State Line*

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Northern Wisconsin impresses a visitor from central Indiana not only with its decided differences in climate but also by the change in the vegetation, the visible expression of the climate. This is, perhaps, less evident to-day than formerly because the vast forests of conifers which a half century ago covered much of the topography have under pressure of lumbering and fire yielded to scrubby growth of aspen and paper birch, or perhaps even to lowly shrubs of the heath family, and especially to *Comptonia asplenifolium*. There are, however, in Vilas county, Wisconsin, and Gogebic county, Michigan, smaller areas of hardwoods and pine still in their natural, undisturbed condition, where phytosociology is representative of the former greater forest expanses of the region before cultural influences modified them. Here, then, was an unusual opportunity to make a pollen study in bog sediments, and fit pollen records into a vegetation complex of to-day, and thus bring the study of the vegetational tendencies in the region up to the present. Four bogs were included in the study. They are located near the Michigan-Wisconsin state line, on the Gillen Nature Reserve. This reserve is a fine 5,500 acre tract lying partly in Vilas county, Wisconsin, and partly in Gogebic county, Michigan. In its geographical location it is close to the Canadian forest, and character species of the boreal forest are prominent dominants in this southern extension, in relic colonies in bogs and along wet river bottoms. The vegetation as a whole is of the true lake forest type, i.e., pine dominating in sandy, dry areas, and northern hardwoods of yellow birch *(Betula lutea)*, hemlock *(Tsuga canadensis)*, and sugar maple *(Acer saccharum)* dominating in forests on better loam soils. Beech *(Fagus grandifolia)* has not extended its range so far west. The northern hardwoods was originally very prominent in the area now termed the Gillen Nature Reserve, and pine had a rather scattered distribution. From pollen profiles of Indiana bogs and lakes we were justified to conclude that the broad-leaved phase of the lake forest complex is a more recent invasion than the pine complex, and as stated before, bogs in the Gillen Nature Reserve appeared to be excellently located to fit pollen spectra into representatives of forest primeval still surrounding some of the bogs studied. Here also was an opportunity to check the reliability of pollen spectra in recording forest complexes and forest changes, and to discover when the hardwoods complex first replaced in part the pine dominance. In compliance with the wishes of Mr. Martin J. Gillen, former owner of the reserve, the three deeper bogs were named in recognition of

* This is contribution 124 from the botanical laboratories of Butler University, Indianapolis, Indiana, and notes and reports 107 from the Limnological Laboratory of the Wisconsin Geological and Natural History Survey, University of Wisconsin.

scientists who have in the past conducted research on this reserve, and the smaller bog near Mr. Gillen's home, was named Killarney Point Bog. The three other bogs studied will, thus, for the first time be named as Birge, Gilbert and Potzger bogs.

The study of vegetational succession during post-Pleistocene times on hand of pollen spectra adds a new significance when records of bogs within the transition lake forest are compared with those from the southernmost limits of Wisconsin glaciation. The worker in peat from Indiana bogs is at once impressed with the "youthful" character of the northern Wisconsin bogs. In the bogs of Wisconsin and northern Michigan the organic deposits are much less consolidated, the peat is coarse and little decomposed. Most mats of the northern bogs are in a quaking state, the present-day vegetation has not entirely lost its boreal aspect, for spruce and fir are still prominent along the periphery and on the bog mats. The average depth of deposits is much less in the north than in the Indiana bogs, where the range is between 32 and 60 feet rather than between 20 and 30 feet as in Wisconsin.

The Gillen Nature Reserve

This reserve is a tract of land totalling approximately 5,500 acres; it is located partly in Vilas county, Wisconsin, and partly in Gogebic county, Michigan. Forest primeval covers about 900 acres, the balance consists of cut-over and disturbed former forested land, lakes, bogs, and river valleys. It embodies, thus, vast areas representative of the three forest cover types characteristic of the lake forest, viz., northern hardwoods, pine, and bog forest, the latter dominated by boreal species. Mr. Gillen dedicated the reserve to native fauna and flora, as a place where life may develop undisturbed according to the laws of nature. It is a vast open laboratory where scientists may study native plants and animals, offering fine opportunity for long-period observations without danger of having equipment disturbed. Several projects, of which the pollen study is one, are already in progress, conducted by research workers from Butler, Notre Dame, Chicago and Wisconsin universities. It is hoped that workers from other universities will begin studies in this area. Plans are being made to provide laboratory facilities where chemical and microscopic examinations can be carried out. Enquiries may be addressed to Mr. Martin J. Gillen, Land O' Lakes, Wisconsin.

PHYSIOGRAPHIC AND GEOLOGIC HISTORY

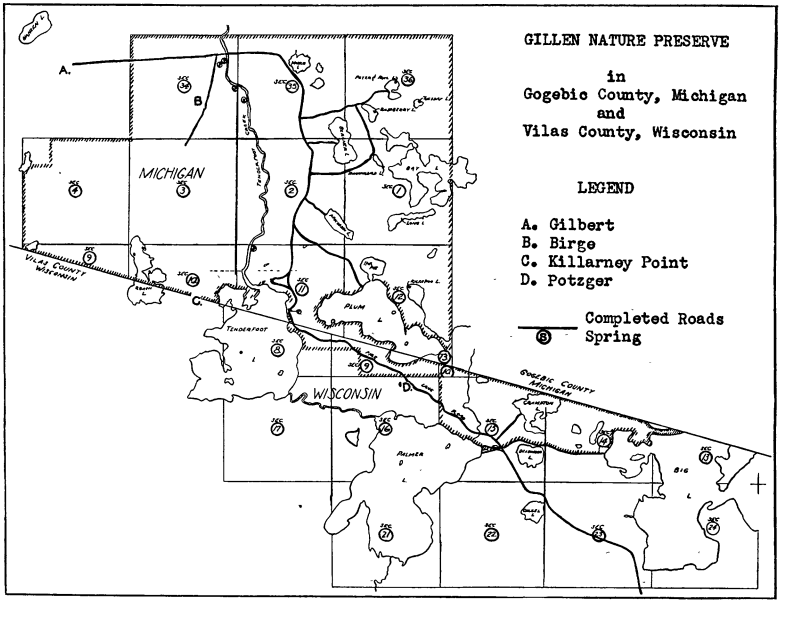
While the region is underlain with strata of the Silurian era, outcrops are few, and so the surface deposits of Pleistocene times alone control and influence the topography and distribution of the vegetation. The topography is of the characteristic irregular glacial type, expressed by moraines and outwash plains. Sandy or clayey ridges and plains alternate with depressions large and small; many of the latter are now filled with water to make lakes or bogs. Some of the smaller, round kettle holes still have a central circumscribed smaller water body, while the long valley-type are completely closed and support forest cover consisting primarily of tamarack and black spruce.

DESCRIPTION OF THE BOGS

Of the four bogs included, two were of the valley type and two of the small kettle hole type. The latter two (Killarney Point and Potzger bogs) are still in the sedge meadow stage, with Chamaedaphne just invading, while the former are forest covered.

BIRGE BOG

The Birge Bog is approximately three miles in length and a half mile wide. It is located in T. 45 N., R. 42 W., Sec. 33 and 34, Town Marinesco, Gogebic county, Michigan. The peat is well consolidated, but still very wet, and supports a forest constituted of black spruce *(Picea mariana)* and tamarack *(Larix laricina)*. The adjacent uplands rise about 20 to 30 feet above the basin. Originally these uplands were very likely covered by a mixed forest of pine and northern hardwoods. At the present the areas are in a stage of secondary succession where paper birch *(Betula papyrifera)* and aspen play a prominent rôle. The surface of the bog is covered by a dense mat of Sphagnum. The peat between surface and 17-foot level is coarse and poorly decomposed. From the 21- to the 29-foot levels sediments consisted of a reddish, finely divided sandy clay with little or no organic matter, and yielded no pollen beyond the 25-foot level. The boring was made as near as possible to the linear center of the basin. Samples were taken at every foot-level to the 29.5 foot depth.



KILLARNEY POINT BOG

This was the smallest and most shallow of the four bogs, and represented a typical kettle hole. It is located almost on the state line between Tenderfoot and Roach lakes. Its exact location is T. 43 N., R. 8 E., Sec. 7, Town of State Line, Vilas county, Wisconsin. To the north, east and northwest the adjacent areas are rather steep, while the south and southwest borders merge into a wet lowland which in early post glacial times was perhaps an arm of water connecting with Roach lake. This lowland is now covered by a mature stand of hemlock-sugar maple-yellow birch forest (Table 2). The mat of Sphagnum and sedges is still in the quaking stage, while Chamaedaphne and Andromeda are early shrub invaders, advancing in scattered colonies or in lines along old logs. Sediment totalled only nine feet.

TABLE 1.—Stems of trees on one-fourth acre in forest near Potzger Bog.

	Size-classes in inches, diameter breast high						
Species	1–2	3–5	6–10	11–15	16–20	Above 20	Total stems
Acer saccharum	8	8	9	5	1		31
Betula lutea			1	2	3	2	8
Thuja occidentalis			1				1
Tsuga canadensis	7	25	29	3	1	3	68
Tilia americana			2	1	4		7

TABLE 2.—Stems of trees on one-fourth acre in forest near Killarney Point Bog.

	Size-classes in inches, diameter breast high						
Species	1–2	3–5	6–10	11–15	16–20	Above 20	Total stems
Acer saccharum		6	2	6	1	2	17
Betula lutea			5	1	4	7	17
Tsuga canadensis		12	17	7	2	1	39
Tilia americana	1	4	1		2	3	11

GILBERT BOG

This bog is of the modified valley type, elongated, but set deeply between high ridges. It is located R. 42 W., T. 45 N., Sec. 33. By automobile it is 1.6 miles west of Tenderfoot river on the Nansen lake road. It is about an-eighth mile south of the road in a deep valley. The surrounding sand ridges were perhaps primarily pine or it represented an important part in the original crown cover of the forest, but along the southeastern border northern hardwoods controlled. The mat is well solidified and now supports a medium dense stand of black spruce, tamarack and balsam fir. Sphagnum forms a thick carpet layer.

POTZGER BOG

The beauty of this deep-set small ice-block type bog immediately attracts attention and interest. The steep slopes rise 40 to 50 feet, ending in flat ridges

which are covered by forest primeval of the northern hardwoods type (Table 1). A small pool occupies the center, while a very quaky mat, barely invaded by trees, covers most of the depression. The poorly decayed and little consolidated peat is coarse and fibrous. The steep flanking slopes indicate that the deepest part of the bowl is beneath the open pool. This suggested the possibility that the boring along the pool's edge may not show the complete profile, beginning with the customary spruce-fir dominance, and present in the completely closed bogs of that region. The bog is located in T. 43 N., R. 8 E., Sec. 16, Vilas county, Wisconsin.

Methods

Borings were made with the movable sleeve, cylinder-type borer. Samples were as a rule taken at one foot intervals. A small amount of the sediment was removed from the center of the core, placed into a vial and stoppered without addition of a preservative. Each vial was at once labelled with bog designation and foot-level. In the laboratory the peat was dissolved with 95% alcohol, according to the procedure suggested by Miss Geisler (1935), stained with a drop of Gentian violet, and mounted in glycerine jelly. 200 pollen grains were counted of woody genera at each foot-level, except where pollen representation was low. Variations in the count were as follows: Killarney Point: surface, 100; 8-foot, 100; 9-foot, 50. Birge bog: 22-foot, 100; 23-foot, 50; 24-foot, 25; 25-foot, 25. Gilbert bog: surface, 100; 21-foot, 150; 21½-foot, 33. Potzger bog: 30-foot, 100.

Observations

In a general way, all four bogs show approximately the same vegetational changes, except that in Potzger and Gilbert bogs pine shows evidence of having been a more prominent constituent of the forest while early depositions were in progress (Fig. 1). All bogs show a sudden decline of spruce and a steep rise in representation of pine, a long time dominance, and the entrance of birch and hemlock when the upper half or third of the deposits began to accumulate. In the Killarney Point, Gilbert, and Birge bogs, around whose periphery the original forest has been greatly disturbed or entirely removed, oak shows a prominent increase in the top foot-levels. This marks, perhaps, the initiation of forest denudation by civilized man. Pollen of hemlock reached its maximum representation of 34 percent in the Killarney Point bog. This well reflects the present status of the genus in the forest on adjacent areas (Table 2). The present study for the first time presented an opportunity to the writer to test the validity of representation of such insect-pollinated species as sugar maple and linden. Potzger bog is at present encircled by a magnificent stand of hemlock-sugar maple-yellow birch forest in which linden *(Tilia americana)* has some very old representatives; the same type forest surrounds about three-fourths of Killarney Point bog (Tables 1 and 2). The pollen spectra shown in Figure 1 are, however, striking by the small representation of both maple and linden. This definitely shows that sugar maple and linden do not contribute sufficient pollen to lake and bog sediments to give them the same status of importance

in the pollen spectrum which they held in the forest cover. All four profiles accurately record decline of pine in the region, and the invasion by hemlock and birch. We can perhaps assume that maple was a co-dominant in this broad-leaved forest even though its pollen representation does not justify such a conclusion. We may also be justified to conclude that these pollen spectra accurately indicate climatic moderation which favored the invasion of this region by the broadleaved genera, and initiated the microclimatically controlled "dual" climax of the lake forest. The successive forest complexes have been made up of few genera, where a forest with simple sociological relationships was superseded by a forest constituted of different genera but likewise of simple sociological makeup, which has persisted up there to this day. Broadleaved genera competed successfully with pine since the upper half to one-third of sediments accumulated. It is, of course, a difficult matter to affix time values to such deposits. The lower foot-levels without doubt represent a longer time period than do foot-levels in the upper layers, where the peat is not compressed by the weight of the overlying sediments. Then, too, bogs do not fill in at the same rate in the various locations. Killarney Point bog has only 9 feet of sediments and shows the complete spectrum, including the spruce-fir period, while Birge bog tells a similar story on succession in a 25-foot profile. If the frequently estimated time of 25,000 years for post-Pleistocene is correct, we might say that the invasion by the northern hardwoods in the Gillen Nature Reserve began between 10,000 and 6,000 years ago, perhaps even later. The spruce period apparently dominated for only a few thousand years. The shorter time implied by the one foot of sediment where spruce shows dominance in the Potzger bog as compared with all others in this series merely indicates that the borings at the edge of the open water in the bog did not strike the place of deepest deposition, and thus was omitted a part of the spruce period.

Discussion

It is rather interesting to note that the early vegetation after retreat of the ice was apparently the same in northern Wisconsin as it had been in late Wisconsin territory in Indiana. The exception is that pine was more prominent and persistent in the Wisconsin region than in Indiana. The Wisconsin and upper Michigan bogs are, however, similar in this respect to those of southern Minnesota, as reported by Artist (1939). In Indiana several foot-levels show only spruce and fir, while in Wisconsin pine is usually associated with these genera. Of course, pine persists longer in Wisconsin than it did in Indiana, where it shows control of the crown cover for only a few foot-levels, as shown by Smith (1937), Moss (1940), Potzger-Wilson (1941), and Potzger-Friesner (1939). The hemlock-birch-maple northern harwoods apparently never was very prominent in Indiana, but oak became a controlling genus soon after the pine climax had passed, and persisted according to records from most bogs to the present time. While hemlock pollen is usually present in low percentages in all Indiana bogs and lakes, it is never abundant. This was always interpreted by us, Smith (1937), Prettyman (1937) as being due to poor preservation of this pollen, and we referred to Sears (1930) for such conception. We acknowl-

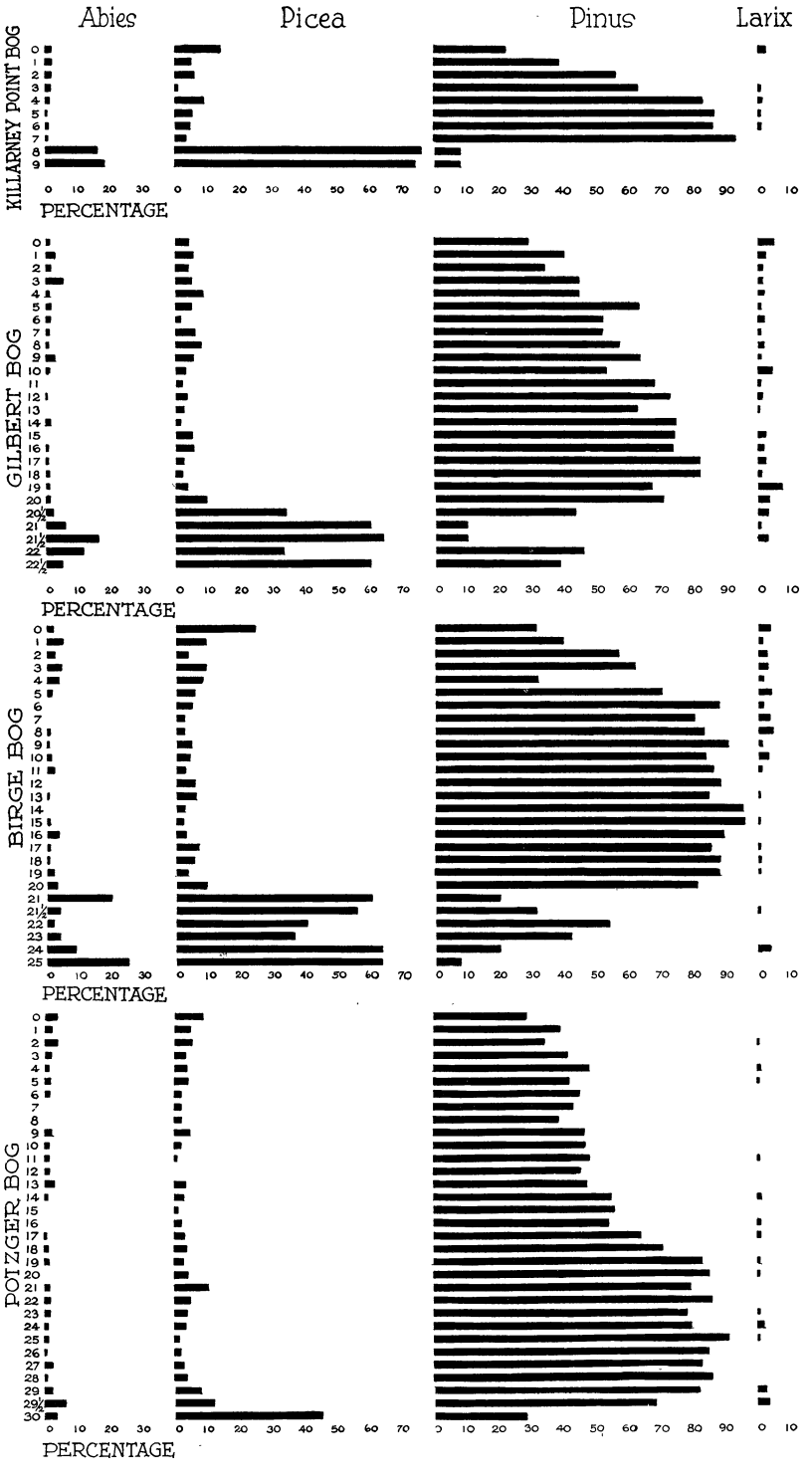
edge our error of having confused Thuja with Tsuga in the above-named author's publication. The excellent preservation and abundance of hemlock pollen in the Wisconsin bogs, and in the sediments of Connecticut lakes, as reported by Deevey (1939), shows definitely that hemlock pollen preserves well in lake and bog deposits.

Early residents and lumbermen of the region represented by upper Vilas county, Wisconsin, and lower Gogebic county, Michigan, say that pine had a very scattered representation in the forest primeval of the region, being primarily of the northern hardwoods type. This is also reflected in the upper third of the pollen profiles shown in figure 1. It is very likely that invasion by the broadleaved genera did not occur uniformly in all areas where they now dominate, which is only to be expected, for succession is a gradual replacement in a mature forest and could take place en masse only after a catastrophic destruction of existing vegetation by fire, sleet, or insect pests. If succession takes place without mass destruction of a previous vegetation it would involve a long time, following replacement of individual trees, which would yield to a gradual increase in dominance by the invader and not occur as a sudden replacement. Killarney Point and Birge bogs indicate a more sudden replacement than the Gilbert and Potzger bogs. While oak never reaches a significant representation in this part of Wisconsin, it appeared very early in the vegetation complex (Fig. 1), even earlier than hemlock.

The pollen profiles in the first place give definite information that from a uniform pine dominance, following a spruce dominance, climatic change enabled broadleaved genera associated with hemlock to replace pine in the more favorable soil locations, and so initiate the usually marked "dual" association complex in the lake forest. The climate is favorable to the northern hardwoods but microclimate, controlled principally by edaphic factors, makes possible the persistence of pine dominance, as a second study of bogs about Trout Lake, only twenty-five miles south of the Gillen Nature Reserve, shows, for there pine dominance persisted from the decline of the spruce control to the present day. In the second place these pollen profiles show approximately when this invasion and ecesis took place (Fig. 1).

We cannot well discuss the replacement of pine by hemlock and birch as shown in figure 1 without saying something about the present day association in this hardwood. The forest surrounding Killarney Point and Potzger bogs has sugar maple as very important co-dominant with hemlock and yellow birch, while linden is of secondary importance. As figure 1 shows, maple and linden are sparsely represented in the pollen spectrum, they should, however, be present at least in the top-level since some of the stems in the adjacent forest must be several hundred years of age. This introduces very forcefully the problem of the representation of insect-pollinated trees in peat deposits. A study is planned in the Gillen Nature Reserve which will consider this problem specifically; very likely the pollen of maple and linden is not carried very far from the parent trees.

An old question which usually enters into the interpretation of climatic and vegetational changes is the time element. It is no doubt the most difficult


Abies
Picea
Pinus
Larix
KILLARNEY POINT BOG
GILBERT BOG
BIRGE BOG
POTZGER BOG
PERCENTAGE
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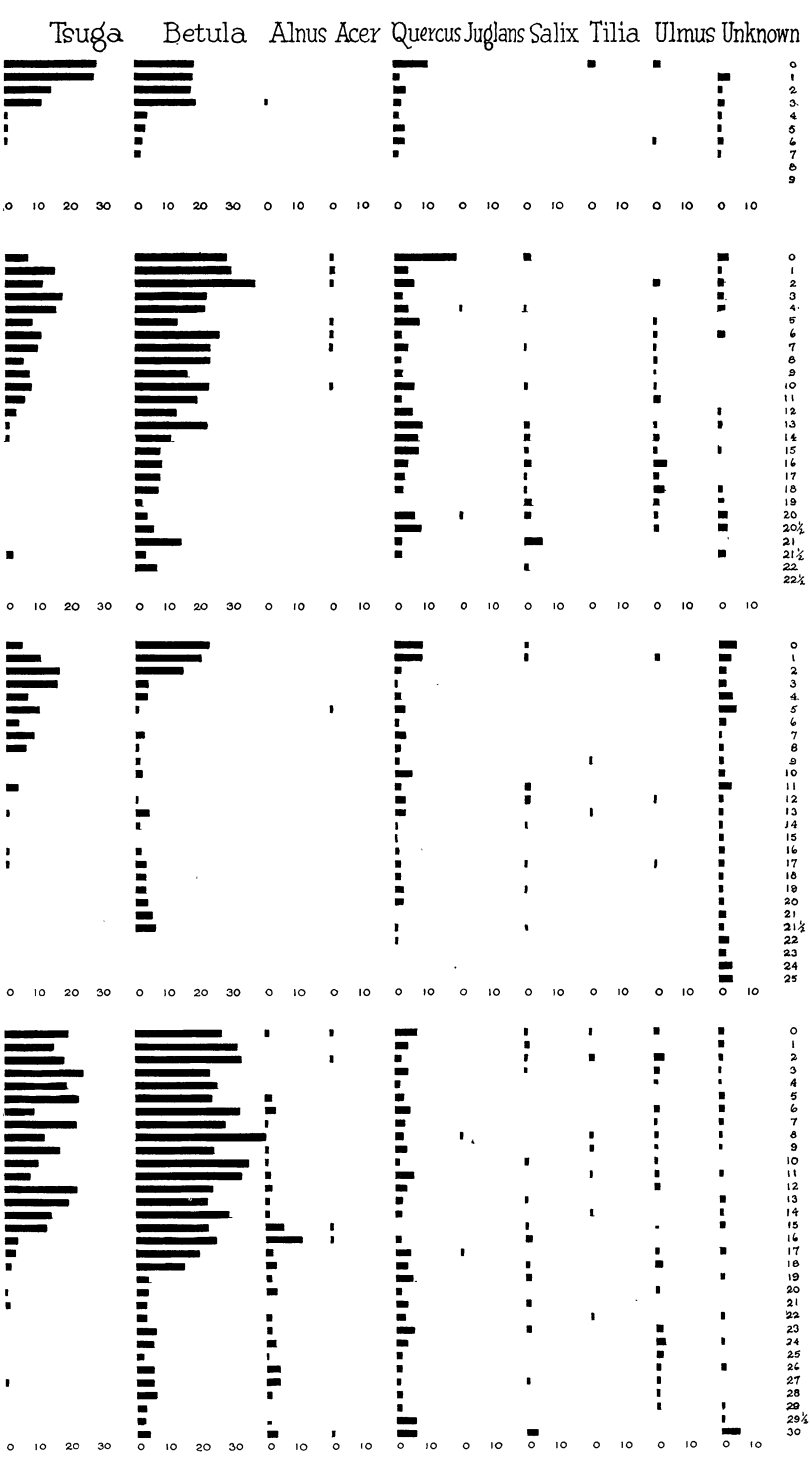
Tsuga
Betula
Alnus
Acer
Quercus
Juglans
Salix
Tilia
Ulmus
Unknown

aspect of the work, as expressed previously by the author (1940). The same difficulty was experienced by Bramlette, M. N and W. H. Bradley (1940) when they attempted to use glacial marine deposits from the North Atlantic as time scales. Bog deposits are perhaps even a little more difficult to use for so definite a mathematical measurement because the weight of the accumulating sediments will warp the uniformity of time in terms of depth of peat, and the ratio in this relationship is not known, and very likely will never be known. In all four bogs of this study the peat was very soft in the upper foot-levels, at times barely sufficiently solidified to provide the resistance necessary to open the sleeve on the borer. Such condition weights the sediment with less years, makes the pollen record of more recent origin than purely proportionally mathematical computations of the total depth of the bogs indicate, so that the upper third may represent at most five to six thousand years; but even this would stamp the northern hardwoods invasion of the region with considerable age.

Pollen profiles point the way to forest planting in sympathy with the climate, and in alignment with natural succession. Since the maple-birch-hemlock forest replaced the pine dominance of many thousands of years standing, it is logical to retain such hardwoods forests in these sites. However, effect of microclimate must also be taken into consideration, in the Trout lake region pine has never been succeeded, as records from four bogs and Grassy lake show in a study by Potzger-Richards (1942). The two studies in Vilas county very definitely show the climatic change which initiated the microclimatically determined pine, and macroclimatically favored hardwoods forest associations in Vilas county, Wisconsin, and Gogebic county, Michigan, area. It furthermore points out that pine was climatically favored for a long period of time. While the pine dominance did not always find expression in regions affected by late Wisconsin glaciation, it did find expression in Indiana at Winona and Tippecanoe lakes (Potzger-Wilson, 1941), Lake Cicott bog (Smith, 1937), Silver lake bog (Moss, 1940) and became more prominent northward from these stations as indicated by the profile from Third Sister lake in lower Michigan (Potzger-Wilson, 1941).

Summary and Conclusion

1. The paper presents pollen profiles from four bogs on the Gillen Nature Reserve, located in southern Gogebic county, Michigan, and northern Vilas county, Wisconsin.

2. All four bogs show approximately the same forest succession, viz., spruce or spruce-pine to pine to hemlock-birch-pine.

3. Replacement of pine by birch and hemlock took place when approximately the upper half to one-third of the total sediments began to accumulate.

4. The forest primeval adjoining Killarney Point and Potzger bogs has sugar maple equal in importance and abundance to hemlock, but is very sparingly represented in the pollen record. Very likely insect-pollinated species like

sugar maple and linden do not receive sufficient pollen representation in bogs and lakes to reflect truly their importance in the former forest association.

5. Climatically the northern hardwoods is apparently favored, and microclimate retains pine dominance in forests on sandy habitats.

6. The opinion is expressed that these pollen spectra might well be used as indicators in reforestation projects.

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