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POLLEN EVIDENCE FOR THE PROTOHISTORIC DEVELOPMENT OF THE "BIG WOODS" IN MINNESOTA (U.S.A.)

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SUMMARY

When the presettlement deciduous forest, as described from land-survey notes of 1854–1860, is compared with relict forest stands of today, it is clear that mesic succession has taken place. The "Big Woods", dominated by *Acer* and *Tilia*, has developed from a forest dominated by *Ulmus* and *Quercus* with some *Tilia* and *Acer*. Two pollen diagrams spanning the past 1,000 years show that this succession was initiated several hundred years before settlement. Three pollen diagrams from the adjacent oak forest suggest a concurrent succession from *Quercus* savanna, as well as a later increase in mesic elements at the time of settlement. An area that was oak barrens (a type of *Quercus* savanna) at the time of settlement, now has relict stands of oak forest; the two pollen diagrams from this area suggest the formation of oak forest since settlement.

The mesic successions are probably a culmination of a long-term change toward a cooler and moister climate, but a postulated decrease in Indian populations and fires after European contact about 1650 and before settlement could have accelerated the vegetation successions.

INTRODUCTION

In Minnesota and adjacent states the nineteenth century was a period of rapid vegetational change. Not only did settlers plow the prairie and clear the forest for farms but succession took place in vegetation not so disturbed.

In northwestern Minnesota, a comparison of the vegetation determined from the presettlement land survey with relict stands showed that *Quercus* savanna had been replaced by *Quercus* forest, areas of *Quercus* forest had succeeded to *Ulmus–Tilia* forest, and areas of *Ulmus–Tilia* have become dominated by *Acer saccharum* (McANDREWS, 1966). In Iowa, McCOMB and LOOMIS (1944) describe the invasion of prairie by *Quercus macrocarpa* and *Ulmus americana* since the land survey of the eighteen-fifties. In Wisconsin, CURTIS (1959) attributes similar forest invasions

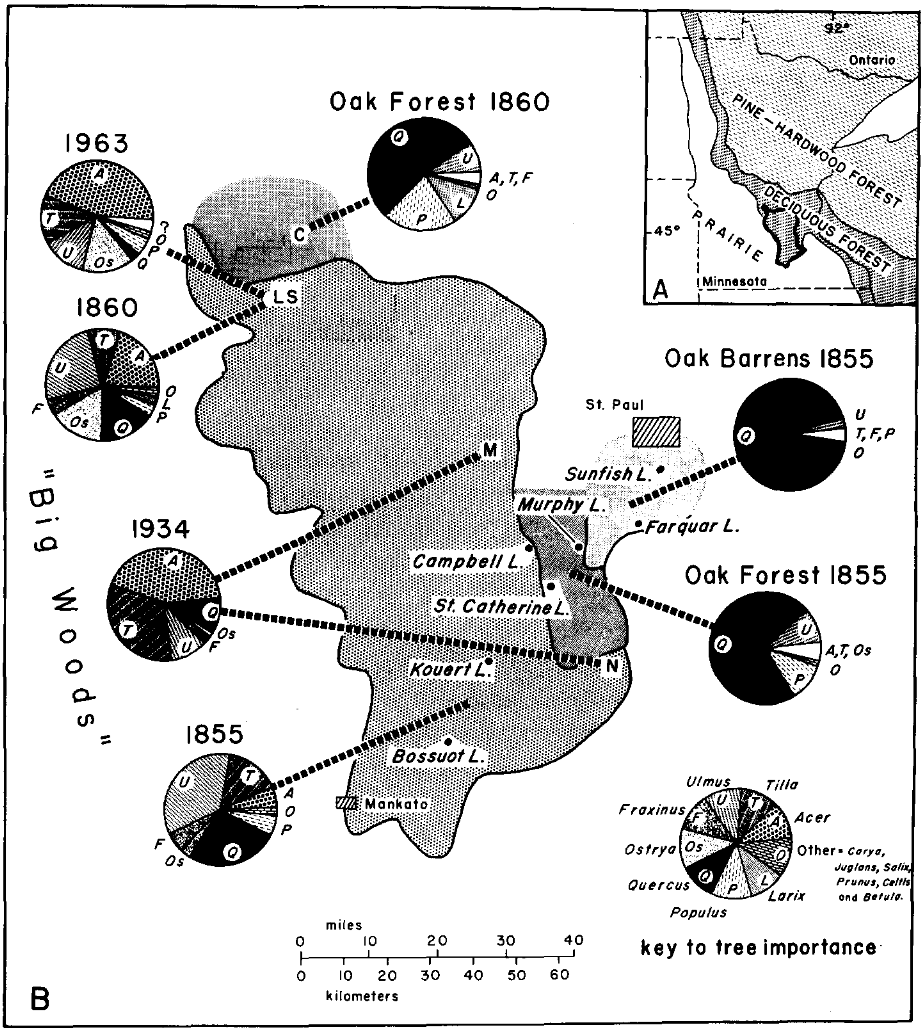

Fig.1A. Map of vegetation formations of Minnesota. The "Big Woods" area of the deciduous forest is outlined.

B. Map of "Big Woods" and adjacent vegetation types together with importance diagrams of tree genera for presettlement and postsettlement times. Oak barrens 1855 (453 trees), oak forest 1855 (222 trees), and "Big Woods" 1855 (983 trees) are summaries of presettlement land-survey notes along a transect between the cities of St.-Paul and Mankato. "Big Woods" 1934 (220 trees) is a combined summary of the Northfield (N) and Minnetonka (M) stands of DAUBENMIRE (1936). "Big Woods" 1860 (about 350 trees) is land-survey data from JANSSEN (1967; and personal communication, 1967) for the Lake Sylvia (LS) region. "Big Woods" 1963 (170 trees) is from JANSSEN (1966) for a stand at Lake Sylvia. Oak forest 1860 (about 350 trees) is from JANSSEN (1967) for the Clearwater (C) region. 1855- and 1934-data are importance percentages (I.P.). 1860- and 1963-data are percent importance values (I.V.). The lakes along the St.-Paul-Mankato transect are sites of pollen diagrams shown in Fig.2.

and successions to a decrease of Indian populations and of Indian-ignited fires in the seventeenth and eighteenth centuries as well as to selective logging of forest *Quercus* in the nineteenth century.

Southeastern Minnesota (Fig.1A) contains an area of relatively mesic deciduous forest, the "Big Woods" which, according to DAUBENMIRE (1936), is dominated by *Acer saccharum* and *Tilia americana*. It is surrounded by more xeric oak-dominated vegetation or prairie. The objective of this paper is to examine this area for evidence of recent succession, through use of both written records and pollen analysis.

Because both the identification of trees in the presettlement records and tree pollen in sediment can usually be made only to genus, some general statements of ecology are useful, and for this I rely largely on CURTIS' (1959) discussion of the forests of southern Wisconsin. *Quercus* spp. are a component of wet-mesic, mesic, dry-mesic, and dry forests, but on the driest sites fire-tolerant oak is almost exclusively dominant. Less fire-tolerant *Acer*, *Tilia*, and *Ostrya* reach their best development on mesic forest sites. The most prominent *Acer*, *A. saccharum*, is the most shade-tolerant tree species and tends to prevent reproduction of other trees. *Tilia* and *Ostrya* are represented by single species; *Ostrya*, a subcanopy tree, is important in dry-mesic as well as mesic forests. *Fraxinus* spp. and *Ulmus* are most abundant on wet-mesic forest sites, especially *U. americana*, but both it and *U. rubra* are prominent in mesic forests.

COMPARISON OF PRESETTLEMENT AND POSTSETTLEMENT VEGETATION

The "Big Woods" area was first contacted by French explorers during the second half of the seventeenth century, and an Indian trading fort was constructed near Mankato in 1700 (WINCHELL, 1884). English-speaking peoples settled St.-Paul about 1820, but it was not until after the period of the land survey (1853–1860) that agricultural settlement and lumbering became important in the "Big Woods" area. The general character of the "Big Woods" shortly after settlement was given by the operator of a sawmill near Mankato (in: WINCHELL, 1884) as:

very plentiful: *Ulmus americana, Tilia americana, Ostrya virginiana;*

common: *Quercus macrocarpa, Ulmus rubra, Fraxinus nigra, Acer negundo, Salix* spp.;

somewhat common: *Acer saccharum, Populus tremuloides, Celtis occidentalis;*

rare: *Juglans cinerea, Carya cordiformis, Acer saccharinum* or *A. rubrum, Prunus serotina, Populus grandidentata, P. deltoides, Juglans nigra, Carpinus caroliniana, Betula lutea, B. papyrifera, Juniperus virginiana,* and *Gymnocladus dioica.*

Quercus rubra has been unaccountably omitted.

For Wright County, which contains Lake Sylvia (Fig.1B), WINCHELL (1884) gives a similar list and states that *Ulmus* and *Tilia* are the most abundant and largest trees and that the less common *Acer saccharum* is gregarious. Thus, it appears that in the nineteenth century "Big Woods" was not dominated by *Acer saccharum* but rather by *Ulmus*.

A more quantitative approach to changes in forest composition can be made by comparing witness tree data of land-survey notes with twentieth-century relict-stand analyses (McANDREWS, 1966). The surveyers laid out a grid system that enabled incoming settlers to find and describe plots of land they wished to occupy. At survey corners, where one-half mile boundary lines intersect, the surveyers marked either two or four trees to witness the corner. They recorded the tree diameter and the species by common name. This low-intensity tree sample may be used to obtain the relative density, relative dominance (relative basal area), and, with difficulty, relative frequency. The difficulty arises when the size of the sample (2 *or* 4 trees) varies among the sampling points (corners). The percent of the relative density and relative dominance is the importance percentage (I.P.) (McANDREWS, 1966); the percent of all three dimensions is the percent importance value (I.V.) (JANSSEN, 1966, 1967). However, for the purposes of this paper, the I.P. and % I.V. are essentially similar.

Fig.1B presents a graphic comparison of tree composition; all species are deciduous, and over 97% of the trees are included in eight genera (seven angiosperms and the bog gymnosperm *Larix*). In the "Big Woods" area, comparison of mid-nineteenth century land-survey data with modern stand analyses of Daubenmire, made in 1934, and of Janssen, made in 1963, shows that among the four leading dominants, which together total more than 80%, *Ulmus* and *Quercus* have been replaced by *Acer* and *Tilia*. *Populus* has decreased, but there is little apparent change in the minor elements *Fraxinus* and *Ostrya*.

THE ST.-PAUL-MANKATO TRANSECT

Along the transect between the cities of St.-Paul and Mankato (Fig.1B) the three vegetation types that have been defined through land-survey notes are related to landform characteristics. The "Big Woods" area, with a prominent component of the mesic *Ulmus—Tilia*—and *Acer* is chiefly situated on undulating ground moraine. The soil, developed on a calcareous silty till, is poorly to moderately well drained and is termed a prairie-border soil partly because of its high content of organic matter. The oak forest, with a predominance of the more xeric *Quercus*, is on similar soil parent material, but the soil is very well-drained because of the hilly topography of an end moraine. Here also the forest soils tend to be drier, because sunlight reaches the soil surface relatively more easily on steep hillsides (CURTIS, 1959). The soil is podsolized.

Oak barrens is a type of *Quercus* savanna where small, scattered, and often shrub-like *Quercus ellipsoidalis*, *Q. macrocarpa*, and *Q. alba* occur in a matrix of prairie (CURTIS, 1959). The oak barrens is situated on hilly end moraine; it is excessively well drained because of this and also because the soil parent material is non-calcareous and sandy. Relict stands in the oak barrens area have succeeded to xeric oak forest described in WRIGHT et al. (1963).

Pollen diagrams were constructed from short cores from seven lakes along the transect, each of roughly 85,000 m^2 area. To prevent mixing of the loose upper sediment, the cores were frozen before extursion from the sample tube, and samples were cut at 10-cm intervals. The results of the pollen counts are presented in Table I–VII.

In the pollen diagrams (Fig.2) the main tree-pollen types are shown together with three herb-pollen types, namely the weedy disturbance indicators *Ambrosia* and Chenopodiineae and the cultivated *Zea*. The herb rise in the upper part of the cores signals the time of land settlement about hundred years ago. Assuming that a century of presettlement sediment is compacted to half the thickness of the century of postsettlement sediment and that there has been no change in the sedimentation rate, then the pollen diagrams span the period from A.D. 1,200 to A.D. 1,600 to the present, i.e., at their base they all predate the advent of European man in the area.

The pollen diagram of Campbell Lake, which is in the "Big Woods" at the border of the oak forest (Fig.1B), is similar to and thus grouped with the oak forest diagrams (Fig.2).

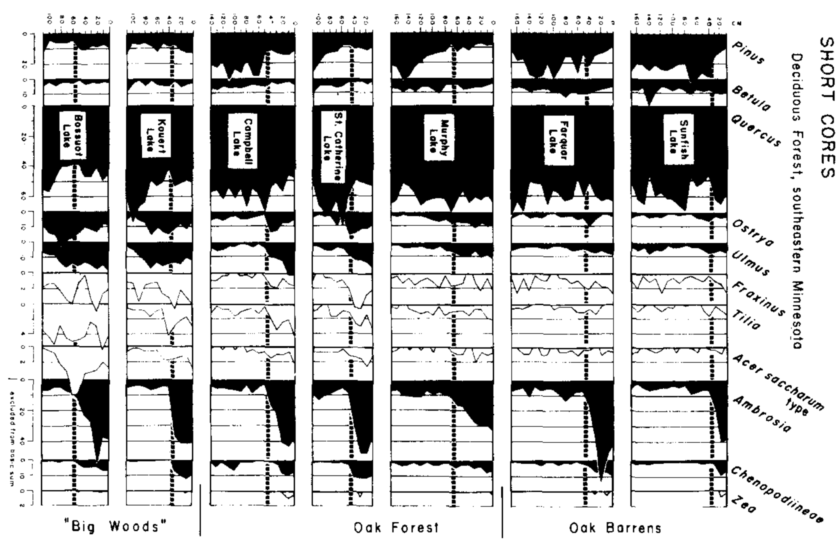

Fig.2. Simplified pollen diagrams of short cores from seven lakes along the St.-Paul-Mankato transect. Vegetation types are at the right. The basic sum, about 300, includes only tree pollen; herb pollen were individually added to the basic sum before their percentages were calculated. The dashed line indicates rise of disturbance indicators due to settlement. Percentage scales for gray curves are exaggerated 5 × with respect to scales for other curves.

TABLE I

POLLEN COUNTS FOR TREES AND SELECTED HERBS FROM SUNFISH LAKE

	Depth (cm)																
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
Pinus	26	40	51	89	87	89	97	104	63	86	74	76	63	83	63	62	77
Betula	28	33	31	22	26	19	29	43	17	28	18	15	25	55	14	25	24
Quercus	169	218	213	142	170	159	141	393	207	236	186	183	182	147	199	190	159
Ostrya/Carpinus	9	13	9	18	16	9	2	7	6	5	3	10	7	12	5	6	11
Ulmus	19	14	21	21	14	8	8	9	8	11	5	14	12	23	8	13	10
Fraxinus	8	5	4	1	4	2	1	3	4	2	3	8	2	4	1	6	3
Tilia	4	3	1	5	3	—	—	1	—	2	1	3	1	—	1	3	1
Acer saccharum type	—	3	2	1	1	—	2	1	—	3	—	1	2	1	—	2	3
Other trees[1]	34	12	19	16	14	17	27	12	14	14	16	12	12	18	18	4	26
Ambrosia	187	231	76	21	22	24	29	16	16	12	14	15	19	23	15	5	19
Chenopodiineae	21	36	9	5	9	4	3	7	3	3	4	5	4	8	6	7	5
Zea	1	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

[1] *Picea*, *Abies*, *Larix*, Cupressineae, *Populus*, *Salix*, *Juglans*, *Carya*, *Acer negundo*, *A. rubrum*, *Platanus*, *Tsuga*, *Celtis*, *Fagus* and *Morus*.

TABLE II

POLLEN COUNTS FOR TREES AND SELECTED HERBS FROM FARQUAR LAKE

	Depth (cm)																	
	1	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
Pinus	25	37	38	45	62	36	80	47	46	68	98	57	82	100	96	52	75	31
Betula	15	17	19	24	28	28	29	23	36	27	29	21	20	27	30	20	23	18
Quercus	189	189	179	187	145	173	137	182	187	172	182	206	148	174	175	217	254	207
Ostrya/ Carpinus	8	5	5	13	27	11	14	6	7	7	2	2	10	9	11	2	6	10
Ulmus	21	19	13	20	16	11	14	15	8	6	6	10	10	9	9	9	15	14
Fraxinus	8	6	5	3	6	5	3	4	2	2	—	3	3	1	8	2	10	1
Tilia	—	—	1	4	2	3	3	1	1	1	2	—	—	—	1	2	2	2
Acer saccharum type	2	1	3	—	1	1	3	1	2	2	—	3	3	—	3	3	1	—
Other trees[1]	35	36	23	24	12	22	16	19	12	13	9	16	12	19	18	9	22	9
Ambrosia	212	282	537	190	61	20	23	32	44	28	19	16	19	12	40	14	25	22
Chenopodiineae	32	26	24	23	10	6	1	5	3	8	2	2	9	5	5	5	2	3
Zea	—	2	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—

[1] *Picea*, *Abies*, *Larix*, Cupressineae, *Populus*, *Salix*, *Juglans*, *Carya*, *Acer negundo*, *A. rubrum*, *Platanus*, *Tsuga*, *Celtis*, *Fagus* and *Morus*.

TABLE III

POLLEN COUNTS FOR TREES AND SELECTED HERBS FROM MURPHY LAKE

	Depth (cm)																	
	1	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
Pinus	24	23	21	24	38	33	38	20	39	39	59	50	57	66	88	95	69	66
Betula	8	12	19	19	21	26	11	11	15	30	32	17	17	25	19	26	20	19
Quercus	200	165	202	199	215	201	189	209	194	184	256	204	206	175	165	149	190	204
Ostrya/ Carpinus	24	26	22	33	23	23	18	22	13	18	22	12	7	7	7	4	7	6
Ulmus	30	22	30	16	29	31	22	15	16	8	17	13	7	9	9	9	5	5
Fraxinus	7	8	7	4	—	5	5	5	1	6	5	2	3	5	2	4	1	2
Tilia	6	5	2	2	5	3	3	3	5	1	6	3	4	3	2	—	2	1
Acer saccha-rum type	2	3	2	6	—	3	3	2	5	1	3	—	1	—	1	—	1	2
Other trees[1]	12	27	24	30	10	39	21	12	25	17	18	22	11	16	16	23	15	12
Ambrosia	152	117	139	126	97	73	57	34	30	24	40	22	36	35	34	32	19	23
Chenopodi-ineae	21	24	13	16	8	8	13	6	5	10	9	2	9	4	8	10	6	3
Zea	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

[1] *Picea, Abies, Larix,* Cupressineae, *Populus, Salix, Juglans, Carya, Acer negundo, A. rubrum, Platanus, Tsuga, Celtis, Fagus* and *Morus.*

TABLE IV

POLLEN COUNTS FOR TREES AND SELECTED HERBS FROM ST.-CATHERINE LAKE

	Depth (cm)										
	10	20	30	40	50	60	70	80	90	100	110
Pinus	34	37	35	32	23	35	38	42	42	61	80
Betula	6	12	7	7	6	20	18	14	14	15	28
Quercus	189	164	175	151	166	345	183	225	207	200	155
Ostrya/Carpinus	28	33	37	42	41	7	25	8	8	5	11
Ulmus	55	39	39	34	22	15	8	14	12	7	6
Fraxinus	8	9	16	14	6	4	4	2	2	—	3
Tilia	12	4	10	8	3	4	5	5	—	2	3
Acer saccharum type	4	8	5	4	3	1	2	2	2	2	2
Other trees[1]	23	13	27	21	17	7	17	13	9	12	23
Ambrosia	192	290	308	138	25	22	21	30	31	43	29
Chenopodiineae	40	41	44	38	7	5	6	3	2	4	6
Zea	—	—	3	—	—	—	—	—	—	—	—

[1] *Picea, Abies, Larix,* Cupressineae, *Populus, Salix, Juglans, Carya, Acer negundo, A. rubrum, Platanus, Tsuga, Celtis, Fagus* and *Morus.*

TABLE V

POLLEN COUNTS FOR TREES AND SELECTED HERBS FROM CAMPBELL LAKE

	Depth (cm)														
	1	10	20	30	40	50	60	70	80	90	100	110	120	130	140
Pinus	40	42	42	42	46	38	105	84	70	103	73	93	53	71	67
Betula	15	6	8	11	10	18	19	13	22	27	19	19	15	23	20
Quercus	168	131	166	149	218	221	214	161	270	209	184	161	172	173	181
Ostrya/Carpinus	15	18	18	35	50	6	8	11	17	18	7	10	16	12	15
Ulmus	74	60	34	30	36	11	2	9	4	2	8	8	13	17	11
Fraxinus	6	4	2	6	7	1	—	2	1	1	—	1	1	3	3
Tilia	15	6	7	10	7	1	5	2	3	4	5	2	2	1	4
Acer saccharum type	9	2	3	3	6	2	3	1	3	—	1	—	1	—	1
Other trees[1]	15	21	14	17	24	16	11	16	16	24	6	5	9	9	17
Ambrosia	212	218	202	84	76	7	17	27	14	31	20	19	15	18	12
Chenopodiineae	31	31	27	10	5	2	1	5	5	6	23	12	4	15	2
Zea	2	3	1	—	—	—	—	—	—	—	—	—	—	—	—

[1] *Picea, Abies, Larix,* Cupressineae, *Populus, Salix, Juglans, Carya, Acer negundo, A. rubrum, Platanus, Tsuga, Celtis, Fagus* and *Morus.*

TABLE VI

POLLEN COUNTS FOR TREES AND SELECTED HERBS FROM KOUERT LAKE

	Depth (cm)											
	1	10	20	30	40	50	60	70	80	90	100	110
Pinus	41	41	37	25	30	20	46	25	20	28	24	43
Betula	8	12	18	4	18	15	17	5	15	6	12	28
Quercus	156	150	163	171	132	146	196	140	191	240	267	195
Ostrya/Carpinus	18	32	23	34	47	37	37	42	20	19	7	15
Ulmus	36	30	44	41	45	43	47	48	35	26	16	8
Fraxinus	13	10	7	15	11	8	5	4	5	14	5	4
Tilia	9	5	7	9	14	2	4	5	3	3	3	2
Acer saccharum type	9	4	4	5	6	5	2	2	2	1	1	2
Other trees[1]	20	26	21	20	27	15	15	16	17	22	16	29
Ambrosia	211	221	229	186	18	14	23	20	14	12	15	19
Chenopodiineae	32	42	34	24	—	2	3	2	2	4	7	2
Zea	—	1	—	—	—	—	—	—	—	—	—	—

[1] *Picea, Abies, Larix,* Cupressineae, *Populus, Salix, Juglans, Carya, Acer negundo, A. rubrum, Platanus, Tsuga, Celtis, Fagus* and *Morus.*

TABLE VII

POLLEN COUNTS FOR TREES AND SELECTED HERBS FROM BOSSUOT LAKE

	Depth (cm)											
	1	10	20	30	40	50	60	70	80	90	100	110
Pinus	44	24	38	27	33	39	18	21	20	21	15	49
Betula	12	8	12	8	12	6	11	9	10	16	8	19
Quercus	203	166	162	152	140	140	136	127	124	161	179	224
Ostrya/Carpinus	37	26	50	36	30	49	58	59	70	49	44	38
Ulmus	84	48	70	46	38	55	49	54	42	29	26	28
Fraxinus	10	9	21	11	1	8	15	12	8	5	5	8
Tilia	19	20	12	8	13	16	20	14	9	19	14	14
Acer saccharum type	13	7	13	11	11	23	23	11	7	3	2	1
Other trees[1]	30	24	30	27	23	28	21	17	17	28	24	20
Ambrosia	289	201	477	126	91	96	34	26	17	18	25	29
Chenopodiineae	35	23	20	17	16	25	5	3	6	4	4	8
Zea	1	1	1	—	—	—	—	—	—	—	—	—

[1] *Picea*, *Abies*, *Larix*, Cupressineae, *Populus*, *Salix*, *Juglans*, *Carya*, *Acer negundo*, *A. rubrum*, *Platanus*, *Tsuga*, *Celtis*, *Fagus* and *Morus*.

It is useful here to distinguish between extra-regional pollen, which comes from beyond the deciduous forest, and the regional pollen, which is derived from the deciduous forest itself (McAndrews, 1967). *Pinus* and most of the *Betula* are derived from the pine-hardwood forest (Fig.1A) and here, despite logging, *Pinus* pollen percentages show no substantial change (Janssen, 1967; McAndrews, 1967). If *Pinus* pollen transport southward is constant, then the larger *Pinus* values for the oak barrens, compared with the "Big Woods", indicate a lesser regional and greater extra-regional component for the pollen rain of savanna compared with forest. The three oak-forest diagrams show an upward decrease in *Pinus* and an increase in regional pollen, suggesting a shift from savanna vegetation to forest.

The diagrams from the "Big Woods" and oak forest show an upward increase of mesic forest components, i.e., *Ostrya*, *Ulmus*, *Fraxinus*, *Tilia*, and *Acer*, but the amount and chronology of the increase differs among the vegetation types. The "Big Woods" has relatively higher pollen values, corresponding to their greater tree values (Fig.1B). In addition, the pollen succession in the "Big Woods" appears to begin long before settlement, whereas a substantial increase of the mesic components in the oak forest begins at or just before settlement. In the oak barrens, the mesic components other than *Ulmus* show no increase; however, at the time of settlement, the increase of *Quercus* at the expense of *Pinus* may reflect the succession to oak forest from oak barrens.

For the "Big Woods", comparison of pre- and postsettlement vegetation analyses with the pollen diagrams shows that whereas *Ulmus* and *Quercus* tree values decrease substantially, their pollen percentages decrease only slightly. A possible explanation is that they were replaced by *Acer* and *Tilia,* which are relatively poor regional pollen producers (JANSSEN, 1967). If this were true, then the extra-regional component should increase, and indeed *Pinus* does increase.

DISCUSSION

Radiocarbon-dated pollen diagrams from the deciduous forest area of southeastern Minnesota indicate prairie during mid-Postglacial time. In the oak barrens area two pollen diagrams from sites within four miles of Farquar Lake show *Quercus* became important about 5,500 years ago (WRIGHT et al., 1963). A pollen diagram from the "Big Woods" shows a substantial *Quercus* increase about 3,000 years ago, followed by the more mesic forest elements (J. Waddington, personal communication, 1967). Thus, the mesic forest succession may record the culmination of a long-term trend toward increased soil moisture. The relatively late *Quercus* invasion of the prairie in the present "Big Woods" area may result from the fact that slower soil drainage in this area discouraged tree growth and allowed the prairie to persist. However, once *Quercus* was established, the more mesic forest elements invaded more rapidly than they did on the better-drained soils of the oak forest. The initiation of the mesic succession from oak forest to the modern "Big Woods" may have coincided with a change toward a cooler and perhaps moister climate about 1550 A.D. (BRYSON and WENDLAND, 1967).

Because the beginning of the "Big Woods" and oak forest succession is probably post-contact and certainly presettlement, the decrease and displacement of Indian populations could have accelerated succession. In colonial New England, the deciduous forests were adapted to Indian fires (BROMLEY, 1935), and succession occurred when the Indians were killed by disease (DAY, 1953). In Wisconsin, Indian fires maintained *Quercus* forest, and fire-intolerant *Acer* and *Tilia* were restricted to moist, less easily burned slopes (MARKS, 1944). Indian populations may have crashed to one-fiftieth of their pre-contact level, for HALL (1962) estimated that the Winnebago tribe of Wisconsin decreased by disease and war from 4,000 to 5,000 men at the time of French contact in 1634 to 60–150 men in the early seventeen hundreds. In the Great Lakes area, the Indian hunting-gathering economy rapidly changed to a fur-trading economy as a result of contact (QUIMBY, 1960). More discussion than can be presented here must be undertaken before the relative merits of the climatic-change and Indian-fire hypotheses can be evaluated as causal factors in "Big Woods" succession.

A recent development in the correlation of vegetation with pollen assemblages has been the comparison of the subrecent vegetation derived from presettlement land-survey data with the recent surface pollen (JANSSEN, 1967). In the "BigWoods" and adjacent deciduous forest types this comparison is of doubtful validity because the pollen rain has changed significantly since settlement and reflects the postsettlement forest succession. Short cores must, therefore, be used to identify the presettlement pollen rain.

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