Comparison of pollen spectra from bogs of Early and Late Wisconsin glaciation in Indiana

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Edited by

Ray C. Friesner

The Butler University Botanical Studies journal was published by the Botany Department of Butler University, Indianapolis, Indiana, from 1929 to 1964. The scientific journal featured original papers primarily on plant ecology, taxonomy, and microbiology. The papers contain valuable historical studies, especially floristic surveys that document Indiana's vegetation in past decades. Authors were Butler faculty, current and former master's degree students and undergraduates, and other Indiana botanists. The journal was started by Stanley Cain, noted conservation biologist, and edited through most of its years of production by Ray C. Friesner, Butler's first botanist and founder of the department in 1919. The journal was distributed to learned societies and libraries through exchange.

During the years of the journal's publication, the Butler University Botany Department had an active program of research and student training. 201 bachelor's degrees and 75 master's degrees in Botany were conferred during this period. Thirty-five of these graduates went on to earn doctorates at other institutions.

The Botany Department attracted many notable faculty members and students. Distinguished faculty, in addition to Cain and Friesner, included John E. Potzger, a forest ecologist and palynologist, Willard Nelson Clute, co-founder of the American Fern Society, Marion T. Hall, former director of the Morton Arboretum, C. Mervin Palmer, Rex Webster, and John Pelton. Some of the former undergraduate and master's students who made active contributions to the fields of botany and ecology include Dwight W. Billings, Fay Kenoyer Daily, William A. Daily, Rexford Daubenmire, Francis Hueber, Frank McCormick, Scott McCoy, Robert Petty, Potzger, Helene Starcs, and Theodore Sperry. Cain, Daubenmire, Potzger, and Billings served as Presidents of the Ecological Society of America.

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COMPARISON OF POLLEN SPECTRA FROM
BOGS OF EARLY AND LATE WISCONSIN
GLACIATION IN INDIANA

By Dayton A. Swickard

As is well known, Indiana was within the path of the Illinoian and both the Early and Late Wisconsin ice sheets. The Illinoian glacier, coming earlier than the Wisconsin glacier, extended the entire length of the state along both the east and west borders, leaving a large south-central portion unglaciated. The unglaciated area has its northernmost boundary in Monroe county with its southernmost limit on the west, Posey county, and on the east, Clark county. The Illinoian drift was covered by the Early Wisconsin glacier, whose southern border made an irregular line from Vermillion county on the west, southeast to Franklin county on the east, with its southernmost extension reaching the tip of Jennings county in the south-central portion of the state.

The Late Wisconsin drift did not extend its outer border so far south. Its southern limit begins in Benton county on the west and makes an irregular line southeastward, as is the Early Wisconsin drift, to Randolph county on the east. These last two glacial periods were most active in that they left vast pits and kettle holes which probably soon became lakes, and by later filling in turned into bogs. Sufficient time has elapsed since the retreat of the Early Wisconsin period to obliterate every lake south of the Late Wisconsin border and only deep deposits of peat, amounting to as much as 43 feet, bear record of their past existence.

Two bogs were included in the present study, Yountsville bog in Montgomery county, within the border of the Early Wisconsin territory, and Mill Creek bog in Laporte county, located within the territory of the Late Wisconsin glaciation. Yountsville bog is 8 miles west and one mile south of Crawfordsville, near the Prairieville road, on the farm of William Runyon. The Mill Creek bog is one mile north of Mill Creek. This is a border county on the Michigan-Indiana line. It is located well in the Northern Moraine and Lake Region and is a part of a great outwash apron which has an altitude of 775-800 feet at the margin of the Moraine. This apron constitutes an extensive gravel plain made by drainages of ice during the deposition of the Kalamazoo Moraine (Malott, 6). The drainage of this
county is chiefly through the broad valleys of Crooked and Mill Creeks.

THE STATUS OF THE BOGS

Yountsville bog is an extinct bog, the peat having solidified enough to permit cultivation. It covers approximately 20-25 acres with a central area of approximately 1200 feet by 800 feet which is still quite wet during the rainy seasons. The portion surrounding this central area has all been disturbed by cultivation, by washing in of the surrounding soils, and by a gravel lane which has been built over its surface. The water table is high, holes dug on the surface during boring observations showed the water within one foot of the top.

Two borings were made in this central area of the bog, designated as boring "A" and "B." Boring "A," the deeper of the two borings, recorded peat accumulation to a depth of 24 feet. Boring "B," made some 200 feet from "A," was only 15 feet deep. The peat from the deeper boring, "A," was used for analysis. The Yountsville bog is of the typical kettlehole type. It is circular in shape with fringing gravel hills around the periphery.

Mill Creek bog is in a more youthful stage; the soil is very soft and wet during the entire year. This bog resembles more nearly an old river bed which has turned into a lake. The length is probably 9 or 10 miles. Following approximately the course of the old river bed is a wet ditch that continues south, emptying into Mill Creek. The drilling was made in what was thought to be the deepest area. Only one boring was made and the depth reached was 59 feet. The drilling took place in the southern half of the bog about one mile north of Mill Creek. A short distance north of the drilled area is an island about which the old river probably made its course. The channel on the eastern side of the island is more shallow than the channel on the western side, because in this channel there is a small wet area which has not as yet filled in and is covered by water. The eastern border is made of forested hills which rise sharply from the edge of the bog.

PRESENT DAY VEGETATION

The present day vegetation of Mill Creek bog is typical of developing bogs. The bog surface itself is a sedge meadow, while the gravel ridges surround. Acer saccharum, Cornus alba, but in the boggy areas, Potentilla fruticosa, Vaccinium angustifolium, and the typical kettlehole type. It is circular in shape with fringing gravel hills around the periphery. Browsing was abundant, individuals Gentiana princeps, Caltha palustris, Cyperus esculentus, growing in the areas of open water. Northern plants such as Betula papyrifera, Pinus strobus, and M. alba, were found here. No special study was made of such northern species because natural habitat. It must be emphasized that the Pine Hills area is typical of such northern species. A sample of vegetation was studied in detail. The samples were collected at one location, but in the laboratory was prepared best as the alcohol small beaker; to
solidified 25 acres which is rounding fishing in the surface, not of the designated borings, 13," made from the little bog a fringing very soft nearly an old river foot area. The mile north area is an The channel the western edge of the de-...
hal. Then from one to five drops of 1% aqueous solution of gentian violet was added and the material was stirred for several minutes. It was found in staining the material from the Mill Creek bog, that the lower depths required more stain. As Smith (17) stated, the alkinity of the lower levels required much more stain to make a well stained slide.

It was found in both bogs that if the slides were allowed to stand for a few days the pollen became more fully stained. This was particularly true of Yountsville bog, where a week or more was required before the grains began to show any color. Pollen determination was made with the aid of a binocular microscope equipped with 43X objective and 15X oculars. To familiarize the observer with the pollen grains encountered, the illustrated references of Sears (18) and Wodehouse (22) were used. There were also available permanent slides of known pollen grains which could be compared with the grains from the bogs.

The pollen frequency was based upon a count of 200 grains per foot-level. Foot-levels 25, 11, 10, 9, and 7 are absent from the spectrum of the Mill Creek bog, because the peat was so dilute at these levels that it was impossible to make collections. This is indicated by a "w" in the graph. At the one-half foot and surface levels in the bog, only 100 grains were counted because of the lower number encountered.

**OBSERVATIONS**

**Mill Creek Bog**

The pollen spectrum from the Mill Creek bog was found to be typical of bogs observed by other workers in Indiana. The lower levels show dominance by Abies and Picea. In the 59-foot level, as well as the 55-foot level Abies has a percentage of 59.5. Picea was represented by 38.5%. Two other genera were represented in the lower levels, viz. Quercus and Pinus, both with low percentages. Abies showed its first signs of losing importance at the 51-foot level, where its percentage dropped to 18.5, while Picea dropped to 11.5. Quercus had been present from the lowest levels and with this decrease in Abies and Picea in the 51-foot level it gained in relative importance. In the next level, however, Abies again increased in importance, having a percentage of 28.5 to 25 for Quercus. Picea
also gained with an increase to 19%. At the 49-foot level Quercus again increased in importance with a percentage of 45. Abies dropped to 2%, and never showed any importance after this foot-level, disappearing entirely at the 33-foot level. Quercus was now the important genus of the spectrum and continued to be up to the 46-foot level. Secondary in importance was Picea which had now gained over Abies and continued to lead until it disappeared completely at the 13-foot level. At the 46-foot level there was a decisive change in the spectrum. Pinus, which had occupied a position of minor importance, now showed a sharp increase from 4.5% in the 47-foot level, to a dominating percentage of 60. This was the only level in which Pinus dominated; but, in the next two foot-levels (i.e. 45 and 44), the percentage was high enough to form a Quercus-Pinus association.

After the dominance of Pinus in the 46-foot level, Quercus became the most important genus of the spectrum. It held a dominance from the 43-foot level on to the surface with percentages which never dropped below 75.5. No Larix grains were found in the lower 3 foot-levels. It appeared at the 56-foot level with a representation of 0.5%. From here to the surface it appeared and disappeared in the various levels. The highest percentage reached was 6.

Tsuga had the least representation of all genera; it was present only in 4 levels in very low percentages. All other genera were represented by unimportant percentages; Salix appeared in the 51-foot level with a percentage of 18.5, the highest representation for it in the spectrum. It finally disappeared in the 21-foot level. Betula came in at the 52-foot level and persisted in low percentages to the 3-level foot.

Other broadleaved genera, Alnus, Acer and Ulmus, were found in small percentages. Acer came in at the 31-foot level and was present until the 2-foot level. The percentage representation was never very high, the highest being 5% in the 22-foot level. Ulmus was persistent in its presence, but never reached significant representation. It made its appearance in the 54-foot level, and its highest percentage was 6.5 in the 15-foot level. Carya, Juglans, Liquidambar and Tilia appeared in small percentages and at varying levels between the 46-foot level and the surface.
Quercus and Abies were dominant in the lower levels as in the Mill Creek bog. The dominance of the two continues for a much longer period of time than in any bog yet analyzed in the Early Wisconsin glaciation territory. Abies showed dominance only in the 24-foot level with a percentage of 56.5. From this level to the 19-foot level Picea was a co-dominant with Abies, but at the 19-foot level Picea became the dominant species and remained so to the 11-foot level. Abies, however, continued its presence in the spectrum and did not disappear until the 5-foot level. This probably is a new record for the presence of Abies in bogs thus far studied in Indiana. Picea was present in almost the entire spectrum of the bog; it was found up to the 0.5-foot level, after having been absent in the 2-foot level. The highest percentage reached was 60, in both the 18- and 16-foot levels.

Pinus was the only genus which was present through the entire spectrum. Howell (5) and Richards (13) reported this to be true also in the Kokomo and Otterbein bogs. Pinus never reached a dominant stage, its highest percentage being 13.5 in the 14- and 15-foot levels. Larix was present in the 24-foot level but disappeared and did not reappear until the 20-foot level. From this level to the surface it persisted in low percentages.

The broad leaved genera Quercus, Salix, and Betula were all present in low percentages at the bottom foot-level. Quercus appeared in the spectrum to the 20-foot level, here it disappeared until the 16-foot level. In the 11-foot level Quercus gained control and remained dominant to the surface level. The highest percentage reached by Quercus was 85, in the 2-foot level. Salix was present in the lowest three levels but, like Quercus, it disappeared not appearing again until the 13-foot level after which it remained in small percentages until it disappeared entirely at the 0.5-foot level.

Like Quercus and Salix, Betula disappeared after the 23-foot level, but reappeared at the 11-foot level. At the 8-foot level it became unusually prominent, reaching a representation of 42.5%, almost equaling Quercus at this stage. In the next level it dropped to 13% and finally disappeared at the 0.5-foot level. Acer was present only in the upper two foot-levels, reaching 11% at the 0.5-foot level but declining in the surface layer. Carya did not appear until the 5-foot level from which it remained in small representation to the
surface. Corylus and Alnus were both present to the 0.5-foot level where it disappeared never reaching more than 7%. Juglans was found in the 4-foot level lasting to the 0.5-foot level, but never having a high percentage. Tilia and Liquidambar were found only once in the spectrum. Liquidambar is listed with hesitation because of its present day range, but measurements and characteristics of the pollen grains agreed perfectly with published descriptions and to date no other pollen of herbaceous or woody species has been found which might be mistaken for Liquidambar.

DISCUSSION

The Early Wisconsin Glacial Drift

A lake is one of the most short lived of all topographic features. Practically all natural depositional agents tend to destroy lake basins by silt, wind-blown sands, or accumulation of plant and animal remains. It has been estimated that about one-fourth of Indiana is still or has been occupied by lakes in recent geological time (Malott, 8). The lakes formed during the Illinoian glacial retreat are all extinct or they have been obliterated by the Early Wisconsin glacier. All of the natural lakes or bogs in Indiana are products of the Early or Late Wisconsin glaciation. Great changes have taken place in the condition of the lakes in Indiana since the state was first settled. According to Malott (8), the last fifty years have witnessed the reduction of actual lake surface by at least one-half, probably due to natural causes coupled with artificial drainage. The lakes of Early Wisconsin drift are all closed chapters as lakes and have changed into mature bogs. The soil of the bogs of the Early Wisconsin glaciation has solidified to such an extent that farm cultivation is taking place upon its surfaces.

The Wisconsin glaciation in Indiana covered approximately 22,900 sq. miles and the margin made by it was distinctly lobate, a characteristic which became accentuated as the ice retreated to the northward. Leverett and Taylor (7) in their discussion of the lobation of the Indiana region states that they were local deployments down major valleys. Malott (8) states that the oldest section of the Late Wisconsin drift in Indiana is a section from Lafayette to Terre Haute; this is marked by large streams such as the Wabash river, and also by considerable dissection of the glacial plain itself.
In this section is located the Yountsville bog, included in this study. The bog analyzed by Richards (17) in Warren county is also within this region. In other sections of the Early Wisconsin boundary, bogs have been analyzed by Howell (6) in Howard county, Otto (12) in Marion county, Prettyman (16), Hamilton county, and Barnett (1) in Madison county. All these bogs were quite similar as to pollen records in the lower levels; all showed a forest dominated by Abies and Picea.

The behavior of Picea and Abies in the Yountsville bog was quite different from that of other bogs in the Early Wisconsin glaciation. In no other so far studied, did Abies and Picea persist so long as they did here. Picea was present to the 1-foot level and Abies persisted to the 5-foot level. Abies was dominant in the bottom level, but lost its dominance in the next level. This dominance was then taken over by Picea, and lasted to the 11-foot level where it gave way to Quercus. In the Otterbein bog, Bacon's Swamp and Kokomo bog, Picea had a similar representation. The dominating percentage of representation of Picea was about the same in all these bogs but the duration of dominance (8-foot levels) was longest at the Yountsville bog. This evidence of a well expressed boreal forest in the lower levels of the Yountsville bog agrees with the results of others and, according to Sears (19), indicates a cool-humid climate. Its persistence for so many foot-levels is hard to explain. A possible explanation is the one given by Howell (6), that the cool seepage water from the northeast and central part of the state drained to the southwest through the Wabash river basin making ideal conditions, i.e. cool soil for the reproduction of Picea and Abies, for a much longer period of time than in other areas from which the ice had retreated. In other words, persistence is evidently due to favorable local conditions, making it possible for these species to persist as relics in a macro-climate belt favoring broadleaved species but with a local micro-climate favoring the boreal species. This same region, as reported by Friis and Panzer (2), has even today a well-developed colony of northern plants, e.g. Pinus strobus, Taxus canadensis, Tsuga canadensis, Cornus rugosa, Dicrælla lonicera, and Gaultheria procumbens at Pine Hills which is only six miles to the south of the big site. The persistence of Pinus to the top foot-levels of the bog indicates that it had up to recent times a wider distribution as a relic in Montgomery county.
Larix was present in Yountsville bog in small percentages at intervals throughout the spectrum. Larix pollen is very fragile, and even the slightest pressure may break the exine, making the pollen unrecognizable. This is probably the reason why it shows such low percentages even though Larix may have had a greater percentage representation in the forest canopy. Yountsville bog had no record of Tsuga. In the other bogs it was found at different foot-levels throughout the spectrum with low percentages. Tsuga pollen is noted for its rapid disintegration when the pollen becomes wet, and so its absence does not necessarily mean non-representation in the forest complex. It is almost certain that Tsuga should have been in the forest complex of that region for it is present even today in the relic colony at Pine Hills which is only a few miles from the bog.

The percentage of Quercus in the Yountsville bog was higher than in any of the other bogs compared in the Early Wisconsin region. In the Yountsville bog it was slow in gaining dominance, much slower than in the other bogs, due to the long persistence of Picea and Abies, but once it gained control it dominated as in all other bogs. It is difficult to say whether the long Abies-Picea dominance is due to delayed change in macroclimate or to some unusually favorable local or microclimate control. Again it may mean that in a shallow lake, represented by the bog, filling was completed before the latter part of the succession could be included in the depositional record. The Otterbein, Kokomo, Cranberry, Fox Prairie, and Bacon's Swamp bogs all have Quercus persistent in the upper levels, but like Yountsville, they had a co-dominant species associated with it in the topmost levels. The usual co-dominant species of the other bogs were either Carya or Acer. In the Yountsville bog Acer became a co-dominant in the 0.5-foot level. Quercus, however, was still the dominant genus and had controlled since the 11-foot level. The spectrum suggests a very slow change from a cool-moist climate, as indicated by the persistent Picea and Abies dominance, to a warm-dry climate as indicated by the Quercus climax. The appearance of Acer in the last two foot-levels probably indicates a change from a warm-dry climate to a warm-moist climate. The percentage of Acer may mean more than it represents in the spectrum, since Acer pollen is not produced in such abundance as Quercus and so a small percentage of this genus may be comparable to a larger percentage of Quercus.

Bacon's swamp was a history of Indian evidence for increase in Bee's foot-levels. Yountsville had no record of Quercus-Acer being a warm-dry, transitional.

The Late Wisconsin, however, was in the lakes of the early drift, which have a history record. The time elapsed has had some evidence for increase in Bee's foot-levels. Bacon's Swamp was neither a history nor lakes of the early drift, which has an early record. The time elapsed has had some evidence for increase in Bee's foot-levels. Bacon's Swamp was neither a history nor lakes of the early drift, which has an early record.
Bacon’s swamp is the only bog studied in the Early Wisconsin territory of Indiana which had an ultimate Acer-Quercus climax. More evidence for the change to a warmer climate was the sudden increase in Betula, in the 8-foot level (42.5%), which persisted for 2 foot-levels. It is thus possible to state that the forest succession of Yountsville bog was: Abies, to Abies-Picea, to Picea, to Quercus, to Quercus-Acer. The climatic change being from a cool-moist to a warm-dry, to a warm-moist.

The Late Wisconsin Glacial Period

The Late Wisconsin glacial advance was not so far southward; neither was it so extensive in area as the early advance. The bogs and lakes of this moraine region are much younger than those of the early drift. The bogs are still in their formative state, many of which have almost filled in but are yet very wet in rainy seasons. The time elapsed since the Wisconsin glacier made its last appearance has had some dispute. Cleland (24), basing his estimates on the recession of the Niagara gorge, and of St. Anthony’s Falls, estimates that the permanent retreat of the Wisconsin ice sheet was between 12,000 and 20,000 years. This would be added to the time during which the ice retreated from the southern limit to the Niagara gorge. According to Miller’s (10) estimate the retreat required about 12,000 years from its southern boundary (about Logansport for Indiana) to the Niagara gorge. Antevs (23), estimates the beginning of the retreat as between 30,000 and 40,000 years. The question had frequently been raised whether or not it is possible to calculate back through the centuries using the bog sediments as criteria. Potzger (14) states, that Dachnowski estimates 200 years for the accumulation of one foot of peat; Soper and Osbon estimate 600 to 1200 years per foot of peat, and Sears, about 300 years to the foot. Potzger (14), also states that the average depths of bogs in Indiana is about 35 feet and if based on Sear’s estimate we would have 10,500; if based on Soper and Osbon it would be 21,000 to 42,000 years, the latter computation correlating more with Cleland and the Niagara gorge recession. It must be kept in mind, however, that there is a possibility of large discrepancy in such estimation.

The withdrawal of the ice north and eastward in Indiana was attended by the position of three distinct sets of roughly concentric terminal moraines. In northwestern Indiana the moraines were built by the Lake Michigan lobe. In the northeastern part of the state the
morraine system is in harmony with the Main Erie lobe, while in north central Indiana the moraines conform to the position of the enclosed Saginaw lobe. These orderly arrangements of the systems are in keeping with the lobation of the ice. Malott (9) considers these formations due to halts or temporary readvances of the ice margin. Since these advances and retreats of the glacial sheet many miniature lakes, left by this activity, have been filled by inwash or accumulations of plant remains. Many larger basins have become smaller, but are still lakes. The areas of these small shallow basins are now marked by level depositions of black earth. In such a region is located the Mill Creek bog with its accumulation of peat to a depth of 59 feet, and is one of the deepest bogs of Indiana yet analyzed.

Abies was dominant in the lower 2 or 3 foot-levels of Mill Creek bog, forming a Picea-Abies climax later. Moss (11), found in Altona bog a very short dominance by Abies with Quercus and Pinus appearing early in the spectrum. In comparison it was found that in all areas Picea-Abies did not endure very long, about 2 or 3 feet, before Pinus assumed control. This means without a doubt that the cool-moist climate was beginning to shift to a cool-dry condition. As the glacier began to melt, the drainage water was carried by the Wabash and Kankakee valleys, and as this water was carried away the conditions became drier. This evidently coincided with the fast reproduction of Pinus. However, the climate still must have been cool since our northern Pines today retain dominance in a cool-dry habitat.

Weaver and Clements (21) say that Larix is a persistent sub-dominant species in the boreal forests of today. The pollen spectra show that Larix held a similar position in the early Post Pleistocene forests. Potzger and Wilson (13) state that Larix is found today as a dominant in relic colonies deep in the deciduous forests, again showing its ability to adjust itself in order to persist over a wide area through Picea and Abies forests to the southern deciduous forests. In the Mill Creek bog Quercus never shared dominance with another genus. In the Lakeville, Round Lake, Loon Lake, Altona and Lake Cicott bogs, Quercus was associated in the upper levels with Caryya. In Winona lake the representation was Acer and Quercus. Tippecanoe lake was very similar to Mill Creek bog in having only Quercus as a major species represented in the upper levels. It is justifiable to assume that the climatic changes were more or less uniform in a warm-dry to assume that region. The situation of the bogs as these are have shown a few hundred max while the Caryya. Such post glacial sites Betula are percentages pecanoe lakes they were slight count of Betula their pollen dif­ fere with their pollen preservation.

Betula in day. These Indiana. Betula be assumed was then their limits.

The most Mill Creek bog climax. At a time when at the Mill Creek had accumu­ more with a that latitude Michigan does not to very high Yountsville (Moss, 11).
lobe, while in position of the systems (9) considers the ice sheet many by inwash or have become shallow basins such a region to a depth analyzed. of Mill Creek (11), found in Pinus and Fimms was found that about 2 or 3 feet, I doubt that the condition. As carried by the is carried away with the fast must have been e in a cool-dry persistent sub-pollen spectra. Post-Pleistocene found today as, again show a wide area xious forests. dominance with Lake, Altona the upper levels Acer and Quercus bog in having upper levels. It are more or less uniform in all instances, probably from cool-moist to cool-dry, to a warm-dry to a more warm-moist climate. Potzger and Wilson (13) assume that this was the case in the Winona and Tippecanoe lake region. The fluctuations between Pinus and Quercus and the association of the two were induced by local control. Characteristics such as these are found in forests of today. Potzger and Friesner (15) have shown that in central Indiana north-facing slopes not over a few hundred feet from south-facing slopes, have a Fagus-Acer climax while the opposite slope was covered with Quercus or Quercus-Carya. Such phenomena must be considered when translating the post glacial successions.

Betula and Salix were represented in Mill Creek bog in small percentages which correlates with conditions in Winona and Tippecanoe lakes, while in bogs observed by Moss (11) and Hamp (4) they were slightly higher. Potzger and Wilson suggest that the low count of Betula and Salix may be due to the fact that these trees shed their pollen early and the frozen condition of the lakes would interfere with the deposition of these pollen to the sediment for preservation.

Betula lutea and B. pumila are found growing in the bog site today. These are northern species growing in their southern limits in Indiana. Betula pollen were first found in the 52-foot level; it may be assumed that this was the time when these species came to what was then their northern limits and which is today their southern limits.

Comparison of Yountsville and Mill Creek Bog

The most outstanding difference between the Yountsville and Mill Creek bogs is, perhaps, the expression of the Picea and Abies climax. At Yountsville the control by Picea and Abies continued to a time when about two-thirds of the sediment had accumulated while at the Mill Creek bog it waned when about one-third of the sediment had accumulated. This bog correlates in the Picea-Abies climax more with a bog that should be located in southern Michigan, or at that latitude. Potzger and Wilson (13) state that bogs studied in Michigan do indicate that Picea and Abies extend in the spectrum to very high levels and percentages. The situation that exists at Yountsville bog may be opposite to the situation found at Altona (Moss, 11).
Yountsville bog is quite shallow and it is possible that it became filled before the complete pollen spectrum to the present could be recorded. Then, too, it is very likely that during the occupancy by civilized man, repeated fires might have eliminated the top-most layers. Such argumentation offers explanation for other features in the spectrum, especially the behavior of Acer, coming in so suddenly in the 0.5-foot level. The Acer-Quercus climax may have been more persistent, but may not be recorded in the sediments now present.

The Mill Creek bog, in the lower levels showed typical Abies-Picea climax for a short period and then its dominance was lost never to be regained. Pines played quite a different role in the Mill Creek bog than in the Yountsville bog. Pines in the Mill Creek bog made a sudden increase for 2.5 foot-levels, enough to establish a dominance or at least to form a strong co-dominance with Quercus. In other bogs of this Late Wisconsin glaciation region shown in table 1, Pines made a similar increase in the correlating foot-levels.

**TABLE I**

<table>
<thead>
<tr>
<th>Name of bog or lake</th>
<th>Number of foot-levels with Pines an important genus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loon Lake Bog</td>
<td>3 feet</td>
</tr>
<tr>
<td>Altona Bog</td>
<td>2 feet</td>
</tr>
<tr>
<td>Winona Lake</td>
<td>2 feet</td>
</tr>
<tr>
<td>Tippecanoe Lake</td>
<td>2 feet</td>
</tr>
<tr>
<td>Lakeville Bog</td>
<td>1 foot</td>
</tr>
<tr>
<td>Round Lake Bog</td>
<td>0</td>
</tr>
<tr>
<td>Mill Creek Bog</td>
<td>2.5 feet</td>
</tr>
<tr>
<td>Lake Cicott Bog</td>
<td>5-7 feet</td>
</tr>
<tr>
<td>Mineral Springs Bog</td>
<td>2 feet</td>
</tr>
<tr>
<td>Center Lake Bog</td>
<td>2-4 feet</td>
</tr>
</tbody>
</table>

*Investigated by Houdek (5).*

In comparison with bogs of the early Wisconsin glaciation it was found that none in areas of Early Wisconsin glaciation showed this sudden increase in Pines. In these bogs Pines persisted only in unimportant percentages to top levels. It is believed that in the Early Wisconsin regions the climate change was a cool-moist turning directly into a warm-dry. In the Late Wisconsin region, farther north, there was an additional change. The Pines dominance showed this, meaning that there was a time in which a cool-dry climate existed. The number of foot-levels with Pines, probably occurred or as influence other interesting differences between the Early and Late Wisconsin glaciations. Much higher foot-level in Wisconsin bogs. Table 1.
that it became recent could be an occupancy by the top-most other features in it so suddenly have been more its now present.

It typical Abies was lost never in the Mill Creek Creek bog made dominance a present. In other in table I, Pinus was a lost thing with Pinus genus.

Since in glaciation it was glaciation showed this existed only in un that in the Early cool-moist turning sin region, farther dominance showed cool-dry climate ex-

| Table II |

Presence of Picea in Various Spectra

<table>
<thead>
<tr>
<th>Late Wisconsin Bogs</th>
<th>Depth of Bog in Feet</th>
<th>Foot-level at which Picea disappeared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop Lake Bog</td>
<td>41</td>
<td>2</td>
</tr>
<tr>
<td>Altona Bog</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>Winona Lake</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>Tippecanoe Lake</td>
<td>59</td>
<td>3</td>
</tr>
<tr>
<td>Lakeville Bog</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>Round Lake Bog</td>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td>Mill Creek Bog</td>
<td>59</td>
<td>12</td>
</tr>
<tr>
<td>Lake Giott Bog</td>
<td>31</td>
<td>13</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Early Wisconsin Bogs</th>
<th>Depth of Bog in Feet</th>
<th>Foot-level at which Picea disappeared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kokomo</td>
<td>32</td>
<td>6</td>
</tr>
<tr>
<td>Bacon's Swamp</td>
<td>32</td>
<td>10</td>
</tr>
<tr>
<td>Fox Prairie</td>
<td>28</td>
<td>23</td>
</tr>
<tr>
<td>Otterbein</td>
<td>44</td>
<td>4</td>
</tr>
<tr>
<td>Cranberry</td>
<td>32</td>
<td>17</td>
</tr>
<tr>
<td>Yountsville</td>
<td>24</td>
<td>0.5</td>
</tr>
</tbody>
</table>

*On outer border of Late Wisconsin glaciation.

In the Matthews bog, Picea was present to the top foot-level. This bog is located close to the border of Late Wisconsin and Early Wisconsin glaciations. The only bog in the Early Wisconsin region that has Picea at the top level was Yountsville.

These results of Yountsville and Mill Creek bogs permit the conclusion that there was a difference in forest succession between areas in Early and Late Wisconsin glaciations in Indiana. However, one must not jump at conclusions, stating that these differences are complete, for there is much work yet to be done before generalizations seem entirely justifiable.

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SUMMARY

1. The paper presents pollen spectra from Mill Creek and Yountsville bogs.

2. Yountsville bog is located in an Early Wisconsin glaciation region, and Mill Creek bog in a Late Wisconsin region.

3. The Yountsville bog is of the kettle hole type, while the Mill Creek bog is of the valley type.

4. Both bogs showed a forest controlled by an Abies-Picea climax while the lower levels were being deposited.

5. Abies-Picea persisted to higher levels in the Yountsville bog than in the Mill Creek bog.

6. Mill Creek bog showed dominance by Pinus at the 46-foot level.

7. Pinus was present in low percentages throughout the spectrum at Yountsville.

8. In all but Round Lake bog, Pinus assumed dominance during one or more foot-levels in all bogs located within Late Wisconsin territory but never in bogs located in Early Wisconsin territory.

9. Picea was consistently present to a much higher foot-level in bogs of Late Wisconsin territory than in bogs located in areas of Early Wisconsin glaciation.

10. Quercus became dominant in Mill Creek bog at the 44-foot level and remained dominant to the top levels.

11. At Yountsville bog Quercus dominated from the 11-foot level to the surface but gave way to a Quercus-Acer association at the 0.5-foot and top levels.

12. Succession at Yountsville was: Abies to Picea-Abies, to Quercus, to Quercus-Acer; succession at Mill Creek bog was: Abies to Picea-Abies, to Pinus, to Pinus-Quercus, to Quercus.

13. Climatic changes at Yountsville may be expressed as cool-moist, to warm-dry to warm-moist; changes at Mill Creek were from cool-moist, to cool-dry to warm-dry.

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**LITERATURE CITED**