

A pollen study in the tension zone of lower Michigan

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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 Daudenmire, Francis Hueber, Frank McCormick, Scott McCoy, Robert Petty, Potzger, Helene Starcs, and Theodore Sperry. Cain, Daudenmire, Potzger, and Billings served as Presidents of the Ecological Society of America.

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A POLLEN STUDY IN THE TENSION ZONE OF LOWER MICHIGAN¹

By J. E. POTZGER

A transition zone between two large vegetation cover types always presents a tantalizing aspect of vegetational characteristics, frequently suggesting instability. In such areas the microclimate of edaphic factors favors first one and then another group of species which are characteristic components of one or the other of the flanking formations, or smaller fluctuations in temperature and moisture find expression in vegetational changes which will not be evident within the boundaries of the definitely expressed formations. This is emphasized boldly by disjunct distribution or intermingling of species of these flanking climaxes, where habitat exerts selective action far greater than is possible under optimum climax control; this may at times even dim the "real climax" status. As Dachnowski (3) points out, pollen profiles can here, perhaps, give the most reliable picture of the climatically favored vegetation. It is, therefore, also logical to expect that small variations, or fluctuations, in climate ought to be recorded first in such tension areas by minor changes in vegetation, especially by variation in degree of importance of certain genera in the association complex.

It hardly requires deep botanical knowledge to note as one travels northward from Indiana to the upper half of Lower Michigan that soon after crossing a line marked roughly by highway 46, running approximately northeast to southwest from Saginaw to Muskegon, Michigan (fig. 1) that forest composition gradually changes by intrusion of more and more coniferous species into the broadleaved forest complex. During the decades which marked the close of the last century and the beginning of the present one, north of the before-mentioned line began the great lumbering activities in the pine forests of Michigan. One naturally wonders why this sharp control existed, and how long it had prevailed. So it was planned to make pollen

¹ This is contribution 192 from the botanical laboratories of Butler University. The field work was supported by a research grant from the AAAS through the Indiana Academy of Science. Sincere thanks is expressed for this aid.

analyses of a series of bogs located along highway 46, and to include also some bogs which are located within 30 miles to the north and the south of the tension line. This 60-mile wide zone, bounded on the south by Allegan County and on the north by Oceana and Clare counties, gave promise of throwing some light on the forest development in the tension area since post-glacial times.

Thanks is expressed to the owners of the various tracts of land where the bogs are located for friendly co-operation and ready permission granted to carry on the work on their property; to my brother Gerhard and to my nephew Elmer Tessin for aid given with the boring operations; to the State of Michigan Department of Conservation, Geological Survey Division for the outline map used as basis for figure 1.

CHARACTERISTICS OF BOGS IN THE AREA

It is perhaps essential to discuss the bogs involved in this study somewhat in general because of certain unusual features associated with them. The author was very familiar with the topography of the counties bordering on Saginaw Bay, however, he had no experience with profiles of bogs of the region. Many lowland areas here are covered by typical bog vegetation, and so, externally, look like the bogs to the north and to the interior of Michigan. It was a distinct surprise, therefore, that the peat overlying sand was so extremely shallow in all of Saginaw and Midland counties, at times not exceeding six inches. As this study shows, not a single bog in Saginaw County yielded sufficient peat to assure a confidence-inspiring pollen analysis. Even in the adjoining counties peat deposits were as a rule still very shallow. It appeared to the writer that the numerous dry kettle holes one encounters west of Saginaw County indicate lack of sufficient bank and bottom sealing to retain water. This is even true in part for such bogs as Mud Lake, Meeuwsen Farm, Berens Bog and the deep Powell Bog whose basins were, perhaps, never filled to the top with water. In the Muskegon area numerous lakes which have become decadent during the last two decades because of decrease of water, suggest the same poorly sealed, reservoir. Included in this category would be Blue Lake, Mud Lake and a number of others where borings disclosed only a shallow accumulation of organic matter which rested on sand.

The Pleistocene history of the region offers an explanation for shallow basins and absence of peat, especially in the Saginaw area. According to Leverett and Taylor (6) the present-day Saginaw and Midland counties are part of an old lake plain of glacial lakes Saginaw and Warren which extended westward to near St. Louis, Michigan. No depressions of any consequence were formed. As a whole, therefore, the whole topography is generally flat and the interdunal marshes, or rather bog-like areas, with typical bog vegetation, did not retain sufficient water to favor accumulation of abundant organic matter. During rainless seasons such areas may always have been quite dry. Vegetation from adjacent locations must, thus, have moved into Saginaw and Midland counties as the waters of lakes Saginaw and Warren receded. On the other hand, forest succession could not have progressed very far previous to recession, for the Dow Marsh (figs. 1, 2) records the *Picea* period as well as the bogs farther west in the state do.

DESCRIPTIONS OF BOGS STUDIED

Meeuwsen Farm. This large, rather deep-set, bog is at present under cultivation, used to raise celery, mint and various other garden crops. A ditch drains at least to a depth of six feet, which probably accounts for the sparse pollen representation in upper foot-levels. It is located about 15 miles east of Holland, Michigan, along the Filmore-Dorr road in upper Allegan County.

Berens Bog. This bog is located on the farm of Mr. John C. Berens, about one mile sw. of the Meeuwsen farm. The extremely deep kettle hole with 50-foot high slopes has a shallow peat deposit of only five feet. At times it is entirely dry, but during wet seasons it presents the aspect of a lily pond.

Duck Lake Bog. This small bog comprises about two or three acres in a pasture along highway C-555, one mile southeast of Duck Lake, Crystal twsp., Montcalm County. The surface has been influenced by fire. Peat and lake sediments totalled ten feet.

Redman Mint Farm. During the early history of Gratiot County a low, wet tamarack swamp occupied several miles a short distance west of Ithaca in Newark twsp., sec. 3. Ditches drain the muck land, and it is at present laid out in extensive mint farms. Peat totals only four feet in depth. It is a difficult matter to locate the deepest part of a depression in such an extensive area, especially since the central

portion may not always be the deepest part. The boring was made on the farm of Mr. Ernest Redman in or near the geographical central part.

Dow Marsh. The wet sedge-meadow is flanked by sandy uplands and represents the best peat deposit found in Midland County. It comprises about ten acres, and it is located on the east side of highway 10, a quarter of a mile southeast of the junction between highways 10 and 20. The land is the property of the Dow Chemical Company of Midland, Michigan. Peat totalled four feet.

Carroll Farm. The peat deposit on the farm of Mr. Carroll is located in a shallow basin which gives the impression of having de-

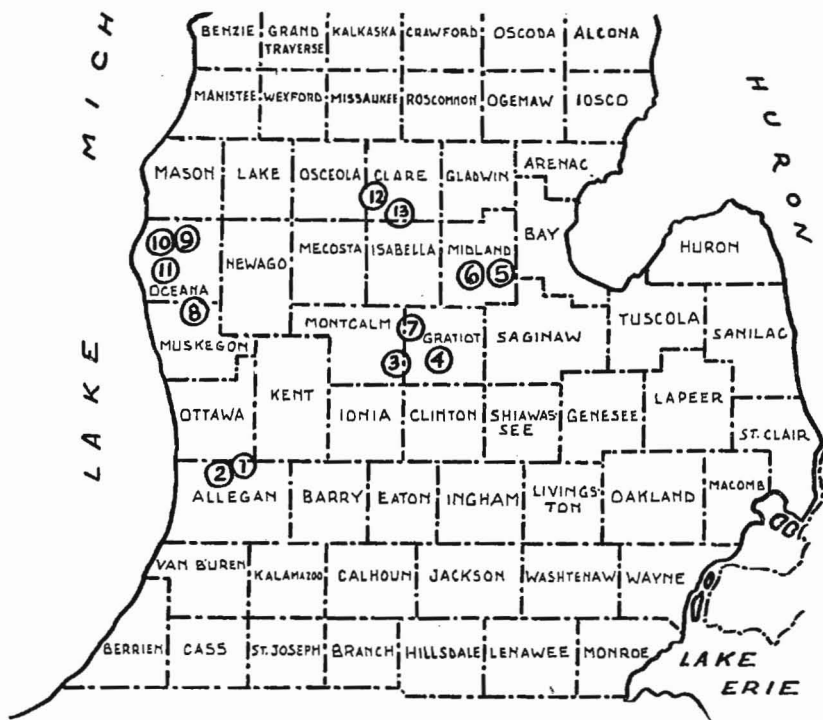


Fig. 1. Map of Central Michigan showing location of bogs studied:

veloped under semi-stream valley conditions. Peat totalled four feet. It is located five miles west of Midland, Midland County, on highway 20.

Austin Bog. This beautifully circumscribed bog is located along

highway 46 on the property of Mr. Alfred Austin, 10.5 miles west of St. Louis, Gratiot County (R.4, T.12, Sec. 20). It comprises an area of about 10 acres.

Blue Lake Bog. About a quarter of a mile north of the nearly extinct Blue Lake, Muskegon County, is a bog in early shrub stage of succession, comprising about 5 acres. It is 8 miles nw. of the little town of Twin Lake on highway 20, located on the west side of the country road. The approximate physiographic center of the bog yielded a 14-foot-deep core. Preliminary examination of the peat showed the *Picea* period lacking. A more careful survey on a second visit disclosed a basin which sloped towards the northern border of the bank. Here 18.5 feet were encountered. In the lowest levels of this second core the *Picea* period was well expressed. A forest of young oaks (about 75 per cent of the crown cover) with scattered *Pinus strobus* intervened as a 500-foot wide strip between the bog and the road.

Mud Lake. The almost decadent Mud Lake is located two miles east and one mile north of Shelby, Oceana County. It, too, is an extremely deep kettle hole with poorly sealed retaining walls of sand and gravel; hence, only the deepest part of the kettle was filled with lake sediments and peat. The western portion is still a muddy pond with shallow water. The boring was made at the very edge of the pond where peat supported weight of the worker only on hummocks of sedges. Preliminary borings disclosed that the slope of the bottom was towards the ponded area. Very likely, several feet of additional depth to that shown in the core taken is to be expected in the center of the muddy pond, though, the boring penetrated the extremely well-defined *Picea glauca* period for a depth of four foot-levels. Thus the whole history of the forest is represented in the core obtained.

Schroeder Bog. The author has repeatedly pointed out that bogs with central open ponds as a rule yield disappointing incomplete pollen profiles. This was also the experience with the beautiful Schroeder Bog, located about two miles west of Shelby, Oceana County. Most of the elongated bog is well solidified, and is covered by dense growth of relic *Picea mariana*, *Tsuga canadensis* and tall bog shrubs. The deepest place in the basin is no doubt covered by the 150-foot wide pond, and even though the boring was made at the very edge of the pond, the *Picea* period was wanting in the core.

The profile was included in this report (fig. 3) to show the later succession, especially as to correlation with changes recorded in the nearby Mud Lake profile (fig. 3).

Shelby Bog. The Shelby Bog represents one section of an irregularly-shaped chain of valley depressions. In one part of the basin a two-foot deep layer of marl has been removed. The bog is located on the property of Edward V. Babinec, on the west side of highway 31, at the very southern limits of Shelby.

Powell Bog. Most of the bogs in central Michigan are comparatively shallow, but the Powell Bog is a striking deviation from the rule. Topographically it represents a magnificent, almost circular, kettle, flanked by 25- to 50-foot high slopes which terminate in sandy uplands. Peat totalled 50 feet in depth (fig. 3). The central portion of the surface is still in Sphagnum and low shrub cover, indicating a rather recent "Verlandung." The border belt is covered with forest composed of young *Picea mariana*, *Larix* and various deciduous shrubs and trees. Results of trial borings suggest that from a gentle slope the kettle suddenly drops into the deep central portion, which alone had a pollen profile recording a decided *Picea glauca* dominance in the initial forest cover (fig. 3). Its location is five miles nw. of Farwell, Clare County, on highway 10, and one mile north of the highway, with pastured lands intervening. The property belongs to Mr. Rufus Powell.

Farwell Bog. Immediately east of Farwell, Clare County, highway 10 bisects a small bog of several acres extent. It is at present covered by one-foot-deep water. The depression is well isolated by encircling low ridges. Several trial borings indicated that the deepest part of the basin is about 25 feet north of the highway. Here the samples were taken.

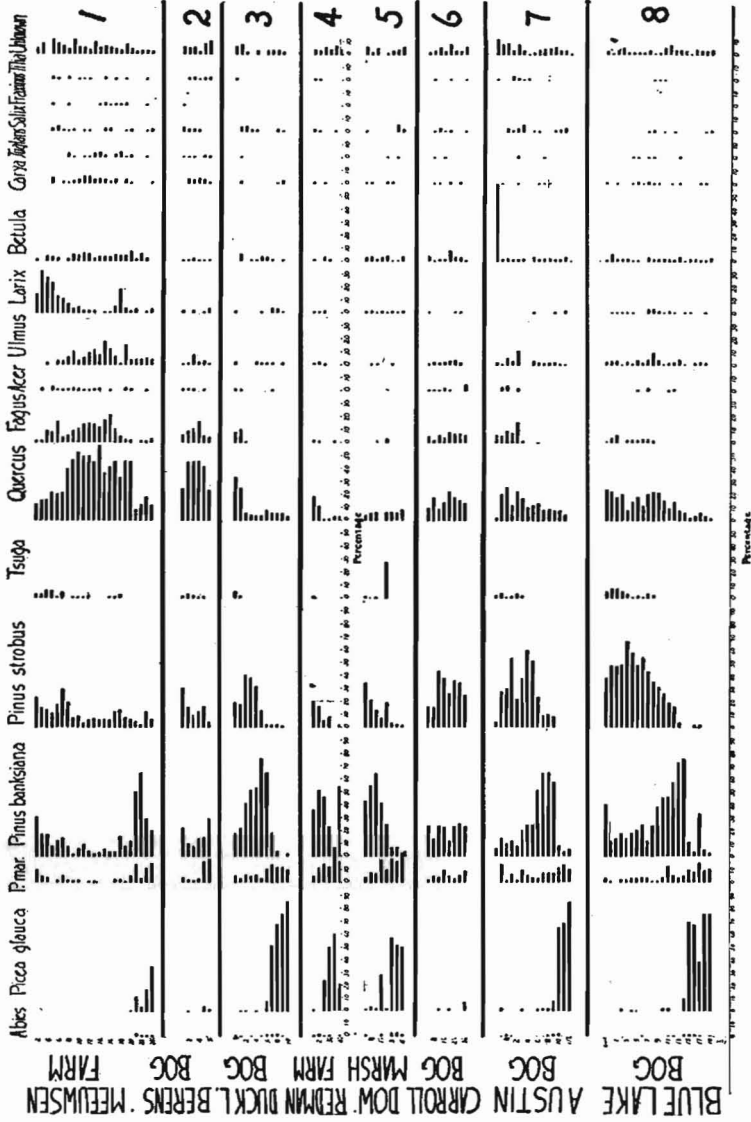
METHODS

Peat samples were taken with a Hiller-type borer. The outer layer of the core within the cylinder was cut off with a knife and the sample was secured from the central part of the core. The samples were placed into one-ounce bottles, and these were securely stoppered. A label indicated location and foot-level. As a rule, samples were taken at one-foot intervals, but in some instances, where sharply differentiated layers appeared in the sediments, samples were taken at closer intervals. The laboratory technique followed closely the

Geisler (4) method; staining was with 5% aqueous solution of Gentian violet. Coarse, raw peat was separated with 95% alcohol and then strained through cheesecloth to remove the large organic particles. Tabulation was carried out under 150X magnification, and critical examination of all small and not easily recognized pollen grains, as well as measurements of all pine and spruce pollens was made with aid of 640X magnification. While a separation was made of small and large pine pollens as suggested by Cain (2) and Buell (1) there is still great doubt in the mind of the author if *Pinus banksiana* can, on basis of pollen size, be separated within a safe margin of error from *P. resinosa*. Pollen of this latter species from Michigan, which was available for examination, has many small pollen grains, some rather aborted in appearance, and so small pine pollen grains present at foot-levels where also large grains had appeared may not be those of *P. banksiana*. It is true, of course, that as a rule when pine pollens first appear in a profile they are strikingly small even to casual observation, differing in general contour from the smaller grains appearing with large grains of pine pollens at higher foot levels. This is true for most interior locations as well as in coastal areas of Maine. The graphs in this study are to be interpreted with such doubt in background.

RESULTS

The great waves of succession up to the initiation of the broad-leaved climax are very similar for the whole area considered in this study, and variation in vegetation determined by small latitudinal differences become accentuated during the time when the upper half of the peat deposits were being laid down. Succession proceeded from *Picea glauca* to *Pinus banksiana* to *Pinus* spp., to deciduous forest cover. Geographical location here introduces variation in the association complexes. Along a convex boundary line determined by the cities Whitehall, Farwell and Midland, *Tsuga* was a dominant of major importance, associated with *Fagus* and some *Quercus*. Its movements are, therefore, again linked with the broadleaved genera. *Tsuga* usually replaced a minor *Quercus* peak. *Pinus* controlled on sandy soil, as it does in these poorer soils in the lake forest today. *Quercus* increases progressively in controlling significance south of the above-mentioned boundary while *Tsuga* becomes very sparse in



Abies glauca P.mar. Pinus banksiana Pinus strobus Tsuga Quercus Fagus Acer Ulmus Larix Betula Carya Juglans Sassafras Thuja Umbelliferae

MUD TOWER LAKE

9

BOG

10

BOG SHELBY

11

Percentage

BOG POWELL

12

BOG FARWELL

13

Percentage

representation and *Fagus* declines at a number of stations south of Farwell and the Oceana County locations.

To some extent lesser representation of these genera is compensated by increase in abundance of *Cary* and *Juglans*, at least in northern Allegan County. When comparing maxima of *Quercus* we find an interesting behavior within the zone. Representation ranged from 50% to 60% in the southern limits (Allegan County), decreasing to 20 to 40% along highway 46, fluctuating between 20 to 30% along the tension zone and Oceana County line, and dropping to 10 to 20% along the northern border of the zone in Clare County.

Maximum fluctuations of species and genera within the whole zone are evident in *Quercus* and *Pinus* (which one would expect in a tension area). The decline of *Ulmus*, *Fagus* and *Tsuga* (in northern locations) during deposition of the upper foot-levels indicates drier climate, which may be the result of warming (reflected in the increase of *Quercus*) towards the time when surface layers were being deposited in the majority of bogs studied along the center of the zone. It may also indicate decreased humidity due to warmer climate. It is a little difficult to explain the striking increase in pine in the upper foot-levels in Allegan County stations. *Ulmus* follows the pattern found in most areas of eastern and central North America, i. e., a maximum abundance near the middle of the pollen profile. The prominent *Betula* peak at the surface layers in several bogs may reflect secondary succession following lumbering activities of 75 to 100 years ago.

A fluctuating climate is suggested by the behavior of such key genera as *Quercus*, *Pinus*, *Tsuga* and *Fagus*, but it was never of sufficient magnitude at any time to involve return to *Picea* once this genus had declined to relic status. Most strongly favored is the assumption of a drier and warming climate (less available moisture may have been due to lessened humidity). This is indicated by decline of *Tsuga* and *Fagus* and the tendency of increase for *Quercus*. Earlier fluctuations between *Quercus* and *Pinus*, or broadleaved genera and *Pinus*, suggest fluctuations in temperature.

DISCUSSION

Comparisons of pollen profiles from lower Michigan, to the north and south of the tension zone area, at once impress one with the fact that the vegetation has experienced more fluctuation and minor

changes along the tension line than to the north and south of it, and that some climatic factors exert a progressively increasing sharp control to bring about marked "tapering off" changes in forest complex within comparatively small latitudinal distances. As Potzger and Wilson (10) have reported for Third Sister Lake at Ann Arbor, a rather long *Pinus* period there was terminated by *Quercus*, and *Pinus* declined gradually to very low representation, while *Quercus* showed a rather uniform control to the topmost levels in the lake sediments. The same authors (15) reported only slight fluctuation between *Pinus* and broadleaved genera (associated with *Tsuga*) for Middle Fish Lake in Montmorency County and Douglas Lake in Cheboygan County. This indicates that climatic factors there are less varying over larger geographical distances than at the tension zone. It is also quite evident that the climatic values must meet with considerable change within the latitudinal distance of about 60 miles in central Lower Michigan, at least in extremes, which exert control on forest distribution. *Quercus* here ceases to be a controlling element in the crown cover in forests northward, declining to a secondary representation of only 10% in the southern Clare County region. Livingston (8) says for Roscommon and Crawford counties that there the oaks lack the vigorous growth shown in Kent County. *Pinus*, on the other hand, southward of the upper limits of the tension zone (at least at some time) declined to relic status in a predominantly *Quercus* crown cover (Meeuwssen and Berens bogs). Along the central section of the belt the two genera (*Quercus* and *Pinus*) fluctuate in importance with time (figs. 2, 3). It is also quite evident that this unstable condition has prevailed there for a comparatively long time. Livingston (7, 8) sensed this tension zone and its unique characteristics when he planned the detailed study of the vegetation of Roscommon and Crawford counties in the north and Kent County in the south. He states that Kent County is the northern limit of many typically southern plants, and it is traversed by the southern boundary of the pine forest region. Roscommon and Crawford counties are somewhat north of the Clare County northern limit of the present study. He concludes his excellent observation by saying: "A study of the transition zone between these two areas will be necessary before the working out of the exact relation of the various societies can be attempted." It is, of course, unfortunate that no study similar to those recorded by Livingston was made for one or more of the inter-

vening counties, it would augment greatly the value of the historical picture as it were projected into the present.

The typical lake forest (*Tsuga*-broadleaved forest and *Pinus* associations) as we know it today was not well expressed along the tension zone and southward of it (fig. 2). *Tsuga* here does not appear in the pollen profile with more than 5%, but apparently it was more abundant in its southward range along the lake shores than in interior locations, as shown by the Oceana County bogs and the Dow Marsh station in Midland County. In the interior locations abundant representation of *Tsuga* arched northward about 20 miles. This definitely points to a humidity control, with greater saturation along the lakes. Of course, *Tsuga* continues to decline in abundance southward until in Indiana it is never represented above 2%, and this in scattered distribution throughout the pollen profile for a given bog.

Livingston (7, 8) leans heavily on soil factors for his interpretation of the forest type distribution, and it seems as if he overlooks entirely the master control, climate. Sandy soil in Kent County and sandy soil in Roscommon County would hardly respond with identical vegetation because climate would militate against *Quercus* in the northern counties but not in Kent County. Likewise, sandy areas in northern Indiana, even in inland locations, once were occupied by *Pinus* and this was replaced by *Quercus*, apparently after moderating climate had made this possible. As Potzger (9) has shown in pollen profiles, when *Pinus* was climatically favored in northern Indiana, in southern Michigan, and also in northern Michigan, it was the controlling forest cover on all types of soil. Being limited to sandy soil, as in Kent County, is an incipient relic status. There is every evidence that the forest tension zone is also climatically transitional, where a number of climatic factors, especially extremes, are closely spaced latitudinally, and the forest is merely expressing the biological values of these environmental factors. One is greatly impressed with the many meteorological phenomena which have important dividing lines at or near the Saginaw-Muskegon tension zone, and this must find expression in biological values. Just to mention a few: The line for average depth of 40 inches of frost penetration for January runs a little south of the tension zone (Visher, 12); the tension zone is the divide between average date of beginning of warm weather (daily normals above 50 degrees F) on April 1 to the south

and May 1 to the north (Visher, 11); a little south of the tension line is the divide between beginning of summer (daily normals above 68 degrees F) on June 15 to the south and July 1 to the north (Visher, 11); a little north of the tension zone is the separating line for end of summer coming August 15 northward and September 1 southward (Visher, 11); the average number of summer days is 50 at the tension line and 75 to the south (Visher, 13); days with temperatures constantly below 32 degrees F (per normal year) in the shade are 60 at the zone limit and 30 southward (Visher, 13). The zone separates regions of long winters, where soil freezes 3 to 6 feet, and region of milder winter, where soil freezes only 18 to 36 inches (Visher, 13); it is the dividing line between dates when 3 inches of snow cover the ground, being Dec. 1 northward and Dec. 15 southward (Visher, 14); it is also the dividing line for dates after which snow no longer covers the ground, being April 1 northward and March 1 southward (Visher, 14). Significant other differences in temperature between the southern and northern limits of this arbitrarily established zone are also evident in the long time observations of weather reports (5). The growing season is ten days longer at St. John than at Alma (about 30 miles difference), and 13 days longer than at Harrison (northern limit of zone). The average last killing frost is 5 days later at Alma than at St. John, and 8 days later at Harrison than at St. John. For other significant differences see table I. These differences in temperature phenomena dealing with shorter growing season, but especially with periodic greater extremes in late and early frosts must exert a tremendous control on more sensitive southern broadleaved genera, such as *Quercus*, thus favoring the pines.

For the southern limits of the zone we have a fine description of the primeval forest by Livingston (7), and for a location somewhat north of the northern limits the same author (8) left an excellent map record of distribution of forest types (Roscommon and Crawford counties).

Livingston (7) presents in a detailed map upland forest associations and their distribution in Kent County, the least common of the several associations he calls the oak-pine-sassafras, and it is found on the poorest soil sites. It appears in small colonies in the southern part of the county and has greatest abundance in the northern part. He summarizes by saying, "In the northern part of the county white pine was almost universally present in the uplands at the time of

settlement." In Roscommon and Crawford counties (8) he found conditions quite different, the southern oak forest was almost wanting, there was lack of "tension," except for the competition between the three species of *Pinus*. Broadleaved forest was a very negligible factor in the forests of the counties. He sums up by saying, "The prominence of the pines in the region under discussion is an expression of the fact that the flora here is a typical northern one. Only one pine (white) is found in Kent County, and there it grows in poorer soil than it holds here."

As one ponders on all climatic and vegetational phenomena which intermingle at the tension zone, one realizes that it must be a southern limit of many atmospheric disturbances associated with the sweep of "highs" across our continent, and that it is not a "time" factor influencing the progressive northward move of plants. The control is rather due to a climatic "ridge" with sufficient difference in climatic values to the north and south of it to induce a "marking time" forest condition. Small temperature variations in the past have found expressions in decline or advance of coniferous and broadleaved genera, and variation in available moisture initiated advance or retreat for *Tsuga* and *Fagus*.

About mid-profile most of the bogs at and north of highway 46 show a *Quercus* peak, this probably represents a warmer or drier period; these same bogs also show an increase in *Quercus* at topmost levels, which suggests a warming climate. For years the author has wondered about the marked change in forest cover in Muskegon County where pinelands of a century ago show a marked succession to *Quercus*. This can hardly be a result of lumbering and fires. In counties a short distance to the north, as well as in northern Wisconsin, such destroyed pine forests of the past are not being replaced by *Quercus*, but these lands have been lying idle, vegetated at best with aspen or sweet fern, bracken and various species of *Vaccinium*. According to reports of the American Geophysical Union (1942) there is a general retreat of glaciers in North America, both in our western mountains as well as in Alaska. It is the writer's opinion that change in forest type is the logical thing to expect along a sensitively balanced border area like central Lower Michigan when small changes in climate occur.

SUMMARY AND CONCLUSIONS

1. A pronounced *Picea glauca* period represents the initial forest vegetation over the whole area involved in this study.

2. *Picea mariana* shows greatest abundance in the foot-levels of the lower third of the profile in all of the 12 bogs which are represented with a complete profile.

3. *Picea* was always associated with low percentages of *Pinus*, even during early history of the bogs studied.

4. *Picea glauca* was replaced by *Pinus banksiana* in all of the 12 bogs.

5. In some localities *Pinus strobus* (or *P. resinosa*) replaced *P. banksiana* dominance; in others it merely depressed abundance of *P. banksiana*.

6. Broadleaved genera and *Tsuga* replaced the *Pinus* period.

7. The tension zone marks the southern limits of important *Tsuga* representation, never exceeding 5% south of highway 46, but reaching 31% at Powell Bog, 23.5% at Farwell, 27.5 at Dow Marsh, 34 to 58% in Oceana County. There was, thus, a tendency for *Tsuga* to show greater abundance southward along the lake shores than in the interior.

8. *Tsuga* usually replaces a *Quercus* peak, but it shows a tendency to decline during the more recent past.

9. *Fagus* has greatest abundance northward, with two peaks as characteristic feature.

10. *Acer* attains greatest abundance in the Oceana County area.

11. *Quercus* exhibits considerable fluctuation with a tendency (in most bogs) to increase towards topmost levels.

12. *Ulmus* shows greatest abundance at mid-profile levels, with decline towards surface layers.

13. A high *Betula* representation in samples from the Austin and Powell bogs may indicate vegetational changes due to lumbering.

14. *Carya* and *Juglans* have significant increase in mid-profile with decline at upper third levels in the Meeuwsen and Berens bogs. At all other stations a consistent but sparse representation is characteristic.

15. *Tilia* is sparsely represented at all locations.

16. There is no indication of decided cooling of climate during recent post-Pleistocene times (no return to *Picea* anywhere) but drier climate is suggested by decline in the upper foot-levels of *Tsuga*

and *Ulmus* and increase in *Quercus* (increase of *Pinus* in southern locations).

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TABLE I

Variations and extremes in temperature phenomena in the tension zone area of Lower Michigan.

Stations	Average date of last killing frost	Average date of first killing frost	Average length of growing season in days	Latest date of killing frost	Earliest date of killing frost	Lowest temperature in Fahrenheit			M
						J	F	M	
Holland	5-8	10-8	153	5-27	9-17	-17	-24	-8	21
St. John	5-7	10-6	152	5-29	9-21	-16	-22	-7	25
Muskegon	5-1	10-16	168	5-27	9-16	-21	-30	-11	22
Hart	5-17	10-7	143	6-23	9-2	-26	-35	-16	18
Alma	5-12	10-1	142	5-29	9-10	-24	-29	-10	21
Saginaw	5-1	10-7	159	5-26	9-14	-15	-23	-5	24
Midland	5-13	10-1	141	6-6	9-1	-24	-30	-20	23
Gladwin						-28	-39	-17	21
Harrison	5-15	10-1	139	5-30	9-4	-20	-36	-16	20