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POLLEN ANALYSIS AND VEGETATIONAL HISTORY OF THE ITASCA REGION, MINNESOTA

Abstract

A transect 105 km long in northwestern Minnesota includes four vegetational formations. From west to east these are prairie, oak savanna, deciduous forest, and pine–hardwood forest; they occupy landforms distinguished by soil texture, topography, and elevation. Drier and warmer summers occur in the western part of the transect.

The natural vegetation prior to settlement was mapped from land-survey notes of 1871–79. Forest occurred on end moraines above 1,500-ft elevation. The pine–hardwood forest occupied coarse-textured soils and was dominated by white pine, jack pine, Norway pine, aspen, and paper birch, with small amounts of elm, maple, oak, and basswood. The deciduous forest occurred on fine-textured soils and was dominated by oak, aspen, elm, basswood, sugar maple, paper birch, and ironwood. Oak savanna occurred from elevations of 1,300 to 1,500 ft between the deciduous forest and prairie. It was dominated by widely spaced bur oak trees, with prairie herbs as ground cover. Prairie occupied elevations below 1,300 ft.

The mapped vegetation was compared with contemporary fossil pollen spectra in the sediment of eleven ponds. The pollen rain from each formation was distinctive, with most dominants except aspen being well represented.

The postglacial vegetational history was reconstructed with the aid of pollen diagrams from four pond sites. From 12,000 to 11,000 radiocarbon years ago the vegetation throughout the area was a boreal-type forest dominated by spruce and aspen. About 11,000 years ago trees essentially disappeared from the west and were replaced by prairie, which persisted until the time of settlement. At the same time, the vegetation on the coarser-textured soils eastward became dominated by pine, probably jack pine.

About 8,500 years ago the pine forest was succeeded by oak savanna, which remained until 4,000 years ago, when it was succeeded by deciduous forest. The deciduous forest persisted on fine-textured soils until the time of settlement.

White pine migrated onto the eastern coarse-textured soils and came to dominate the forest about 2,000 years ago. About 1,000 years ago it was joined by jack pine and Norway pine and, together with hardwoods, the three pine species formed the present pine–hardwood forest.

The interpretation of postglacial pollen diagrams in terms of vegetational change rests upon a knowledge of the relationship between the pollen rain and the vegetation from which it was derived. Because of such factors as differential production and dispersal, the proportion of the pollen of different species usually is not the same as the proportion of the species in the vegetation. A quantitative approach to rationalize this discrepancy through the application of correction factors to the components of the pollen rain has been advocated by Davis (1963). More promising is the semiqualitative approach whereby geographically distinguishable vegetational units and associated physiographic features (landform–vegetation zones) are characterized by their contemporary pollen assemblages (Lichti-Federovich and Ritchie, 1965). Working with atmospheric pollen samples and surface samples, these workers have shown that the several landform–vegetation zones within the transition from boreal forest to prairie in southern Manitoba can be distinguished by their pollen spectra. They applied their knowledge of the relationship between vegetation and pollen assemblages to identify periods of grassland and deciduous forest in pollen diagrams from what is now the southern boreal forest.

Not far away, in the forests of northwestern Minnesota, Janssen (1966a) made a study of the pollen dispersal from many of the upland and lowland communities. After detailed analysis of the vegetation and of numerous surface samples, he identified pollen assemblages representing three types of pollen rain within a community: local, extralocal, and regional. The regional pollen rain includes the pollen rain that is common to all communities within the largest vegetational unit, i.e. the formation. I here recognize an extraregional component of the pollen rain: pollen derived from species not present in the immediate formation.

Surface samples were used to identify the regional pollen rain in a reconstruction of the vegetational history of the various landforms and associated vegetational formations in the Itasca region of Minnesota (McAndrews 1966). A summary of the methods and results of this work follows.

The Itasca region is centered around Lake Itasca, the source of the Mississippi River; it lies in the pine–hardwood forest formation about 50 km east of the prairie (Fig. 1). Between these two formations lies a belt of deciduous forest or, to the north, aspen parkland. The transition from the deciduous forest to the prairie is through an oak savanna. The distribution of these formations is conditioned by an east–west climatic gradient and by Pleistocene landforms exposed upon the retreat of the Wisconsin glacier 12,000 to 13,500 years ago.

The vegetation of an east–west transect of eleven townships that contains Lake Itasca and crosses from the forest into the prairie has been studied by Buell and Cantlon (1951), Buell and Facey (1960), McAndrews (1966), and Janssen (1966a,c). The region of the transect provides an ideal situation for the study of postglacial vegetational and climatic history because of the close correspondence among vegetation, landforms, and climate within a relatively small area. Pollen analysis is a practical method for vegetational reconstruction because of the presence of many ponds with pollen-bearing sediments. The interpretation of fossil pollen spectra is facilitated by the use of surface samples collected from such areas as Itasca State Park, where

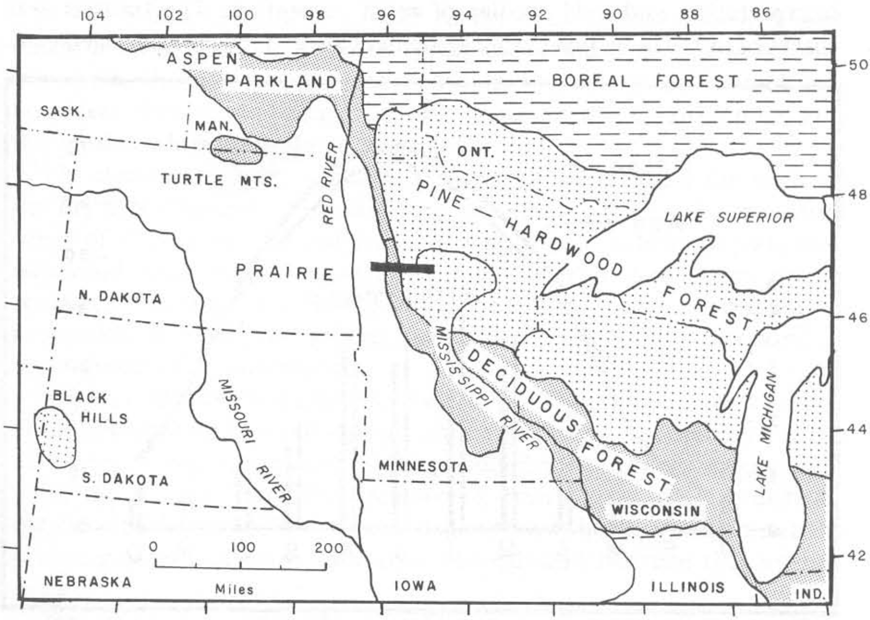

FIG. 1. Map of major vegetational formations of Minnesota and surrounding states and provinces. The Itasca transect is shown at the source of the Mississippi River.

the vegetation has been little disturbed since the area was settled at the beginning of the twentieth century (Janssen, 1966a). However, in most areas, especially the prairie, the presettlement vegetation has been radically altered or destroyed. Fortunately, a good description of the natural vegetation is available, and the pollen spectra in near-surface sediments that corresponds in time to the description can be identified.

VEGETATION, LANDFORMS, AND CLIMATE

The eastern two thirds of the transect is forested; it is situated on end moraines that range in altitude from 1,500 to 2,000 ft. The western third is mostly treeless prairie situated on ground moraine at lower altitude (1,000–1,200 ft). The high-altitude end moraines have lower summer temperatures and higher precipitation than the lower-altitude western third of the transect (Fig. 2). The oak savanna is between the forest and prairie and lies between 1,200 and 1,500 ft; it presumably has intermediate climatic values, but unfortunately there are no weather stations in this formation.

The vegetation was characterized and mapped after study of the notes of the General Land Office Survey supplemented by air-photo interpretation and field studies of relict vegetation. The transect was surveyed in 1871–79, just before settlement altered the natural vegetation.

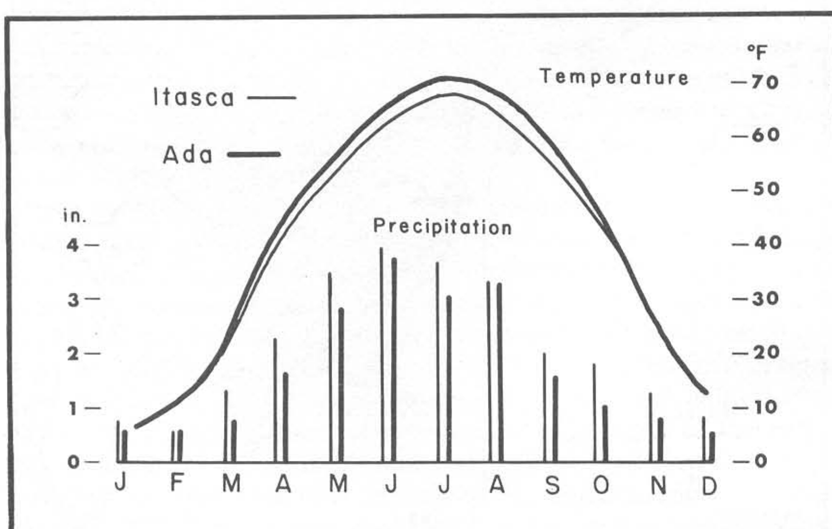

FIG. 2. Monthly mean precipitation (1931–55) for a prairie station, Ada, and a pine-hardwood forest station, Itasca. Ada (el. 906 ft) is 9 miles west of the Itasca transect, and Itasca (el. 1,500 ft) is at Lake Itasca.

The survey notes not only provide a qualitative description of the vegetation but also contain a record of the species and size of trees that were used to witness survey corners in forested areas. Counts of these witness trees may be used to form quantitative estimates of the relative importance of the species. These quantities may be used to measure forest changes since settlement and also to calibrate the contemporary pollen rain in terms of vegetation. The distribution of the witness trees also aids in drawing boundaries of vegetational units.

The pine–hardwood forest occupies the sandy till and outwash soils of the Itasca moraine. White, jack, and Norway pines are dominant both in size and abundance. The hardwoods, in decreasing order of importance, are aspen, balsam poplar, paper birch, red oak, bur oak, elm, sugar maple, basswood, ash, and ironwood (for Latin names see Table 1). Boreal conifers are also present; white spruce and balsam fir grow on the uplands, and black spruce and tamarack occur on bog soils. A subdivision of the pine–hardwood forest into three types was made, based on the prevalence of the different pine species. A jack-pine type occupies a sandy outwash plain in the eastern part of the transect, and here white pine and hardwoods are essentially absent. On the till soils there is a mixture of pine species and hardwoods. Westward, white pine and hardwoods prevail to the near exclusion of jack and Norway pine. The boundary between the white-pine–hardwood and mixed-pine–hardwood types does not now conform to a landform boundary (Fig. 3). Logging after 1900 removed much of the pine, and the hardwoods have become more important.

The deciduous forest occupies the silty-till soils along the crest of the Big Stone moraine. Pine is absent, and the hardwoods in decreasing order of importance are red oak, bur oak, aspen, balsam poplar, elm, basswood, sugar maple, paper birch, ash, and ironwood. A few boreal conifers are also present. Stands along the western boundary are almost exclusively bur oak and aspen. Sugar maple has greatly increased in importance since settlement.

The oak savanna occupies the west flank of the Big Stone moraine. Here open-grown bur oaks occur singly or in groves situated on the east sides of ponds. Apparently the ponds check fires burning eastward from the prairie. With the decrease of prairie fires after settlement, the savanna has succeeded to oak–aspen forest that has shaded out the prairie grasses and forbs that grew beneath and between the savanna oaks.

The prairie occupies the silty-till soils of lower altitudes. It is essentially a treeless grassland except for gallery forest of mixed hardwoods along a river and a few bur oak and aspen on the crest of the

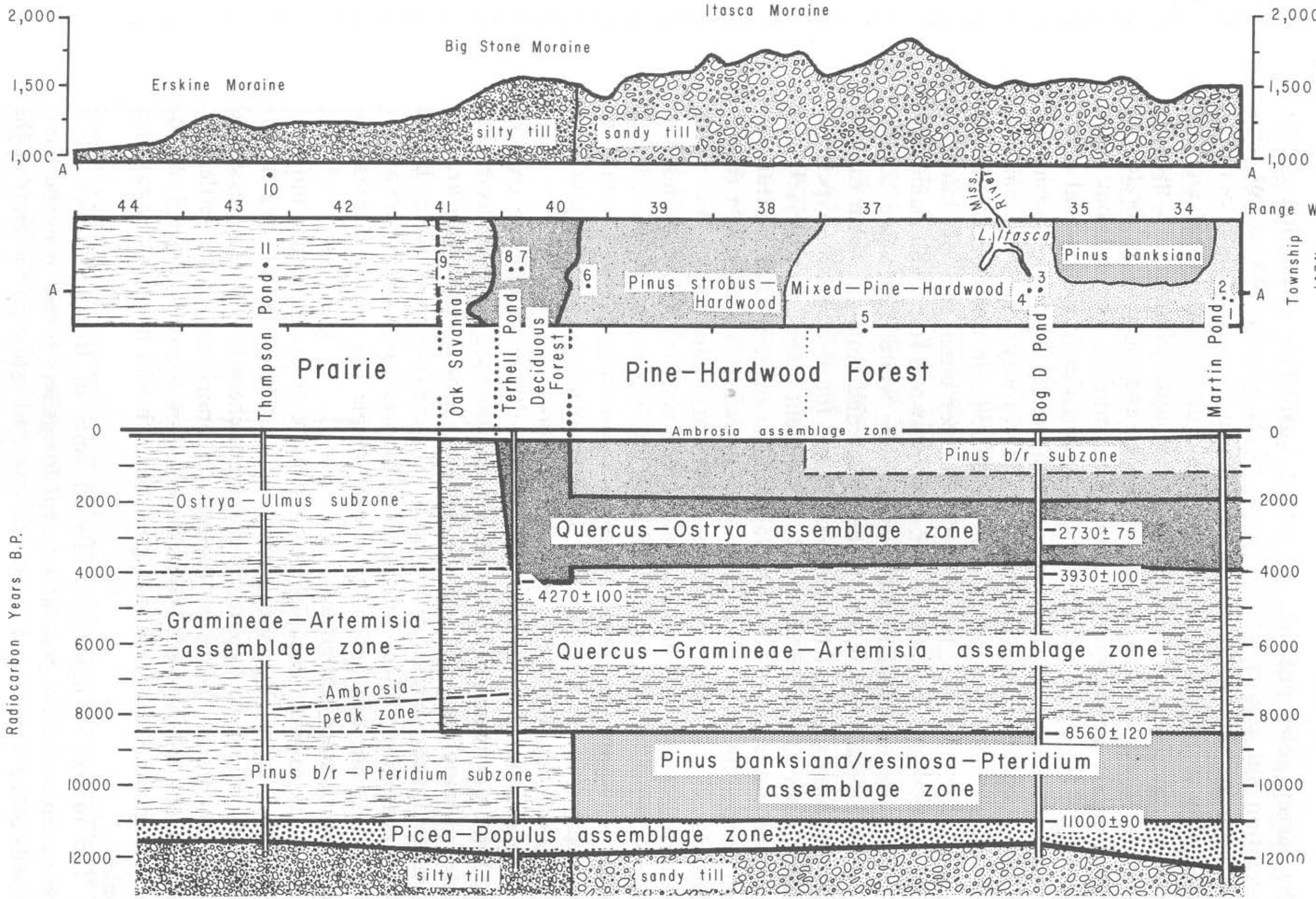

FIG. 3. Itasca transect: landforms, vegetation, and chronosequence of pollen assemblage zones. The transect is 66 miles long and 6 miles wide. On the map the ponds from which short cores were taken are numbered to correspond with the diagrams of Figure 4.

TABLE 1. Common Names with Their Botanical Equivalents

	Trees		*Herbs*
ash	*Fraxinus*	aster	*Aster*
aspen	*Populus tremuloides*	bracken fern	*Pteridium*
balsam poplar	*P. balsamifera*	goldenrod	*Solidago*
basswood	*Tilia americana*	grass	Gramineae
birch	*Betula*	ragweed	*Ambrosia*
paper birch	*B. papyrifera*	sage	*Artemisia*
elm	*Ulmus*		
balsam fir	*Abies balsamea*		
hazel	*Corylus*		
ironwood	*Ostrya virginiana*		
juniper	*Juniperus*		
maple	*Acer*		
sugar maple	*Acer saccharum*		
oak	*Quercus*		
bur oak	*Q. macrocarpa*		
red oak	*Q. rubra*		
pine	*Pinus*		
jack pine	*P. banksiana*		
Norway pine	*P. resinosa*		
white pine	*P. strobus*		
spruce	*Picea*		
black spruce	*P. mariana*		
white spruce	*P. glauca*		
tamarack	*Larix*		

Erskine moraine. Absence of trees is not only a function of a relatively warm, dry climate but also of relatively low relief, which results in poorly drained soils and the near absence of fire-breaking hills and ponds. The prairie is dominated by tall grasses and such forbs as aster, goldenrod, sage, and ragweed. The prairie has mostly been destroyed by plowing, and aspen groves have increased in response to decreased fire frequency. Ragweed is a common field weed.

Vegetation and Pollen Assemblages

Eleven cores of sediment were collected from permanent ponds of 600 to 1,000 ft diameter (Fig. 3). Seven were short cores of the upper meter of sediment (Fig. 4) and four were long cores containing the entire postglacial record (Figs. 5–8). The pollen analyses were made at intervals of 20 cm or less, and the pollen sum was more than 300 grains of trees and wind-pollinated herbs, excluding aquatics. Only the more important pollen types are summarized in the pollen diagrams.

At each pond the upper 25 cm of sediment contains a sharp rise in *Ambrosia* pollen that marks the beginning of forest clearance and

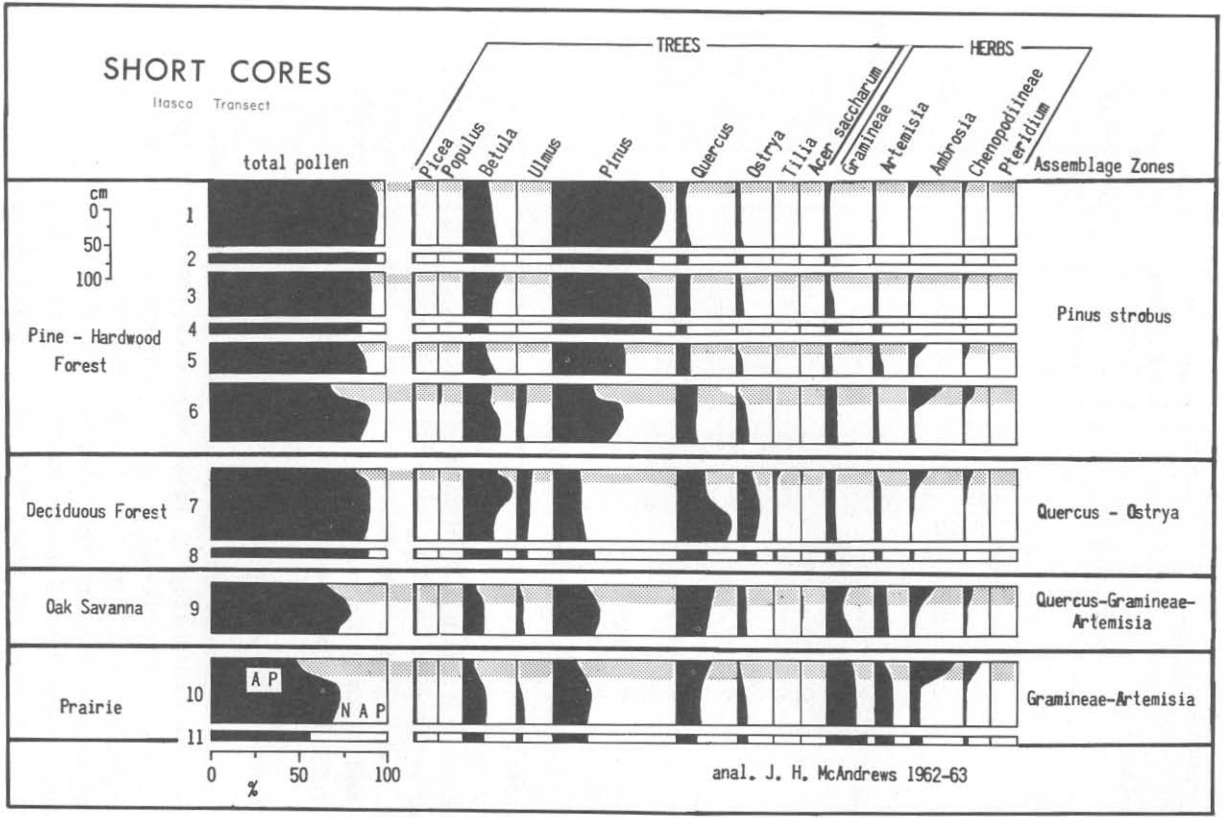

FIG. 4. Summary pollen diagrams from the upper meter of sediments in the seven short-core sites (numbered 1, 3, 5, 6, 7, 9, 10), together with an average spectrum for each of the four long-core sites from levels just below the settlement horizon. Vegetational formations are named at the left. AP, arboreal pollen; NAP, nonarboreal pollen.

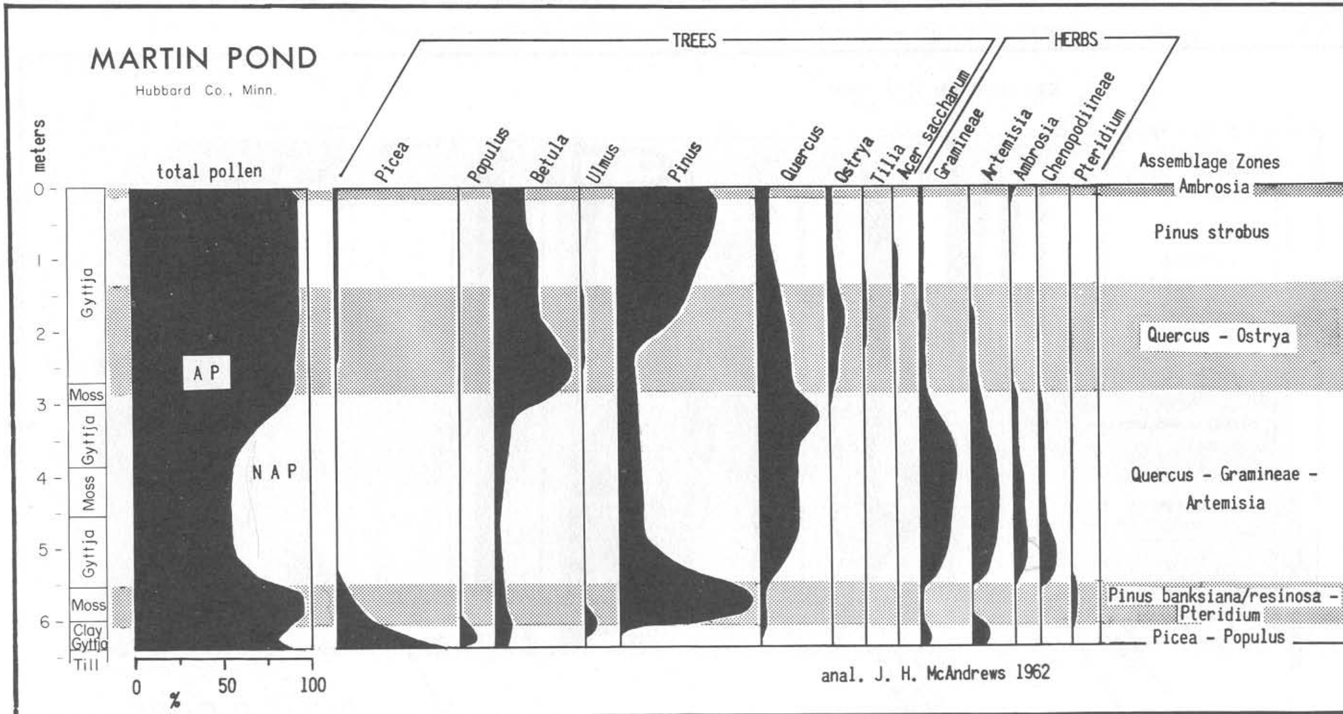

FIG. 5. Summary pollen diagram from Martin Pond.

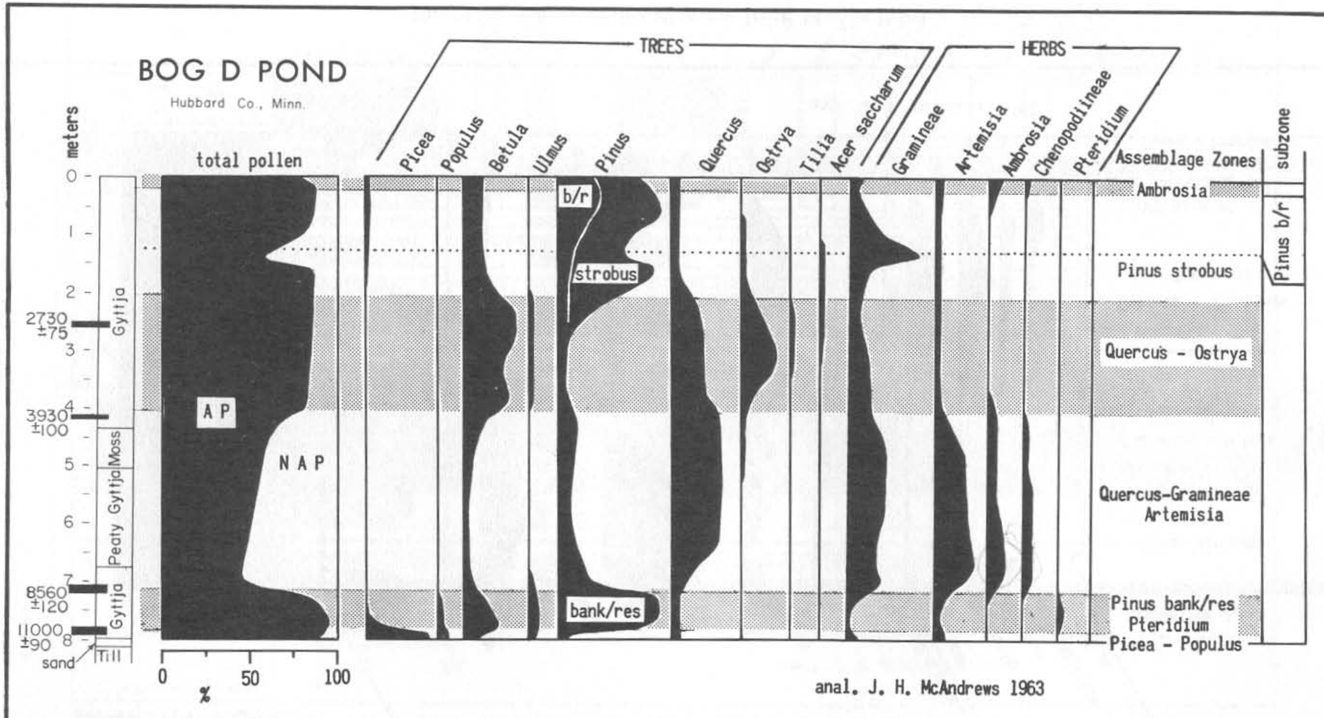

FIG. 6. Summary pollen diagram from Bog D Pond.

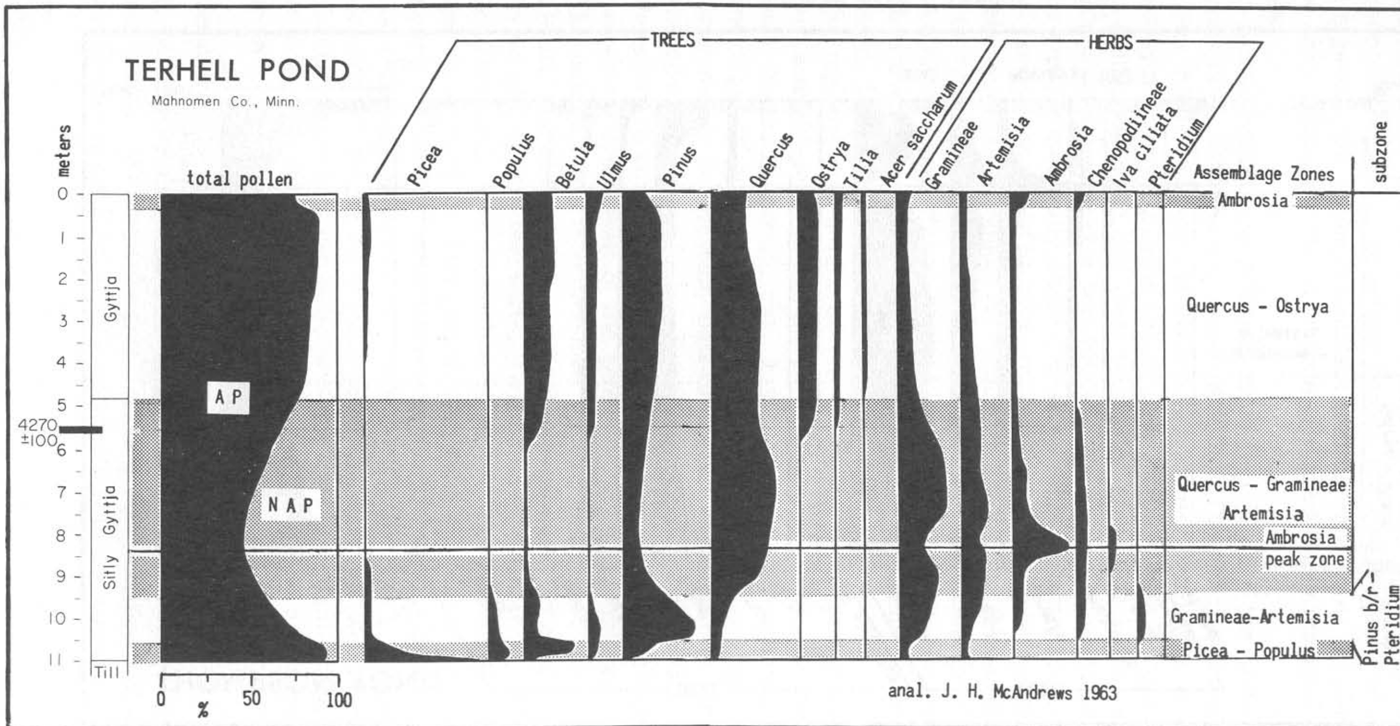

FIG. 7. Summary pollen diagram from Terhell Pond.

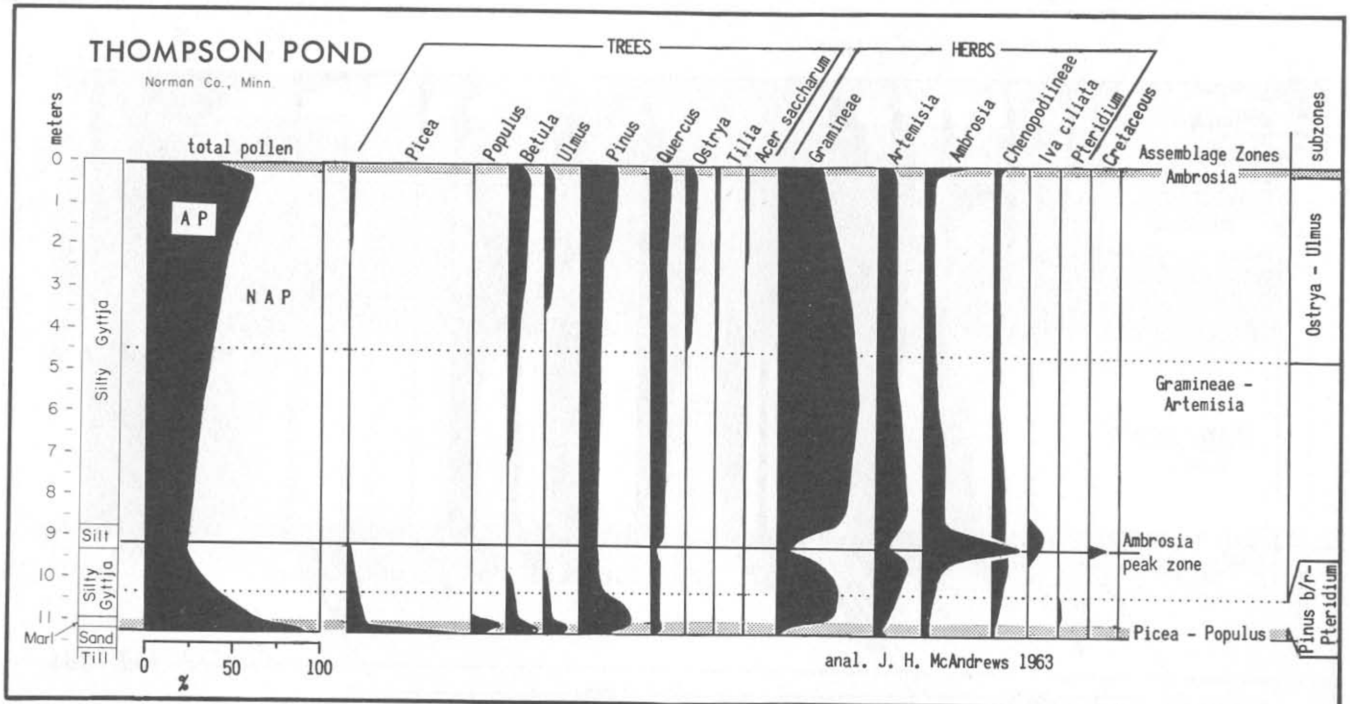

FIG. 8. Summary pollen diagram from Thompson Pond.

agriculture. Also characteristic of this *Ambrosia* assemblage are the Chenopodiineae, many of whose species are also agricultural weeds, like ragweed. The pollen assemblage immediately below the *Ambrosia* zone thus represents the vegetation described from the land-survey notes.

In forested areas tree pollen is more that 75% of the pollen sum, whereas in the savanna and prairie it is less. The pollen assemblage of the pine–hardwood forest is distinguished from that of the deciduous forest by relatively high pine values (over 35%). At Bog D Pond white-pine pollen was separated from the pollen type of jack and Norway pine and in some spectra was found to be more abundant than the latter type; consequently, these spectra and contemporary spectra from other ponds were named the *Pinus strobus* assemblage. Other components of this regional assemblage are such pollen grains as *Betula*, *Quercus*, and *Ostrya*. Quantitatively the percentage of pine pollen approximately represents the importance of pine trees in the vegetation, whereas birch is over-represented by its pollen and aspen is under-represented (Janssen, 1966a).

The regional pollen rain of the deciduous forest is the *Quercus–Ostrya* assemblage. It is dominated by pollen of deciduous trees such as oak, birch, ironwood, elm, basswood, and sugar maple. Again aspen is greatly under-represented in the pollen assemblage, and to a lesser degree so are elm, basswood, and sugar maple. Birch and ironwood are over-represented. Twenty per cent of the pollen assemblage is *Pinus*, which comes from another formation and is here termed an extraregional component of the *Quercus–Ostrya* assemblage.

The oak savanna is represented by one short core that contains moderate but characteristic percentages of herb pollen (26%) and *Quercus* (15%). Of the herbs, Gramineae is highest at 12%, and *Artemisia* is 8%. This assemblage is termed the *Quercus*–Gramineae–*Artemisia* assemblage. Tree pollen other than *Quercus* is mostly extra-regional; it is derived from the forest many kilometers distant.

As in the oak savanna, the prairie spectra have 25% or more herb pollen; of the prairie dominants, grass and sage are well represented in this Gramineae–*Artemisia* assemblage. Less important prairie species that make important contributions to the pollen rain are ragweed and Chenopodiineae.

Assemblage Zones and Vegetational History

The pollen assemblage zones shown in the diagrams of the four long cores (Figs. 5–8) are stratigraphically, geographically, and chronologically related on Figure 3. The chronology of the zones is based on five radiocarbon dates. The ages of the zone boundaries not directly dated were calculated from rates of sedimentation derived from the available radiocarbon dates. The geographic boundaries of the assemblage zones and the vegetational formations that are inferred from them are placed at the boundaries of the landforms that delimit equivalent modern assemblages and formations.

The four pond basins resulted from the melting of ice blocks buried in the till. The Wisconsin glacier retreated from the Big Stone moraine about 12,000 B.P. and from the Itasca moraine about 13,500 B.P. (Wright and Ruhe, 1965). According to the chronology given in Figure 3, sedimentation in the ponds did not begin until 11,500 to 12,300 B.P. Thus there was no sediment deposited and no pollen record for the first 500 to 1,200 years after the area became available for plant occupation. The uppermost till in the cores from Martin and Bog D ponds is mixed with humus, and it appears that a vegetation-covered soil developed on the till before the beginning of sedimentation. During this period the transect may have supported a tundra vegetation such as has been described for northeastern Minnesota (Fries, 1962; Baker, 1965).

The earliest pollen spectra in all four long cores constitute the *Picea–Populus* assemblage zone. *Picea* is dominant along with relatively high values of *Populus*, *Betula*, and *Ulmus*. Although not shown on the diagrams, *Larix*, *Juniperus*, and *Fraxinus* pollen are higher in this zone than in succeeding zones. Macrofossils from this zone include spruce, tamarack, aspen–poplar, and paper birch.

The *Picea–Populus* assemblage does not resemble any modern one in the transect, and such an assemblage containing appreciable *Ulmus* and *Fraxinus* is difficult to match from any modern boreal forest (Lichti-Federovich and Ritchie, 1965). This assemblage is the only one common to all the landforms of the transect and is found throughout Minnesota and in southern Manitoba (Cushing, 1965), although at some localities *Populus* pollen is low or absent. *Populus* pollen is infrequent or absent in surface samples (Janssen, 1966a) and in all but the earliest assemblage of the transect. However, it is abundantly represented in the modern pollen rain (Lichti-Federovich and Ritchie, 1965); thus *Populus* pollen appears not to have been preserved under the sedimentary conditions of the postglacial.

About 11,000 years ago the *Picea–Populus* assemblage was succeeded, in cores from the sandy soils of the Itasca moraine, by the *Pinus banksiana/resinosa–Pteridium* assemblage which is similar to the recent *Pinus strobus* assemblage except that pollen of *P. strobus* is essentially absent (Janssen, 1966b) and spores of bracken fern are abundant. Jack pine was present in the vegetation, for C. T. Shay (personal communication) has identified cones of this species in the *Pinus b/r–Pteridium* zone of Nicollet Creek bog in Itasca Park. That this was not the only pine species in Minnesota at this time is indicated by the occurrence of Norway pine needles in lake sediment in eastern Minnesota (W. A. Watts, personal communication). Although bracken fern is common in modern pine forests, it does not contribute many spores to the regional pollen rain (Janssen, 1966a); perhaps in the past it grew in more open pine stands, and because of this it sporulated more freely. Birch, elm, aspen, and spruce were probably also present in significant quantities in the vegetation.

In cores on the silty soils to the west, the *Picea–Populus* assemblage was succeeded about 11,000 years ago by the Gramineae–*Artemisia* assemblage, which represents prairie that has persisted in the low-altitude part of the transect to the time of settlement. This assemblage zone contains several subzones delimited by increased amounts of extraregional tree pollen; these changes resulted from the changing forest composition on the moraines to the east. The lower part of this zone contains distinct but relatively subdued peaks of *Pinus* and *Pteridium*, but *Pinus* pollen is less than 35%, which indicates that most if not all the pollen was derived from the pine forest that grew on the sandy soil of the Itasca moraine.

About 8,500 years ago *Pinus* in all the cores decreased to less than 20%; this relatively low amount indicates that pine had disappeared from the transect. On the high-altitude moraines a vegetation of oak and herbs produced the distinctive *Quercus*–Gramineae–*Artemisia* assemblage that represents oak savanna. As in modern oak savanna, the oaks were probably grouped in groves on the east side of the many lakes and ponds of the moraine, where the frequency and intensity of fire would be relatively low.

The high *Ambrosia* peaks at Thompson and Terhell ponds that occurred between 7,000 and 8,000 years ago suggest a local or extralocal source of *Ambrosia* pollen. Also in this peak zone are significant amounts of *Iva ciliata* pollen and, at Thompson Pond, Cretaceous spores. *Ambrosia* and *Iva* are plants of disturbed soils, and they probably grew abundantly on the slopes and shores of the ponds at the time of deposition of the peak zone. Further evidence for the presence of disturbed soils is the silt horizon of Thompson Pond, which was eroded from the till surrounding the pond. The till contains Cretaceous shale, which was the source of the Cretaceous spores.

About 4,000 years ago there was a strong increase in deciduous-tree pollen and a decrease in herb pollen in the diagrams from the Big Stone and Itasca moraines. *Quercus* remains high, and *Ostrya*, *Ulmus*, *Tilia*, *Acer saccharum*, and *Betula* have their highest values. This *Quercus–Ostrya* assemblage represents the deciduous forest, which persisted on the crest of the Big Stone moraine until settlement. The invasion of the moraines by the deciduous forest is reflected at Thompson Pond by a small increase in extraregional deciduous tree pollen in the Gramineae–*Artemisia* assemblage; this increase is named the *Ostrya–Ulmus* subzone.

Beginning about 2,700 years ago there is a gradual increase of *Pinus*, probably extraregional, in the two eastern diagrams, which indicates an advance of pine from that direction. The Bog D Pond diagram shows the pollen was predominantly that of *Pinus strobus*. About 2,000 years ago *Pinus* pollen increased to over 35% in locations on the Itasca moraine; the presence of pine trees and the arrival of the modern pine–hardwood forest is thereby indicated. Extraregional *Pinus* pollen also increases at the same time in the deciduous forest and prairie to the west.

At Bog D about 1,000 years ago, an increase in *Pinus banksiana/resinosa* pollen suggests the arrival, or at least an increase in numbers of, one or both of these species in the vegetation. This shift from predominantly white pine to mixed pine is supported by a similar stratigraphic sequence of fossil needles of the three pine species in the upper sediments of Martin Pond. The late and perhaps still continuing invasion of jack and Norway pines may be responsible for the division of the pine–hardwood forest into the mixed-pine–hardwood and white-pine–hardwood types.

The Gramineae peak at 1 m in the Bog D Pond diagram is unaccompanied by increases in other herbs and thus is part of the local rather than the regional pollen rain. Janssen (1966a) has found high values of Gramineae pollen in Lake Itasca in shallow sediments that support stands of wild rice, an aquatic grass. Such a local stand was probably the source of the Gramineae in Bog D Pond.

Climatic Interpretation

The climatic interpretation of past vegetational formations will be made here only in a general way, for more work is needed to understand the modern vegetation and its relation to climate. During deglaciation and subsequent melting of buried ice blocks, the climate must have been very cold. The melting of surficial glacial ice and buried ice blocks indicates a moderating cold climate. The first recorded vegetation, a boreal-type forest, indicates a cooler climate than at present. The uniformity of this boreal-type vegetation suggests a uniform climate not conditioned by the altitudinal differences along the transect. The disappearance of the boreal-type vegetation and its replacement in the west by prairie and in the east by pine forest indicates a warming to essentially modern climatic conditions. The absence of a deciduous forest on the crest of the Big Stone moraine may be more apparent than real, for the crest might have been largely occupied by aspen, which did not leave a pollen record. A further trend toward higher temperature and lower precipitation is indicated by the disappearance of the pine forest and the occupation of the eastern end moraines by oak savanna. Although prairie remained at lower altitudes, a disturbance in the vegetation and a decrease in ground cover, perhaps because of extreme drought during this time, is indicated by the silt horizon and *Ambrosia* peak at Thompson Pond.

A reverse trend toward a cooler and moister climate caused the deciduous forest to replace most of the oak savanna except on the west flank of the Big Stone moraine. Further cooling, perhaps with lower summer temperatures and higher winter snowfall, allowed pines to migrate into the transect and change the character of the deciduous forest on the sandy soil to a pine–hardwood forest. However, this climatic change was not enough to allow deciduous forest and oak savanna to advance westward much if at all. Thus the modern deciduous forest and oak savanna are relicts of formations that once had a more extensive distribution and now have been squeezed into a small area with favorable landforms.

The Itasca region has proved ideal for reconstructing the history of several vegetational formations that occupy discrete landforms. The soundness of investigating vegetational history with reference to landforms, the vegetational formations that they support, and the pollen assemblages produced by those formations may be seen in the nearly identical pollen curves of Bog D and Martin ponds, which are located on the same landform. On diagrams from contrasting landforms some levels exhibit identical curves, but in general the assemblages are unique; and where pollen curves are congruent, an extraregional pollen source can be shown.

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