

THE
PLANT ECOLOGY
OF THE
HAZELWOOD BOTANICAL PRESERVE .

o o o

A dissertation submitted in partial
fulfillment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

to the Graduate School of the
University of Cincinnati

1929

by

John Gustav Segelken
A.B. University of Cincinnati 1927
M.A. University of Cincinnati 1928

o o o

CINCINNATI
UNIVERSITY
LIBRARY

UMI Number: DP16052

INFORMATION TO USERS

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleed-through, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.



UMI Microform DP16052
Copyright 2009 by ProQuest LLC
All rights reserved. This microform edition is protected against
unauthorized copying under Title 17, United States Code.

ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106-1346

CONTENTS

I. Introduction	1
II. Topography and Geology	6
III. Vegetation	13
A. Communities	13
1. Swamp	13
2. Forest	19
3. Ruderal	25
B. Successional Relations	26
1. Primary Successions	26
2. Secondary Successions	30
C. Transects	32
1. Description	32
2. Summary	39
IV. Habitat Factors	40
A. Description	41
B. Climatic Features	45
C. Evaporation	47
D. Soils	50
1. Soil Moisture	51
2. Soil Temperature	53
3. Colloidal Content	56
4. Chemical Features	58
a. H ion	58
b. Analyses	60
V. Relic Community	62
A. Present Environment	62
B. Relationship and Source	64

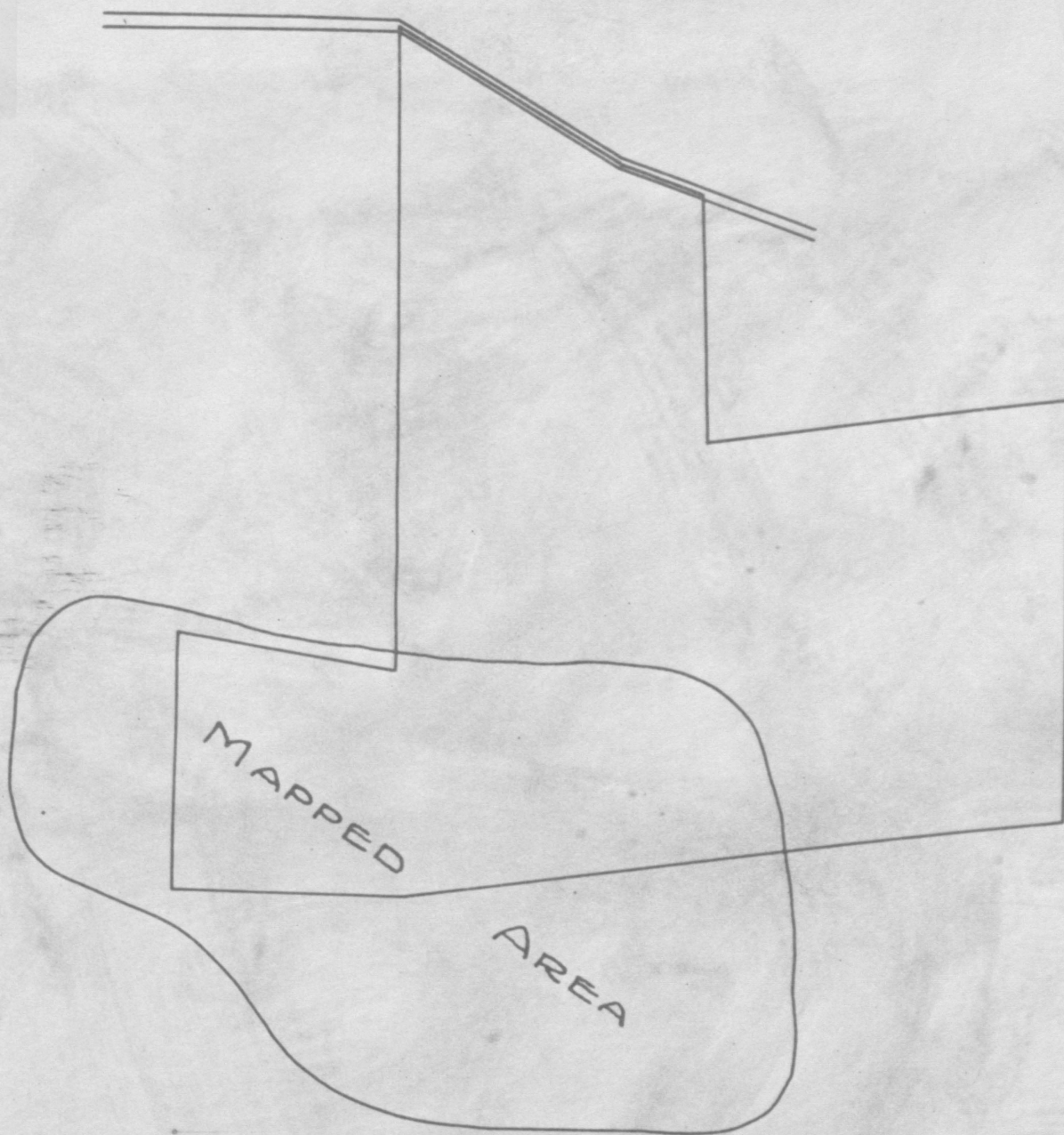
C. Distribution	65
VI. Summary	67
Acknowledgements	69
VII. Literature Cited	69

THE
PLANT ECOLOGY
OF THE
HAZELWOOD BOTANICAL PRESERVE

I. INTRODUCTION

The Hazelwood Botanical Preserve, situated sixteen miles north of Cincinnati, Ohio, is a seventy acre tract of ground, secured through the activities of the Blue Hydra Botanical Society and is to be devoted to the study of botanical problems. In 1926, this Society sponsored a campaign to secure the tract for the Department of Botany of the University of Cincinnati. Through the generosity of a group of men and women of this city and vicinity, a fund of twenty-five thousand dollars was secured to purchase and endow this tract.

The occurrence of a colony of unusual plants was one of the main reasons for the acquisition of this tract. The existence of this colony, composed of several northern species in the midst of the regional climax mesophytic forest of southern derivation, offered a problem that has been approached from various angles. Their method of entry, the study of factors contributing to their survival, the geological formation and development of the area as indicated by the stratification of the swamp soil and the rock outcroppings, are phases of the investigation. Studies relating to evaporation, soil moisture and temperature and soil structure and composition have been made, enabling comparisons to be drawn of the habitats occupied by the relics with those occupied by other types of vegetation. The discontinuous distribution of these boreal relics and the other unusual plants of the colony is also an item



The
HAZELWOOD
BOTANICAL PRESERVE
SCALE
0 500 1000
FEET

Fig. 1. General location of the area studied.



Fig. 2. Air view of the Hazelwood Botanical Preserve and vicinity.

of interest. All are absent from or are rare in the floras of this and neighboring states.

Of the seventy acres included in this Preserve, approximately ten acres are swamp land, forty acres are in forest, and the remainder under cultivation. The area mapped has a total relief of sixty feet and covers the southwest corner of the Preserve and other abutting property, necessarily included. A perusal of the maps (Figs. 1 and 3) will show that the Preserve is traversed in the southwest corner by a main ravine in a general northwest-southeast direction with several smaller tributary ravines entering at approximately right angles. The main ravine and the two larger branches have swampy, flat-bottomed floors and are cut by streams that have their sources on this and neighboring property. The angle of slope of the south bank of the main ravine is relatively steep in comparison with that of the north bank. The slopes and uplands are forested.

The upland of the south bank and that portion of the north bank down to the tenfoot contour, is composed of clay loam; the remaining areas of snady silt.

The possibilities of this tract for botanical work are great: the area presents a wide range of habitat conditions and a varied flora including an interesting relic colony; excellent opportunities are afforded for successional studies relating to hydrophytic and mesophytic communities; cleared portions and openings give concrete examples of the return of forests into denuded areas; recently farmed areas provide ample room for work in propagation, tree seed germination and related problems. The acquisition of this area was the more desirable because of the position of the Cincinnati region between the great centers of dispersal, namely, the boreal, the south-eastern mesophytic and the prairie.

The forest is mostly primary growth, climax in nature, and is one



Fig. 3. General map, showing locations of stations, transects and borings.

of the few areas of this type remaining in this region. With the exception of some white oak (*Quercus alba*) and tulip (*Liriodendron tulipifera*) cut out fifty years ago, the woods have been unmolested. Second growth woods are confined chiefly to the south bank; on the north bank are a few openings and a clearing, the latter probably used for farming many years ago.

II. TOPOGRAPHY AND GEOLOGY

Areas of Illinoian drift are found on the uplands of both banks. From this period until early Wisconsin glaciation, it is probable that a ravine existed in the present location but the direction of flow of any stream or streams in that ravine, their inlet or outlet, are no longer evident. It is the change wrought by Wisconsin glaciation that is of interest at present. The southern margin of the Wisconsin ice sheet is tentatively placed about one mile north of the Preserve (), but local evidence indicates that it is much closer if not on the area under discussion.

At present, two terraces can be discerned along the north bank (Figs. 3, 4 and 7). At the union of the main ravine with the largest arm from the north, the lower terrace merges into the swamp floor. At the eastern end, this terrace is about twenty feet above the ravine floor and quite broad. Fifteen feet above this terrace, another indistinct terrace is noted. This may be the result of a temporary lake, such as could be formed by the accumulation of ice.

A protruding arm of ground from the north bank (A, Fig. 3) and the position of another large ravine opposite, indicate a former outlet or overflow of this temporary lake. The abrupt head of this ravine appears artificial; conversations with older residents indicate that improvement



Fig. 4. Junction of terrace and swamp floor

of a road required filling-in to level the grade. A few hundred feet south of the road another ravine, beginning at "B" in the aerial picture of the region Fig. 2), may have been the continuation of the larger arm that served as the lake outlet. Cooper creek receives the water of this small ravine and flows in a direction parallel to the main ravine of the Preserve. It also serves as the main drainage stream of the region. The nature of its rock bottom with a width of more than fifteen feet indicates the passage of much water, all this in marked contrast to the stream now flowing through the Preserve east of the lake barrier with its gently sloping banks and very slightly eroded channel, the banks portraying age and the channel youth.

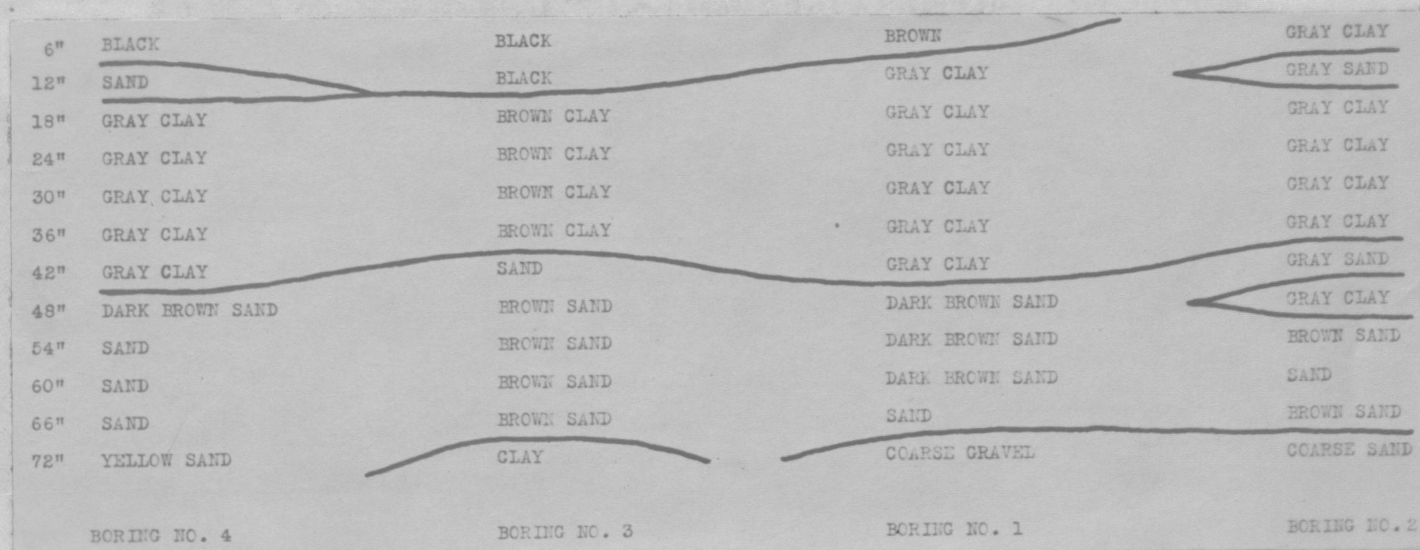


Fig. 5. Stratification of the swamp as indicated by borings.

With the preponderance of water from the north or perhaps because of the nearness of the ice margin, the main stream was forced along the south bank, accounting for the pronounced steepness of that bank in contrast to the north bank. The retention of steepness is due to the sandy soil allowing interior drainage and thus preventing surface wash.

The two terraces and the flat-bottomed ravine indicate a former lake formed by one or more ice or boulder obstructions. The present indefinite outline of the higher terrace implies a brief existence of the lake at that level. Accumulated ice, superimposed on a more permanent boulder base, may account for the formation of these terraces. With larger quantities of drift-laden water coming from the melting ice sheet, much material was deposited in this ravine, favorably located for the

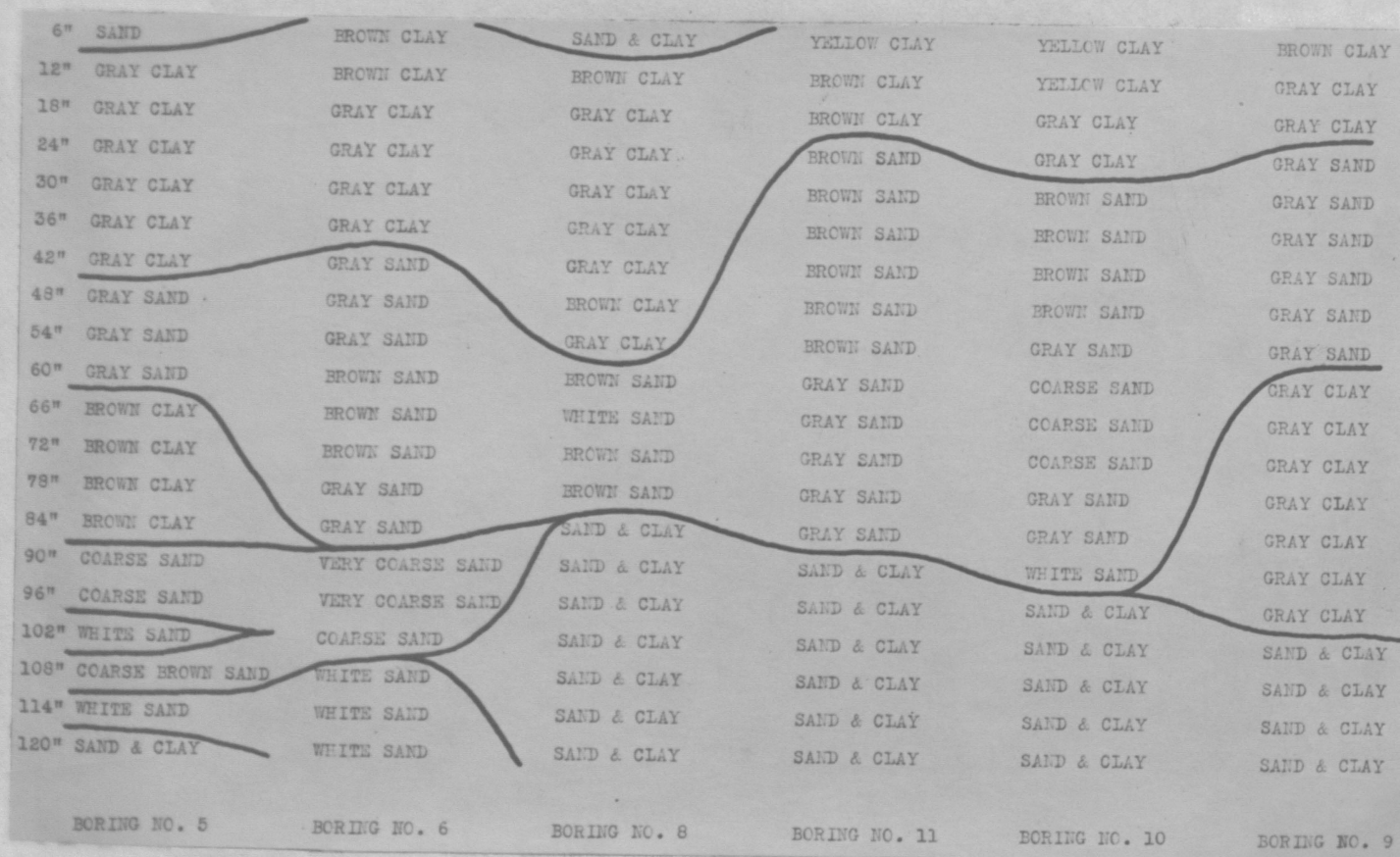


Fig. 6. Stratification of the swamp floor as indicated by borings

drainage of the large flat undissected area to the north. Boulders of various sizes bear witness that such deposition took place near the eastern end of the Preserve.

The whole area to or somewhat above the level of the higher terrace,



Fig. 7. View of lower terrace at the eastern end of the mapped area.

was probably flooded. Later and for a longer time, a lake stood at the lower terrace level. With the water at this level, the present ravine floor below the main tributary would have been flooded; above this a swamp, or a swamp with numerous ponds was formed. Into this lake, at either or both levels, the greater quantity of detritus was brought from the north. Much of this was deposited on the north bank, hence the more gradual slope of that bank. That the lake was of long duration is indicated by the depth of the stratified deposits of the valley floor (Figs. 5 and 6); by the well-marked terrace, now cut by smaller ravines whose extremely youthful topography is in contrast to that of all other ravines in the area; and by the stratified sand (now sand rock) deposits appearing in some of the banks. Later, after the main body of the lake had been drained by the formation and downcutting of an outlet by the present stream at the eastern end of the lake area, a part of the valley deposits may have been reworked by a meandering stream, still partially blocked, thus accounting for the slope of the apparently flat-bottomed ravine floor.

Very recently the cutting of the forest on land west of the Preserve has added a superficial deposit on the former swamp floor. The main stream has cut a definite channel in the swamp floor throughout its entire length and drainage of the swampy areas has started. Areas that a few years ago were impassable, are now only moist and solid except during periods of excessive rainfall.

In order to study more fully the development of the ravine floor and possibly obtain some information concerning inlets or outlets, two series of borings were made. The position of these can be found on the general map, figure 3. Marked stratification of the swamp filling is noticed from figures 5 and 6. In the study of these figures, the seem-



Fig. 8. Plant communities throughout the area.

ingly abrupt differences in thickness of layers are due to the extreme lateral crowding of the diagram. The distance from hole 4 to hole 2 is about three hundred and twenty feet while that from hole 5 to hole 9 is slightly more than one thousand feet. The first of these series of borings is located in the main lateral ravine with holes 4 near the head of the lake filling and holes 3, 1 and 2 located in the middle of the main swamp. The second series is in the main ravine with hole 5 near the head and holes 6, 8, 11, 10 and 9 down the center of the ravine floor to the east limit of the mapped area. Greater differences of thickness occur in the strata of the main swamp due to the faster filling of the south and the probable position of an outlet opposite hole 10. The layers appear quite definite and regular until in the proximity of this hole where several discrepancies appear, best explained by the foregoing reasons. At hole 8, the thicker clay and sand-clay layer is due to the effect of washing from the north. The great preponderance of sand at holes 10 and 11 would be very possible with an outlet at the south ravine, the heavier sands being deposited, the colloidal clays carried off by the flowing water. The very tenacious sand-clay layer covers the lower levels of the whole area once subjected to inundation.

III. VEGETATION

The vegetation of the area can be grouped into three major communities: swamp, forest and ruderal.

A. COMMUNITIES

1. SWAMP

The swamp communities occur in habitats that range from extremely wet, i.e., with standing water over smaller or larger areas for the greater part of the year, to approximately mesophytic conditions with



Fig. 9. Impatiens-Polygonum community on the swamp floor of the main ravine.

standing water present but a short time during the spring months. The whole range of conditions is found on the western half of the main ravine floor, in the side arms and at places along the bases of slopes, excessively wet because of seepage. The remaining parts of the ravine floor resemble, in moisture content, the forest floor of the slopes, because of the drainage effected by the deeply cutting stream.

On the wetter areas, the herbaceous far outnumber the woody plants both in species and individuals. Due to differences in time of blooming, the aspect changes with the progress of the growing season. During the early spring months, marsh marigold (*Caltha palustris*) with its yellow flowers is very conspicuous. In May and June, rice cut-grass (*Leersia oryzoides*), arrow-leaved tear-thumb (*Polygonum sagittatum*), touch-me-not (*Impatiens biflora*) and cat-tail (*Typha latifolia*) appear. *Leersia* and *Typha* dominate in those locations where standing water is present throughout the year; the *Polygonum* and *Impatiens* in habitats submerged for shorter periods. A willow (*Salix nigra*) community of young individuals is growing on the ravine floor west of the Preserve where standing water is prevalent during the spring and summer, and where later, the soil is very boggy.

Two other communities, dominated by older willows, are found where the land is drier, due to the depth of stream cutting. As one goes eastward, these willows increase in size, the individuals of the last community averaging over two feet in thickness. This soil drainage is probably of recent occurrence, as informed residents claim that ten years ago most of the floor tenanted by the willows was well-nigh impassable. A grazed grassy meadow is present under the oldest willows. Bordering the stream which has cut a bed over five feet in depth, ironweed (*Vernonia fasciculata*) is common, especially in the more open spaces. Single communities



Fig. 10. Swamp floor vegetation near boring No. 6.

of Joe-pye weed (*Eupatorium purpureum*) and elder (*Sambucus canadensis*) are found on the floor in the drier places.

Between the latter willow communities, purple willow (*Salix purpurea*) was planted years ago in an effort to overcome cattle losses caused by a quicksand formation. This planting has flourished and today is a very prominent community in the swamp area.

Elm (*Ulmus americana*) and sycamore (*Platanus occidentalis*) are found distributed where hydro-mesophytic conditions prevail as along the sloping margins of the north bank. Young elm and sycamore are present as an understory in those places where they form part or all of the canopy.

Near the eastern boundary where the creek bed is some five or six feet below the mean floor level, the influence of grazing is seen in the presence of many typical meadow grasses. Gardens and pastures occupy these flats except at the bases of the slopes where seepage renders the soil too wet and rice cut-grass and tear-thumb dominate.

These communities, especially the willows, demonstrate the change which has taken place because of the simultaneous actions of deposition and stream entrenchment. Especially is stream entrenchment, progressing headward, altering the nature of the swampy area which previously covered the whole ravine floor. The oldest willow community occupies the part of the flat where the stream is most deeply intrenched. Accompanying this change will be an invasion of the more mesophytic trees, already started by the elm, ash and sycamore along the margin.

Following is a list of the herbaceous plants of the hydrophytic and hydro-mesophytic communities of the ravine floor:

<i>Agrimonia parviflora</i>	<i>Lappula virginiana</i>
<i>Alisma plantago-aquatica</i>	<i>Lobelia syphilitica</i>
<i>Amphicarpa pitcheri</i>	<i>Mimulus alata</i>
<i>Apocynum cannabinum</i>	<i>Nepeta hederacea</i>
<i>Asclepias incarnata</i>	<i>Parietaria pennsylvanica</i>



Fig. 11. Vegetation in the north arm swamp, showing Impatiens-Polygonum, Typha, willow, tree fringe and climax communities.

Caltha palustris
Carex lurida
Carex sp.
Cryptotaenia canadensis
Chelone glabra
Eleocharis ovata
Equisetum arvense
Equisetum praealtum
Eupatorium perfoliatum
Eupatorium purpureum
Geum virginianum
Hypericum punctatum
Impatiens biflora

Penthorum sedoides
Pilea pumila
Polygonum arifolium
Polygonum sagittatum
Polygonum acre
Prunella vulgaris
Sambucus canadensis
Scutellaria lateriflora
Solidago patula
Typha latifolia
Verbena urticaefolia
Vernonia fasciculata
Vitis aestivalis

2. FOREST

The forest communities cover all but one of the slopes. Over half of the forest is original growth or only slightly modified by cutting. when this study was started and grazing has altered the composition of the eastern part on the south bank. Second growth timber is best developed on the south bank but is present in the opening and the cut-out area on the north bank. Young secondary forest is also encroaching upon the ruderal community.

Beech (*Fagus grandifolia*) is the most important component of the original forest. This forest occupies generally, the slopes and upland level portions that have not been cleared. On the steep slope of the south bank at the western end, the stand is mostly beech with some sugar maple (*Acer saccharum*), tulip, red oak (*Quercus rubra*). On the north bank at the western end, beech is the dominant; sour gum (*Nyssa sylvatica*) and the stumps of red and white oak and tulip indicate a mixed composition in past years. Continuing eastward on the north bank, the percentage of beech becomes increasingly greater. The canopy of the beech forest contains the following species, in the order of their importance:

Fagus grandifolia
Acer saccharum
Quercus alba

Liriodendron tulipifera
Nyssa sylvatica
Ulmus americana

Quercus rubra
Prunus serotina
Juglans cinerea

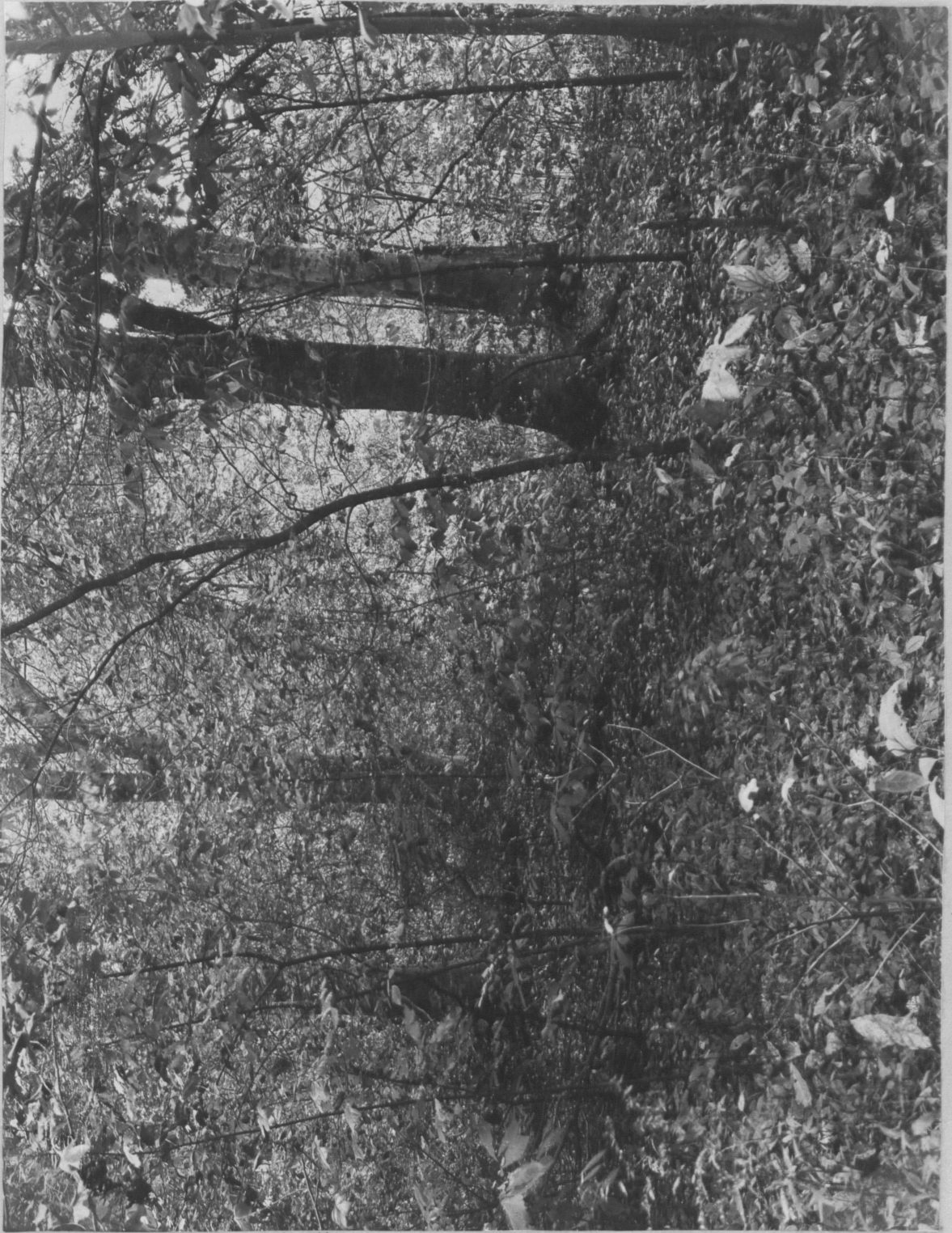


Fig. 12. Climax forest with *Chimaphila* in the floor cover. Station "B" is located in this grove.

This forest represents a phase of the climax type of the Cincinnati region. It differs from the usual regional climax in the greater importance of beech(6).

The understory of the climax forest is similar in composition to the canopy. While beech is prominent in this layer, its frequency among trees that are to form the canopy of the next generation is far below that of the present canopy. The indications are that the canopy of the future will more closely approach the mixed mesophytic regional climax. In the following list, the first four are in the order of their importance, the others are arranged alphabetically.

<i>Fagus grandifolia</i>	<i>Acer rubrum</i>	<i>Nyssa sylvatica</i>
<i>Liriodendron tulipifera</i>	<i>Carya ovata</i>	<i>Prunus serotina</i>
<i>Quercus rubra</i>	<i>Juglans cinerea</i>	<i>Quercus alba</i>
<i>Acer saccharum</i>		<i>Sassafras variifolium</i>

Other tree species of smaller stature, shrubs and lianes, as,

<i>Benzoin aestivale</i>	<i>Ostrya virginiana</i>	<i>Smilax hispida</i>
<i>Carpinus caroliniana</i>	<i>Smilax glauca</i>	<i>Viburnum acerifolium</i>
<i>Cornus florida</i>	<i>Smilax herbacea</i>	<i>Vitis aestivale</i>
<i>Hydrangea arborescens</i>		<i>Vitis cordifolia</i>

add to the variety of the forest understory. Their distribution is general throughout the area except the *Hydrangea* and *Viburnum* which are confined to the slopes of the south bank.

On first appearance, the herbaceous layer of this forest seems rather meager, even uninteresting. The fewness of individuals and consequent wide spacing would indicate a paucity of species, a fact that closer observation does not bear out.

The herbaceous plants of the forest are chiefly those common to such areas throughout the Cincinnati region; however, nine species occurring in small patches are of special interest. These are:

<i>Chamaelirium luteum</i>	<i>Hieracium paniculatum</i>	<i>Mitchella repens</i>
<i>Chimaphila maculata</i>	<i>Lycopodium lucidulum</i>	<i>Mitella diphylla</i>
<i>Epipactis pubescens</i>	<i>Medeola virginiana</i>	<i>Pyrola elliptica</i>



Fig. 13. Climax forest on the south bank, portion of the swamp community in the foreground.

Of these, only *Mitella*, *Mitchella* and *Hieracium* occur elsewhere in this region, but are nowhere common.

The following is a list of the herbaceous species found in the forest communities of the mapped portion of the Preserve.

<i>Adiantum pedatum</i>	<i>Amphicarpa monoica</i>
<i>Asplenium platyneuron</i>	<i>Oxalis stricta</i>
<i>Polystichum acrostichoides</i>	<i>Rhus toxicodendron</i>
<i>Onoclea sensibilis</i>	<i>Celastrus scandens</i>
<i>Botrychium virginianum</i>	<i>Impatiens biflora</i>
<i>Lycopodium lucidulum</i>	<i>Impatiens pallida</i>
<i>Equisetum arvense</i>	<i>Psedera quinquefolia</i>
<i>Equisetum praealtum</i>	<i>Vitis cordifolia</i>
<i>Panicum dichotomum</i>	<i>Vitis aestivalis</i>
<i>Panicum bosci</i>	<i>Hypericum punctatum</i>
<i>Poa sylvestris</i>	<i>Hypericum canadense</i>
<i>Brachyelytrum erectum</i>	<i>Viola papilionacea</i>
<i>Carex rosea</i>	<i>Viola palmata</i>
<i>Carex platyphylla</i>	<i>Viola eriocarpa</i>
<i>Arisaema triphyllum</i>	<i>Circaea lutetiana</i>
<i>Luzula campestris</i>	<i>Aralia racemosa</i>
<i>Chamaelirium luteum</i>	<i>Sanicula marilandica</i>
<i>Uvularia grandiflora</i>	<i>Sanicula canadensis</i>
<i>Allium tricoccum</i>	<i>Osmorhiza claytoni</i>
<i>Lilium canadense</i>	<i>Chimaphila maculata</i>
<i>Erythronium albidum</i>	<i>Pyrola elliptica</i>
<i>Smilacina racemosa</i>	<i>Monotropa uniflora</i>
<i>Polygonatum biflorum</i>	<i>Cuscuta gronovii</i>
<i>Medeola virginiana</i>	<i>Phlox divaricata</i>
<i>Smilax hispida</i>	<i>Hydrophyllum macrophyllum</i>
<i>Smilax glauca</i>	<i>Hydrophyllum appendiculatum</i>
<i>Smilax herbacea</i>	<i>Cynoglossum virginianum</i>
<i>Sisyrinchium angustifolium</i>	<i>Lappula virginiana</i>
<i>Epipactis pubescens</i>	<i>Prunella vulgaris</i>
<i>Orchis spectabilis</i>	<i>Hedeoma pulegioides</i>
<i>Corallorrhiza odontorhiza</i>	<i>Scrophularia marilandica</i>
<i>Liparis liliifolia</i>	<i>Veronica virginica</i>
<i>Urtica dioica</i>	<i>Epifagus virginiana</i>
<i>Laportea canadensis</i>	<i>Phryma leptostachya</i>
<i>Boehmeria cylindrica</i>	<i>Galium aparine</i>
<i>Aristolochia serpentaria</i>	<i>Galium triflorum</i>
<i>Polygonum acre</i>	<i>Galium concinnum</i>
<i>Polygonum virginianum</i>	<i>Mitchella repens</i>
<i>Silene stellata</i>	<i>Lobelia inflata</i>
<i>Ranunculus recurvatus</i>	<i>Eupatorium urticaefolium</i>
<i>Thalictrum dioicum</i>	<i>Solidago caesia</i>
<i>Hydrastis canadensis</i>	<i>Aster cordifolius</i>
<i>Podophyllum peltatum</i>	<i>Aster lateriflorus</i>
<i>Heuchera americana</i>	<i>Gnaphalium polycephalum</i>
<i>Mitella diphylla</i>	<i>Actinomeris alternifolia</i>
<i>Ribes gracilis</i>	<i>Bidens vulgata</i>

Potentilla canadensis
Geum canadense
Geum virginianum
Agrimonia mollis
Rosa humilis
Desmodium paniculatum
Desmodium grandiflorum
Desmodium nudiflorum

Erechtites hieracifolia
Krigia amplexicaulis
Lactuca villosa
Lactuca floridana
Lactuca spicata
Prenanthes altissima
Hieracium scabrum
Hieracium paniculatum

Groves of second growth forest of different age and composition occupy areas on the uplands and slopes that had been cleared. While some of the species of the climax are present, in no sense do they dominate. In parts of this forest, pronounced grouping or dominance of certain species is evident; instead of a mixed canopy, local segregation into communities composed of but one or two species, usually one, indicates the operation of a selective process or local peculiarities of seeding. Black cherry (*Prunus serotina*), red oak, sour gum, hornbeam (*Carpinus caroliniana*), white ash (*Fraxinus americana*), tulip and sumac (*Rhus glabra*) form such pure stands.

Communities of younger age and more varied composition occupy those areas presenting greater extremes of habitat conditions. In these mixed communities, the number of species of a particular community appears to bear a definite relationship to the age of that community. The younger stands have more varied make-ups and include species that do not become members of the canopy or lose out with the increasing age of that community unless particular habitat conditions favor them. Among such communities the following groupings are typical: (1) butternut (*Juglans cinerea*), red oak, dogwood (*Cornus florida*); (2) red oak, tulip, dogwood; (3) tulip, sassafras (*Sassafras variifolium*), butternut; (4) black cherry, white ash, tulip and (5) tulip, sugar maple.

Tulip, maple, black cherry, red oak and sassafras have a general distribution; butternut is most abundant on the south bank, ash and hornbeam on the north bank (Fig. 8).

The herbaceous layer of the secondary communities contains some of the plants found in the climax forest. Where the community is close to the swamp floor, intermingling of swamp and forest forms occurs.

The beech forest on the property west of the Preserve was lumbered in 1926. An indiscriminate shrubby growth with rank-growing weeds is now occupying the ravine slopes except at the south end where poke (*Phytolacca decandra*) has established itself abundantly.

3. RUDERAL

The ruderal community is confined to a small area on a north slope, hemmed in by an encroaching forest. Golden-rod (*Solidago nemoralis*, *S. altissima*), cinquefoil (*Potentilla canadensis*), tick trefoil (*Desmodium paniculatum*, *D. canescens*) and blackberry (*Rubus frondosus*) dominate, with grasses and lichens occupying the intervening spaces. On all sides however, the surrounding forest is encroaching upon this tract, with young tulip and tulip-ash communities occupying considerable portions.

Whether this area was once cleared for farming or is one of several similar places where plant life is absent, is difficult to determine. The size of the trees in the ash and oak communities that partially separate it from a field on the north, indicate that if cleared for farming, a rather long time has elapsed. Another explanation might be that material had been removed for the manufacture of bricks, used in the early homes. This latter idea would assist in the interpretation of the present vegeta-

tive cover. The maturity of this cover is much less than that of the tree communities on the cleared areas of the south bank. The exposed subsoil might have delayed plant establishment, thus accounting for the herbaceous-sapling growth on the north bank in contrast to the almost mature tree communities of the south bank, both produced in about the same period of time.

On both sides of a lane that skirts the east boundary of the Preserve, are single east-sloping areas that have been bare for fifty years and which residents claim are similar to the ruderal covered area. A few berry vines and plants comprise the present growth.

The soil of these latter areas is very loose and mealy and erodes easily while that of the former is more comparable to that of the adjacent field, i.e., clayey.

B. SUCCESSIONAL RELATIONS

Stages in primary and secondary successions, both hydrarch and mesarch are discernable in the Preserve. The primary hydrarch series presents a greater number of stages because of the constant and rapid changes taking place in the habitat.

1. PRIMARY SUCCESSIONS

Water covers the floor of the west end of the main ravine for the greater part of the year. Sufficient water is lacking however, for the establishment of a true aquatic stage in the hydrarch succession. In this and similar habitats, such as exist at the base of the steeper slopes where excessive seepage is encountered, rice cut-grass is present as a single dominant. It also appears that cat-tail may have been, in other localities

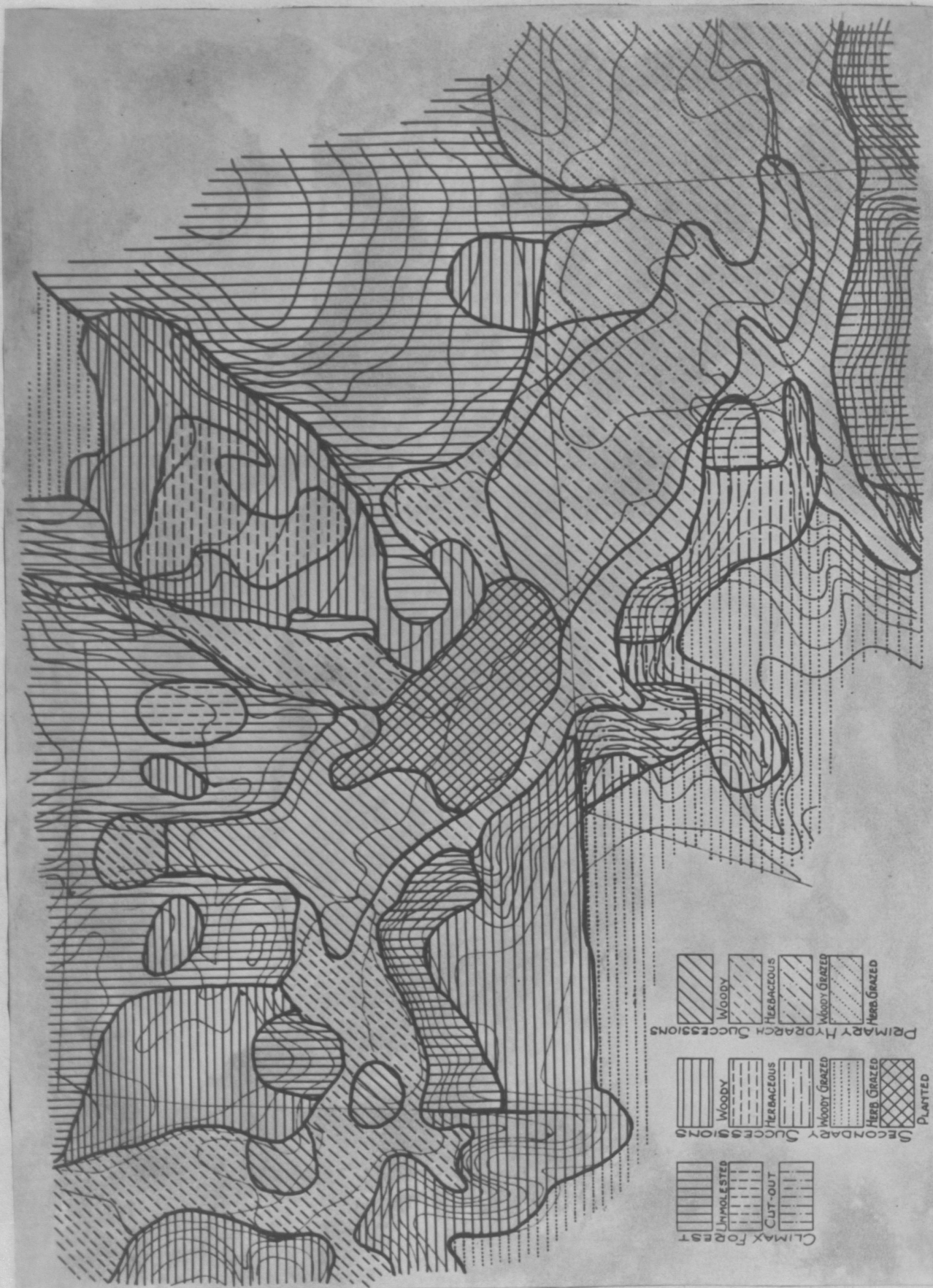


Fig. 14. Successional stages in the mapped area of the Preserve.

a pioneer with the *Leersia*. Present evidence indicates that willow and cat-tail have invaded the rice cut-grass with standing water present but the rapid changes that have taken place on the swamp floor, due to deposition and stream intrenchment, have obscured transitional stages.

Filling-in of the arms and active stream cutting in the main ravine drained much of the submerged area. New species grew on these adjacent boggy places. Marsh marigold is very conspicuous in the early spring, with *Polygonum*, *Impatiens* and *Carex* becoming increasingly evident as the season progresses. With continued drainage, the *Leersia* and *Typha* become less numerous and dense stands of the *Polygonum*, *Impatiens* and *Carex* occupy the drier areas. The present communities of *Impatiens* and *Polygonum* may or may not have had the cat-tail as a predecessor.

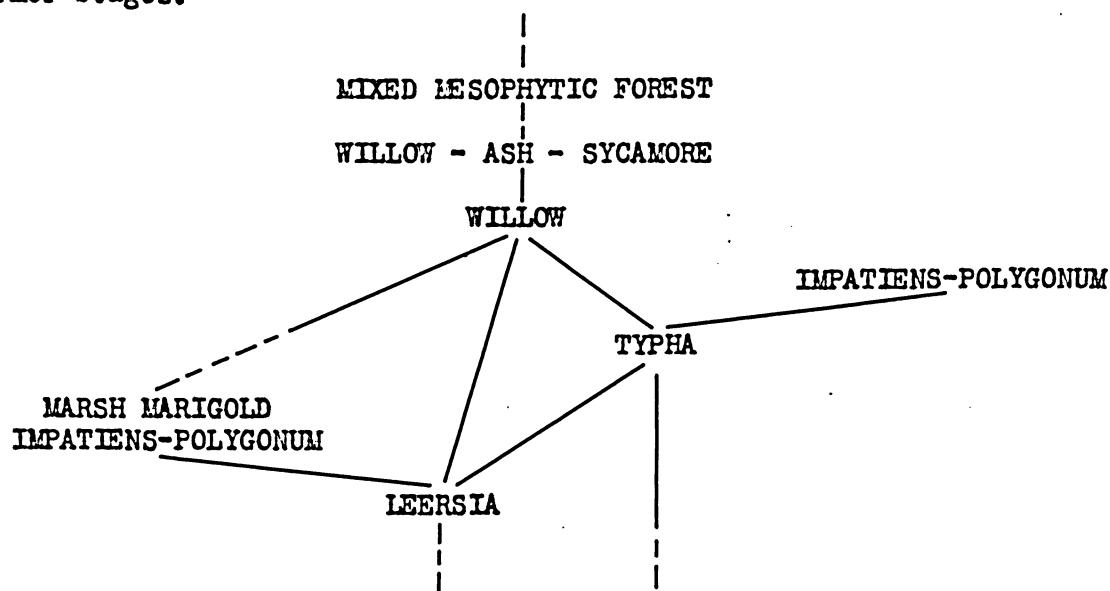
Before drainage had proceeded far enough to remove the boggy places, willow had established definite communities. Stream damming and fan formation have caused an apparent reversal of conditions, the oldest willows being located farthest downstream, i.e., where the lake may have stayed longest. The three definite willow communities indicate that many swampy habitats existed at different times. The swamp of most recent formation in the main ravine head is the basis of discussion in the preceding paragraphs. At the junctions of the two streams in the center of the main ravine floor (Fig. 3) a distinct difference in elevation is noted.

Fans formed by material from the large arm may have so reduced the gradient of the main ravine floor as to induce swampy conditions, culminating in the establishment of the intermediate willow community.

The present vegetation cover of the main north arm is similar to that found in comparable habitats in the main swamp and has undergone the

same succession of stages. The only exception noted is the absence of the marsh marigold.

The eastern and oldest willow community may be the direct outgrowth of conditions resulting from the early glacial lake, (See II). Recent grazing has effectually removed any remnants that may have remained of former stages.



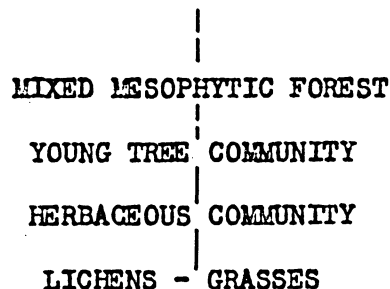
With decreasing quantities of soil water, tree individuals that generally indicate the presence of a more mesophytic habitat entered. Their entrance is more noticeable on those more completely drained areas as the raised mouths of the smaller ravines. Sycamore, green ash (*Fraxinus pennsylvanica*, var. *lanceolata*), elm and tulip are the new entrants that mark the transition from hydrophytic to mesophytic conditions.

The swamp floor in the drier areas also supports a herbaceous mesophytic growth with great lobelia (*Lobelia syphilitica*) and dogbane (*Apocynum cannabinum*) prominent in the unmolested parts and ironweed in areas devoted to grazing.

Early stages of the primary mesarch succession are absent. Later stages of the succession indicate the development of communities similar to the present climax but with the beech less numerous. In the cut-out areas between the remaining beech, the younger trees are the same species as found in the understory of the climax forest (III, 1, b).

2. SECONDARY SUCCESSIONS

The large clearing on the north bank offers the only opportunity for the observation of various phases in the secondary succession on denuded areas. Here, and as noted elsewhere on surrounding property, lichens and grasses are among the first invaders after clearing, plowing and crop removal. The present herbaceous growth includes many of the species found on neighboring fields. Golden-rod, Potentilla, Desmodium and blackberry are most prominent. On all sides however, are evidences of tree invasion with tulip most important. Closely following are the species distributed around the margin with maple, sassafras, black cherry, red oak and ash most numerous, indicating the future occupancy of a mixed mesophytic forest.



SECONDARY SUCCESSIONS

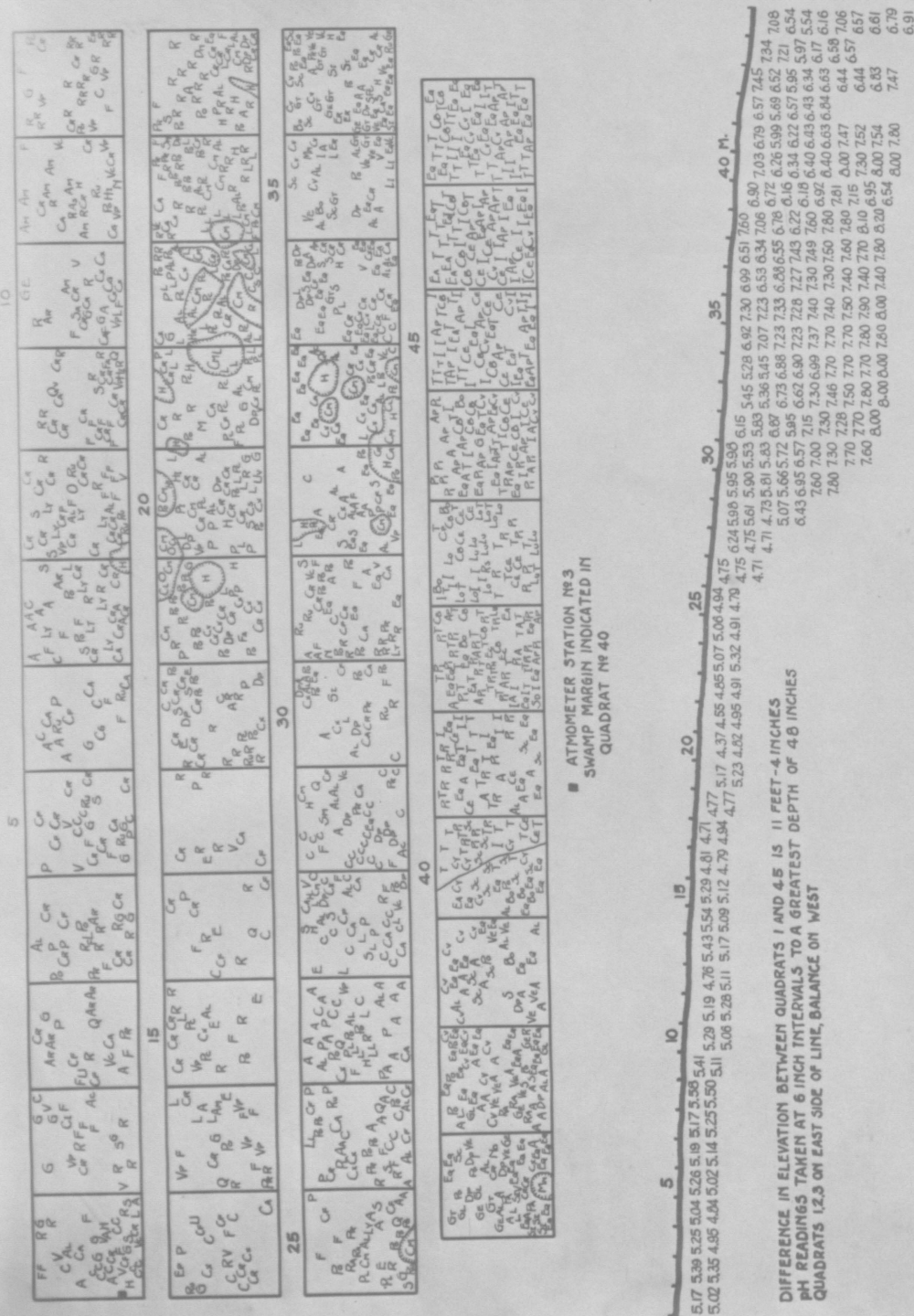


Fig. 15. Profile, quadrats and hydrogen ion concentration readings of Transect No. 1.

C. TRANSECTS

Because of the acquisition of this Preserve and to secure information concerning migrations and successions in this region and on this area in particular, four permanent transects, each one meter wide, were laid out (see general map, Fig. 3).

1. DESCRIPTION

Transect No. 1 (Figs. 3 and 15) begins at Atmometer Station No. 3 and continues southeast to a point in the black willow community, forty-four meters distant. The climax forest, the tree fringe bordering the swamp and representatives of the herbaceous and woody components of the swamp are included. Most significant however, is the pipsissewa (*Chimaphila maculata*) society. Here this relic is found in greatest abundance and undoubtedly finds a most agreeable habitat, in contrast to other recorded stations on the Preserve. Competition with swamp and moist soil forms, together with the broken canopy of the fringing trees is tending to inhibit its spread swampward. This is shown in a comparison of Quadrats 33 and 34. In greater shade and where assisted by a slowly decaying leaf cover, reproduction is progressing. Quadrat 34, five and one-half meters from the swamp margin, contains the last plant and marks the beginning of competition with other forms.

The soils of this transect are all sandy silts, common to the lower levels of the north bank and have a pH range of 4.37 to 7.60. The alkaline soil of the swamp and swamp margin gives way to soil that becomes increasingly acid on the slope. A pH range of 4.37 to 5.58 is found in the quadrats in the climax forest. A heavy slowly-decaying leaf cover, a water supply lower than that of other stations with pipsissewa coupled with a

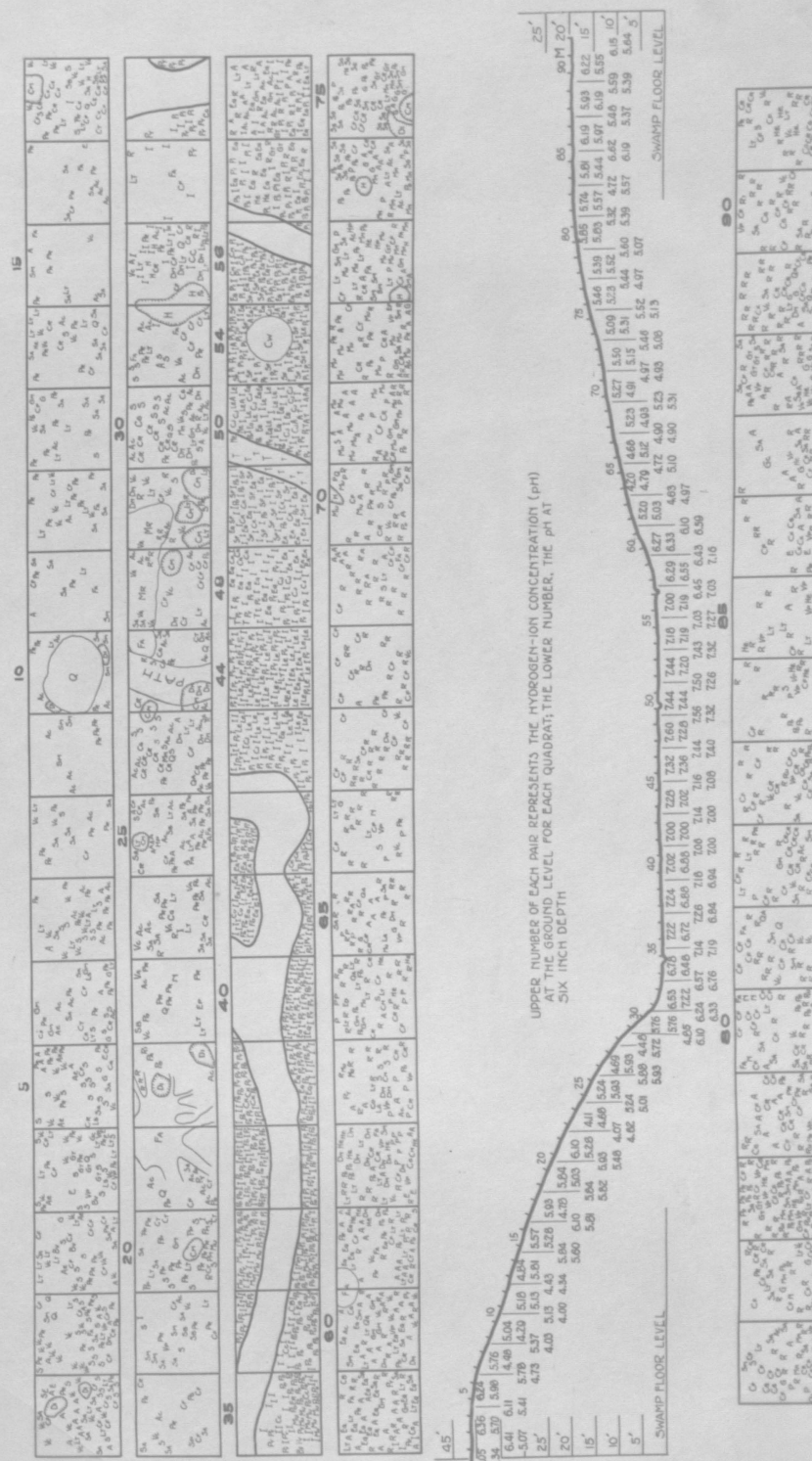


Fig. 17. Profile, quadrats and soil reactions of Transect No. 3.

excess of other stations, high acidity (pH 4.37 to 4.86) and poor drainage with consequent poor aeration appear to be unfavorable for plant growth.

Transect No. 3 (Figs. 3 and 17), ninety-one meters in length, traverses the greatest possible variety of habitats. Beginning at the top of the south bank in the secondary forest, it proceeds northward through the swamp to the north bank and into the climax association. The soils encountered vary from the clay on the top of the south bank and the slope of the north bank to the sandy silt on the south bank slope and ravine floor. The acidity relations are the same as in the other transects, in general with the clay very acid, the swamp floor neutral to alkaline and the sandy soils intermediate.

It is on the north end of this transect that the greatest differences between soil water content and evaporation are encountered. A high silt-sand content (85%) provides good drainage and exposure to the prevailing westerly winds produces a high evaporation rate. Acidity is somewhat less than in other similar soil localities, probably occasioned by the better drainage.

The quadrats of the swamp floor have a dense cover of *Polygonum arifolium*, *P. sagittatum* and *Impatiens biflora* with *Equisetum arvense*, *Pilea pumila* and several species of *Carex* and grasses interspersed. The water content of the swamp floor has been greatly altered during the past few years because of the deeper cutting of the draining stream and the deposition of soil washed from the denuded slopes immediately west.

The soil of the south bank is composed of a sandy silt, generally dry and exposed to the west winds. Soil acidity varies from pH 4.07 to

TABLE 1.
SYMBOLS AND PLANTS FOUND
IN
TRANSECTS

Ae	<i>Acer rubrum</i>	Er	<i>Erigeron annuus</i>
Ac	<i>acer saccharum</i>	Ed	<i>Erigeron philadelphicus</i>
Aa	<i>Actinomeris alternifolia</i>	Ea	<i>Eupatorium perfoliatum</i>
Am	<i>Agrimonia mollis</i>	Et	<i>Eupatorium purpureum</i>
A	<i>Amphicarpa monoica</i>	E	<i>Eupatorium perfoliatum</i>
Ap	<i>Amphicarpa pitcheri</i>	Fa	<i>Fagus grandifolia</i>
Ar	<i>Aristolochia serpentaria</i>	F	<i>Fraxinus americana</i>
Al	<i>Aster lateriflorus</i>	Gm	<i>Galium circaeasans</i>
Bv	<i>Benzoin aestivale</i>	G	<i>Galium concinnum</i>
Bi	<i>Bidens vulgata</i>	Ga	<i>Galium trifidum</i>
Bo	<i>Boehmeria cylindrica</i>	Gt	<i>Galium triflorum</i>
Cp	<i>Caltha palustris</i>	He	<i>Hedeoma pulegioides</i>
Cb	<i>Cardamine bulbosa</i>	Hp	<i>Hieracium paniculatum</i>
Cu	<i>Carex diandra</i>	Hi	<i>Hieracium scabrum</i>
Ck	<i>Carex frankii</i>	Hy	<i>Hydrangea arborescens</i>
Ct	<i>Carex laxiflora</i>	H	<i>Hypnum sp.</i>
Ce	<i>Carex lurida</i>	I	<i>Impatiens biflora</i>
Cx	<i>Carex platyphylla</i>	K	<i>Krigia amplexicaulis</i>
Cr	<i>Carex rosea</i>	Ls	<i>Lactuca spicata</i>
Cd	<i>Carex sparganioides</i>	La	<i>Lappula virginiana</i>
Cw	<i>Carex sp.</i>	Le	<i>Leersia oryzoides</i>
Cv	<i>Carex vulpinoidea</i>	Lp	<i>Liparis liliifolium</i>
Ca	<i>Carpinus caroliniana</i>	Lt	<i>Liriodendron tulipifera</i>
Cg	<i>Carya glabra</i>	Lo	<i>Lobelia syphilitica</i>
Co	<i>Carya ovata</i>	Lu	<i>Ludvigia palustris</i>
Cm	<i>Catharinea sp.</i>	L	<i>Luzula campestris</i>
C	<i>Chimaphila maculata</i>	Ll	<i>Lucopodium lucidulum</i>
Cc	<i>Cinna arundinacea</i>	Ly	<i>Lycopus americanus</i>
Ci	<i>Circaea lutetiana</i>	Mm	<i>Mimulus alata</i>
Cl	<i>Cladonia sp.</i>	Mr	<i>Mitchella repens</i>
Cz	<i>Clavaria sp.</i>	Mn	<i>Mnium sp.</i>
Cj	<i>Collinsonia canadensis</i>	M	<i>Morus rubra</i>
Ch	<i>Corallorrhiza odontorrhiza</i>	Mu	<i>Muhlenbergia sp.</i>
Cf	<i>Cornus florida</i>	Ne	<i>Nepeta hederacea</i>
Cs	<i>Crataegus sp.</i>	No	<i>Notothalus sp.</i>
Cn	<i>Cynoglossum virginianum</i>	N	<i>Nyssa sylvatica</i>
Cy	<i>Cyperus sp.</i>	O	<i>Osmorhiza claytoni</i>
Dn	<i>Desmodium nudiflorum</i>	P	<i>Panicum boscii</i>
Dp	<i>Desmodium paniculatum</i>	Pa	<i>Panicum dichotomum</i>
Di	<i>Dicranum sp.</i>	Pu	<i>Panicum phuachucae silvicola</i>
Ep	<i>Epifagus virginiana</i>	Pu	<i>Panicularia nervata</i>
Ec	<i>Epilobium coloratum</i>	Pe	<i>Peltigera sp.</i>
Eq	<i>Equisetum arvense</i>	Ph	<i>Philonotis fatana</i>

Pp Phryma leptostachya
Pi Pilea pumila
Po Poa sylvestris
Ps Polygonum acre
Py Polygonum arifolium
Pg Polygonatum biflorum
Pm Polytrichum ohioense
Pc Potentilla canadensis
Pl Prunella vulgaris
Pr Prunus serotina
Pt Pyrola elliptica
Qa Quercus alba
Qi Quercus imbrecharia
Q Quercus rubra
Qv Quercus velutina missouriensis
Ra Ranunculus recurvatus
Rs Ranunculus sceleratus
R Rhus toxicodendron
Ri Riccardia pinguis
Ru Rubus frondosus
Sd Salix discolor
S Sanicula marilandica
Sa Sassafras variifolium
Sc Scirpus atrovirens
Sf Scutellaria lateriflora
Si Sisyrinchium angustifolium
Sm Smilacina racemosa
Sb Solidago caesia
Sg Solidago canadensis
Sp Solidago sp.
Th Thalictrum dioicum
T Typha latifolia
U Ulmus americana
Uv Uvularia grandiflora
Ve Vernonia fasciculata
Va Viburnum acerifolium
Vp Viola palmata
V Viola sp.
Vc Vitis cordifolia

more than 6.00, being generally more acid midway down, where a small colony of *Mitchella repens* is established. The vegetation on the upper portion is very poor, composed mostly of tree seedlings, but improves as the soil moisture increases toward the base of the slope. Moss mats are numerous with *Hypnum* and *Catharinea* commonest. The clay silt forming the top of the south bank is less acid than the slopes, with a pH between 5.75 and 6.41.

Transect No. 4 (Figs. 3 and 18) is composed of thirty quadrats and includes the upland clay silt of the south bank and the sandy silt on the slope. The large moss-covered areas and the society of *Pyrola elliptica* are distinctive. Both are found on the slopes, the mosses distributed over the upper half, the *Pyrola* just above the seepage zone. A few pipsissewa are also found at the beginning of the transect in the clay silt, the only station for pipsissewa in the Preserve, with these conditions. The hydrogen ion concentration is the same as for similar soil areas and the vegetation it supports is comparable to that of Transect No. 3 in quadrats at the same elevation. Tree seedlings are very numerous. On the slopes with more soil water and a lower evaporation rate, the amount of growth increases. Soil acidity in general is greater than that of other slope transects.

The *Pyrola* community appears to be in a static condition with no noticeable change in population. The steepness of the north slope in the vicinity of this society, effectually prevents the reception of direct sunlight. A sandy acid soil, a medium water supply with a not too great evaporation rate, seem to be the characteristics of the environment (Figs. 19, 20 and 22).

The exposure of this transect is more to the north east than is that of No. 3 and a better growth would be expected because of the absence of the drying winds and their evaporative effect.

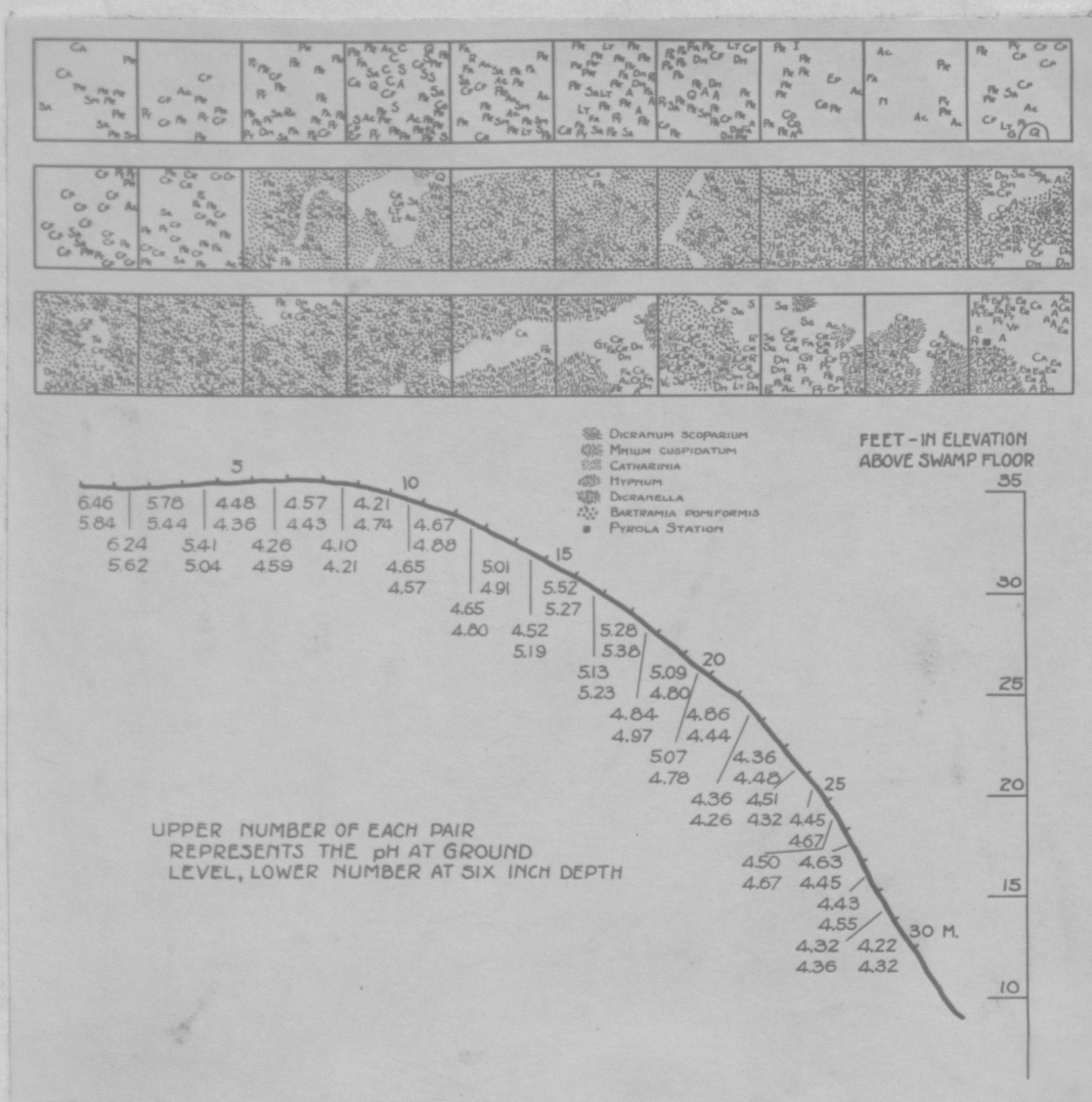


Fig. 18. Profile, quadrats and soil reactions of Transect No. 4.

b. SUMMARY

An analysis of the four transects shows a range of soil reactions from pH 3.83 to 7.30 on surface soils other than those of the swamp floor. Within

such wide limits the occurrence of many different species would be expected. Certain of these comprising the relic group occur in isolated or restricted colonies. While such restriction of the relic species is evident, it is believed that this restriction is due not to the hydrogen ion concentration, per se, but to a group of factors, of which pH is probably one of the least important. Conclusions seem to warrant the premise taken by Geisler (9) and Kurz (11) that many species grow under widely varying soil reactions and that there is nothing to indicate that soil reactions are responsible for species distribution in general. Soil acidity or alkalinity is more of a mediate than an immediate factor.

Variations in the swamp soils are less marked; reactions range from 6.09 to 7.60 pH with very few below neutral. These may be due to local conditions. Acidity here, as on the slopes and uplands, appears to have a very minor role in the presence or distribution of species.

IV. HABITAT FACTORS

The study of habitat factors, including soil moisture, temperature, chemical composition, colloidal content and acid reactions, and evaporation was undertaken to determine environmental variations and to ascertain from these variations, reasons for the persistence of the relic species. Since these elements in the flora of this Preserve occupy no definite position in the successional scheme, the study of their environment alone may indicate the conditions, favorable or unfavorable, for their persistence. It is also reasonable to believe that a knowledge of this particular area, one of the few remaining examples of the regional climax forest, one in which competition of unlike climatic vegetation groups - climax forest,

under growth and local relic colonies - is proceeding; and, one unique in its proximity to the Wisconsin ice sheet, will serve future purposes as well as those of the present.

A. DESCRIPTION

This factor study includes two phases:

1. A general survey of the western part of the Preserve (1926-7) with selected stations that will enable the comparison of habitats with and without relic species.
2. A more detailed study of special locations (1928), centering about the presence of pipsissewa. This plant has the widest distribution and greatest number, of the relic group.

For the work of the survey, six stations were chosen:

No. 1. Climax forest on the north bank; soil a sandy silt having a very thin humus layer, generally less than one inch. With the exception of two pipsissewa plants, there is a complete absence of low vegetation. A heavy leaf cover persists in this area.

No. 2. Climax forest on the north bank, about fifty feet north of Station No. 1. A clay soil supports a cover of mosses, lichens, poison ivy and beech-drops but pipsissewa is absent. The soil difference impelled the choice of this station.

No. 3. Climax forest on the north bank about eighty-five feet southeast of Station No. 1. Pipsissewa, Viola, Amphicarpa monoica, Carex diandra, Galium concinnum and other varieties are found on a soil similar to that of Station No. 1, but with a generally lower water content.

Pyrola. Climax forest on the south bank, near the lower end of Transect No. 4 and about eight feet from the base of the slope. The soil is a sandy

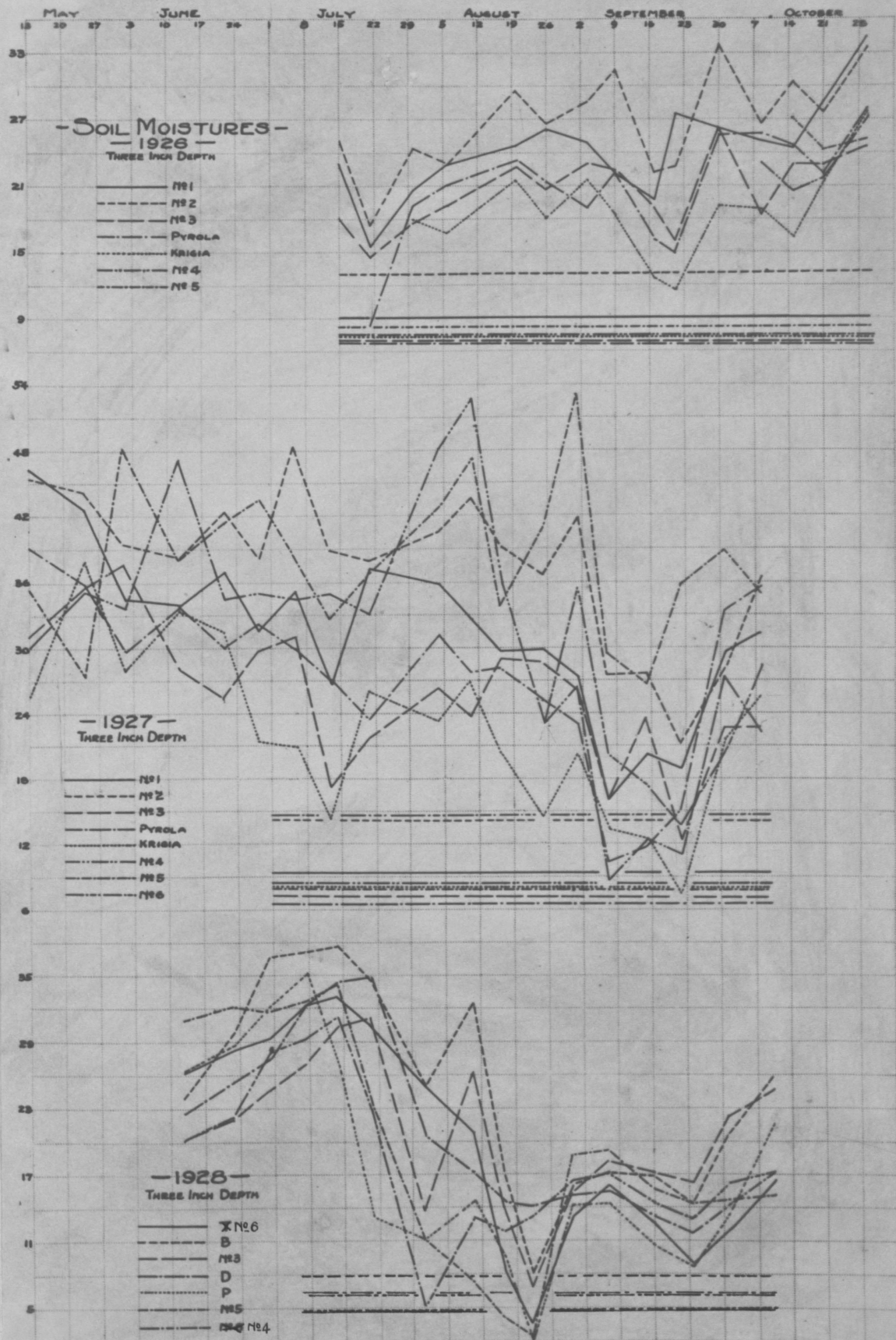


Fig. 19. Soil Moisture content and Wilting Coefficient at three inch depth.

silt with a medium water content. Pipsissewa is absent.

Swamp. This station is located in the center of the main ravine floor, about one hundred and fifteen feet from the west boundary fence, swampy, though rapidly drying out because of recent deposition and drainage. It marks the area of greatest development of the Impatiens-Polygonum community.

Krigia. Climax forest on the north bank with a sandy silt soil. This location was chosen to note the effect of exposure. Pipsissewa is absent while at Stations No. 1 and 3 it is present under a similar canopy and in a similar soil.

No. 4. Climax forest on the south bank, about four feet above the swamp floor and but a few feet from Quadrat No. 28 of Transect No. 3. The soil contains a large quantity of white sand and also much humus, consequently is darker than others mentioned. The pipsissewa is at the upper margin of the seepage zone in the midst of many moss cushions and a varied herbaceous growth. This station, in common with No. 5 was established later in the season of 1926 and only soil moistures and temperatures were taken.

No. 5. Climax forest on a steep east face of the south bank. The soil is a sandy silt and supports a plant community of varied make-up.

No. 6. Red Oak Community. The red oak merges with the beech at this station, on a clay soil with a poor herbaceous growth. Located on the upland near the slope, it is subjected to winds that are too high to be affected by the more humid atmosphere immediately above the swamp. A relatively high evaporation rate results.

In the second phase of the work (1928) seven stations were used, four of those just described, Nos. 3, 4, 5 and 6, and in addition:

"B" Climax forest on the north bank with a sandy silt soil near the

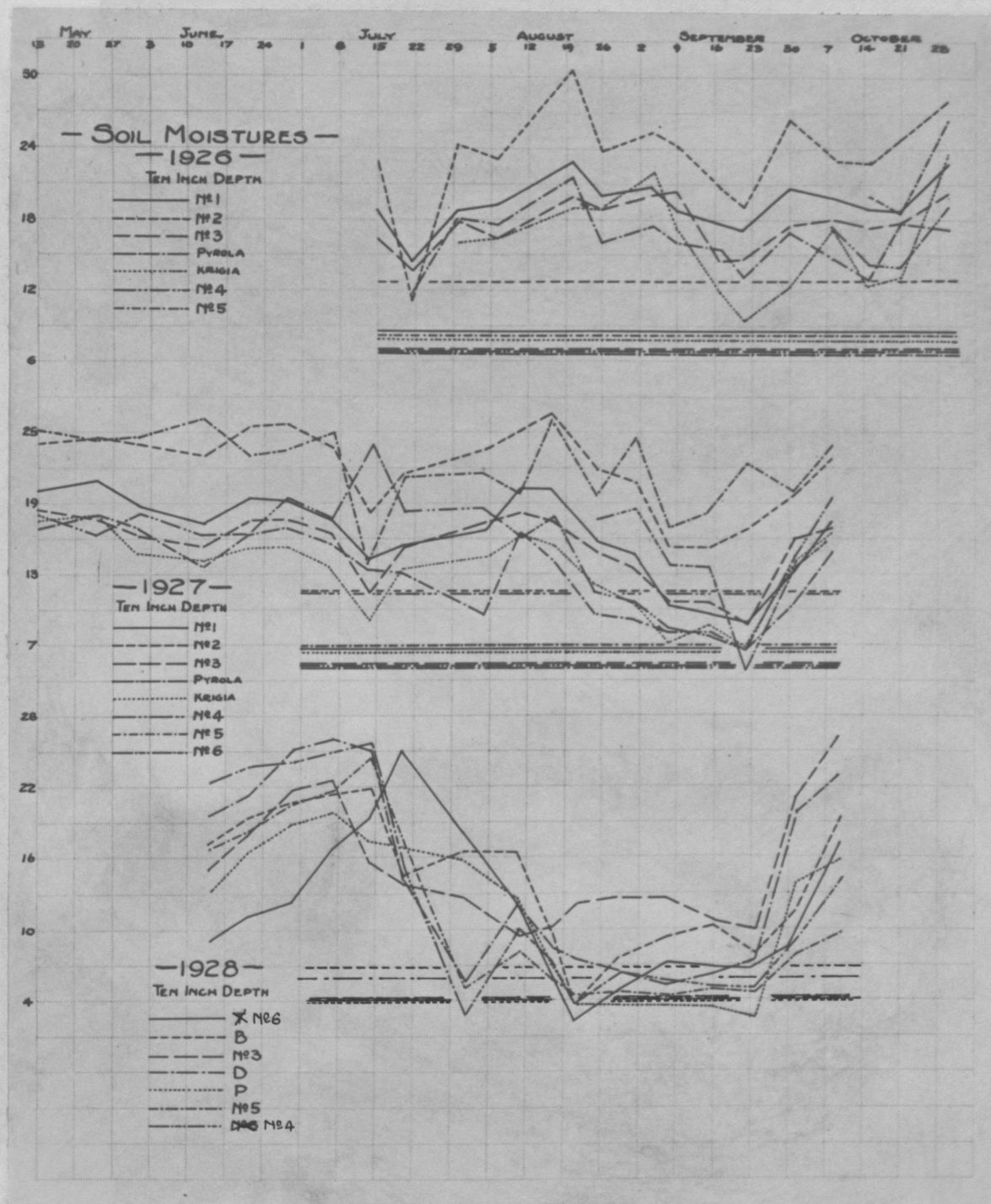


Fig. 20. Soil Moisture and Wilting Coefficient for ten inch depths.

junction of the terrace, formed during glacial times, and the ravine floor. Pipsissewa is present with a general mixture of herbaceous forms locally present.

"P" Oak-Dogwood Community that fringes the swamp margin of the north bank and merges into the climax forest. The sandy soil supports a transition type of Vegetation, swamp and swamp margin varieties intergrading with the herbaceous plants of the forest floor. It is in this particular area that pipsissewa finds its greatest development and where the other herbaceous growth begins to thin out under the heavier canopy of the beech forest.

"D" Climax forest on the silt upland soil of the north bank just outside the Preserve. These plants are over four hundred feet from the closest known plant (Station No. 1) and more than five hundred feet from its area of best development (Station "P"). A varied herbaceous growth covers the forest floor. The individual beech trees are among the largest found in the mapped area.

Soil moisture, temperature and evaporation readings were taken at the stations described for all or part of the time covered by this work. Soil analyses, determinations of colloidal content and hydrogen ion concentration are also covered

B. CLIMATIC FEATURES

The temperature-rainfall curves are included in order that a better conception may be had of the general climatic conditions (Fig. 21). These are based on the readings of the Cincinnati Station of the Weather Bureau and the time intervals are so arranged as to coincide with the time intervals of the experimental data. A considerable variation was often noted between temperatures and rainfall of Cincinnati and Hazelwood (Table 2),

these places are about 14 air-miles apart, and led to the establishment of a local observatory in July, 1928.

TABLE 2.

TEMPERATURE-RAINFALL COMPARISON
OF
CINCINNATI AND HAZELWOOD

	Temperature		Rainfall		Inches	Rains
	Cincinnati	Hazelwood	Cincinnati	Hazelwood		
July	76.0°	72.0°	.50" (2)	1.12"		(2)
August	75.6°	71.0°	2.85" (5)	1.49"		(8)
September	63.8°	62.1°	1.27" (5)	1.32"		(6)
October	59.8°	61.2°	3.18" (7)	4.01"		(10)
November	42.0°	45.1°	2.85" (10)	2.93"		(9)
Mean	63.4°	62.0°	Total 10.65" (29)	10.88"		(35)

The average rainfall for the Cincinnati region is 38.55 inches, 52% of which falls in the season between the average date of the last and the average date of the first killing frosts, i.e., in the growing season.

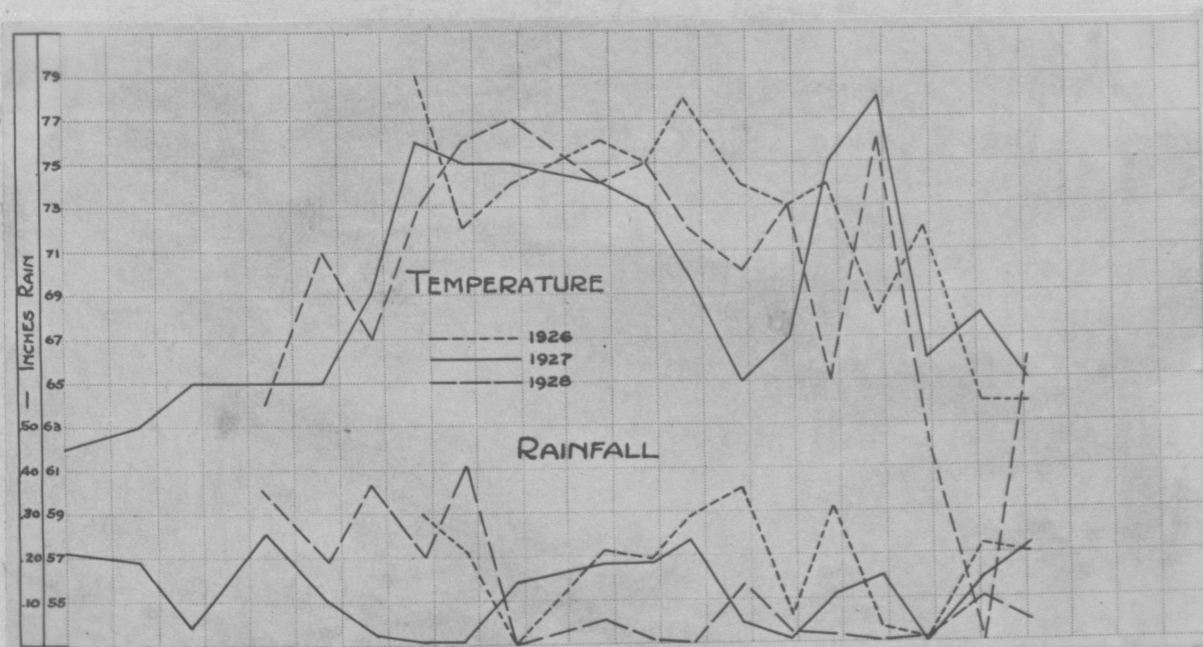


Fig. 21. Climatic Features of the Cincinnati region.

From the average date last killing frost on April 14 to the average date first killing frost on October 25, is 194 days, the growing season. From the limited information available, the tendency seems to be for less temperature differences at Hazelwood between summer and fall. With approximately equal precipitation, the rainfall is less evenly distributed over the latter part of the growing season though the number of rains was larger. The location of the Preserve on the high level uplands in contrast to the dissected topography of Cincinnati may help explain these differences.

C. EVAPORATION

Standardized cylindrical porous cups atmometers with simple rain-correcting mountings were used for all stations except the Swamp and Krigia, where Shive type mountings (12) as checks, were run parallel with the former types. Discrepancies began to appear in the readings of the Swamp atmometer with the increase in growth of the vegetation (Table 3). The heavy dew and consequently, the saturated atmosphere of the night and early morning and evening hours in the dense *Polygonum-impatiens* growth, caused a reversal of flow when the ordinary mercury valve was employed. Two Shive mountings were constructed, the duplicate at the Krigia Station being used as a check upon the standard instrument, (Table 3). Immediately after use in the field, all cups were restandardized with no factor changes greater than .02. All Swamp readings given in the figures are made from the instrument with the Shive mounting.

The consistently high evaporation rate of the Krigia Station is caused by the exposure brought about by the forest removal to the west. Every wind from the western sector blows over this station and with the higher temperatures generally encountered, conditions for increased evaporation

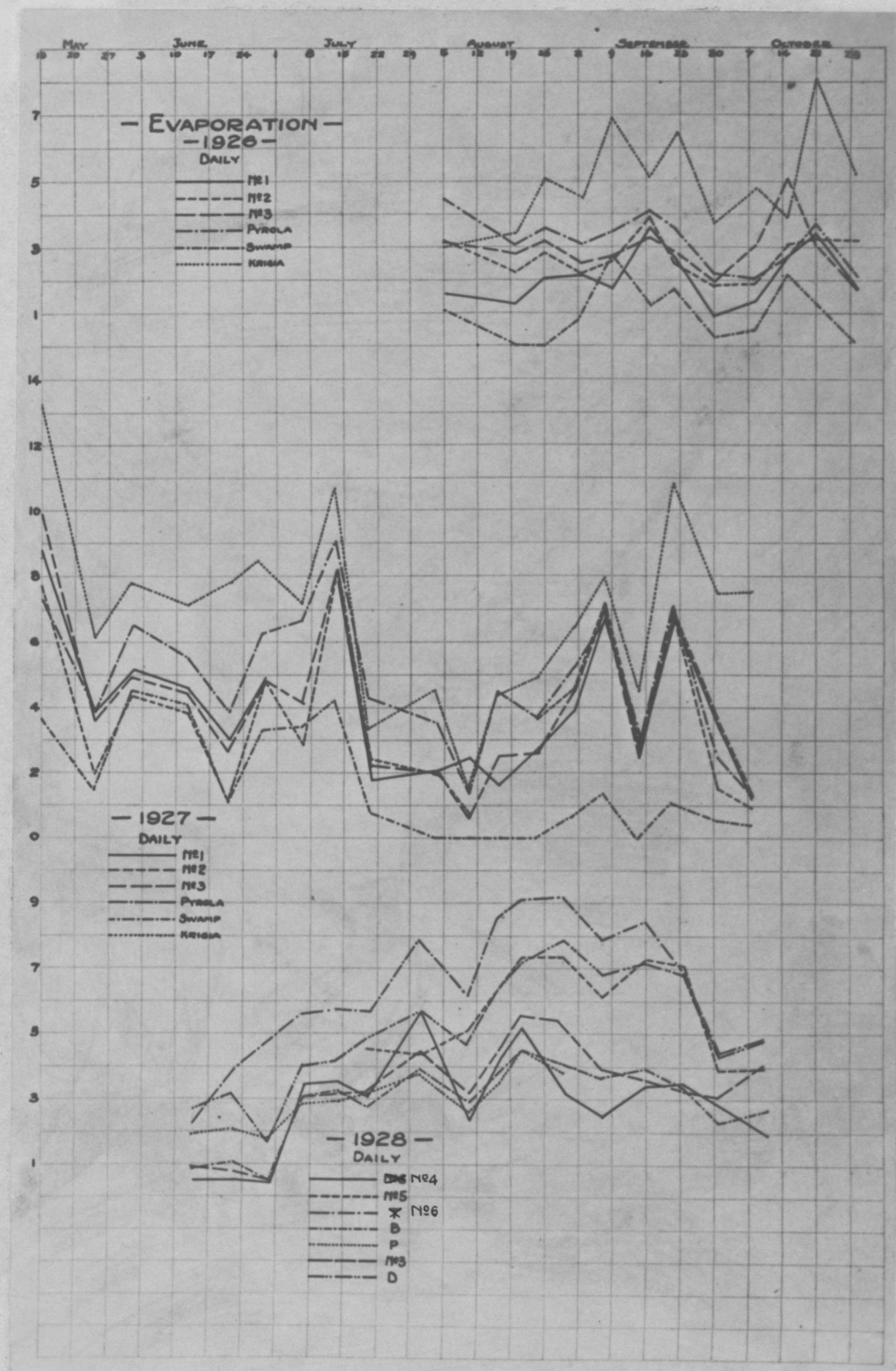


Fig. 22. Average daily evaporation for all stations.

are produced. Since the Krigia and Swamp Stations, the latter when vegetation is still immature, are exposed to west winds, they consequently show higher evaporation rates. During 1928, Station No. 6, also with a western exposure, exhibited the same responses, but the canopy of the slope trees

TABLE 3.

COMPARISON OF EVAPORATION RATES
OF ATMOMETERS WITH
SHIVE AND STANDARD MOUNTINGS.

		SWAMP		KRIGIA	
		Shive	Standard	Shive	Standard
Sept.	4	.83 cc.	.44 cc.	4.53 cc.	4.46 cc.
	9	2.72	1.68	6.94	7.00
	17	1.28	--	5.10	5.08
	21	1.70	--	6.46	6.41
	30	.23	--	3.70	3.60
Oct.	9	.53	--	4.84	4.61
	15	2.15	--	3.98	4.02

The above values are for daily evaporation.

tends to ameliorate the effect and prevent such extremes as beset the Krigia Station.

The Pyrola Station curve illustrates the tempering effect of tree crowns with the gradual diminution of the evaporation rate in proportion to the increased extent of leafage as summer progresses. Station "D", situated on the uplands is affected by north and northwest winds but their travel through a portion of the beech forest greatly reduces their evaporative power.

All other stations have evaporation rates that generally parallel each other, varying only as minor or very local influences enter, and reacting only to atmospheric elements that are modified in their passage through the forest or over the swamp.

D. SOILS

Clay silt and sand silt soils are found in the mapped area. The former are confined to areas on the top of the south bank and the slopes of the north bank above the ten foot contour. A rather close agreement in percentages of clay, based on the colloidal material, is noticed for all stations; except No. 2 and 6. These clay soils are always acid in reaction and when dry are light gray in color and very hard.

The sand silt soils of the slopes vary in appearance. To the soils on the south bank slopes the extra humus content imparts a darker color than is generally found in similar soils on the north bank. The sand content is composed of coarser material, the silica crystals being very conspicuous when the soils are examined. On the north bank slopes the humus content is lower with the soils light brown or light gray in color. The reactions are always acid except near the swamp margin where the alkaline swamp water neutralizes this acidity. Most of the plants listed (III, A, b) are found on the sandy silts of the swamp floor, slopes and uplands though a few also occur on the clay soils.

The clay areas studied have a plant cover composed very largely of tree seedlings, poison ivy (*Rhus toxicodendron*) and the parasitic beech-drops. Stunted scattered individuals of *Smilacina racemosa*, *Chimaphila maculata*, *Polygonum arifolium*, *Desmodium nudiflorum*, *Sanicula marilandica*, *Amphicarpa monica*, *Carex rosea* and *Poa sylvestris* comprise the remaining herbaceous growth. The clay soil alone is not felt to be the controlling influence, rather, in certain localities as Station No. 2, it intensifies the cumulative effect of other factors. Soil likewise is secondary in importance to other factors as exposure and topography at Station No. 6 where clay silt is present.

The soils of the swamp floor vary from clay to sandy silts, depending upon the source of the deposited material. Their color varies from light to very dark brown because of the difference in humus content. Excluding those areas close to the acid seepage zone, all tests give a neutral or alkaline reaction due to the alkaline water of the swamp.

The unimportance of soil composition is found on the swamp floor where intermixing of the two types produces no visible difference in the vegetative cover. Excepting Stations No. 2 and 6 which are on the clay silt soils of the north and south banks respectively, and certain portions of the swamp floor, all other stations are on soils of the sand silt type.

1. SOIL MOISTURE

Samples were taken at intervals of seven to nine days, with moisture percentages based upon the dry weights. Depths of three and ten inches were used, samples being taken with a soil auger. Moisture equivalents were determined^o for all stations, based on a sample from the well-mixed and quartered aggregate. The wilting coefficient was determined mathematically from the moisture equivalent using the formula,

$$\text{Wilting Coefficient} = \frac{\text{Moisture Equivalent (14)}}{1.84 \pm .007}$$

The general trend of the curves in figures 19 and 20 for each year are very similar. Krigia Station on a west facing slope with a heavy plant cover and favorably situated for a high evaporation rate because of this exposure to the prevailing winds, consistently shows a lower soil water percentage for the years indicated. The effect of topography on drainage is well shown in the curves of Stations No. 2 and "B". Station No. 2 on a clay area with practically no slope and "B" on the flat terrace-swamp junction gener-

ally have the higher soil moisture content. The interaction of precipitation, topography, exposure, soil texture and plant cover produce the particular variations noted at each station.

The soil moisture percentages are greater, at any single time of investigation, at the three inch depth than at the ten inch for all stations and generally parallel each other throughout the season. Extremes are less marked at the ten inch depth and a general softening of the curve is apparent. The same inferences as to influences and causes will hold for the ten inch as were applied to the three inch depths.

Only a very general comparison can be made between the physical composition of the soil and the moisture equivalent. The two soils of highest colloidal content, Stations No. 2 and 6, have the highest moisture equivalents.

From figures 19 and 20 it will be noticed that in several instances the total water percentage is lower than the wilting coefficient but in no case was wilting of the plants observed.

In the spring of 1928, a number of transplantings were made. A plant particularly sensitive to water, *Eupatorium urticaefolium* (White snake-root), was employed. On June 14, a quantity of these plants were taken from a dense luxuriant society about one hundred feet west of Station "D". Six individuals were planted at each one of the stations and given attention only until danger of loss due to transplanting was over. All plants were approximately five and one-half inches tall. With the exception of the slight wilting of one plant at noon of August 21 at Station "P" there were no indications of a water deficit.

Since the wilting coefficient is usually indirectly determined from the moisture equivalent, the latter character becomes of interest because

of the apparent failure of the wilting coefficient to represent conditions exactly.

When the moisture equivalents are considered, a possible reason appears. From Table 5 a wide divergence is found in the results given by different operators, in one instance, Station No. 2 at the ten inch depth, a difference of 8.07% is found. A variation of 2% is the closest approach to a check.

The importance of the soil water content is well illustrated in the various stages of the hydrarch succession. Vegetation adapted to standing water as *Typha* and *Leersia*, is being gradually excluded with the draining of the swamp. This has permitted the establishment of such plants as *Eupatorium perfoliatum*, *Impatiens biflora*, *Nepeta hederacea*, *Polygonum arifolium* and *Pilea pumila* on previously swampy areas. The entrance of the arborescent forms, ash, elm and sycamore, is attributed to the same cause. Other factors may later influence such invasion, but soil water remains as the initial one.

In other locations the effect of soil water is more or less modified by other factors. The general distribution of herbaceous and woody plants throughout the area indicates that a sufficient quantity of available water is present; other factors determine local distribution.

2. SOIL TEMPERATURE

Marked similarities exist in the average temperatures of the various stations (Table 4). The differences between the highest and lowest averages at the one inch depth are 1.9° for the period of observation in 1926 and 1.8° for the period in 1927. This can be partially accounted for by the closeness of the averages, 1.6° and 1.3° for 1926 and 1927, in the air

temperatures, taken one inch above the soil. At the ten inch depths, the difference of the yearly averages is greater, 0.9° for 1926 and 1.8° for 1927. Since these values are based on weekly readings, the difference may be due to the fact that the mean temperatures, based on 24-hour observations at the Cincinnati Weather Bureau, were 20.3° and 19.7° for comparable periods during 1926 and 1927. The higher seasonal temperature of 1926, may have caused the smaller temperature difference. It is also evident from these figures that but slight differences occur between stations in a season.

An unusual condition is found at Krigia Station in 1926. The soil at the ten inch depth has a higher average temperature than the three inch. Also, the greatest variation between the average air and soil temperatures occur at this and No. 5 stations. Krigia Station on a west slope, responds more slowly to morning insolation while at Station No. 5 the morning rise in air temperature exceeds that of the soil. An examination of the weekly readings shows that these variations occur during late spring and early autumn. These and the opposite variations in temperature are evident in a comparison of the upper and lower soil layer temperatures for the other stations, but within narrower limits.

The highest average soil temperatures, for the duration of the growing season, are found at the Swamp Station. Because of the absence of overhanging foliage, the stream water becomes warmer as it approaches this station. All other stations are located under the forest canopy hence direct insolation is impossible.

Due to direct western exposure, the highest average air temperatures prevail at the Krgia Station.

TABLE 4.

AVERAGE SOIL TEMPERATURES
ONE INCH

	No.1	No.2	No.3	Pyr.	Swp.	Kga.	No.4	No.5
1926	18.0	17.8	17.1	17.8	19.0	17.1		
1927	16.8	16.8	16.6	16.9	18.0	16.6	17.1	16.2

TEN INCH

1926	17.2	17.0	17.2	17.1	17.9	17.8		
1927	16.0	16.0	16.0	15.9	16.0	16.0	16.2	15.1

AVERAGE AIR TEMPERATURES

1926	21.2	20.6	21.3	20.6	21.5	22.0		
1927	18.6	18.9	19.6	19.3	19.5	19.9	19.5	19.5

At the Swamp and No.5 stations the greatest average temperatures differences between the soil layers investigated, occurs. The eastern exposure of Station No. 5 and the steepness of the slope insure a better reception of solar energy, causing a morning rise in temperature, while at the Swamp Station the large quantity of water prevents rapid warming of the lower soil layers.

A quantitative comparison of air temperatures and evaporation cannot be made. Krigia Station with the highest average temperatures has the highest evaporation rate but in contrast, the Swamp Station with nearly the same average temperatures has the lowest rate and Station No. 3 with nearly the same averages as the Swamp Station has an intermediate rate. The effects of wind, humidity and location are so great that they entirely outweigh those of temperature.

The effect of temperature on soil acidity still remains a problem, though increased temperature, to a certain degree, would cause better decomposition. Should insufficient water be present to complete the process of decay, the intermediate acid formed would tend to remain thus

producing an acid soil. At the other extreme, too much water with lower temperatures would produce the same results. No relations can be drawn as to the effect of temperature on acid formation from data collected in this area.

The variation in degrees in average soil temperatures for the two depths and including all stations were 2.0° in 1926 and 2.9° in 1927. Temperature, therefore cannot be considered as of primary importance in the distribution of plants in the area studied. By itself, it cannot affect succession or the rate at which it proceeds unless extremes are encountered.

3. COLLOIDAL CONTENT

The Bouyoucos method (3, 4, 5) for the determination of colloidal content, silt and sand was employed. Duplicates were run and gave very close checks. All samples were obtained from the weekly total soil water content samples.

As stated under "SOIL MOISTURE", only a very general comparison of colloidal content and moisture equivalent can be made. In addition, another peculiar relation is evident (Fig. 5). Normally, the greater the percentage of colloidal material, the higher the moisture equivalent. In all but a few results, the opposite prevails, probably caused by a different reaction of the silt fraction to experimental conditions.

Since the plant cover at the two stations of highest colloidal content, No. 2 and 6, differs greatly, it can be assumed that this factor exerts no direct influence. Water content and acidity, modified by the colloidal material, undoubtedly have a greater effect.

TABLE 5.

COMPARISON OF
SOIL COMPOSITION, MOISTURE EQUIVALENT
AND WILTING COEFFICIENT

LOCATION	COLLOIDS	SILT	SAND	COLLOIDS	SILT	SAND	1926	1927			
No. 1 - 3"	14.9	19.7	65.4	15.0	17.4	67.6	16.6 ^o	17.3	19.3	9.0	9.4
10"	15.2	18.8	66.0	19.1	15.5	65.4	15.7	12.4	15.1	8.5	6.7
										8.2	8.2
No. 2 - 3"	32.1	38.3	29.6	25.8	35.2	39.0	23.7	26.2	29.5	12.9	14.2
10"	38.8	28.2	33.0	33.6	38.4	28.0	23.4	21.2	24.1	12.7 ⁺	11.5
										16.0	13.1
No. 3 - 3"	12.8	14.8	72.4	12.1	13.7	73.2	13.0	13.4	16.3	15.7	7.1
10"	13.8	11.4	74.8	17.3	14.1	68.6	13.0	1.0	13.6	7.1	5.4
										7.3	8.9
Pyrola 3"	14.4	14.0	71.6	11.0	12.0	77.0	12.8	12.0	16.6	7.0	6.5
10"	17.4	10.2	71.4	17.8	8.2	74.0	12.4	9.3	12.2	6.7	5.1
										6.6	6.6
Krigia 3"	19.5	11.9	69.6	14.3	14.9	70.8	13.5	14.6	16.8	15.7	7.3
10"	15.6	21.0	63.4	19.6	12.8	67.6	14.4	11.6	14.4	7.8	6.3
										7.1	8.5
No. 4 - 3"	11.4	19.4	69.2	13.8	16.2	70.0	13.7	15.4	19.9	7.4	8.4
10"	16.8	13.8	69.4	17.7	11.7	70.6	12.5	9.7	12.0	6.8	5.3
										7.1	7.1
No. 5 - 3"	14.8	21.8	63.4	11.9	15.5	72.6	15.2	14.8	18.7	8.3	8.0
10"	13.2	21.8	65.0	18.7	12.5	69.8	15.1	12.7	15.3	8.2	6.9
										8.3	8.3
No. 6 - 3"				31.0	40.0	29.0		26.7	33.4	14.5	18.2
10"				37.4	37.6	25.0		21.1	34.6	11.5	13.4
										20.3	11.1

^o Determined by L.L. Corwin, Univ. of Minnesota, Dep't of Agriculture
 " " U.S. Dep't of Agriculture, Bureau of Soils
 + " " Dr. G.D. Fuller, University of Chicago

4. CHEMICAL FEATURES

The investigation of the chemical features of the soils of the Hazelwood area included the determination of the hydrogen ion concentration and the magnesium, calcium and silicon oxides.

a. HYDROGEN ION

All determinations were made by the electrometric method using the quinhydrone electrode. During 1926 assembled apparatus was used and superseded by the Youden model in 1927. The speed and accuracy of this method in comparison with that of the colorometric, warranted its use. In common with other general soil investigations (2, 15) a drift in potential is noted that may produce erroneous results. After a series of tests with the hydrogen electrode, it was decided to use the potential reading obtained immediately after the first, though perhaps temporary, equilibrium was established.

The handling of the soil after sampling was considered. Tests were made on air and oven dried (105°C.) samples and material in the field. While the results of the air dried samples more closely approached those of the field tests, the variations encountered favored the field testing of soils. A soil:water ratio of 1:5 was used for all tests.

These results are shown immediately below the profiles for each quadrat in figures 15, 16, 17 and 18. The hydrogen ion concentration basis classifies the soils into two groups; those neutral to alkaline, comprising the swamp floor; and the acid soils of the slopes and uplands.

The alkaline condition of the ravine floor is caused by the mildly alkaline stream water that varies in concentration throughout the year from pH 7.0 to 7.8. A slight seasonal change is noticed when the values,

determined for quadrats of Transect No. 3 and shown in table 6 are compared.

TABLE 6.

August 18

Quadrat Number

<u>35</u>	<u>36</u>	<u>37</u>	<u>38</u>	<u>39</u>	<u>40</u>	<u>41</u>	<u>42</u>	<u>43</u>	<u>44</u>	<u>45</u>	<u>46</u>	<u>47</u>
7.14	7.22	7.36	7.24	7.18	7.02	7.06	7.00	7.14	7.28	7.16	7.32	7.44
7.19	6.72	6.84	6.86	6.94	6.88	7.00	7.00	7.00	7.02	7.08	7.36	7.40

November 24

7.36	7.41	7.28	7.44	7.24	7.48	7.54	7.46	7.44	7.36	7.33	7.40	7.63
7.28	7.38	7.30	7.36	7.34	7.42	7.48	7.44	7.40	7.40	7.36	7.34	7.48

August 18

Quadrat Number

<u>48</u>	<u>49</u>	<u>50</u>	<u>51</u>	<u>52</u>	<u>53</u>	<u>54</u>	<u>55</u>	<u>56</u>
7.60	7.56	7.44	7.50	7.44	7.43	7.18	7.03	7.00
7.20	7.32	7.44	7.36	7.30	7.33	7.19	7.37	7.19

November 24

7.71	7.64	7.61	7.33	7.60	7.36	7.42	7.33	7.23
7.66	7.56	7.41	7.30	7.44	7.36	7.32	7.29	7.20

This change is probably due to the increase in the more readily soluble calcium carbonate on the glacial subsoils and carried down in the ground water.

The slopes and upland soils show a hydrogen ion concentration (Table 7) varying greatly at each station throughout the year.

There appears to be no correlation between this factor and others at the various stations. No. 2 (Fig. 16) shows low pH values but Station No. 6 also on a clay soil has an acidity averaging pH 6.0 (Table 7). The latter station is subjected to such influences as better drainage, greater exposure and slightly higher temperatures than the former.

Variations in plant cover of a single soil type, as the sandy silt, are hardly to be expected, unless such variations result from the influence of other than soil factors.

The effect of hydrogen ion concentration appears to be a minor factor in the distribution of communities or in succession. With slopes and uplands

supporting forest and ruderal growths, the acid composition of the respective soils indicates no major outward relation to plant growth. However, continued constant acidity, extreme or otherwise, may often be an important consideration. It is probable that certain of the plants as those of the relic group, could not persist here if it were not for the general acid reactions of these soils.

TABLE 7.

SEASONAL COMPARISON OF
H-ION AT SELECTED STATIONS

<u>Location</u>	<u>6/30</u>	<u>7/7</u>	<u>7/19</u>	<u>8/1</u>	<u>8/10</u>	<u>8/22</u>	<u>9/7</u>
No.4 - 3"	5.07	5.33	4.41	6.18	4.34	5.17	5.44
10"	4.66	4.49	4.63	5.76	4.92	4.79	4.94
No.5 - 3"	5.88	7.32	7.46	4.83	6.52	6.01	6.23
10"	5.33	6.35	5.79	4.94	5.65	5.76	5.60
No.6 - 3"	5.78	5.67	4.50	4.54	5.59	5.69	5.58
10"	5.23	4.62	4.54	4.88	4.58	4.99	5.15
"B" - 3"	4.23	4.41	5.76	6.10	5.44	6.35	5.59
10"	5.94	6.50	5.96	6.38	6.01	6.78	6.27
"P" - 3"	6.09	6.18	6.14	5.65	5.72	6.27	5.42
10"	5.50	5.48	5.26	5.38	5.33	5.46	5.60
No.3 - 3"	6.03	5.88	6.15	6.10	6.01	6.23	6.28
10"	5.13	5.45	5.79	5.67	5.97	6.18	5.88
"D" - 3"	5.74	6.74	5.10	5.93	4.92	5.13	5.60
10"	5.09	5.17	5.03	5.25	5.30	5.00	5.24

b. CHEMICAL ANALYSES

Chemical analyses were made of the composite soil samples used in the weekly determinations of total soil water content. Soils representative of Stations No. 1, 2 and Pyrola were used as these represent contrasting conditions with pipsissewa present at No. 1, absent at No.2 and another relic, Pyrola, present at that named station. The soils from these

stations also vary greatly in their physical properties (Table 5), No. 2 being clayey, No. 1 a sandy silt and Pyrola also sandy but with coarser material. The partial analyses are as follows:

TABLE 8.

SOIL ANALYSES

Station No. 1	SiO ₂	39.38%
	CaO	7.45%
	MgO	0.21%
Station No. 2	SiO ₂	38.88%
	CaO	7.53%
	MgO	1.54%
Pyrola	SiO ₂	37.25%
	CaO	7.87%
	MgO	0.82%

The effect of the two materials, silicon and calcium oxides, cannot be considered because of their close agreement. The relatively high percentage of magnesium in the clay soil of No. 2 may be a limiting factor, but in water cultures, using *Eupatorium urticaefolium* as the test plant, results obtained gave no indication of deleterious magnesium effects. Whether this is the reason for the restricted local distribution of the relics and the poor plant cover as at Station No. 2, and the absence of *Eupatorium* at those places where the relic are found, is problematical. More analyses are necessary to determine this.

Judging from the general distribution of plants throughout the area, chemical composition assumes a very minor role.

V. RELIC COMMUNITY

A. PRESENT ENVIRONMENT

A relic community consisting of six plants, unknown elsewhere in the Cincinnati region, *Chimaphila maculata*, *Pyrola elliptica*, *Lycopodium lucidulum*, *Epipactis pubescens*, *Medeola virginiana* and *Chamaelirium luteum*, and perhaps three other very uncommon species, *Mitella diphylla*, *Mitchella repens* and *Hieracium paniculatum*, is the feature of particular significance in the Hazelwood Preserve. This community, made up of evergreens, is unique in the region. It is composed of scattered individuals of some of the species and patches, single or several, of others as *Pyrola* and *Chimaphila*.

In their distribution on this area, *Pyrola*, *Lycopodium*, *Mitchella*, *Hieracium*, *Chamaelirium*, *Mitella* and *Epipactis* favor such habitats as prevail on north slopes or between protruding roots. *Medeola* is confined to the upland of the south bank. More data is available for an analysis of the present environment of *Chimaphila* because of its rather wide distribution in the area in habitats differing considerably from one another.

Habitats such as the Swamp with its continued high soil-water content or *Krigia* with an evaporation rate of very high extremes, are not favorable to pipsissewa. Personal knowledge recalls the location of several plants at the swamp edge of the north slope, directly south of the *Krigia* station. These have disappeared since the removal of the forest to the west greatly altered edaphic conditions.

It is very possible that widely varying soil water contents cause no permanent injury. Extremes of 2% at Station "P" and 53% at No. 5 for the three inch depth and 3% at No. 4, 6 and "P" and 26% at No. 4 and 5 for the ten inch depth have been noted (Figs. 19 and 20). Evidence seems to indicate

that any condition except continued saturation or drought with other factors equal, are permissible.

The daily evaporation rate also shows large differences with a range of from 1 to slightly more than 9 cc. per day, as at Stations No. 1, 3 and 6. Higher daily rates of from eleven to thirteen cubic centimeters such as occur at Krigia may be a factor contributing to its absence.

An acid soil appears to be desirable, though the absence of alkalinity does not guarantee establishment. The hydrogen ion concentration varies from pH 4.34 to 7.33, though in no places is *Chimaphila* present where the average of all pH determinations is 7.0 or more.

Colloidal content of the soil also has wide limits, varying from 11.4% to 31% and from 13.2% to 37.4% in the three and ten inch depths respectively.

If conditions at Station "P" can be used as an expression of the optimum, for here *Pipsissewa* attains its best development, then a soil water content of 14% and 10% at the three and ten inch depths with an evaporation rate of 3.5 cc. per day would be desirable. The colloidal content of the soil would approximate 13% and the hydrogen ion concentration would lie between pH 5.30 and 6.20. Definite requirements are few. The absence of continuous extremes of soil water, direct insolation and perhaps a very high rate of evaporation with the preference of an acid soil comprise these requirements.

The effect of light has not been studied because of the late development of a possible method (13). The relation of light to other factors is thought to be of importance but little work has been done to verify this.

Pyrola occurs in a small colony on the slope of the south bank with full northern exposure. Soil water varies from 9% to 39% and from 6.5% to 22% for the three and ten inch depths, with an average daily evaporation

rate of about 3 cc. The soil is a sandy silt with a colloidal content of about 16%. Acidity is usually lower than that of pipsissewa, ranging from pH 3.9 to 6.0

Careful measurement of all habitat factors, light excepted, extending over a period of three seasons, fails to produce any information that would enable the assignment to any single factor or group of factors, the reason for the persistence of this community. Distinct contrasts are not present, it is therefore believed that in the total effect produced by all factors, is the answer to the problem.

B. RELATIONSHIP AND SOURCE

Relic colonies serve today as an important guide to past migrations and floral ranges. When several species that normally grow together in one section of the country are found associated in a colony, such as occurs on the Hazelwood Preserve, it indicates that at some time in the past, these colonies were more numerous as was the vegetation of which they are a part.

In order to more fully understand the relationship and source of this relic colony, an explanation must be made of previous conditions.

Accompanying the advance of each ice sheet was the destruction or retreat of the vegetation before it. As Gleason (11) pictures it, the vegetation of this region at the close of the Illinoian period consisted essentially of the conifers of the present northeastern forests, located as a narrow belt between the retreating ice and the deciduous forest of southeastern derivation. Another plant retreat was compelled by the advance of the Wisconsin glacier resulting in a condition at the time of its most southern extension, similar to that which prevailed at the close of the

Illinoian.

Some doubt exists (7) as to the climate during this period. Evidence in the form of fossils and relic prairie colonies, seems to indicate that a mild and semi-arid climate persisted for at least a portion of the time required for the retreat of the Wisconsin ice sheet.

The Hazelwood Preserve is in the Illinoian drift area and because of its proximity to the ice margin probably was soon covered by plants closest to it, namely those of the coniferous forest, on their northward advance.

The nearness of the Preserve to the Wisconsin ice margin and the possible presence of a glacial lake (see II), prevented the persistence of the then-existing vegetation. This removal necessitated a reestablishment of vegetation, composed, it is reasonable to assume, of coniferous and associated plants. Whether the present relic colony can be traced to survivors of the post-Illinoian advance that had migrated from the south or to the waves, as Adams (1) calls them, preceding the Wisconsin advance, or both, is problematical. All of these are possibilities for the present southern extensions of these species (Fig. 23) indicates that edaphic and climatic factors were favorable for their persistence in southern stations.

With the retreat of the early Wisconsin glacier came another northward migration of the vegetation. Due to the climate, the conifers disappeared locally, deciduous forest became dominant and surrounded herbaceous communities that once formed the ground layer of the retreating coniferous forest.

C. DISTRIBUTION

The present distribution of the species forming this relic colony implies the presence of edaphic and climatic features comparable, on the

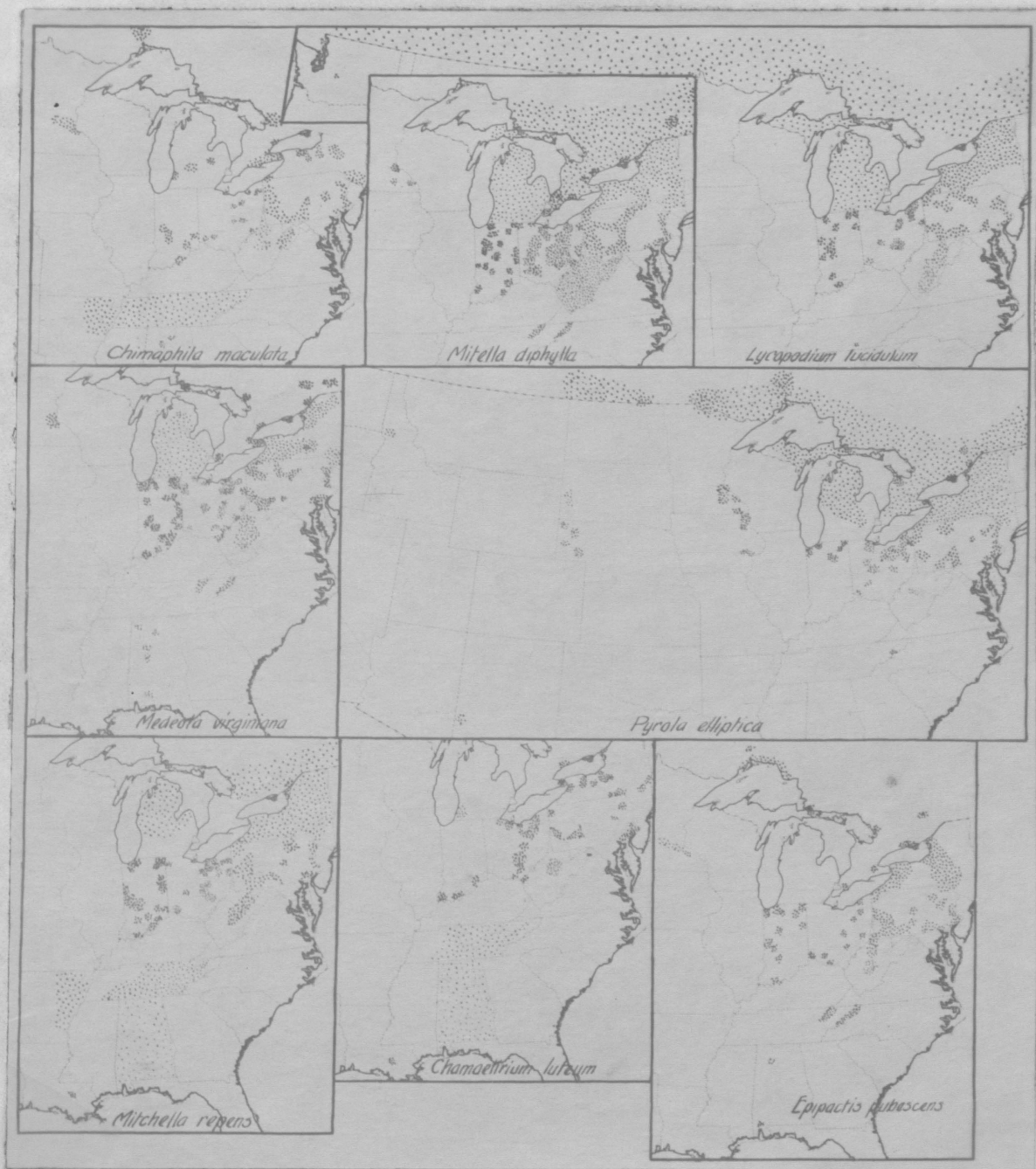


Fig. 23. General distribution of the plants forming the relic colony.

whole, to those existing at the time of their invasion. Any pronounced alteration of these features would have resulted in the elimination of these plants. Their presence then might be expected then in sections, climatically comparable to the Cincinnati region, unless factor compensation can occur. The adaptability of these plants is doubtful, their discontinuous distribution marks them as being essentially non-plastic in this respect.

As mentioned elsewhere (III, A, b), these species are absent from or are very rare in the Cincinnati region. On the Preserve, *Chimaphila* is represented by more than five hundred known plants, some vegetatively connected. All other species are much less numerous. Elsewhere, but in the vicinity of the city of Cincinnati, one to several stations for *Mitella*, *Mitchella* and *Hieracium* are known.

From correspondence and a detailed investigation of state floras (16) the general distribution was mapped (Fig. 23). It is evident from this figure that their range is confined to the more northern latitudes and in the higher elevations of the eastern mountain system. Altitude with its attendant lower temperatures and more favorable moisture conditions, presents habitat conditions favorable for their persistence.

VI. SUMMARY

1. The Hazelwood Botanical Preserve, a seventy-acre tract devoted to botanical research, contains a boreal colony of nine relics and associated plants in one of the few remaining unmolested forests of southern derivation of the region.

The present swamp is thought to have resulted from the formation of a glacial lake during the period of Wisconsin glaciation. Remains of two terraces bespeak different depths due to ice or boulder dams.

3. The soils of the forest area are of two types: the clay silts generally found on the uplands of the south bank and the upper areas on the slope of the north bank, and, the sandy silts on the south bank slope and the lower portions of the north bank slope. Characteristics of each soil type are indicated.

4. Two classes of vegetation are described: (1) the climatic group comprising the swamp, forest and ruderal communities, and (2) the relic community composed of plants which occur locally in the ground layer of the mesophytic forest.

5. The presence of the relic colony is undoubtedly due to the conditions caused by advancing and retreating glaciers. Of general northern range, their distribution is quite limited in the United States. All are absent from or are very rare in the floras of this and neighboring states. With the exception of *Chimaphila*, their distribution is restricted to small areas in the Preserve. *Chimaphila* is found well distributed over the western end of the tract, in clay and sandy soils, of dry and rather moist conditions.

6. A detailed study of the habitat factors, covering a period of three years, was made and results given with figures, tables and diagrams. Soil moisture, evaporation, soil and air temperatures, hydrogen ion concentration, colloidal content and chemical analyses of the soils were made.

7. The study of the vegetation and habitat of the Hazelwood Preserve has shown a close dependence of various plant communities on measurable habitat conditions. Differences in evaporation rate, of soil moisture and of acidity of the soils, may account for the unlike communities of the area. Past influences, due to Pleistocene climates and post-glacial migrations,

and the early post-glacial lake which occupied the present swamp area, together with present environmental conditions, make possible the persistence of the relic colony.

ACKNOWLEDGEMENTS

The author hereby desires to express his sincere thanks to those who made this work possible, to the Graduate School of the University of Cincinnati for financial assistance to carry-on, to Messrs. Arthur R. Morgan and George D. Crabbs who contributed so materially to the permanent establishment of this Preserve and to the many, who through correspondence, gave valued information relative to the present distribution of the relic forms. Lastly, to Dr. E. Lucy Braun, whose direction, help and kindnesses have been of inestimable value.

VII. LITERATURE CITED

1. Adams, Charles C. Postglacial origin and migration of the life of the northeastern United States. Jour. Geography I: 8 and 9, 1902.
2. Bayer, L. D. The drift in potential of the quinhydrone electrode. Jour. Amer. Soc. Agron. 20: No. 11, 1928.
3. Bouyoucos, George John. The hydrometer as a new and rapid method for determining the colloidal content of soils. Soil Science: 23: 319-330, 1927.
4. --- The hydrometer as a new method for the mechanical analysis of soils. Soil Science 23: 343-352, 1927.
5. --- The hydrometer method for studying soils. Soil Science 25: 365-370, 1928.
6. Braun, E. Lucy. The physiographic ecology of the Cincinnati region. Ohio Biol. Surv., Bull. 7.
7. --- Glacial and post-glacial plant migrations indicated by relic colonies of southern Ohio. Ecology 9: 284-302, 1928.

8. Briggs, L. J. and Shantz, H. L. The wilting coefficient of plants and its indirect determination. U.S. Dept. of Agr., Bur. of Pl. Ind., Bull. 230, 1912.
9. Fenneman, Nevin M. The Geology of Cincinnati and vicinity.
10. Geisler, S. Soil reactions in relation to plant successions in the Cincinnati region. Ecology 7: 163-184, 1926.
11. Gleason, H. A. The vegetational history of the middlewest. Annals Ass. Amer. Geogr. 12: 39-85, 1923, and Contr. N.Y. Bot. Gard. No. 242.
12. Kurz, Herman. Hydrogen ion concentration in relation to ecological factors. Bot. Gaz. 76: 1-29, 1923.
13. Segelken, John G. The determination of light intensity. Ecology, July, 1929.
14. Shreve, J.W. An improved nonabsorbing porous-cup atmometer. Plant World 18: No. 1, 7-10, 1915.
15. Snyder, E.F. A comparative study of the quinhydrone and hydrogen electrodes for determining the hydrogen ion concentration of soils. Jour. Ag. Res. 35: No. 9, 1927.
16. List of state floras used in mapping distribution of members of the relic colony.

Contributions U.S. National Herbarium, Vol. II, No. 2.

Vol. XI,

Vol. 19,

Vol. 25,

Catalogue of Vasc. Plants of Ohio, Ohio Biological Survey.

Flora of Wyoming, Wyoming Exp. Sta., Bull. 28, 1896.

Flora of the Rocky Mountains and Adjacent States, P.A. Rydberg, 1917.

Flora of Southeastern Washington and Adjacent Idaho,

Piper and Beattie, 1914.

Flora of Colorado, U.S. Dept of the Interior, Misc. Pub. 4, 1874.

Flora of Colorado, Agr. Exp. Stat., Bull. 100, 1905.

Higher Seed Plants of the Minnesota Valley, Geol. and Nat. Hist.

Survey of Minn., 1892.

Minnesota Plant Life, C. MacMillan, 1899.

Plant Life of Alabama, Geol. Surv. of Ala., 1901.

Proceed. U.S. Natl Museum, Vol. VIII, No. 29.

Tennessee Flora, A. Gettinger, 1889.