THE PHYSIOGRAPHIC ECOLOGY

of the

CINCINNATI REGION

by

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I. Introduction

Dynamic plant geography or physiographic ecology, is intimately related to topography and to soil, and consequently, to physiographic history and to geologic formations. It is therefore necessary to know the essential features of the geologic and physiographic history of a region before its plant associations can be understood.

In this paper, the area considered is that generally known as the Cincinnati region. It includes Hamilton and Clermont counties, the southern parts of Butler and Warren counties, in Ohio, and that part of Kentucky included in the Cincinnati quadrangle (see map, fig. 48).

Considerable has been published on the geology and on the topography of the Cincinnati region; and a recent contribution by Fuller and Clapp (1912) gives a brief treatment of both the geology and topography, preliminary to a discussion of the underground waters. But believing that the reader of plant geography does not wish to search geological literature, especially when it is as scattered as it here is, a brief summary of the features most essential to the ecologist is here given.

The flat hill-tops or uplands are but remnants of the Tertiary peneplain, uplifted and partially dissected. Near Cincinnati, these uplands are merely flat-topped divides, a half mile or a mile in width, for near the Ohio and its larger tributaries - the Miami, Little Miami, Licking, and Mill creek - dissection of the peneplain has progressed far enough to leave few level areas. Farther from drainage lines, in Butler, Warren, and Clermont counties, the upraised peneplain becomes the general level, over which sluggish creeks meander in valleys little below this level, and into which occasional streams are cutting toward the temporary base level of the Ohio, nearly 500 feet below.

The whole of the Cincinnati region has been glaciated; drifts of two epochs, the Illinoian and the Earlier Wisconsin, being represented within the area. Over the uplands is spread a covering of drift from five to twenty-five feet thick (fig.1). Little of the Illinoian till now remains on hillsides or in ravines, but some of the older valleys are partially filled with it. In the Illinoian till, "clay predominates, making a firm, compact, impervious mass, in which pebbles are relatively few and of small size".[1] This older drift affects but little the topography of the region, but does help to produce poor surface drainage on the flat uplands.

North of Cincinnati, and extending into Hamilton county in the vicinity of Mill creek and the Miami, is the covering

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[1] U.S. Geol. Surv., Water-supply paper 259, p. 26.

of the younger drift - the Earlier Wisconsin. This "commonly contains less clay and more numerous and larger bowlders".[2]

In many places within the area of Wisconsin glaciation, a distinctly glacial topography may be found. Low gently sloping hills, and valleys, not undrained but still not stream valleys, are common features of the upland topography within the area which was covered by the Earlier Wisconsin ice. Some areas on the uplands are flat, and except for soil differences, are much like those covered only by the Illinoian. As a rule, it is the uplands covered with the younger drift which are the better drained.. Where the glacial hills occur outside the upland districts, as is the case along the west side of Mill creek valley from Lockland almost to Hamilton, they present a forest succession peculiarly their own.

The loess or white clay, which is associated with the Illinoian deposits, is not found north of the Wisconsin glacial boundary. It covers the highest terraces and filled valley flats (at an altitude of 600 feet or more) and is spread out in varying thickness over the upland. It is a very fine-grained material which holds water for a long time.

Outwash gravels from the Wisconsin ice sheet partially filled some of the valleys, and now remain as terraces in many

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[2] U.S. Geol. Surv., Water-supply paper 259, p. 26.

places along the Ohio, the two Miamis, the Licking, and Mill creek (fig. 1). These terraces are composed of coarse gravels in the northern part of the area, along the Miami and Little Miami; and of finer material, farther south along the Ohio and Licking. The gravel, because of its large pore content, has a high water capacity, but drains rapidly at the surface, and where exposed on river bluffs. It is for this reason that terrace edges are among the most xerophytic habitats of the region.

In most parts of the area, stream valleys cut through the glacial deposits, and expose the bed-rock beneath. However, along the small sluggish streams of the upland, and in the deeply filled valleys, bed-rock is seldom seen.

The bed-rock is of Upper Ordovician age, and five formations are represented in the region (fig.1). Three of these, the Pt. Pleasant and the Utica at the bottom, and the Richmond at the top, seldom outcrop within the area, and have little or no effect upon the kind of vegetation. The other two, the Eden shale and the Maysville, it will be shown, affect the character of vegetation, because of their different physical natures.

The Eden shale is made up of compact thinly bedded shales interrupted at intervals of about ten feet by thin limestone layers. This material is easily eroded and weathers rapidly.

The altitude of its upper surface varies from over seven hundred to less than six hundred feet within the area considered, owing to the dip of the strata. This variation in altitude of outcrop has considerable effect upon stream profile and ravine slopes, and through these, upon the vegetation.

The Maysville is made up of alternating thin-bedded shale and limestone layers. The frequent occurrence of limestone layers makes this formation much more resistant than the underlying Eden shale. Only one division of it (the Bellevue) outcrops except where relatively rapid erosion is in process. The Maysville, however, weathers so much more slowly than the Eden shale, that it produces noticeably steeper hillsides where removed from the influence of actively eroding streams. And it is resistant enough to withstand extremely rapid stream cutting, so that valleys in it are less gorge-like than those in the Eden shale.

The lower formations, Utica and Pt. Pleasant, are usually covered by the thick alluvium which fills the valleys to a depth of 100 to 200 feet (fig.1). Along the larger streams - especially the Little Miami and Miami above New Baltimore - the broad flood plains are a conspicuous feature of the topography. The flood plains along the Ohio and lower courses of its tributaries reach an altitude of 500 feet, rising upstream to 600 feet in the vicinity of Hamilton and Loveland. This large area is occasionally flooded, and supports the characteristic flood plain vegetation of the region.

Thus it may be seen, that the topography of the region presents a complex of forms - some erosional and some constructional. Uplands, flat or rolling, broad or much dissected; ravines and valley slopes; broad flood plains; glacial terraces and filled valleys, are striking features of the topography.

Soil water is a controlling factor in a consideration of the vegetation of these four areas. While the water table in general conforms to surface contour, it is nevertheless in a measure dependent upon the character of the soil. The approximate position of the water table in the four areas is shown in the accompanying diagram (fig. 1).

The compact clays of the upland retain the ground-water, so that in wet seasons, the water table beneath the broad uplands may rise to within five feet of the surface, while in spring it so nearly coincides with the surface, that depressions but a few inches deep are filled with water for several months. Cultivated fields in such areas are always trenched at ten or twelve foot intervals, and it is no uncommon sight to see the trenches filled with water, and the fields dotted over with crayfish holes.

The different rock formations differ in their ability

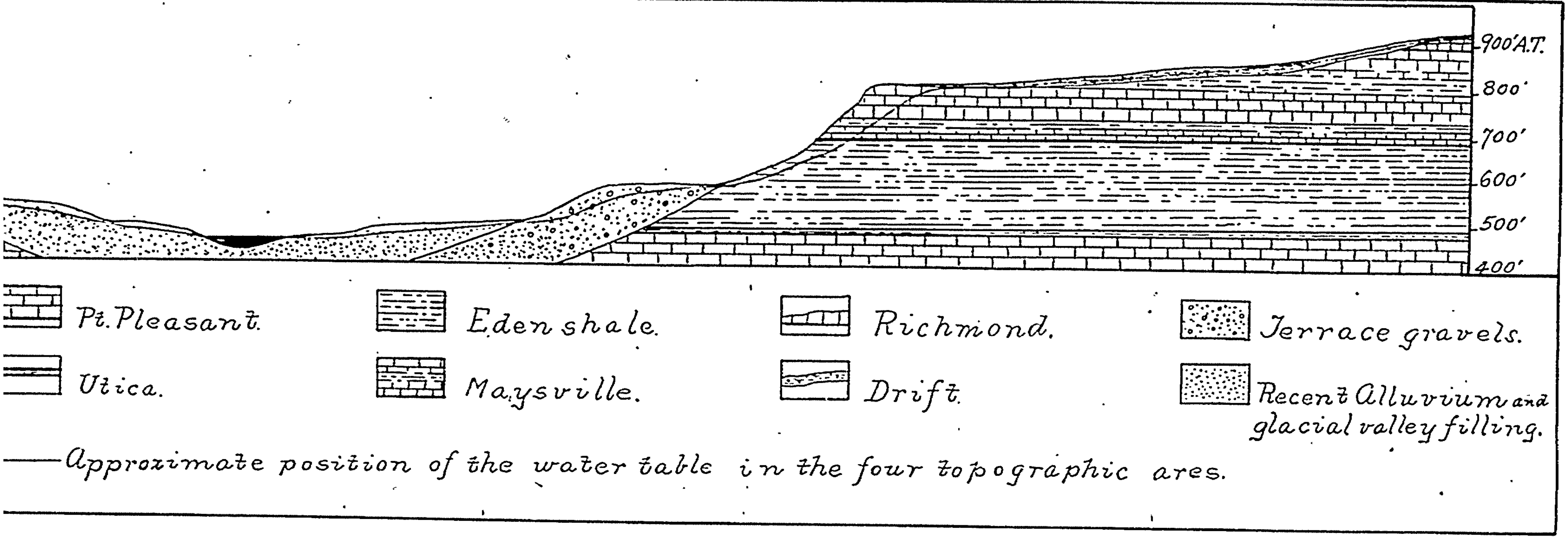

Fig.1. Diagrammatic section showing the geologic formations and level of ground-water in the four principal topographic areas.

to retain water. Both the Richmond and the Maysville, because of their relatively large percentage of limestone, are traversed by numerous solution channels, through which ground-water rapidly drains away. The Eden shale which is very impervious, nevertheless has little effect upon the water table, for it is never the surface rock over any considerable area.

Terrace gravels and the deeper valley fillings are much alike in their high water capacity, for they both have a large pore content (porosity 25 to 40 per cent)[3]; but the loose gravels are unable to hold the ground-water much above neighboring drainage lines. For this reason, the water table is relatively high in the filled valleys, and low in terraces, which usually stand from 40 to 70 feet above the flood plain or stream which they border.

In the flood plain area, the height of the water table necessarily varies with stream height, rising with the spring floods, and sinking during the dry summers. Here flood water and not ground-water, is the important factor, as the vegetation must be able to withstand prolonged periods of complete submergence.

The four topographic forms previously mentioned present different conditions of soil and ground-water. Each possesses

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[3] U.S. Geol. Surv., Water-supply paper 259, p.32.

its own general vegetational types, dependent for their existence upon the cumulative effects of past and present conditions; but constantly changing in accord with the constructional and destructional processes tending toward the ultimate mesophytic base level.

My thanks are due to Prof. H. M. Benedict of the University of Cincinnati and to Prof. Henry C.Cowles of the University of Chicago for their suggestions during the course of my work.

To Prof. N. M. Fenneman I am under obligations for the use of the surficial geology maps of the Cincinnati, Hamilton, and Mason quadrangles.

II. Upland Series

The upland is the oldest habitat presented, as well as temporarily the most stable. On many parts, no indications of erosive work are seen. Wherever undissected, the till plains and loess-covered areas are still essentially as they were at the close of the glacial epoch. Since that time, a forest cover has appeared - by what steps it is now impossible to say. Conditions somewhat similar have been noted by Cowles (1901) in the Chicago region.

A. Forest Associations

1. Depressions.-- The till plain is not everwhere even, but sometimes has shallow depressions upon it a few feet in depth, and a hundred or several hundred feet in diameter. Such depressions are almost imperceptible, and would be passed by unnoticed, were it not for the character of their vegetation. In central and northern Ohio, and elsewhere, in regions having a distinctly glacial topography, depressions of a more pronounced character and contaoning a very decided swamp or bog vegetation, are not uncommon. These have been described or mentioned by a number of authors -- those in Ohio by Bonser (1903), Dachnowski (1910, 1912, 1912a), Detmers (1912), and Schaffner, Jennings, and Tyler (1904); at Woods Hole by Shaw (1902); and in northern Michigan, by Whitford (1901).

One of the most pronounced of the depressions of this region, a one which may be considered as typical, is located on the Mill creek - Miami divide a mile north of College Hill. The center of the depression, as is shown on the map, fig. 2, lies six feet below the general level of the flat upland, and one foot lower than the strip of land one hundred feet to the north, which borders the ravine. Yet this slight depression is sufficient to produce a hydrophytic forest. The associations are of a character commonly found in shallow morainic depressions elsewhere. A very similar association is noted by Cowles (1901) in the morainic areas of the Chicago region.

Facies of depression.-- The lowest part of the depression is occupied exclusively by swamp trees, red maple (Acer rubrum)[4] and some shell-bark hickory (Carya ovata), and swamp herbs, Cardamine bulbosa, Bidens frondosa, Eupatorium perfoliatum, and Carex sp. (fig. 3).

Up to an elevation of five feet above the center of the depression, swamp trees-- red maple, shell-bark hickory, sour gum (Nyssa sylvatica), pin oak (Quercus palustris), and white oak (Quercus alba)-- are common (fig. 4).

Higher than this, more mesophytic trees appear, advancing into the depression, and finally becoming the facies

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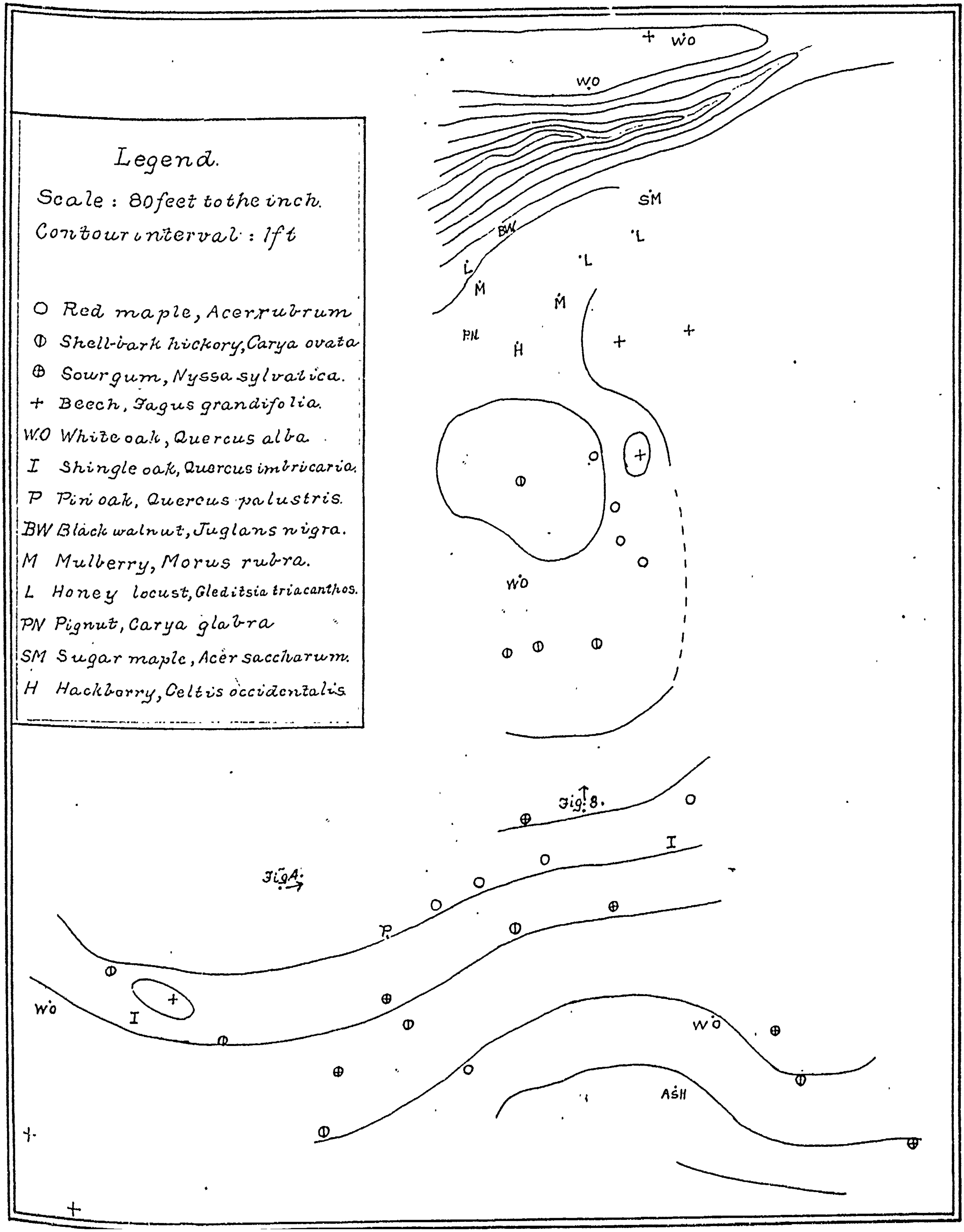
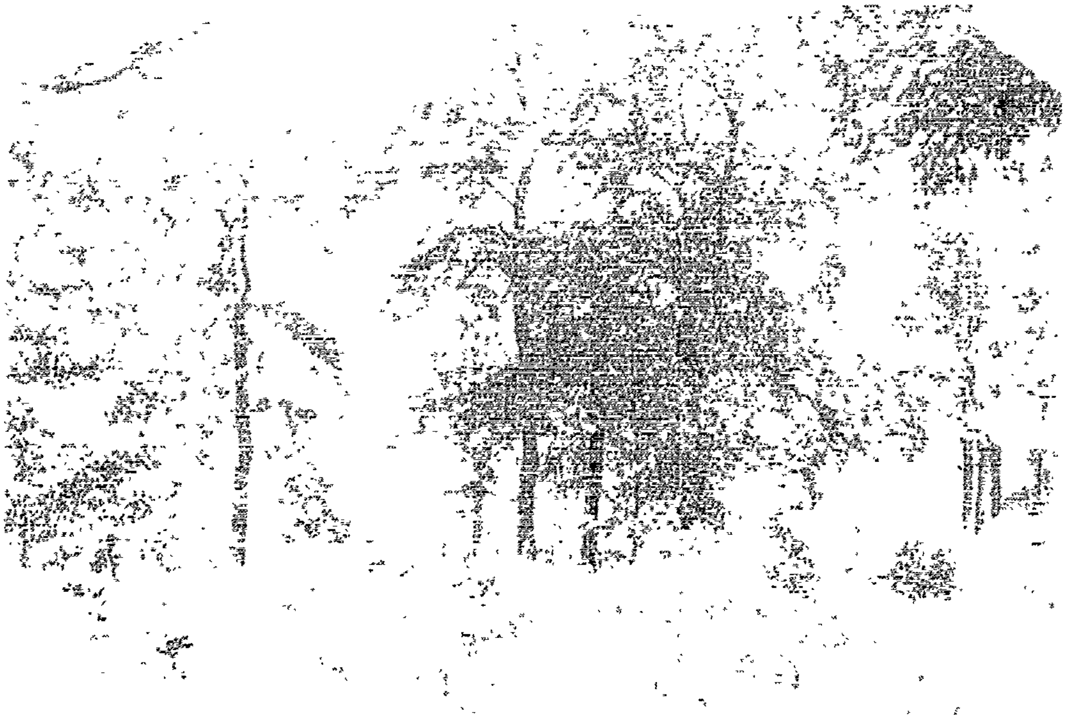
[4] Names used are those of Gray's New Manual of Botany, seventh edition.


Legend.
Scale : 80 feet to the inch.
Contour interval : 1 ft
O Red maple, Acer rubrum
Shell-bark hickory, Carya ovata
Sour gum, Nyssa sylvatica.
+ Beech, Fagus grandifolia.
W.O White oak, Quercus alba.
I Shingle oak, Quercus imbricaria.
P Pin oak, Quercus palustris.
BW Black walnut, Juglans nigra.
M Mulberry, Morus rubra.
L Honey locust, Gleditsia triacanthos.
PN Pignut, Carya glabra
SM Sugar maple, Acer saccharum.
H Hackberry, Celtis occidentalis
WO
SM
BW
PN
Fig. 8.
Fig. A.
ASH



into the depression, for the saplings now growing beneath the hydrophytic trees are largely mesophytes and xerophytes. Of course, saplings of the swamp trees are scattered over the whole depression, but the facies of the undergrowth everywhere but in the center is of mesophytic nature as evidenced by the presence of such trees as sugar maple (Acer saccharum), red elm (Ulmus fulva), wild cherry (Prunus serotina), and white oak (Quercus alba). The center of the depression maintains its swamp character, and saplings of red maple, sour gum, and shell-bark hickory far outnumber those of the other trees. The hydrophytic herbs still persist in every local depression, and commonly near the center of the major depression.

Elimination of depression.-- Two agencies in particular are at work in the elimination of the depression: one biotic-- the gradual accumulation of humus, which is slowly building it up; the other topographic-- running water, which is cutting a ravine across it, and so draining it. The first is progressive, tending directly toward mesophytism. The latter is retrogressive, for it initiates a long and varied xerarch[5]

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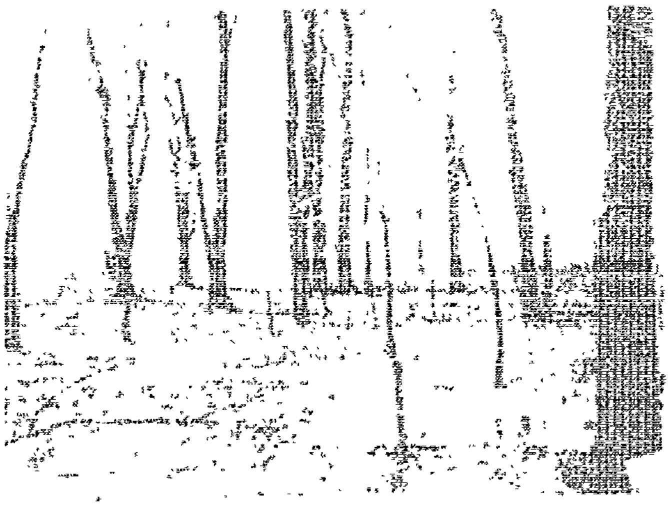
[5] The terms xerarch and hydrarch were first used by Cooper in 1913. The following is his footnote defining them: "The terms xerarch and hydrarch are here used for the first time, for the purpose of indicating a natural and important classification of plant successions. The former is applied to those successions



later in connection with the forests of undrained flats. Often the depression, though small, is decided enough to produce a pond. Such ponds, however, are temporary, and dry up during the summer. They are bordered by sedges and buttonbush (Cephalanthus occidentalis), or overgrown by a rank growth of poison ivy (fig. 7).

Depressions of all sizes occur on the till plain of the upland, from the small ones just described, to those so large that they are scarcely distinguishable from the undrained flats.

2. Undrained flats.-- Wherever the uplands are broad and undrained, a hydrophytic forest similar to that of depressions is found. In the immediate vicinity of Cincinnati, such areas rarely occur, as stream dissection has progressed too far. The hydrophytic forest of the undrained flat is never extensive here. But eastward, in Clermont and Brown counties, where the old peneplain is uncut for many miles, except for shallow valleys, the swamp forest is the prevailing type. Were it not for cultivated fields, this type of forest would be unbroken except along shallow ravines, or deeper valleys, where it gives way to mesophytic or xerophytic woodlands.

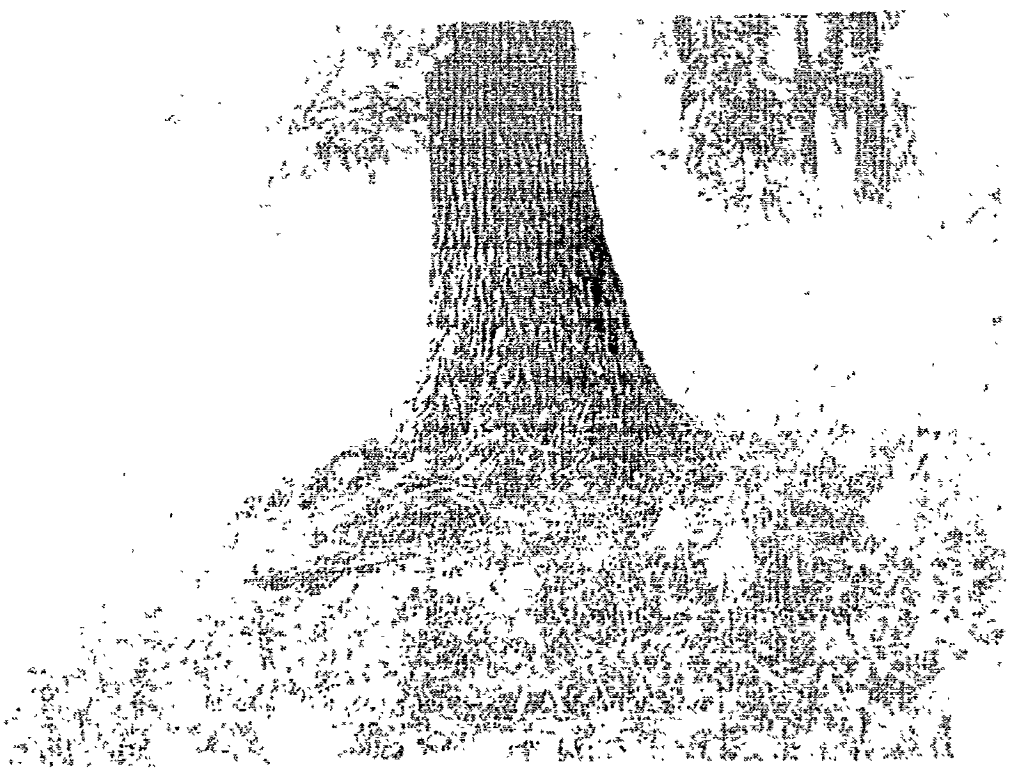
The dominant trees of the upland hydrophytic forest are not everywhere the same, nor is the general appearance of the woods necessarily the same. Some woodlands are open and grassy, and others are dense with scant herbaceous vegetation.

atrovirens, several species of Carex, and a number of other plants, usually less common; or it may be dense, consisting largely of poison ivy, and saplings of the same trees which make up the forest (fig. 9). In either case, fleshy fungi are usually abundant, and such mosses as Thuidium, Climacium, Polytrichum, Catharinea, Leucobryum, and occasionally Sphagnum form extensive mats.

Forest openings.-- White oak is a minor constituent of almost all these upland woods, where individual trees or groups of trees occur scattered through the denser pin oak forest. Such spots are more open than the rest of the woods, and are grassy. Here are usually found a number of herbs characteristic of sunny swamps and meadows-- Scirpus cyperinus, Ludvigia alternifolia, Bidens frondosa, Lobelia siphilitica, Solidago graminifolia, Eupatorium perfoliatum, Ilysanthes dubia, Steironema lanceolatum, and a number of Carices.

Where white oak becomes the dominant tree, the ground is usually less swampy, though still very wet; the herbaceous vegetation is more abundant, but made up largely of the same species as are found in the other parts of the forest. Kentucky blue grass (Poa pratensis) often forms a close sod in the more open parts, and other grasses, Poa sylvestris, Cinna arundinacea, and Agrostis perennans are not infrequent.

White oak.-- The general occurence of white oak (Quercus



water may stand in puddles for several months. Where white oak becomes the dominant tree, the ground is not so wet, and water is found on the surface in but few places. Such a forest does not however seem to succeed the pin oak forest, but rather to occupy areas which always have been different. Either a pin oak or a white oak forest may pass directly into a beech forest.

In the advancing mesophytic forests, white oak rapidly drops out with the other hydrophytic trees. In the ultimate mesophytic forest of this succession, it forms no part. It will be shown later, that white oak is a character tree in the xerophytic associations of slopes. It is equally characteristic of these two opposing types of forest. Possibly it may be considered as the ecological equivalent of some of the conifers, for example, white pine, and to take the place of such trees in this region.

Mixed forest.-- Contrasted with the almost monotonous forest of the pin oak type, are the mixed woods found upon many parts of our uplands. What evidences of succession there are indicate that these mixed hydrophytic forests probably were once similar to the more extensive forests previously discussed, and that they are rapidly becoming more mesophytic.

Upon the older drift, a representative area of mixed forest about 400 by 1000 feet is found a little less than a mile west of Hazelwood. It is estimated, that here 84 per cent of the large trees belong to species commonly found in wet soil in this region; 31 per cent are shell-bark hickory (Carya ovata), and the remaining 53 per cent include in the order of their abundance, red maple (Acer rubrum), pin oak (Quercus palustris), white oak (Quercus alba), white-heart hickory (Carya alba), white ash (Fraxinus americana), shingle oak (Quercus imbricaria), swamp white oak (Quercus bicolor), sour gum (Nyssa sylvatica), and white elm (Ulmus americana). The red maples usually occur in groups, in the wettest part of the woods. No decided mesophytes are found among the larger trees, though white ash and shingle oak (18 percent) often occur in mesophytic woods also, and might be listed here as mesophytes. Xerophytes are, however, well represented (16 per cent), and include redbud (Cercis canadensis) (8 per cent), black oak (Quercus velutina), black walnut (Juglans nigra), and locust (Robinia Pseudo-Acacia).

Xerophytes make up a much larger proportion of the saplings than of the large trees. Here red elm, walnut, redbud, hackberry, mulberry, and Sassafras are common, and compose probably 50 per cent of the young tree growth. Wild black cherry (Prunus serotina), a mesophyte, is found, and white ash has increased in importance.

The large trees stand rather far apart, so that the ground in many places is not well shaded. This may in part account for the scarcity of saplings of mesophytic trees, which are appearing only in the more shaded portions.

In the wetter parts of the woods, are saplings of the hydrophytic trees, and many herbaceous plants, among which are Scirpus atrovirens, Scirpus lineatus, Juncus tenuis, Potentilla canadensis, Epilobium coloratum, Ludvigia alternifolia, Pycnanthemum flexuosum, Bidens frondosa, and several species of Carex. Carex squarrosa frequently forms large patches.

Few such areas are found upon the Illinoian till plain; but upon the gently rolling surface of the younger drift, and even on its flattest parts, the mixed swamp forest is more common than that in which pin oak prevails. Extensive flats of Wisconsin age are absent in this region, and for this reason the swamp forest is limited in extent. The forest succession seems to have advanced more rapidly here, probably because of the more porous nature of the substratum, so that the areas of the two drifts may often be distinguished by the character of their plant cover.

3. Stages of the succession in depressions and on undrained flats.-- The earliest steps in t e hydrarch succession in progress in the depressions and on the undrained flats are problematic. At first, of course, the succession was climatic, and the earliest stages were not such as could exist in these

places to-day. If we may compare the sequence of events here after the retreat of the glaciers, with what we find in the north to-day, we would expect tundra and meadow vegetation, slowly encroached upon and restricted by the advancing forests. To-day, small natural openings are found in the upland forests. Some are still ponds, with their typical marginal vegetation of sedges and buttonbush (Cephalanthus occidentalis). In others (fig. 3), are a few red maples and a number of sun plants instead of the shade plants of the rest of the forest. Still others are the openings about the white oak trees, with their meadow-like vegetation. Are these perhaps, relicts of a former and more extensive formation, in time doomed to destruction by the encroachment of the forests? At least, they give some clue to the possible earlier stages leading up to the present hydrophytic forests. The succession indicated here is also further substantiated by what is now going on in many clearings.

Upon the broadest uplands, there are no indications of what will follow the swamp forest. In the next generation, at least, it will succeed itself. But on the smaller uplands, and wherever streams are draining the flats, or around the margins of depressions, is developed a mesophytic forest.

4. Drained and gently rolling uplands.-- It was shown in discussing the depression forest, that it is being succeeded by

a more mesophytic vegetation, because of the draining and gradual filling of the depression, Small streams are working headward into the broad flats, carrying off the surface water, and leaving areas drained but still moist. Few such upland valleys are cut through the till mantle; often indeed, their bottoms are but five or ten feet below the general level of the upland. This slight drainage has served to change a hydrophytic into a mesophytic habitat. Further dissection and deeper cutting will so thoroughly drain the surface layers, that a xerophytic habitat will then be produced.

Succession.-- Occasionally a horizontal succession from the hydrophytic to the mesophytic forest is seen. More rarely, the succeeding mesophytic vegetation is foretold by the appearance of mesophytic trees in the undergrowth of a hydrophytic forest. The succession consists of but few stages. Sometimes a mixed mesophytic forest intervenes between the pure hydrophytic and the ultimate association of the succession. Often, however, the jump is sudden. If horizontal succession, upon a very gradually changing topography, may be used as an indication of vertical succession in a place bound to pass through those same topographic changes shown in the area of the horizontal succession, a beech forest will follow the hydrophytic association. A beech forest is the climax of the hydrarch succession of the upland.

The beech forest.-- A beech woods is sometimes found upon flats which are still so wet that swamp herbs are not uncommon. Sometimes even, water stands between the trees. But a beech tree in such a situation, occupies a mound one or two feet above the wetter places (fig. 2). Thus, its habitat is essentially different from that of the swamp herbs. The same feature was noticed by the writer along the C.E. and W. Electric R.R., in Lorain Co., Ohio, where, in forests composed chiefly of beech and red maple, beech occupies occupies distinctly higher ground, being either on low ridges or on individual mounds.

The mesophytic forest of the upland is composed almost entirely of beech (fig. 11). Occasionally sugar maple (Acer saccharum) and white ash are found, but beech forms about ninety five percent of the tree growth. Of the saplings, sometimes fifty per cent are sugar maple; beech is next in abundance, and white ash, hickory, and wild cherry are found. The large percentage of sugar maple among the saplings does not necessarily indicate that it will become an important species in the succeeding forest, as the mortality among the smaller trees is higher in this species than in beech.

Herbaceous plants are not common in these beech forests. The vernal vegetation is composed chiefly of spring beauty (Claytonia virginica), toothwort (Dentaria laciniata), water-

imposed here were never extreme. The slopes are gentle (about 10 degrees); the soil a stiff bowlder clay.

The forest association to-day is mesophytic, but scarcely climax. Beech and sugar maple are dominant trees, but with them occur black oak (Quercus velutina), white oak (Quercus alba), the small-fruited hickory (Carya microcarpa), and Sassafras. Only a few remnants of this forest association remain upon the uplands. The character of the undergrowth is nowhere displayed.

The contrast between this morainal forest, and the hydrophytic forest of the flat upland to which it is adjacent, is striking. The sudden change in vegetation, which is so generally found along the geologic boundary between the two drift sheets in this region, is due chiefly to the change in topography. The vegetational line is almost as marked as the topographic, and is closely related to it; for wherever the topographic line is indistinct, the plant associations grade into one another. In places, the morainal forest is almost lacking, and the mesophytic or hydrophytic forest of the flat uplands to the south (area of Illinoian till) passes indistinctly into the mixed or hydrophytic forest of the rolling Wisconsin till plain.

This distinction between the vegetation of the two drifts is only possible upon the uplands, whose topography has been changed by the till cover. Soil fertility in the two areas is very different, and farms within the area of Wisconsin drift are worth two or three times as much per acre as those south of its margin. But similar topographic situations upon the two areas support similar types of natural vegetation, and the differences which can be noticed are due chiefly to the differences in the topography.

7. Margins of uplands; narrow divides.-- In some places, the remnants of the Tertiary peneplain are so small or so well drained, that none of the characteristic upland forest associations are found. Such conditions are to be seen in the vicinity of the major streams, especially near the Ohio and along such narrow divides, as the Ohio-Licking, upon which Fort Thomas is situated. In these places, the multitude of ravines afford rapid surface drainage, and their deep valleys have so lowered the water table beneath the upland, that a xerophytic habitat is presented.

The forest association is essentially that of the dryer ravine slopes. It is the association of the tops of ravine bluffs, where xerophytic conditions remain the longest. The association is a retrogressive step in the succession, and with the continued dissection of uplands, and the headward working of ravines, will spread back farther and farther into the uplands. The hydrophytic forests will give place to mesophytic ones, which mark the temporary climax of many upland successions. But this temporary climax forest will in time give way to the xerophytic association, which initiates the xerarch succession characteristic of slopes.

A forest of xerophytic oaks (Quercus Muhlenbergii, Q. rubra), sugar maple (Acer saccharum), red elm (Ulmus fulva), basswood (Tilia americana), hop hornbeam (Ostrya virginica), and thorns (Crataegus), replaces the mesophytic beech forest of the upland. The undergrowth is usually of saplings of the same kinds of trees, although the proportions vary considerably, depending on the stage in the succession. In the more mesophytic places, sugar maple is dominant. Near the margins of steep bluffs, it may be entirely absent. Even where it is an important constituent of the forest, it may be almost lacking from the undergrowth, if the trend of the succession is toward a less mesophytic forest.

B. Clearing Associations

The forest cover has been removed from a large area of the uplands, and in many parts of this area, a clearing succession is in progress.

1. Meadows.-- It will be remembered that natural openings in the upland forests contained a characteristic herbaceous vegetation. Wherever a few trees are removed, this herbaceous

with water for only a short time. Their position is indicated throughout the year by the patches of Scirpus atrovirens and Carex typhinoides, which usually surround or even fill them (fig. 13).

The sedge zone is followed by a meadow association in which grasses, sedges, and rushes often predominate. Other plants which commonly occur in the wet grassy meadows are Arisaema Dracontium, Cardamine bulbosa, Polygala sanguinea, Viola papilionacea, Lythrum alatum, Ludvigia alternifolia, Ilysanthes dubia, Gerardia tenuifolia, Diodia teres, Houstonia coerulea, and Solidago graminifolia. A number of mosses (Hypnum, Mnium, Polytrichum, Climacium, and Dicranum), and occasional hepatics and lichens are found. In a few places, Bidens trichosperma is the dominant plant, and grows so abundantly, that the meadows are a mass of golden-yellow blossoms early in September.

Dry meadows.-- The dryer parts of the uplands, when cleared, are soon occupied by a number of the more xerophytic grasses (Poa compressa, Aristida gracilis, Panicum capillare, Andropogon virginicus). As was the case in the wet meadows, other plants also occur, among which are Pentstemon glaber, Pycnanthemum flexuosum, Rudbeckia hirta, Solidago nemoralis, and S. canadensis, Anaphalis margaritacea, and Aster ericoides var. villosus. In some places, this dry meadow is a later stage in the pond-swamp-meadow succession.

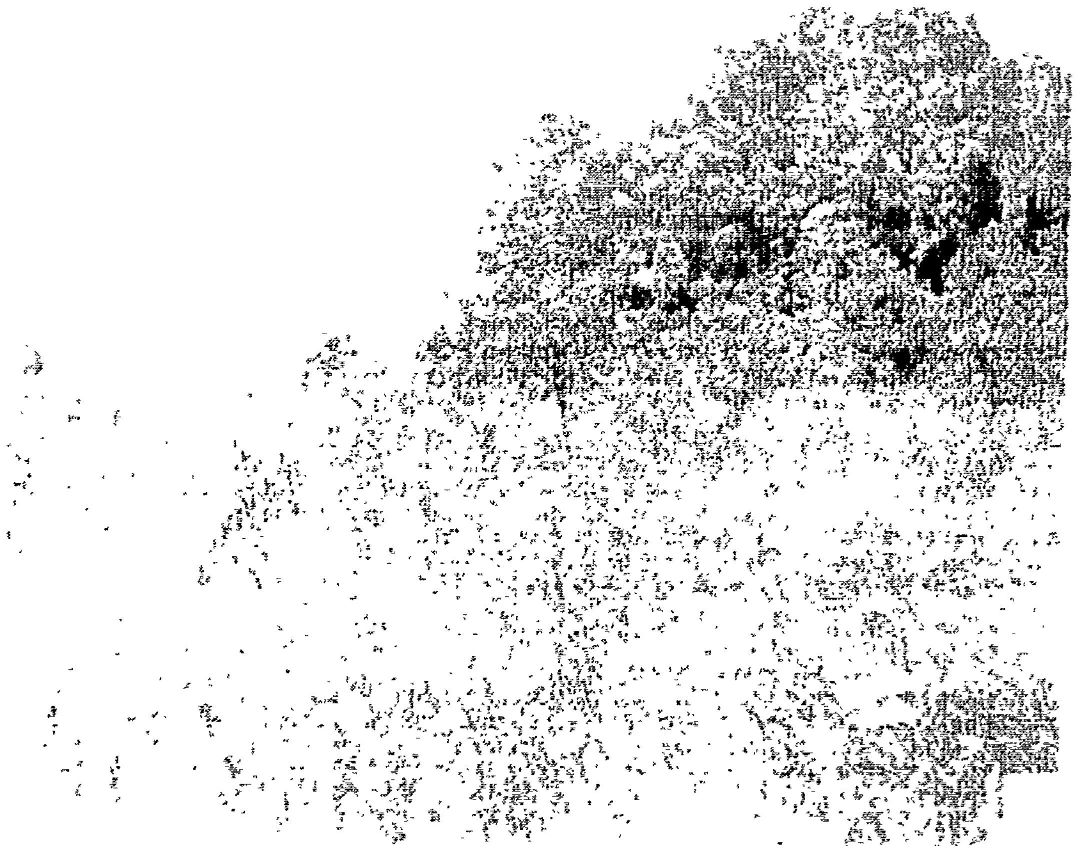
The meadow may be only a rapidly passing stage in the forest succession, or it may be relatively permanent. The first condition is expected; the second is difficult to explain.

Certain areas of the upland which are known to have been cleared of their forest cover at least twenty-five years ago, are still meadow. Such an area is shown in fig. 13. It is true, a few scattered trees (Quercus bicolor, Q. palustris, and Acer rubrum) occur, but not enough to be considered as the beginnings of a forest cover. That conditions are still suitable to the growth of hydrophytic trees, even though the water table may have been somewhat depressed and conditions of light and exposure made severe by the removal of the forest cover, is proven by the red maples which have been planted along the roadsides. It is possible, that during the interval, the succession may have been set back by burning or by cutting. Grassy meadows are common upon the Little Miami-Mill creek divide. Few of the flattest parts of this upland show any tendency toward reforestization. Woodlots retain their straight edges, and do not encroach upon the meadows. Cleared areas reach, in a few years, a meadow stage which is more persistant than elsewhere in the region.

The causes which produce this condition are not understood. Certainly the meadow can be but temporary, and must in time give way to forest. Meadows, not now reforesting, are in all cases covered with a thick and dense turf of grass and a few other low herbaceous plants. Where this is occasionally broken, as at the edges of plowed fields or along roadsides, a few trees are found. It may be that as the turf becomes thinner in the shade of the few trees which do appear, seedlings will be able to get a foothold, and a new forest will start. Conditions which appear to be similar to these of our cleared uplands, have been noted by Shimek (1913) as occurring near Amana, Iowa, in the heart of a forest region.

2. Reforesting areas.-- The usual clearing succession reaches the meadow stage either directly, by the rapid spreading of meadow plants growing in natural openings, or through the earlier hydrophytic stages. Early in the succession, saplings usually begin to appear: xerophytes (Sassafras, red elm, and locust) in the dry meadows, and mostly hydrophytes (pin oak, red maple, shell-bark hickory, and white ash) in the wet meadows.

If the clearing is large, or the meadow distant from areas of original forest cover, the saplings are apt to be somewhat scattered. The succession, however, definitely shows its forest trend; and this meadow differs from the more permanent ones in that grass is a less important constituent. The aspect of such a meadow is therefore much more varied (fig. 14). A large number of species are found, among which are a few grasses



The species of saplings appearing are controlled to a large extent by the kind of trees in the vicinity. In the region of sweet gum forests, this species is an important constituent of the new growth. Elsewhere it is entirely absent. Pin oak is the most common species, and with it occur red maple, swamp white oak, and white ash. In almost every case, a considerable number of red elms (Ulmus fulva) appear.

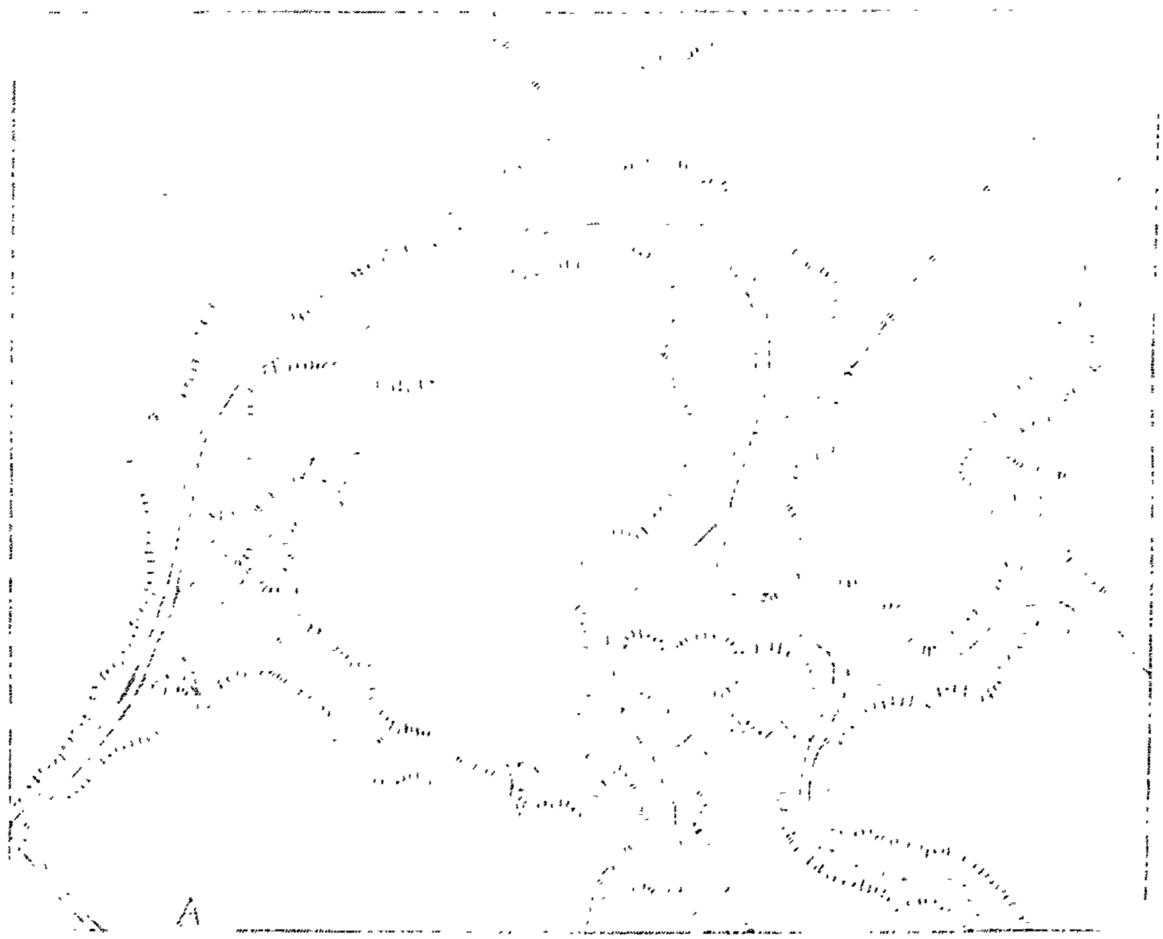
Forest openings indicated in the clearing succession.-- Very near to a tract of forest-- within about fifty feet (probably the effective limit of seed distribution)-- saplings are much more numerous than at greater distances. This growth is composed of the same species as are found in the neighboring woodland, and is often so close, as to almost exclude meadow vegetation. But openings are found in this, and each contains a rich meadow flora. These will grow smaller as the trees increase in size, and the quantity of meadow, and probably also the number of species, will decrease. It is such spots as these which probably form the openings in the upland forests.

It is likely that the original upland forests grew up in a manner very similar to that now shown in clearings. Natural meadows do not occur in this region, and the only meadow plants outside of clearings, are found in the small openings in the forests. The history of such spots is probably that outlined above. Conditions are still favorable to the development of extensive meadows, if the forest is removed. Then the plants which still maintain a foothold in the openings, will spread rapidly and cover the cleared area, only to be slowly restricted again by the growth of new forests.

III. Slope Series

The slopes of the region naturally fall into two principal divisions, ravine slopes and major valley slopes or river bluffs. That such a separation of slopes should be made, may at first sight seem strange. In following a growing ravine from its source to its entrance into one of the larger streams crossing the region, a connected history is involved. Such a stream is, in physiography, termed subsequent. But here the sequence may stop. The large valley is not always older than the small one. The Ohio and lower Miami rivers did not, in preglacial times, follow their present course. Because of the drainage changes shown in the accompanying map, fig. 15, parts of the Ohio and Miami valleys exhibit marks of extreme youth. And youth in a large valley does not impose the same conditions upon vegetation, that youth in a ravine does. The narrow and deep ravine is quite different from the xerophytic bluff (Cowles, 1901,a). The history of the river valley is not the history of its tributary valley.

The river series of Cowles (1901), including the ravine,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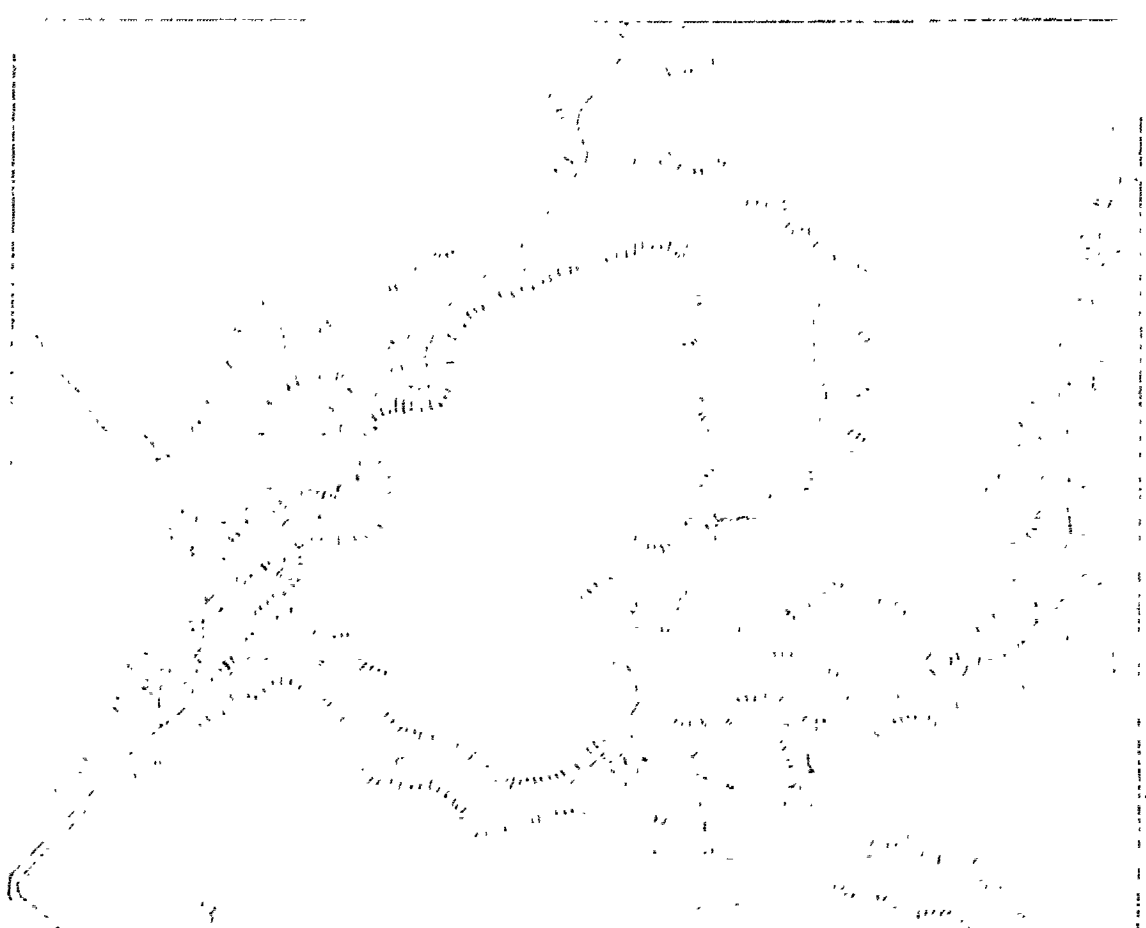
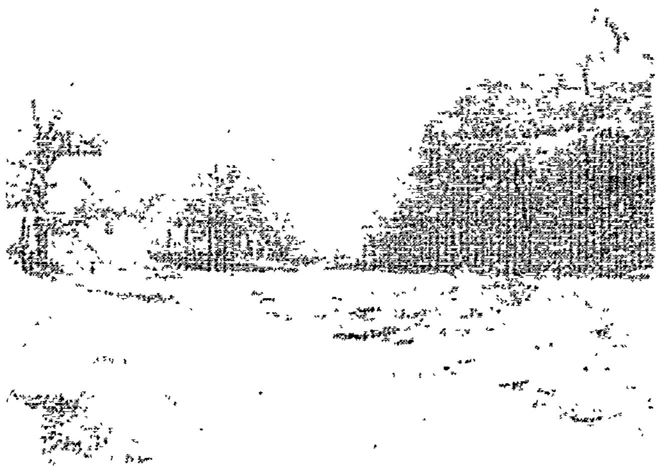




tection afforded by the slopes, which are still too gently, however, to cause xerophytic conditions. But this is only temporary; for, on the steeper parts of the hill, oaks are appearing. These indicate that as the stream cuts deeper, and its slopes become steeper, the mesophytic forest must change.

Occasionally on the remnants of the old bottoms, are large sycamores (Platanus occidentalis) and bur oaks (Quercus macrocarpa), relicts of a former hydrophytic association; but most of the newer vegetation is xerophytic. Red elm (Ulmus fulva), red-fruited thorn (Crataegus mollis), locust (Robinia Pseudo-Acacia), and hop hornbeam (Ostrya virginiana) grow along the top of the bluff. The stream is not yet actively cutting, and has some flood plain. Its bed is only full of water after heavy rains. Pools remain upon the unequal surface of the limestone floor. Here, and along the margin of the stream, are found a few hydrophytes-- Eupatorium perfoliatum, Bidens laevis, several species of Polygonum, Carex and Cyperus.

Third stage.-- The stream is now flowing about one hundred feet below the level of the upland, and has traversed about one third of its course. Its gradient has materially increased, but is very irregular. For the heavier limestone layers of the Maysville are fairly resistant, and so the stream must flow for sometimes a hundred feet over the horizontal surface of a stratum, before it drops several feet over shale and

Because of the very dense shade of this forest, summer herbaceous vegetation is scarce. It consists only of a few thin-leaved shade plants, as Pilea pumila, Impatiens pallida and I. biflora, Actaea alba, Desmodium pauciflorum and D. grandiflorum, Aralia racemosa, and a number of ferns, often in large patches (fig. 25). The vernal vegetation is extremely luxuriant. The ground is carpeted with dense mats of squirrel corn and Dutchman's breeches (Dicentra canadensis and D. Cucullaria), dog's tooth violet (Erythronium americana and E. albidum), twin-leaf (Jeffersonia diphylla), and many other species less abundant.

This mesophytic forest prevails on all slopes up to about 25 degrees. Steeper slopes have some oaks upon them (Quercus Muhlenbergii, Q. alba, and Q. rubra), and the herbaceous growth is less mesophytic. Here are usually found buttercup (Ranunculus septentrionalis), Greek valerian (Polemonium reptans), rue anemone (Anemonella thalictroides), meadow rue (Thalictrum dioicum), Hepatica (Hepatica acutiloba), and Christmas fern (Polystichum acrostichoides).

<u>Southward flowing streams</u>.-- The forests developed along the steep southward flowing streams are always less mesophytic than those of the northward slopes. It is only in very sheltered spots that a truly mesophytic association is found. Elsewhere, the associations are xero-mesophytic or even xero-

robin (Trillium sessile), larkspur (Delphinium tricorne), rue anemone (Anemonella thalictroides), buttercup (Ranunculus septentrionalis), sickle-pod (Arabis canadensis), and a number of the more xerophytic sedges (Carex laxiflora, C. pubescens, and C. varia). Later, are found species of Desmodium and Lespedeza, Thaspium pinnatifidum, Cynoglossum virginianum, Scutellaria canescens, Seymeria macrophylla, Ruellia strepens, Solidago ulmifolia, Aster cordifolius, and Aster Shortii.

This type of xerophytic forest is found only on the steeper south exposures. Hillsides sloping in other directions and gentler slopes are more mesophytic, and on these the kinds of trees are more numerous. Sugar maple is an important species, sometimes becoming more abundant than the chestnut oak. Other trees which may occur are wild black cherry, sweet buckeye, tulip, basswood, Carya microcarpa, shell-bark hickory, black oak and red oak. In such a forest, sugar maple is dominant in the undergrowth. The vernal vegetation is richer than on the more xerophytic hillsides, and a number of more mesophytic plants are appearing.

North slopes are always more mesophytic than south slopes of equal steepness. In some places, the north side of the stream may be bordered by the xerophytic association above described, and the south side by a xero-mesophytic or even mesophytic association, in which beech is a secondary species.

deep at its beginning but its walls are almost vertical. The stream has reached the Eden shale, and the character of the valley has changed. The fall is rapidly receding, carrying the gorge back into the open valley through the Maysville formation. The walls of the gorge are dripping with moisture in many places. But the shale erodes so rapidly that almost no vegetation is found upon it. Here and there are patches of algae, and occasionally some moss (Hypnum sp.). Near the top of the gorge, or wherever the banks are not rapidly cutting, are patches of Impatiens and Hydrangea. Instead of the bluff xerophytes found higher up the stream, there are saplings of sugar maple, ash, and white elm (see fig. 26). This narrow gorge is mesophytic. But the mesophytic forest gives way higher up the slopes to the xerophytic forest described above.

The length of this gorge is largely dependent on the altitude of the Eden-Maysville contact, and of the flood plain of the river, into which this stream is flowing.

Fifth stage.-- Soon the valley widens out and the slopes become gentle. The stream is essentially a depositing stream. Its bed is full of broken pieces of limestone; its valley floor built up with rubble, into which the stream cuts during freshets. The flat limestone reaches, with their groups of hydrophytic plants are gone. Scattered sycamores and willows mark the course of the stream.

course, have profiles more nearly resembling the normal.

2. Modifications of the typical ravine.-- Many of the ravines of the region do not exhibit all of the features above outlined; few have all well developed. Some exhibit peculiar features which are dependent upon the particular physiographic and soil conditions of the area through which they flow.

A number of the smaller streams begin near the margin of the upland. In these, the sluggish upland course is lacking. The fall of the stream is rapid, and its valley sides much steeper than is the case with longer streams. Along such streams are found many of our steepest slopes. The valleys are so narrow everywhere that the contrast between the Maysville limestone and the Eden shale is not well marked.

Northward flowing streams.-- North flowing and south flowing streams of this sort show much the same fifferences that were noted between north and south slopes. Along the northward flowing streams, are the most mesophytic forests of the region. The tree growth is more varied than elsewhere, and almost every mesophytic species of the region may occur. In such a forest, beech forms about fifty per cent of the tree growth. The remaining fifty per cent is made up chiefly of sugar maple (Acer saccharum), tulip tree (Liriodendron Tulipifera), wild black cherry (Prunus serotina), rock elm (Ulmus racemosa), white ash (Fraxinus americana), big shell-bark hick-

Because of the very dense shade of this forest, summer herbaceous vegetation is scarce. It consists only of a few thin-leaved shade plants, as Pilea pumila, Impatiens pallida and I. biflora, Actaea alba, Desmodium pauciflorum and D. grandiflorum, Aralia racemosa, and a number of ferns, often in large patches (fig. 25). The vernal vegetation is extremely luxuriant. The ground is carpeted with dense mats of squirrel corn and Dutchman's breeches (Dicentra canadensis and D. Cucullaria), dog's tooth violet (Erythronium americana and E. albidum), twin-leaf (Jeffersonia diphylla), and many other species less abundant.

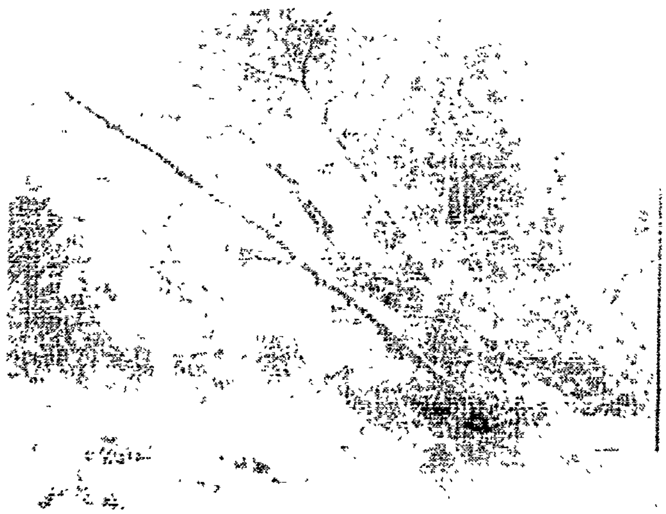
This mesophytic forest prevails on all slopes up to about 25 degrees. Steeper slopes have some oaks upon them (Quercus Muhlenbergii, Q. alba, and Q. rubra), and the herbaceous growth is less mesophytic. Here are usually found buttercup (Ranunculus septentrionalis), Greek valerian (Polemonium reptans), rue anemone (Anemonella thalictroides), meadow rue (Thalictrum dioicum), Hepatica (Hepatica acutiloba), and Christmas fern (Polystichum acrostichoides).

Southward flowing streams.-- The forests developed along the steep southward flowing streams are always less mesophytic than those of the northward slopes. It is only in very sheltered spots that a truly mesophytic association is found. Elsewhere, the associations are xero-mesophytic or even xerophytic on the steepest slopes. Beech is almost always absent, and sugar maple is not everywhere abundant. Instead of Dicentra and Erythronium, are larkspur (Delphinium tricorne), false rue anemone (Isopyrum biternatum), and wild hyacinth (Camassia esculenta).

The short steep ravines seldom carry permanent streams. The sluggish lower course is always short. The marginal vegetation, if present at all, is hardly more than an inward lobe of the marginal flood plain association of the larger stream.

Absence of gorge.-- In a number of streams of the region, the gorge-like valley through the Eden shale is absent. This is due either to the relatively high level of the stream into which the tributary flows or to the deep and broad valley filling through which the little stream must cut during the latter part of its course. The altitude of the Eden-Maysville contact is a contributing factor in the elimination of the gorge-like valley.

Elongated sluggish course.-- When the stream must cross a broad flood plain, or flow through a filled valley, the sluggish part of its course is often long. This is true of many streams flowing into the Little Miami below East Fork, and of some flowing into the Ohio. But the greatest development of this sluggish portion of the stream course is found along Mill creek valley. In fact, Mill creek flows for most of its



site bank of the stream, for the valley is too wide. Almost everywhere a flood plain of greater or less width has been built at the foot of the bluff, so that the earliest stages in the development of rock bluffs are seldom seen.

The bluffs of the Ohio rise from 300 to 400 feet above the river, gently at first but precipitous above. The Bellevue division of the Maysville, which is by far the most resistant rock of the formation, stands out prominently. It outcrops near the tops of the higher bluffs, there forming almost vertical cliffs, fifteen feet high. The slope above this is gentle; below, steep as far down as the Eden-Maysville contact about one hundred feet below, where it changes to a gentler slope on all but the youngest bluffs. In a few places along the Miami and Little Miami rivers, Mill creek valley, and the pre-glacial valleys, similar though lower rock bluffs may be found.

Pioneer herbaceous association.-- The steepest bluffs and those showing the youngest stages in the succession, are found in the position of pre-glacial cols and on the outside of meander curves (fig.15). In rare instances, eroding bluffs (never high however) may occur. The on;y plants which are seen on these are a few annuals. The earliest associations in the bluff succession may be compared to those found on abandoned quarry faces. The first plants to appear are black mustard

(Brassica nigra), sweet clover (Melilotus alba and M. officinalis), parsnip (Pastinaca sativa), and Aster ericoides. A few years suffice to cover all but the steepest parts with this herbaceous growth. The shale, which is everywhere interbedded with the limestone, weathers rapidly and soon supplies enough soil for woody plants.

The first tree stage.-- Ability to withstand strong light is apparently a factor in determining what trees shall appear. The first are locust (Robinia Pseudo-Acacia), honey locust (Gleditsia triacanthos), red elm (Ulmus fulva), and blue ash (Fraxinus quadrangulata). With or soon after these, are redbud (Cercis canadensis) and red-fruited thorn (Crataegus mollis). Sycamores are not uncommon as pioneers, appearing in gullies or along horizons of abundant seepage of ground-water. The herbaceous plants of the open slopes begin to disappear, and in their places come the purple aster (Aster Shortii), cleavers (Galium Aparine), motherwort (Leonurus Cardiaca), catnip (Nepeta Cataria), and wild onion (Allium cernuum).

All parts of the slope do not reach this stage with equal rapidity. The succession progresses most rapidly upon the gentler slopes below. Here, and on the steeper slopes beneath the cliffs the succession is very similar. After the first tree stages are reached, mesophytism increases more rapidly on the shale area than above, and the undergrowth becomes denser than that found on steeper slopes.

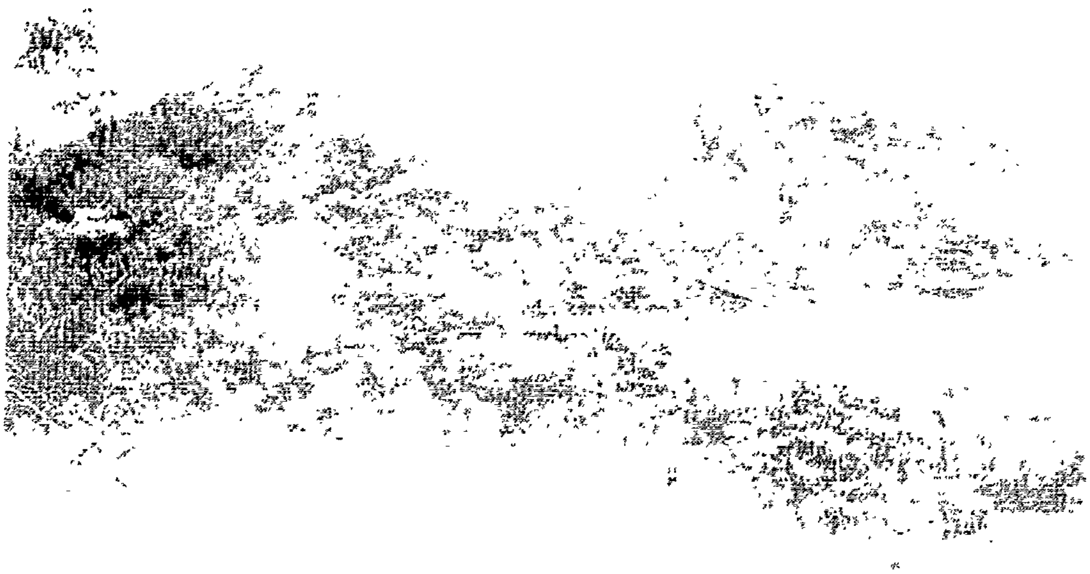
Bellevue limestone cliffs.-- In every situation thus far mentioned, the pioneer stages are passed rapidly. This is not the case on the cliffs of the Bellevue limestone. No soil is found here except in crevices. The rock surfaces are covered with crustose lichens (Endocarpon pusillum Hedw., Verrucaria nigrescens Pers., and Placodium siderites (Tuck)), and patches of xerophytic mosses. In the crevices are a few herbaceous plants, Aster Shortii, Solidago canadensis, and Poa compressa, with here and there a small red elm, blue ash or hop hornbeam. The cliffs have still but few trees upon them, when the succession on the slopes below has reached the oak forest stage. Where the Bellevue does not cap the bluffs, the slopes are often less steep, and the summits rounded instead of cliff-like. In either case the tops of the bluffs support a similar vegetation, which is, however, always in a more advanced stage than that of the steepest slopes. Thus the cliffs may be bordered above by large oaks (Quercus Muhlenbergii, Q, rubra, and Q. coccinea) and sometimes sugar maples a short distance back from the edge.

The succession on the Bellevue limestone cliffs is typical of resistant rock bluffs. It is similar to that outlined by Cowles (1901,a) as occurring on limestones and dolomites of the Illinois region, except that the conifer stage is here entirely absent. The first tree stageis its ecological equivalent, being followed here, as in the Illinois region, by an oak forest. The river bluffs nowhere show a later stage in the succession than this oak forest.

The oak forest.-- The oak forest varies somewhat on different exposures. On south slopes, oak predominates, and with it are some honey locust, hackberry, blue ash, and red elm. The undergrowth is made up largely of redbud and Crataegus with saplingsof the trees named above. Sugar maple is occasionally an important constituent of the younger growth. On north slopes sugar maple is sometimes a secondary species of the forest. Sweet buckeye (Aesculus octandra), basswood (Tilia americana), wild black cherry (Prunus serotina), and walnut (Juglans nigra) are also mixed with oak, which is still the most abundant tree.

Rate of progress in bluff successions.-- Some idea of the rate of progress of the bluff succession may be gained from clearing successions of known age. These are of course more rapid than the original successions. Many of the river bluffs were cleared by the early settlers and vineyards planted upon them. In 1864 and 1865, many of these vineyards were cut down, and some of the hillsides left uncultivated.

The hillside above Anderson's Ferry is one of these. Here the south slope toward the river varies from 15 degrees to 30 degrees, but the west slope toward a deep ravine presents



stage. Redbud (Cercis canadensis) and red-fruited thorn (Crataegus mollis) are dominant, and with them is a low growth of hackberry, blue ash, honey locust, red elm, locust, Ohio buckeye, and hop hornbeam, mixed with saplings of chestnut oak (Quercus Muhlenbergii), the beginning of the oak stage. The vernal vegetation is very characteristic of warm south slopes. The dwarf larkspur (Delphinium tricorne) is by far the most abundant plant. With it are found wake robin (Trillium sessile), wild hyacinth (Camassia esculenta), meadow rue (Thalictrum dioicum), toothwort (Dentaria laciniata), Solomon's seal (Polygonatum biflorum), sickle-pod (Arabis canadensis), wild onion (Allium cernuum), and blue violet (Viola sororia).

In large part, the vegetation of the west slope is similar, with this difference, however, that the ground layer is moreopen. The larkspur is much less abundant, and in some of the steepest places, Viola triloba is almost the only plant growing under the few scattered trees. Rock ledges and scattered limestone slabs are lichen-covered, and patches of xerophytic mosses occur here and there.

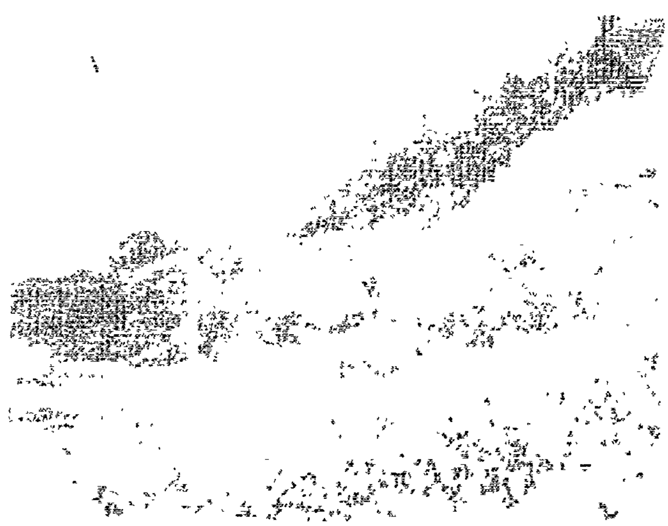
At the edge of the bare cliff, are red oak and Ostrya with spring beauty (Claytonia virginica), meadow rue (Thalictrum dioicum), alum root (Heuchera americana), and early saxifrage (Saxifraga virginiensis) beneath them (fig. 29). As the slope becomes gentle above the top of the cliff, this asso-

contrast between them is marked. Mesophytes form a large proportion of the forest. Redbud is entirely absent; the more mesophytic sweet buckeye (Aesculus octandra) replaces the Ohio buckeye (A. glabra); sugar maple and wild black cherry are common. Almost no xerophytes are found among the saplings. The herbaceous vegetation is mesophytic, consisting of Dicentra canadensis, Corydalis flavulum, Cystopteris fragilis, Hydrophyllum appendiculatum, and Stylophorum diphyllum (Celandine poppy). The vegetation of the lower part of the slope is even more mesophytic. But it belongs essentially to the ravine.

Opposite the large ravine, a clearing succession of the same age is found on east and southeast slopes. The associations here are very similar to those of south and west slopes, but somewhat less xerophytic. An east exposure has a richer spring flora than the opposite west slope of equal steepness. The prevailing winds of this region are west- southwest, and their drying effect is evidenced in this difference in the vegetation of slopes sheltered from and exposed to these winds.

Thus, all the different exposures are exhibited in this limited area. The succession on the south slope is the slowest; the associations here the most xerophytic. While the associations of south slopes are still pioneers those of north exposures have progressed almost to a climax forest.

If the associations now existing on river bluffs of



annuals or young perennials (fig. 30). The vegetation of the till banks is more scattered than that of the stratified deposits. Each year the banks are undermined by floods, and the plants that have started are destroyed. At the upstream part of the cut, where active river erosion has ceased, perennials and woody plants advance rapidly. Locust is a common pioneer. Occasionally red cedar is the first tree to advance, and sometimes these may be seen dotted over the face of the bluff.

The succession resembles that of the less resistant rock bluffs, but is more rapid. The greatest vicissitudes are encountered in the early part of the succession because of the instability of the material. Parts of these clay bluffs usually slump each spring, but during the remainder of the year these banks are firm unless interbedded with sand. Slumping plays an important part in the clay succession, by bringing down plants from above. Thus woody plants may advance not only from the upstream margin of the bluff, but also from slump centers.

A clay or sand bluff rapidly loses its original steepness, and after the ground is shaded, the succession progresses rapidly. Oaks appear on relatively young bluffs, and the first forest cover is composed largely of oaks (Quercus Muhlenbergii, Q. alba, and Q. rubra).

Old bluffs.-- The old clay bluff is clothed with a forest much resembling the mixed oak forest of the typical ravine. The vernal vegetation usually consists of a large variety of plants, among which may be mentioned Hepatica acutiloba, Ranunculus septentrionalis, Polemonium reptans (Greek valerian), Uvularia grandiflora (bellwort), Anemonella thalictroiaes (rue anemone), Thalictrum dioicum, Cynoglossum virginianum, and Erigeron pulchellus. Beech and sugar maple are abundant among the saplings, as are also the hickories (Carya laciniosa and C. glabra villosa), basswood (Tilia amercana), dogwood (Cornus florida), and the oaks which are the facies of the upper layer of the forest. The red cedar has almost entirely disappeared. In sheltered ravines in the old bluff, is found a mixed mesophytic forest similar to that found on northwardflowing streams.

3. Gravel bluffs.-- The Little Miami and Miami rivers are, in many places, cutting bluffs in the gravels with which these valleys were partly filled during the Wisconsin glacial epoch. The gravel bluffs vary from forty to seventy feet in height. The undercut banks stand at high angles, owing to a partial cementation of the gravel at some horizons.

The new bluffs are devoid of vegetation, except that brought down from the top by slides, as the loose gravel is constantly slipping. At the top of the bluffs, and in those parts where erosion is not very active, a few xerophytic herbs appear, among which are Verbena stricta, Kuhnia eupatorioides, Arabis Drummondi, and Poa compressa. These are all sun plants, and persist but a short time in the life of the succession.

Toward the upper end of the undercut bluff, a few xerophytic trees and shrubs are seen advancing upon the open herbaceous association. Foremost among these are red elm, chestnut oak, blue ash, hop hornbeam, red cedar, and Rhus canadensis.

Up-stream, the bluff decreases in steepness as it becomes older. At the same time the vegetation becomes denser. A young forest made up of oaks (Quercus Muhlenbergii, Q. rubra, and Q. alba), hackberry, basswood, thorn (Crataegus mollis), hop hornbeam, and red cedar, shades the banks. The undergrowth is made up of a few smaller saplings, and the shrubs, Rhus canadensis, Physocarpus opulifolius (nine-bark), and Cornus asperifolia. The Rhus is by far the most important and characteristic of these shrubs, as in this locality it is entirely restricted to such habitats. It often forms large patches to the exclusion of other vegetation. The original xerophytic herbs are largely driven out, and in their places are Aquilegia canadensis (wild columbine), Phacelia Purshii (Miami mist), Phlox divaricata, Sanguinaria canadensis (blood root), Arabis canadensis, Silene virginica (fire pink), and Aster Shortii. The numerous bowlders which lie on the surface are covered with lichens and moss.

Soon a number of marginal trees appear at the foot of the bluff, but these belong to the life history of the flood plain which is now being built. The bluff succession in progress is entirely independent of this. The demarcation between flood plain and bluff is sharp. The original xerophytes retain their position at the top of the bluffs long after they have disappeared from the slopes. Above the marginal trees at the foot of the bluffs, a few mesophytes appear, sugar maple first and then beech.

The terrace retains its steep and bluff-like margin long after the flood plain has grown wide at its foot, and all stream erosion has ceased. The mesophytic tendency displayed on the lower slopes is an indication of what the future forest will be. But even the oldest bluffs show little more than a small percentage of mesophytic trees. Oaks predominate, and in some places along the Little Miami, red cedar is important. Sugar maple saplings are not uncommon, and sometimes flowering dogwood (Cornus florida)is seen. The herbaceous flora retains much the same aspect as on the younger bluffs, but is a little more varied and denser. The summer blooming plants are not abundant, for the steep gravel slopes are very dry except during the spring when rains are frequent.

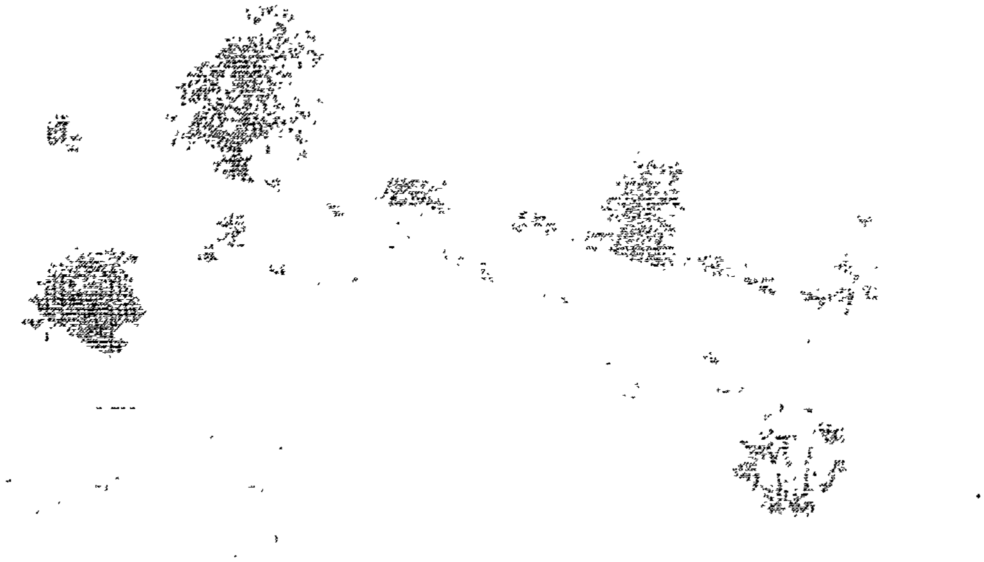
The gravel bluff exhibits many peculiarities not seen on bluffs of rock or clay. Under-cutting banks in gravel are even more unstable than those in clay, at least as far as the surface layer is concerned, and more xerophytic than most rock bluffs. A number of the plants of these bluffs (Rhus canadensis, Physocarpus opulifolius, Verbena stricta, Kuhnia eupatorioides, and Arabis Drummondi) are seldom found elsewhere. Gravel bluffs and hillsides may be said to have the most characteristic vegetation of any habitat of the region.

C. Clearing Associations

The use to which a cleared slope has been put influences the character of the earlier clearing associations. Pastured land is occupied by a turf composed chiefly of Kentucky blue grass (Poa pratensis), over which are scattered a few scrubby trees and herbaceous plants, among which ironweed (Vernonia fasciculata) is always prominent. Long after the pasture land is abandoned, the sod retains its hold (fig. 31). Slowly the number of broad leaved herbs increases, and more trees, sometimes in great variety, appear.

Cultivated lands, lying waste, grow up in tall weeds among which may be a few of the taller grasses, but never blue grass, at least in the earlier stages. Saplings are more abundant on such areas than on pasture land.

Land which has been cleared or partially cleared, and not cultivated returns to forest much more rapidly than is the case in the two former instances, doubtless because of the presence



by the plant cover and by the stage in the physiographic cycle. The former plant cover affects the new association because of its modifying influence on the soil. Second, if any of the original trees remain in the clearing, they will be represented in the new growth, and often in larger numbers than would otherwise be possible. For this reason, a few mesophytes are sometimes represented in the first clearing association.

Clearing always has a retarding effect on the succession. An oak forest is commonly replaced by one composed almost entirely of the pioneers of new slopes. In many places groves of locust (Robinia Pseudo-Acacia) occupy the cleared slopes. Though not an indigenous tree, this is probably the most common pioneer of clearings. In bluff successions, it does not long retain the precedence which it may have originally had, but is soon replaced by native trees. In clearings there is however, often no indication of what will succeed it-- the groves are pure stands of locust. The predominance of locust, when once it is introduced into a clearing, may be partially accounted for by the rapid vegetative propogation of this tree by root shoots[6], which gives it an advantage over other bluff

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[6] The terms water shoot, water sprout, shoot, sprout, and sucker, are largely used indiscriminately for shoots from roots, both at and far from the main stem. It is here suggested, that root shoot be used to designate those shoots arising from roots

xerophytes.

Other common clearing pioneers are honey locust (Gleditsia triacanthos), thorns (Crataegus mollis, C. Crus-galli, and C. punctata), Sassafras, and red elm. These may be found together composing a mixed thicket, or separately forming almost pure stands (fig. 31).

In a few localities, especially in the Little Miami drainage basin, red cedar (Juniperus virginiana) is the facies of the early stages of slope successions, in clearings as well as on young bluffs. Locust may be mixed with it in greater or less abundance, but in older associations, the red cedar stands almost alone (fig. 32). In other places it is mixed with white and chestnut oaks, in which case it forms a very prominant and important part of the young forest. In most of the area under consideration, however, red cedar is not even a secondary species in any of the pioneer associations, and never becomes the facies. Its limited distribution within the region is not understood.

The direction and steepness of the slope, together with the nature of the soil, influence the rapidity of the clearing succession, as they do the original succession. Slopes of from 20 to 30 degrees usually retain their xerophytic flora

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at a distance from the original plant.

growth mesophytic forest. The direction of slope must be northerly--northeast, north, northwest, or rarely east or west. The soil must be deep, and of such a nature that it retains water. These requirements are met along a number of ravines which cut in deep glacial deposits composed largely of fine sand and silt. A single clearing formation changes from a xerophytic forest association on the south slope to a mesophytic one on west and northwest exposures of equal steepness. The succession passes from an association in which locust and sumach (Rhus typhina) are dominant among the trees, to one in which beech, sugar maple, and tulip are most abundant. Very few species are common to the two associations. With the locust and sumach of the south slopeare red elm, hackberry, and mulberry. Blackberry thickets form a lower layer in this open forest, and on the ground are a few herbs among which are Venus's looking glass (Specularia perfoliata), wild pansy (Viola Rafinesquii), the ebony spleenwort (Asplenium platyneuron), and some Cystopteris fragilis. On the west and nortwest slopes, with the beech , maple and tulip, are dogwood, sweet buckeye, ironwood, a few large chestnut and red oaks, and basswood. The herbaceous flora is not that of a climax forest, but is remarkably different from that of the south slope. Here, Cystopteris fragilis is common, and with it are the maidenhair fern (Adiantum pedatum), Jack-in-the-pulpit (Arisaema triphyllum), bloodroot (Sanguinaria canadensis), May apple (Podophyllum peltatum), black snakeroot (Cimicifuga racemosa), and Solomon's seal (Polygonatum biflorum).

Later stages in the clearing succession are very similar to corresponding associations of the original succession.

D. The Erosion Climax Forest.

The mesophytic forest which is found upon a number of the gentler or more protected slopes, it has been shown, differs from that of the uplands. It contains a larger variety of trees, and its herbaceous growth is extremely rich and varied (fig. 25). The relatively simple life history of the upland forest is not found here. Topographic changes have played an important part in the succession. Retrogressive periods must have had some place in it. This is the mesophytic forest which develops at the end of a long and varied succession. It is the climax of every erosion succession now in progress, and of the forces of erosion must sooner or later modify all areas, it may be considered as the probable climax forest of the region. In contrast to the pre-erosion climax forest of the upland, is this forest, which will be termed the erosion climax.

IV. The Flood Plain Series

In places along the ravine course, small areas of flood plain with their attendant vegetation were noted. Along the rivers of the region, flood plains are sometimes several miles wide. The vertical range is greatest along the Ohio, which has an annual variation in height of about sixty feet. It is the flood plains of the larger streams-- the Ohio, Miami, Little Miami, and Licking rivers, and Mill creek -- which constitute one of the four great topographic and vegetational areas of the region. Along these rivers, flood plain vegetation reaches its greatest development.

Although the beach and the islands are genetically a part of the flood plain, it is convenient here to separate the frequently submerged and open beach associations from the closed associations of the broad and higher flood plain.

A. The Beach

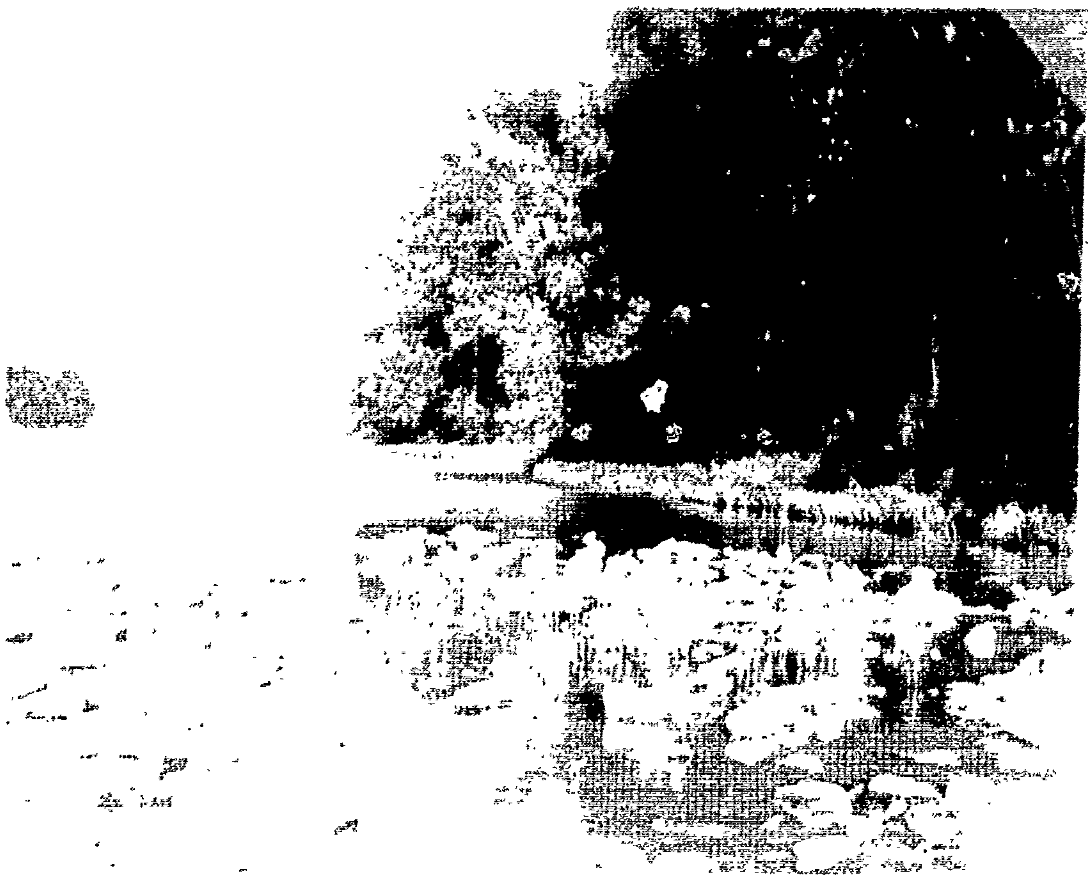
1. Gently sloping beaches.-- In many places the river beach is broad and rises gently from the water's edge. Along the Ohio, such beaches are of sand or silt. On the two Miamis, they are usually of gravel or cobblestones with more or less mud. There is not a great deal of difference in the vegetation of these two kinds of beaches.

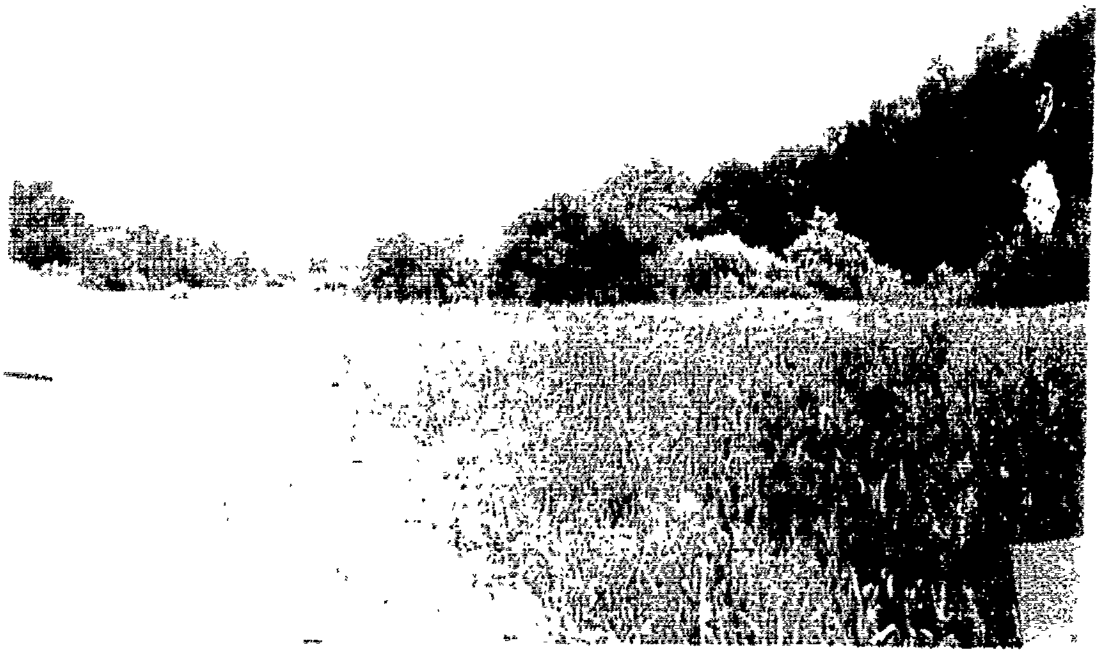
The open beach is submerged several times each year.

Its vegetation is composed of annuals and a few perennials.

Sandy beaches.-- On sandy shores, the density of the vegetation increases up the beach, but there are no definite zones below the marginal tree zone. The wettest places are occupied by Eleocharis olivacea. On other parts of the beach, may be found a variety of plants among which are a number of grasses (Echinochloa Crusgalli, Panicum dichotomiflorum, Cenchrus tribuloides, and Eragrostis hypnoides), knotweeds (Polygonum pennsylvanicum and P. lapathifolium), Amaranthus hybridus, Strophostyles helvola, Ambrosia trifida, and Bidens laevis. Here and there are seen a few small willows (Salix nigra and S. longifolia), and cotton-wood (Populus deltoides) advancing into the zone of annuals. These presage the advance of the marginal tree zone. The width of the zone of annuals is determined by the slope of the beach and the average summer fluctuation of the river. The plants of the beach are transients. They are plants which come late, after the rivers have gone down to low summer heights.

Cobblestone beaches.-- The beaches of gravel or cobblestones are occupied by an association of herbaceous plants very similar to that found on sandy shores. The principal difference lies in the fact that there is no definite advance of woody plants from a distinct tree zone above the beach. The willows are few and scattered.





wide cobble beach of the Little Miami.

The third zone is a closed association similar to the corresponding zone of sandy beaches. This belongs more properly to the flood plain forest than to the beach.

2. Steep river beaches.-- The open beach association extends higher up the steep river banks than on gently sloping ones. But this beach association is not the same as that previously described. In vertical range it corresponds approximately to the first three zones of the flood plain forest to be described later. It is itself divided into distinct belts.

Bed-rock beaches.-- These steep beaches are of several kinds. In rare instances they are of bed-rock (Pt. Pleasant) in position, with large pieces broken off and scattered over the surface. Such beaches have very little vegetation. A few annuals in the crevices of the rock, and scattered willow bushes are all that is found.

Rocky beaches.-- A later development of this type of beach is sometimes found. Instead of ledges of rock, and large blocks lying around, the banks are covered with small angular fragments (fig. 35). The slope of this kind of beach averages about 10 degrees. There are more plants here, but the association is still open. For a few feet back from the water's edge, the banks are almost bare. This zone corresponds approximately to the open beach of gently sloping shores.

of this association are not hydrophytes. During the summer months, these banks are dry. They are in some ways similar to the high cobblestone beaches. The perennials of such localities are deeply and strongly rooted. Such beaches as these are not depositional. They are found only along eroding parts of a river's course. These herbaceous plants, which present no obstruction to flood waters, retain their foothold, even when the willows of the same association, or the trees higher up, are torn out.

Steep river beaches are found at or near the foot of bluffs. They are always narrow and often short-lived, as a flat beach may be built out in front of them.

Undercut banks.-- All the streams except the Ohio, are undercutting their flood plains. These undercut banks are comparable to bluffs in steepness, but they belong essentially to the flood plain area. Whatever vegetation may appear upon them during one year is swept away the next spring. It is only after under-cutting ceases, and the slopes become more gentle, that the flood plain vegetation gets a foothold.

The plant associations of these steep river banks in silt or sand resemble most closely those of the gently sloping beaches in the same material. On the narrow flat at the base of such banks are the hydrophytic herbs of the broader beaches. Above this are the other associations of gently sloping shores.

These are often so intermingled, that they can not be separated into zones (fig. 33). In other places the zones are very narrow and at times one or more are eliminated entirely.

B. Islands

The islands of the Miami and Little Miami rivers are residual. They vary in size from a few hundred to several thousand feet in length. It is only the smaller ones which can properly be called islands. The larger ones are areas of the flood plain separated from the mainland by cut-offs (sloughs). They can be considered as islands only in that they are bounded on all sides by parts of the river and that their origin is the same as that of the smaller islands. It is the smaller islands which will be considered here.

All gradations between the island and the cobble beach are found. Many projecting stretches of beach are separated from the higher flood plain by a depression, which during the summer is either swampy or partly filled with water (fig. 36). Some beaches connected with the mainland in but one or two places become islands during high water. The islands may be well in the center of the river so that the waters divide nearly equally in passing them (fig. 36), or so much to one side, that the river is very unequally divided. Sometimes the shallow channel at one side of an island is filled up during a flood, and the island becomes a part of the beach. And, *vice*

show any older association than this.

Factors limiting beach associations.-- The plant associations of the gravel or cobble beach, whether of main land or island, are not controlled by newness of land, but by water height and topography. The open beach association occupies the area which is exposed during low water. The second zone, or upper beach, is submerged in the summer only for very short periods, if at all, during unusually high water. The lower beach is not being built up or extended outward by deposition; neither are the islands increasing in size by gradual accession of deposited material at their lower ends. The succession is not related to sloww constructional changes, as is the succession of depositing shores or depositional islands; nor is it accompanied by gradual encroachment of one association upon the next younger. The streams along which the cobble beaches, and in which the residual islands are found, are essentially eroding streams. The lower beach is cut below the upper beach; the upper beach, cut below the general level of the flood plain. The materials of which the islands are composed are too coarse to be moved during low water, even by the swift current assumed by these rivers in passing through the narrow channels around the islands. Changes are effected only during high water, when the cutting and carrying power of the stream is enormously increased. Nevertheless the beaches and the residual islands of the two Miamis are remarkably stable. Changes of sufficient magnitude to destroy the upper beach vegetation rarely occur.

C. The Flood Plain

1. Pond-swamp associations.-- Swampy conditions or ponded waters are found in a number of places on the flood plain. Here are included natural and artificial depressions, and sloughs.

Low places which are filled with water for at least a part of the year, are very commonly found at the foot of a pronounced rise in the flood plain. They owe their existence to the levee nature of the alluvial deposits. Other depressions are found whose origin is not as easily explained. Artificial conditions also have contributed more or less in the formation of a number of flood plain ponds. And a number also have been destroyed by draining or filling. Those that remain are small, and do not contain the wealth of aquatic vegetation which local check lists credit to larger ponds of the region which were drained years ago.

True aquatics are scarce or entirely absent, but the amphibious plants are numerous. These are seldom arranged in distinct zones, as these flood plain ponds are often very irregular in outline. Cat-tail (Typha latifolia), arrow-head (Sagittaria latifolia), and bulrush (scirpus validus) usually occupy the margin of the pond, or are scattered through it in patches. Each wetter spot in the general swampy area is occu-

channel is full of quiet water. It is bordered by willows (Salix nigra, and S. cordata).

This marginal zone of bushy willows is a continuation of the first tree zone of the rivers. It completely surrounds the "island" which is enclosed between the slough and the river. Commencing with this zone of willows, the slough succession and the river bank succession are identical.

2. Meadow associations; clearings.-- In its natural condition, almost the whole of the large flood plain was forested. Now most of it is cleared and cultivated, and only a few natural woodlands and uncultivated clearings remain.

The pond-swamp associations are usually followed by forest associations. In places, however, an herbaceous association composed of sedges, grasses, and field plants (Helianthus strumosus, Vernonia fasciculata, Ambrosia trifida, and Solidago canadensis) follows the amphibious. This condition is only temporary, and if undisturbed, trees begin to appear in the meadow-- willows, poplar, honey locust, and elm.

Clearings on the flood plain, which are uncultivated for a number of years, are usually occupied by a rank growth of tall weeds, only a few of which are in any way characteristic of flood plains. Most abundant among these, is the giant ragweed (Ambrosia trifida) which, though common in moist soil in clearings everywhere in the region, reaches its highest development in these situations. Where this is not abundant, the vegetation is sometimes quite varied, consisting of such plants as Helianthus strumosus, Silphium perfoliatum, Echinochloa Crusgalli, Lycopus americana, Sicyos angulatus, Lippia lanceolata, Polygonum pennsylvanicum, etc.

In some places the fields are grassy instead of being filled with tall weeds. The aspect of these clearings changes with the season, for they always contain a number of plants other than grasses and sedges. Miami mist (Phacelia Purshii), lamb's lettuce (Valerianella radiata), field sorrel (Rumex acetosella), cinquefoil (Potentilla monspeliensis), and mistflower (Eupatorium coelestinum) are perhaps the most noticeable.

3. Forest associations.-- The forests of the flood plain are of two types, belonging to different successions. One of these, the depression forest, is uncommon, occurring in undrained situations on the flood plain. The other, which is best known as the flood plain forest, is almost universal. It occupies the wet but well drained margins of streams.

Depression forest.-- The depression forest of the flood plain is very similar to the depression forest of the upland. The trees are those most typical of undrained situations, namely, pin oak, swamp white oak, and red maple. Only three such areas are known, two on t e flood plain of the Ohio, and one in Mill creek bottoms. They lie on broad plains, and as on the uplands, the depressions are so slight, that they are not easily noticed. All three are on high flood plains, only reached by exceptional floods, as those of March, 1913.

It is probable that this type of forest arises late in the pond-swamp succession. At least the ponds of the flood plain occupy the only other similar positions. None of these show any tendency toward the development of a swamp forest, but this may be due to the artificial conditions which surround them.

Little can be learned of the probable trend of the succession from the depression forests themselves, for they are completely cleared of their undergrowth. A comparison of the three depressions shows that their forests are not in the same stage of development. The largest one (on the flood plain of the Ohio river at Melbourne, Ky.) is undissected by small ravines. Its trees are of different ages and range from several inches to a few feet in diameter, some of the pin oaks being exceptionally large. On the margin of the depression, and not far from the willows and sycamores of the flood plain forest is a single beech tree. This gives the only clue as to the possible future of the depression forest of flood plains, if undissected -- a mesophytic forest, probably similar to that which follows the depression forest of the upland.

The other two depressions are broken by ravines. One, on the Ohio river flood plain at Finney, Ohio, is trenched by a deep gully, along which are a few ravine trees. The third depression, north of Lockland, is traversed by several shallow valleys along which are sycamores. As on the uplands, the conditions which produced the depression forest are being destroyed by dissection.

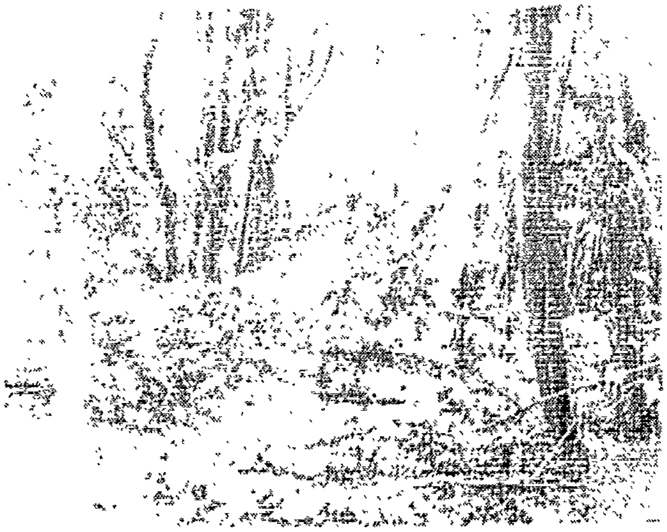
The depression forests of the uplands and flood plains are alike in that they contain the same kinds of trees, and their successions are proceeding in the same general course, either toward mesophytism by gradual filling, or toward xerophytism, by dissection. The depressions of the upland depend upon rainfall, ground-water, and impervious soil for their supply of water. Those of the flood plain depend upon rainfall and ground-water during only a portion of the year, for at times t ey are filled by the river. The alluvial soil is light and porous, very different from the till and white clay of the uplands. Topographic situation is a big factor in the production of swamp forests in the flood plain depressions.

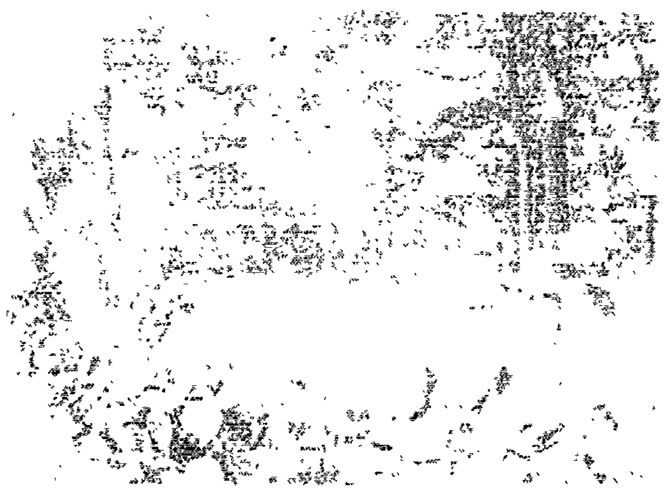
Flood plain forest.-- The flood plain forest is closely related, in its development, to the constructional phases of river activity. It exhibits a number of zones whose extent and degree of development are dependent on the slope and breadth of the flood plain. A general view of a forested area on the flood plain of the Little Miami river near Gwendolyn, is shown

tion, bordering all rivers, except along under-cut banks, and extending up smaller streams to their upper limit of flood plain formation (cf. fig. 23). It consists most commonly of small willows and cotton-woods, but in many places other trees may enter in, among which are sycamore, white elm, box elder (Acer Negundo), and silver maple (Acer saccharinum). In the succession shown in fig. 42, this zone is made up of willows and poplars showing the same banding that was noted in the first zone. The trees here are from eight to ten feet tall. Herbaceous plants are fairly abundant and are a mixture of beach herbs with those of later associations.

Competition becomes keener with the increase in size of individuals. A large number of the trees which started die out; and those remaining are standing farther apart. Banding, even if it did once exist, is not apparent in later stages of the succession.

c. In the next association, the third flood plain zone, fig. 43, willow and poplar do not everywhere hold the ascendency in numbers that was once theirs. Silver maple is now proportionately more abundant than in the two previous zones. This is an association of small flood plain trees. The compact growth of the second zone, which was due to the bushy character of its trees, is now gone. Here there is very little herbaceous or low woody growth. A few plants of wood nettle





growth. The ground is covered with herbaceous plants, growing in dense patches of single species. The most abundant of these are the wood nettle (Laportea canadensis), touch-me-not (Impatiens pallida), skullcap (Scutellaria laterifolia), and in sunny spots, the giant ragweed (Ambrosia trifida). Saplings are not uncommon in this association, but because of the dense shade, willow, poplar, and sycamore are almost excluded. White elm and box elder are frequent, and sugar maple (Acer saccharum) occasionally occurs. This last is the first indication of an advance toward mesophytic conditions.

This association, in various aspects, is the most widespread of any of the flood plain formation. It often occupies a number of successive levels, very slowing changing toward a more mesophytic forest, as the flood plain is built up. On some of the broadest flood plains, it is capable of further subdivision on a basis of age, and the character of its herbaceous growth.

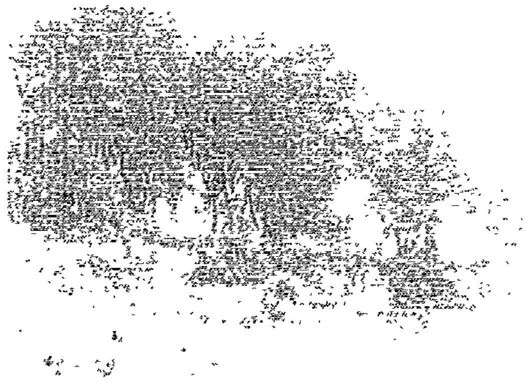
e. The next zone of the flood plain formation is not of the same character along all the streams. Much depends on the history of the valley and on its topography.

e,1. In the area shown in fig. 41, the fourth zone is the last that is typical of floodplains. The next zone occupies the lower slopes of the hills. It is a zone only reached by exceptional floods, as those of March, 1913. Its trees are a medley of flood plain types, slope xerophytes, and mesophytes. Here are found hackberry (Celtis occidentalis), walnut (Juglans nigra), honey locust (Gleditsia triacanthos), red elm (Ulmus fulva), red-fruited thorn (Crataegus mollis), and buckeye (Aesculus octandra), with the last remaining trees of the flood plain, white elm and box elder. Among the saplings, sugar maple (Acer saccharum) and wild cherry (Prunus serotina) are abundant, with a few of the other trees. Herbaceous plants are very scarce in this zone, possibly because of the erosive work of the floods. Succeeding associations do not belong to the flood plain formation. This mixed zone is the last which shows any indication of connection with the depositional phases of river activity.

e,2. With slight modifications, the succession just outlined is characteristic of most of the flood plains of the region. Along the Miami, however, is found a different and later stage in the flood plain succession. Much of the flood plain area of that river lies at a level which is very rarely flooded; some of it above the level of the highest floods of historic times. The forest found here is not that typical of the lower flood plains. On this high-level flood plain, is a mixed mesophytic forest in which are found white elm (Ulmus americana), bitter nut (Carya cordiformis), sugar maple (Acer saccharum), wild black cherry (Prunus serotina), walnut (Juglans nigra), black ash (Fraxinus nigra), red ash (Fraxinus pennsylvanica), and oaks (Quercus macrosarpa, Q. imbricaria, Q. alba, and Q. rubra). The white elms are large and as before stated, are among the last of the typical flood plain trees to persist. Of the other trees, Quercus macrocarpa (bur oak) and Carya cordiformis are particularly characteristic of high-level flood plains, both of rivers and small streams. Although this mixed mesophytic forest of the high-level flood plain differs from the erosion climax forest in some respects, it resembles it more closely than it resembles any other forest in the region. It is probably a fore-runner of that forest.

The most complete successions are found on the inside of broad curves of the rivers. In such places, the rivers are essentially depositing streams, and their flood plains are constantly being built upward and outward. It is this constant addition to the flood plain, which permits of the gradual advance of flood plain vegetation.

Even the mature flood plain forest is not always permanent. In the course of its wanderings on the flood plain, the river may destroy the land it has built up, and the trees that have grown upon it. On the Miami and Little Miami rivers this process is not slow. On under-cutting parts of the flood plain, many trees are destroyed each year. Across the river from the very complete flood plain formation shown in figs. 41



V. Terraces and Filled Valleys

Terrace associations may be grouped into two classes, the associations of gravel terraces, and the associations of sand and silt terraces, each dependent on the physical character of the terrace material. Between these two classes, there are a number of intermediate forms, for the terrace materials intergrade.

A. Gravel Terraces.

Gravel terraces are limited to a few small areas. Most of these lie along the Miami and Little Miami rivers. Because of their very favorable situation above the reach of floods, and their nearly level surface, the terraces have been cleared for many years, and it is only in a few spots that any of their original vegetation remains.

1. Forest associations.-- A few large trees remain upon the terraces. These are usually beech, but here and there is an occasional wild black cherry or sugar maple. From these few remnants it would appear, that the original forest of the gravel terrace was dominated by beech, and probably resembled the beech forest of the upland. Near the top of river bluffs or of ravines in the terrace, the mesophytic forest is replaced by one resembling the forests of the margins of uplands. Red oak, white oak, chestnut oak, and sometimes red cedar replace the

mesophytes of the level terrace.

2. Clearing associations.-- Most of the clearings are occupied by a dry meadow association different from that found in any other location. Wire grass (Poa compressa) is the most common grass, except in some of the older clearings, where Kentucky blue grass (Poa pratensis) almost supercedes it. Saplings are usually scarce, and represented only by a few red elms, locusts, and red cedars. It is among the herbaceous vegetation that the characteristic plants are found. Kuhnia eupatorioides, Verbena stricta, Arabis Drummondi, Pentstemon hirsutus are the most characteristic. With these, some other wide spread herbs occur.

These cleared fields are covered with the layer of soil which has accumulated since the deposition of the gravels. Although xerophytic, they do not present the extreme conditions of dryness of exposed gravels.

Gravel pits are very artificial habitats, but possibly they present conditions somewhat parallel to those existing before the accumulation of the soil cover. The material is so coarse and loose, that almost no water is retained near the surface. In no place, except on under-cut gravel bluffs or on bare rock, are conditions of equal dryness found. Only the most extreme xerophytes can exist. Even these are not abundant. The association is an open one. The ordinary xerophytes

and walnut. Tulip, in one instance, becomes the facies, constituting nearly 80 per cent of the tree growth.

The undergrowth of this mesophytic forest of the terrace is relatively dense, consisting of saplings of the trees noted, with summer grape (Vitis aestivalis), poison ivy (Rhus Toxicodendron), spice bush (Benzoin aestivale), and mesophytic herbs, among which blue violet (Viola papilionacea), waterleaf (Hydrophyllum appendiculatum), black snakeroot (Cimicifuga racemosa), richweed (Pilea pumila), Joe-pye weed (Eupatorium purpureum), and white snakeroot (Eupatorium urticaefolium), are abundant.

The sand and silt terraces differ from those of gravel, in that they lack the usual xerophytic margin of the latter. The trees of the flood plain are followed immediately by the mesophytes of the terrace, even where there is considerable difference in the altitude of the flood plain and the terrace.

Clearings on these terraces have nothing characteristic about them. The associations are not extremely xerophytic, as are those of gravel terraces, and the characteristic herbs of the latter are not found on these sand and silt terraces.

C. Filled Valleys.

The pre-glacial valley of the Ohio, which is partially filled with deep glacial deposits, is divisable into three parts, differing somewhat in soil features and plant associations. One of these, commonly known as the Norwood trough, extends from the Little Miami in the vicinity of Plainville and Red Bank to Mill creek. This part of the valley is filled with deposits of Illinoian age, covered with a thick mantle of loess.

A second portion of this valley, includes the upper part of Mill creek valley from about Hartwell northward to Hamilton, and the belt of low hills on the west side of the valley. The hills are of Wisconsin till, the valley filled with undifferentiated glacial deposits.

A part of the former valley of the Ohio, which is not included in the present discussion, is now occupied by the Miami river, from Hamilton almost to New Baltimore. Nothing but recent alluvium is exposed in this valley, and its associations belong almost entirely to the flood plain series. The remainder of the valley, extending from the Miami in the vicinity of New Baltimore westward to the Whitewater river, is filled with till of Illinoian and Wisconsin age.

In general features, the vegetation of all filled valleys is similar.

1. The Norwood trough.--

Pond-swamp-meadow associations; hydrophytic forest.-- A few depressions are found in the Norwood trough, which are usually smaller, but more decided than those of the upland. These not uncommonly contain shallow ponds of small size in which the only aquatic plants are algae. They are bordered by the usual marginal plants-- buttonbush (Cephalanthus occidentalis), bitter cress (Cardamine pennsylvanica), poison ivy, and sedges. There is no gradation between the depression vegetation and that of t e surrounding area. A swamp may succeed the pond, by the closing in of the marginal vegetation, but this is not succeeded by meadow. The area is too small, and usually so well shaded, that the plants of the surrounding forest can occupy the area as soon as it is dry enough. Occasionally, there are a few hydrophytic trees around the depression. These are the same as found on the uplands-- Nyssa sylvatica, Quercus bicolor, and Q. palustris.

Parts of the Norwood trough are flat and undissected. Drainage conditions are therefore poor and a wet meadow association prevails. This is especially true in the vicinity of Norwood, where the divide between east and west drainage lies. Little of the natural vegetation remains here, and it is difficult to say what did cover this area. Clearings are much like the wet meadows of the upland. A few scattered pin oak and shell-bark hickory trees indicate that the forest of undrained portions of the valley may have resembled the hydrophytic forest of the upland.

Forest associations.-- The relief is never great and ravine slopes in the clays are usually gentle. The forests

slopes of surrounding hillsides, usually to the top of the gentle slope of the till. It is in strong contrast to the oak forest of the rest of the hillside. The view across the Norwood trough (fig. 47) shows a number of forested areas in the valley, in all of which, beech is dominant. The beech forest is also seen on the lower slopes of the hill in the foreground. The oak tree in the left foreground higher up this hill, is a remnant of the oak forest characteristic of rock slopes.

It is only along the crests of narrow divides, or upon unusually steep slopes, that the beech forest is superceded by a xerophytic or mixed forest. Such areas are, however, always small.

2. Upper Mill creek valley area.--

The valley.-- A part of the broad flat valley of upper Mill creek is covered with recent alluvium, and belongs to the flood plain area. In the rest of the valley, glacial deposits are at the surface. Nothing of the original vegetation of this part remains. It is all farm land.

The glacial hills.--The low glacial hills along the western side of the valley are a continuation of the morainal hills of the upland. In origin and topography, they are related to these. In situation within an old filled valley, they are a part of the latter. Their vegetational features are to some extent a combination of those of both areas. Their slopes are always very gentle (3 to 8 degrees), their tops broad and rounded.

Unlike the forests in the Norwood trough, which are mesophytic whether on ravine slopes or on flat areas, the forests on the slopes of these hills are always less mesophytic than those on their almost flat tops. A general view over this area gives somewhat the same impression as a view over the Norwood trough. For the area as a whole, beech is the dominant tree. A closer examination shows that beech occupies the tops and the longest and gentlest slopes of the hills and mush of the space between the hills. With the beech on the tops of the hills, are other trees, the most important of which are sugar maple (Acer saccharum), big shell-bark hickory (Carya laciniosa), white oak (Quercus alba), and red oak (Q. rubra). On steeper slopes, beech is absent, and then the above mentioned trees are relatively more abundant. On the flats between the hills, the hickories (Carya ovata, C. alba, and C. cordiformis), bur oak (Quercus macrocarpa), and white ash (Fraxinus americana) occur with beech.

Many of the streams in this area wander among the hills, finding rather than making their valleys. The larger streams which cross the area have, however, cut fairly deep valleys in the till. These valley slopes, though gentle (6 to 10 degrees) are not clothed with beech forest, as was the case on ravine slopes in the Norwood trough. In fact, beech is always entirely absent, for the porous soil of this gravelly till drains readily. The forest here is composed of oaks (Quercus Muhlenbergii, Q. velutina, Q. texana, and Q. alba), sugar maple, walnut, and white ash. A short distance back from the edge of the ravine slopes, beech is again dominant.

3. The Miami-Whitewater valley.-- Much of that part of the Miami-Whitewater valley, covered with till of Wisconsin age, is quite flat. Streams start in indefinable depressions much as do those of the flat uplands. Their margins are swampy and they are bordered by willows (Salix nigra and S. longifolia), cat-tail (Typha latifolia), ditch stonecrop (Penthorum sedoides), swamp milkweed (Asclepias incarnata), monkey flower (Mimulus ringens), and boneset (Eupatorium perfoliatum). The woods are similar to the mixed forests of the uplands, and bear little resemblance to those of other parts of the valley. Sugar maple and white oak are most abundant, and with them are a few shell-bark hickory (Carya ovata), bitternut hickory (C. cordiformis), and sour gum (Nyssa sylvatica).

The parts of the area which are sloping are much less mesophytic than are slopes in the Norwood trough, and a little less so than those of the hills of Mill creek valley. Here an oak woods prevails (Quercus Muhlenbergii, Q. alba, Q. velutina), in which sugar maple and hickory (Carya microcarpa) are usually secondary species.

The most striking feature of this area is the absence of beech. It is found neither on the flats nor on the slopes. Although a few hydrophytic trees occur in the forests of the flats, the rest of the forest and the undergrowth are more xerophytic than upon similar topographic situations in the Norwood trough or in Mill creek valley. This difference may be accounted for partly ~~partly~~ by the absence of loess in this area of the Miami-Whitewater valley, and partly by the different natures of the drift deposits.

The loess, which covers the Illinoian till in the Norwood trough, is an exceedingly fine-grained material, holding an abundant water supply. Thus it ameliorates conditions on slopes making it possible for mesophytes to grow where otherwise they could not grow. It has the same effect on flats, of increasing the moisture content of the soil, especially where underlain by an impervious material, as the Illinoian drift. Although drainage conditions are usually good, the water content is high. Where the loess is absent, the water supply, though not necessarily always lower, is less constant.

The drift deposits of the Norwood trough and Miami-Whitewater valley, because of their different physical character, affect differently the moisture content of the soil. The more impervious till is also the one covered with loess. In the

Norwood trough, the two materials therefore combine their effects.

A comparison of that part of the Miami-Whitewater valley covered with Wisconsin drift, and the upper Mill creek valley, shows little difference in the nature of the soil. Loess is absent from both areas, and in both places, Wisconsin till forms the subsoil. In the first area, the material is partly water-laid and almost everywhere gravelly. The low hills of Mill creek valley were formed by the ice, and the drift, though less impervious than the Illinoian, is nevertheless relatively compact. For this reason, the water supply in the till of the Miami-Whitewater valley is apt to be less constant than that in the glacial hills of upper Mill creek valley, and the associations therefore less mesophytic.

VI. General Conclusions and Summary.

It has been shown that the plant formations of the Cincinnati region are closely related to its topography. The four principal topographic areas-- uplands, slopes, flood plains, and terraces-- are also, to a large extent, soil areas. Each exhibits its own plant associations, dependent, as has been shown, primarily upon topography and its changes, and only secondarily, upon the soil.

Soil influences may be overcome by topographic conditions. Dissimilar topographic forms, in the same soil, are occupied by different plant associations. Similar topographic forms, in different soils, support plant associations which are related to one another. Although the vegetational features of young bluffs in gravel, rock, and clay differ from one another in many respects, they are more nearly related to each other, than are the associations of a gravel bluff and a gravel beach. Numerous examples point to the conclusion that topographic influences are usually more powerful than soil influences.

In most of the region, there is some relation between vegetational and geological areas due to the influence of soil. Fresh exposures of gravel, rock, and clay are more different from one another, than are weathered ones. For this reason, the differences between the vegetation of different soil areas are more pronounced early than late in the succession.

Soil has an indirect influence on vegetation through its effects on topographic forms. Resistance or ease of erosion of rock material retards or accelerates the progress of the erosion cycle, and with that, the vegetative cycle dependent upon it. The effects of difference in resistance are best disclosed where two materials, in contact, are acted upon by the same agent. These effects may be seen along a stream which cuts through two or more unlike materials. The differences in the associations along such a stream are partly due to differences in topography arising as a result of differences in the ease of erosion of the soil. The associations, as existing along that stream, do not illustrate exactly the succession of associations at any one place, for this is modified by the soil of the area in which the succession occurs.

In some instances, topography and the physical character of the soil, together produce the plant association. An undissected flat is usually a poorly drained area. If, added to the absence of drainage lines, the soil is of such a nature that it drains slowly, the features of bad drainage will be more pronounced, and the plant associations which depend upon poor drainage for their existence, will be better developed.

Both xerarch and hydrarch successions are illustrated in the Cincinnati region.

The xerarch successions embrace those of dry flats, whether on upland or terrace, and of slopes, whether of rock, gravel, or clay. The successions on dry flats are relatively rapid. They are dependent for their advance upon biotic agencies. Topography is as yet little changing. Erosional features are almost absent. Biotic cycles are not complicated by the progress of a topographic cycle(see Cowles, 1911).

The successions on slopes are slow and varied. They are produced by a combination of biotic and topographic agencies. Of these successions, that on rock bluffs is the slowest and includes the greatest number of stages. Soil or rock is here influencing the succession, because of its resistance to erosion, and its effect on soil water.

Hydrarch successions are of two kinds, those of undrained and those of drained situations. The former are exhibited in three widely different topographic situations, namely, on uplands, in filled valleys, and on flood plains; the latter, which is the typical flood plain succession, along the margins of streams. During the hydrophytic stages, these two kinds of successions are characterized by different types of vegetation.

The hydrarch succession of the upland depends upon topography and soil. An undissected flat, combined with an impervious soil, produces the moist conditions necessary to the growth of hydrophytes. That soil is an important factor in producing these conditions, may be learned by comparing flats having different soils. Hydrophytic associations are best developed on uplands covered with a relatively thick deposit of Illinoian drift. Where this deposit is very thin or absent, and only the loess (white clay) reaches its usual thickness, as in the southern part of the region, decidedly hydrophytic forests are not found. Only a few hydrophytic trees occur in an otherwise mesophytic forest. South of the limits of glaciation and the extent of loess, wet upland flats appear to be uncommon. Owen (1857) mentioned the "soggy beech flats" in Fayette Co., Ky. There, as in this region, they seem to be intimately related to soil conditions, i. e. the substratum is composed of fine-textured mudstones and shales, which produce a poorly drained soil. On comparing an area covered with till of Illinoian age with one covered with the Earlier Wisconsin, a similar, though less pronounced difference is seen. Thus the imperviousness of surface material on the uplands modifies the character of the vegetation through its effects on soil water.

The hydrophytic associations of the filled valleys are similar in character and causal relations to those of the uplands.

The depression hydrophytic forests of the flood plain occur in habitats formed by streams, but now removed from the influence of their activity. Soil is not the important factor here. Low situation in combination with undrained conditions determines their existence.

The typical flood plain succession is a direct result of stream action. Changing topography is the chief cause of the progress of the succession.

All successions in the region, whether xerarch or hydrarch, in whatever topographic situation they may be, are progressing toward a mesophytic forest. The relatively short successions on a topography as yet unchanging, and the long and varied successions on ever changing topographic forms, all lead to a mesophytic forest-- a climax forest. The climax mesophytic forest exists in two distinct forms. One is the beech forest of the uplands and filled valleys, the forest developed on an unchanged or very youthful topography. The climax of the vegetative cycle precedes, or accompanies the initiation of the erosion cycle. This beech forest is the pre-erosion climax.

The second form of the climax forest is the mixed mesophytic forest of gentle slopes. All long successions dependent on topographic changes lead to this forest. The successions in ravines, the successions in progress on flood plains, both end in a mixed mesophytic forest. Both depend on topographic change, the first on stream degradation, the second on stream aggradation. The climax of these vegetative cycles follows a period of erosive activity. Ot comes within an erosion cycle. This mixed mesophytic forest is the erosion climax.

The pre-erosion climax forest of the Cincinnati region resembles the beech forests of northern Ohio and of Michigan. Its closest affinities are northward. The erosion climax forest resembles the deciduous forest of the Southern Appalachians. It is poorer in variety of trees, but it has much in common with the southern forest. Northern and southern forest types here occur side by side.

The pre-erosion climax forest is temporary. It can endure only as long as the pre-erosion topography. The

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