

# A GEOLOGIST LOOKS AT THE NATURAL VEGETATION MAP OF OHIO<sup>1</sup>

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## ABSTRACT

Boundaries on the new map of the *Natural Vegetation of Ohio* by Gordon (1966) neatly follow, in most places, geologic boundaries. Where this is not true, conditions controlling this distribution are either aspect, microclimate, or the result of some as-yet unrecognized variation in the geology.

Vegetation-geology correlations may be generalized as follows. *Beech* (-maple) forests occur on better drained Wisconsin till and in outwash-free valleys in eastern Ohio. *Oak-sugar maple* forests occur where the geological substrate is moist enough for sugar maple, but not for beech. *Mixed mesophytic* forests occur on shale and on north-facing slopes in unglaciated eastern Ohio, as well as in other areas where a variety of environmental conditions results in a variety of communities, best mapped as mixed mesophytic. *Mixed oak* forests are composed of either dry-site ("dry") species, occurring on south-facing slopes and sandstone hills in unglaciated eastern Ohio and on well-drained gravel deposits in western Ohio, or of wet-site ("wet") species, growing on very flat plains with heavy clay soils. *Swamp forest* is also shown on flat, poorly drained plains, as are prairies, which are mainly "wet". What specific characteristics actually determine whether a flat, poorly drained plain will support prairie, swamp forest, or "wet" oaks are not understood.

Despite these striking vegetation-geology relationships, there is much yet to be learned, particularly in the large-scale refinement of this mapping. With geologists who have learned some plants, and botanists who have learned some Ohio geology, exciting new results are possible which will help to advance both sciences.

## INTRODUCTION

For the geologist well versed in Ohio's bedrock and glacial geology, and with some knowledge of the simpler edaphic relationships of Ohio's common trees, the new map by Robert B. Gordon (1966), *Natural Vegetation of Ohio, at the Time of the Earliest Land Surveys*, is very thought-provoking. Many contrasts in the underlying geology, such as those between bedrock and glacial deposits or between till and gravel materials, are faithfully reproduced on this strictly vegetational map, prepared on the basis of original surveyors' records and with no reference at all to either of the Ohio geological maps (that showing the bedrock—Bownocker, 1920—and that showing the glacial geology—Goldthwait, White, and Forsyth, 1961). A few of these contrasts are also referred to by Gordon in his written report, which appeared somewhat later (1969) than the map. Also in this report, he acknowledges the premise basic to the present paper: "types of natural vegetation should reflect the habitat conditions in which they are found" (Gordon, 1969, p. 74).

Correlation between the vegetation shown and the associated geology is expectable, for what has been mapped is the original vegetation, which has had thousands of years in which to adjust to the underlying substrate. This is not to say that the geological substrate is the only factor affecting the distribution of these trees. On the contrary, it is well known that a variety of environmental factors, including other associated plants, all interact to create the conditions under which the trees grow. Therefore, the striking similarities of the Vegetation Map (Gordon, 1966) and the Glacial Map of Ohio (Goldthwait, White, and Forsyth, 1961) is especially remarkable. And it is with these similarities and their probable explanations that this paper deals.

There are some geological contrasts which are not evident on Gordon's map. In some cases, these vegetational areas contain more than one plant association,

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as outlined in Gordon's 1969 report, though the details of distribution of these associations are not given. In other cases, these absences can probably be explained by similarities in edaphic characteristics of two geologically different substrates, for a difference in geological materials does not always mean a difference in the characteristics of those materials in terms of plant germination and development—characteristics such as available soil moisture, oxygen, nutrients, etc.

There are also some significant vegetational contrasts on this map which do not appear to reflect any major geological boundaries. In most cases, such vegetational contrasts may be explained by factors other than the underlying geology, factors such as differences in topography, slope, and relief, coupled with aspect (the direction toward which a slope faces, relative to the sun and to the prevailing winds). Even here, though, geology is basic, for it is geologic erosion that has produced these contrasts in topography. Consequently, the geologist who is well acquainted with the normal results of geologic erosion and with Ohio's geological history, together with a knowledge of the bedrock and of the glacial materials which make up all the substrates of the state, is capable of seeing a great deal on this challenging new map.

In a few cases, neither the bedrock, nor the glacial deposits, nor the topography appear to explain some vegetational contrasts shown on this map. In these situations, there may well be critical differences in the geologic material which have not yet been recognized by geologists and whose presence may be learned only by reference to this map. It is also possible that the generalization of the original vegetational distribution from the original surveyors' records may in places be misleading or inaccurate. If and when more detailed mapping of Ohio's vegetation becomes available, data based on more detailed analysis of the surveyors' records plus more critical observations of distributions of modern mature plant communities, it will probably be possible to learn even more about local differences in Ohio's geologic parent materials from otherwise unexplainable vegetational boundaries shown on those more detailed maps.

#### *Vegetational contrasts related to the Glacial Boundary and Adjacent Areas*

The most striking line of the vegetation map, geologically speaking, is the strong, relatively straight line extending from Mansfield south through Mount Vernon and Newark to near Lancaster. This line duplicates very closely the boundary of the Wisconsin glacial deposits as shown on the Glacial Map of Ohio (Goldthwait, White, and Forsyth, 1961). It is significant that this line correlates with the Wisconsin boundary, not with the outermost glacial boundary in this area; Illinoian glacial deposits extend farther eastward from here by as much as 10 to 15 miles. This area of Illinoian drift, however, is located on the margin of the Appalachian Plateau, where bedrock is resistant sandstone and shale (Bownocker, 1920), all deeply dissected by streams of the Muskingum drainage system. The deposits left by the Illinoian glacier in this steep, hilly country were all relatively thin and much of what was left has subsequently been washed away. Thus, most of the effective substrate throughout the belt mapped as Illinoian drift is bedrock, like that to the east beyond the glacial boundary. It is only to the west, at the boundary of the Wisconsin deposits (which are thick enough to completely bury the bedrock in most places), that there is a significant change in substrate, and therefore a noticeable change in the original vegetation. To the west of that line are typical till-plain beech-maple forests (called "Beech Forests" on Gordon's map) (Region 8 on Figure 1); to the east of that line are unglaciated mixed oak (Region 24) and mixed mesophytic (Region 26) forests. The importance of the Wisconsin boundary over the Illinoian boundary was also recognized by Braun (1950, p. 307, 312), and by Gordon in his 1969 report: "A major vegetational change (beech-maple to mixed mesophytic or mixed oak) occurs at the Wisconsin drift boundary" (p. 88).

The forests called "Mixed Oak" on Gordon's map are confusing because there are really *two* main kinds of mixed-oak forests, which represent "a wide variety of primary forest types" (Gordon, 1966). In his 1969 report, Gordon identifies and discusses the White Oak-Black Oak-Hickory Association, the White Oak-Black Oak-Chestnut Association, and the Chestnut Oak-Chestnut Association in the Allegheny Plateau areas of eastern Ohio, and, in the west, the White Oak Type on the Cable Moraine and the Oak-Hickory Forests on the flat glacial till plains. Basically what he is doing is separating oaks occurring characteristically on dry

<i>Region</i>	<i>Dominant Natural Vegetation Present</i>	<i>Significant Geology</i>
1.	beech (-maple)	Wisconsin till plain
2.	mixed oak ("dry")-savanna	deep sand
3.	mixed oak ("dry")-savanna	deep sand
4.	mixed oak ("dry")-prairie	dolomite bedrock "high" with sand bars
5.	mixed oak ("dry")-prairie	limestone bedrock "high" with some sand
6.	swamp forest	very flat land with very clayey till
7.	swamp forest	very flat land with till containing much fine clay
8.	beech (-maple)	Wisconsin till plain; ground moraine and end moraines
9.	mixed oak ("dry")-prairie	dolomite "highs" with intervening low marsh
10.	mixed oak ("wet"-some "dry")-prairie	shallow lake basins with limestone bedrock "high" to south
11.	mixed oak ("wet")	very flat land with lake clay and silt
12.	mixed mesophytic	Appalachian north-facing escarpment (sandstone) cut by deep valleys
13.	mixed mesophytic; mixed oak; beech (-maple); oak-sugar maple	Wisconsin till thin (locally thick) over sandstone bedrock
14.	mixed mesophytic	high ridge of resistant sandstone and conglomerate; locally gravel kames in valleys
15.	mixed oak ("dry")	gravel kames
16.	beech (-maple)	Wisconsin end moraine
17.	oak-sugar maple	silt (loess)-covered till (Wisconsin and Illinoian)
18.	mixed mesophytic (western type)	deep valleys in bedrock of limestone and shale
19.	beech (-maple); swamp forest	Illinoian till plain
20.	oak-sugar maple	gravel kames, locally capped by till
21.	mixed mesophytic	mesic slopes in shale capped by sandstone
22.	mixed mesophytic	valleys cut in sandstone capped by till
23.	mixed oak ("dry") (beech (-maple) in valley bottoms)	sandstone bedrock cut by deep valleys
24.	mixed mesophytic	deeply dissected valleys
25.	bottomland hardwood	broad floodplain; silt-filled, high-level, abandoned Teays valleys
26.	mixed mesophytic	mesic slopes on shale
27.	mixed oak ("wet") ("dry" in far northwest); prairie	flat clayey poorly drained till plains; till-capped gravel kames in far northwest

sites from those found in wetter sites. The "dry" group of oaks includes white oak, black oak, chestnut oak (on acid substrates such as sandstone), and sometimes scarlet oak (on especially dry sites and on acid permeable substrate, such as sand or sandstone forming hilltops). These "dry" oaks occur commonly in areas of abundant sandstone bedrock exposures, such as that mentioned above (Region 24), or on hilly, well-drained sand and gravel deposits, such as kames (Regions 2, 3, 4, 5, and 15). In contrast, growing in areas of excessive moisture (and commonly of low soil aeration), are the "wet" oaks—mainly pin oak and

swamp white oak, with red oak where conditions are less wet and provide better aeration. These "wet" oaks occur characteristically on the flat, poorly drained clayey till plains of western Ohio (regions 6 and 23). Sampson (1930, p. 353) associated them, especially pin oak, with "heavy clay soils" and swampy conditions. Also included with these "wet" oaks should be bur oak, for it characteristically grows on the same kind of substrate, though in slightly less swampy sites. Dominantly, however, the bur oak is a prairie-margin species (both in Ohio and farther west), which commonly grew around the edges of and as "islands" ("oak savannas" of Gordon, 1969, p. 62) within Ohio's ancient prairies (most of which were "wet" prairies—Sears 1926, p. 145).

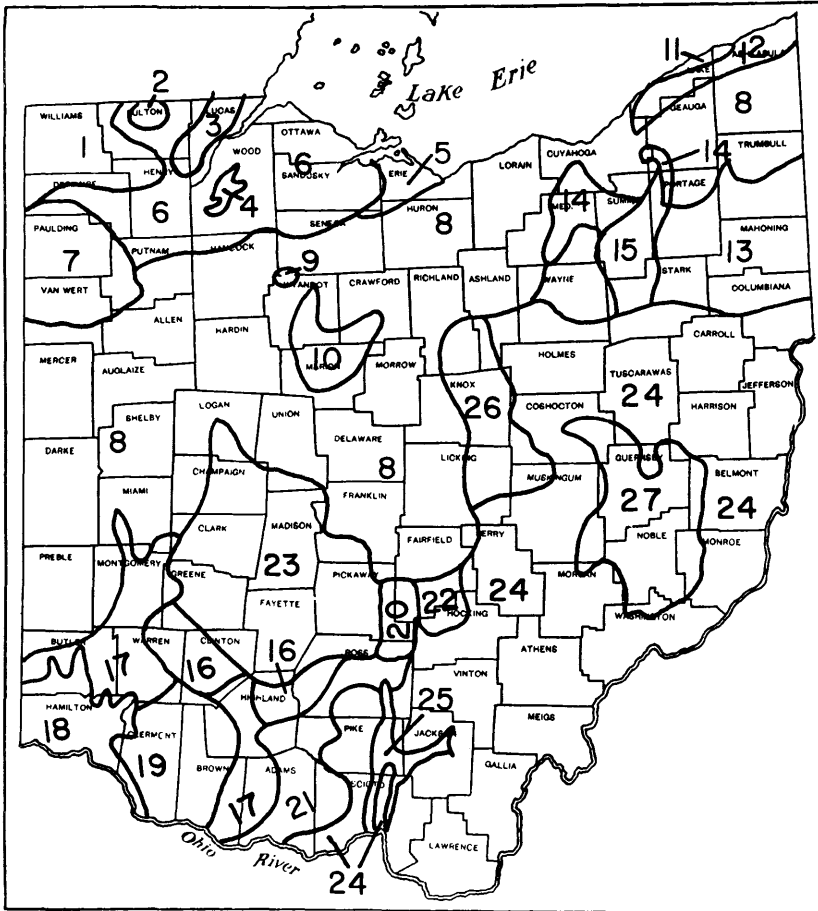


FIGURE 1. Geology of Major Regions shown on Map of Natural Vegetation of Ohio. Key to numbered areas given at left.

South of Lancaster, the major vegetational line continues to correlate with the Wisconsin glacial boundary, but the forests to the west, on the Wisconsin drift, lack beech trees and are mapped partly as mixed mesophytic and partly as oak-sugar maple forests. There appear to be good geological reasons for the presence of these beech-free forest associations inside the glacial boundary. In southern Fairfield County, immediately south of Lancaster and within the area of Wisconsin drift, resistant sandstone bedrock forms high hills cut by deep val-

leys, the glacial material in many places providing only a thin veneer over them. Because of the deep dissection of this sandstone area, with north- and south-facing slopes, plus only local thick deposits of till, it is not surprising that the resulting variety of habitats produces many different plant communities, best mapped as mixed mesophytic forest on the vegetation map (Region 22). Farther west is a broad north-south band of oak-sugar maple. This outlines an extensive area of gravel. Though locally capped by clayey till, the very permeable gravel is apparently everywhere so shallow that soil moisture readily moves down through it, producing a rather xeric surface, too dry for beech but adequate for sugar maple, and especially favorable for the "dry" oaks (Region 20).

In southwestern Ohio (Highland, Clinton, Brown, and Clermont Counties), beech (-maple) forests are shown on Gordon's map on both Wisconsin (Region 16) and Illinoian (Region 19) drift. Here there were no high sandstone hills to impede the advance of the Illinoian glacier and to prevent significant deposition of till by this earlier glacier. In addition, the advancing ice had moved across the easily eroded limestone of western Ohio, and across the clayey till and lake deposits of an earlier glacial age, so that the resulting Illinoian materials are thick and impermeable. The result is a broad area of flat plains throughout much of southwestern Ohio, locally dissected by tributaries of the Ohio River. Some of these plains, within the areas of both Illinoian and Wisconsin drift, are so flat and poorly drained that elm-ash swamp forest occurred, as shown on the vegetational map. Elsewhere shallow valleys improved the drainage, permitting development of beech (-maple) forests. In the region of Wisconsin drift, the higher land of the end moraines provided broad areas of better drainage, allowing extensive development of beech (-maple) forests. The outer edge of the outermost Wisconsin end moraine, the Cuba Moraine, is clearly shown on the vegetation map by a line extending from Martinsville northwest to Clarksville in Clinton County, separating a band of beech (-maple) on the Cuba Moraine to the northeast (Region 16) from swamp forest on the flat, poorly drained Illinoian till plain at its base to the southwest (Region 19).

Broad areas of oak-sugar maple (Region 17) in western Adams County, in a narrow band extending north-south across Highland and Clinton Counties, and in Warren County farther west, may relate to fairly thick (three to six feet) surficial deposits of loess, composed of silt blown eastward, during glacial times, by the prevailing wind from outwash-filled valleys just west of these locations. The small discrete silt grains tend to hold water, but, where the silt occupies an upland situation, water moves through the silt fairly readily, and thus can produce a somewhat drier soil; where the land is lower and less well drained, silt provides a wetter, more poorly drained substrate. The lack of the more mesic beech on the upland areas probably reflects the slightly dryer nature of the silty soil here. In southwestern Clinton County, on the other hand, the thick loess occurs on low, less well-drained Illinoian ground moraine, resulting in swamp forest vegetation.

The relatively large area of mixed mesophytic forest shown in western Hamilton County (Region 18), which, according to Gordon (1966), has a somewhat different composition (with much buckeye, beech, white basswood, and tulip tree) than the more eastern forests called mixed mesophytic, appears to correlate with the only occurrence of Kansan(?) drift in Ohio (Goldthwait, White, and Forsyth, 1961). However, it is unlikely that this difference in the age of the drift explains the character of the vegetation mapped here. Stream dissection in this area near the junctions of the Ohio, Miami, and Stillwater Rivers has produced many deep, steep-sided valleys. Such valleys, with their great variety of moisture conditions and their steep, continually eroding banks, would probably support many different species of trees, producing a tree association best mapped as mixed mesophytic forest. Furthermore, the underlying bedrock in this area consists of alternating layers of limestone and limy shale, the latter of which is so clayey that, on more

gentle slopes, with abundant moisture, it rapidly develops into slippery mud, and, on steeper slopes, it would be so rapidly drained of any moisture that a relatively xeric substrate would result. Thus, both lime-indicator plants and plants able to survive on dry, unstable shale slopes should be present, together with less restrictive plants. Such a great diversity of plant species should presumably best be mapped as a form of mixed mesophytic forest. Gordon (1969, p. 89) explains this: "Ordovician limestone and shales form the bedrock in the Cincinnati region. . . . Oak-sugar maple forest cover is shown on the natural vegetation map where glacial till contains such rock fragments. Elsewhere, the western mixed mesophytic forest and beech-sugar maple forest prevailed at the time of settlement."

In northeastern Ohio, beech (-maple) forests are shown restricted to the Wisconsin deposits (Region 8); the area of Illinoian drift has vegetation like that of the unglaciated region to the south and therefore is not apparent on the vegetation map. The reason is the same as that farther to the southwest—in this hilly area, where resistant sandstone bedrock dominates the landscape, Illinoian deposits were thin and in many places have probably been mostly washed away. Indeed, high sandstone hills are present farther to the north, in the area of Wisconsin drift, where a similar effect is produced, also resulting in a dominance of the local bedrock as the effective substrate (Region 13).

Locally, resistant sandstone and conglomerate (mainly basal Pennsylvanian rock units) form especially high, steep, relatively narrow ridges, which extend as far north as Cleveland. These ridges account for some of the strange patterns of mixed mesophytic forests (Region 14) in southwestern Geauga, southwestern Cuyahoga, and northeastern Medina Counties. The effect is not a simple one, though, for thick till overlies the bedrock in many places, especially on the flat tops of the hills (where it has not subsequently been washed off), and locally at the bases of steep slopes. Mixed mesophytic forests are shown on the vegetation map (Gordon, 1966) on the slopes of these ridges, with oak-chestnut forests, mapped as mixed ("dry") oaks, on the xeric sandstone and conglomerate crests and as beech (-maple) on the till-capped uplands. Gordon (1969, p. 88) also acknowledges the influence of this rock: "the natural vegetation types may change abruptly. Good examples are outcrops of Sharon conglomerate . . . with . . . expressions of the mixed mesophytic forest such as the oak-chestnut-tulip tree association surrounded by areas of the beech-sugar maple forest type over deeper ground moraines and end moraines." In addition, sandstone and conglomerate are very permeable, so that moisture moving down through them may emerge as springs at the bases of slopes, or at the tops of included clay or shale layers. Such moisture is not only remarkably persistent during dry periods, it is also generally cooler (during the plants' growing season) than are normal sun-warmed surface waters. Thus, the types of habitats available in the regions of these ridges are great, so it is not surprising that many species of trees occur, with the result that the mixed mesophytic unit is the only one that could adequately represent the vegetation of these areas.

There is a big area of mixed ("dry") oak (oak-chestnut and oak-history, according to Gordon—personal communication, 1968) in and north of the Akron area (Region 15), occupying most of Summit, northern Stark, eastern Medina, and western and northern Portage Counties. This reflects a large area of gravel deposits in this region: kames occurring in a broad belt extending from the Canton area north to Barberton, Kent, and Burton, and gravel outwash filling a large number of intersecting stream valleys in the Barberton-Akron-Cuyahoga Falls area. Gravel deposits are so very permeable that, except where they stand so low that the water table is near the surface, they provide the most xeric of habitats, which probably explains the absence of sugar maple and beech, and the presence of the "dry" mixed oaks.

*Vegetational Contrasts within Unglaciaded Ohio*

Most of unglaciaded Ohio is mapped as either mixed oak (Region 24) or mixed mesophytic (Regions 26, 27, and 21) forests, the mixed ("dry") oaks occupying the greater extent. This is in accord with the geology, for the bedrock here is dominantly sandstone (with some shale) which, because it is so permeable, permits moisture to percolate on down through it, creating a relatively xerophytic substrate. Locally there is less sandstone and more shale, resulting in more dissected slopes which are less dry and which produce mixed mesophytic forests, especially on the north- or east-facing slopes. Farther west, in the area of the Mississippian formations, shale is also present. Hyde (1953) has shown that the Mississippian Black Hand Formation is sandy and locally conglomeratic in certain areas which he interpreted as deltas, built westward into that ancient Mississippian sea. Between the deltas, especially in the Knox-Licking-Coshocton County area, muddy sediments accumulated along that ancient shore between the deltas, but contemporaneously with the deposition of the deltaic sands, muds which have become the shales of this central Ohio area and which supported stands of mixed mesophytic forest (Region 26). The area of mixed mesophytic forest shown in Noble County and adjacent areas (Region 27) occurs in a deeply dissected area where available moisture is increased by reduction in evaporation in the deep valleys, resulting in mixed mesophytic vegetation.

In the deep valleys of unglaciaded Ohio, where moisture is abundant and evaporation low, beech (-maple) forests are mapped. Only in the more northern part of unglaciaded Ohio (Harrison, Carroll, Tuscarawas, Coshocton, and northern Muskingum Counties) are beech (-maple) forests missing from such valleys. Here valley bottoms are filled with glacial outwash, whose permeability creates a substrate too dry for these mesic trees. It is mainly farther south, in valleys that did not tap the melting glaciers and their outwash deposits, that the river-bottom deposits become more silty and less permeable, and therefore more mesic, permitting the development of beech (-maple) stands.

Along the valley of the Ohio River, beech (-maple) is mapped in some places, bottomland-hardwood forest in other places, and, where the Ohio valley is narrow, upland-type vegetation is shown right up to the river margin. The valley is narrowest in Monroe County, because this was the site of a major preglacial divide; postglacial cutting, since the time of the glacially produced drainage reversal here (Stout, Ver Steeg, and Lamb, 1943), has resulted in only a very narrow valley. Narrow terraces, like those supporting beech (-maple) forests elsewhere, are therefore actually present even here, but the area occupied by the vegetation on these features is too narrow to be shown effectively on a map of this scale.

Bottomland-hardwood forest is shown in several places along the Ohio valley, in the Scioto valley below Circleville, and also in the main abandoned valley of the preglacial Teays River (Region 25) (Ver Steeg, 1946) between Waverly and Wheelersburg, in Pike and Scioto Counties. The floor of this ancient high-level valley, where it has not been too greatly dissected by postglacial streams, is covered by thick silts (glacially derived calcareous silts and clays, locally covered by thin sandy noncalcareous colluvium—Goldthwait, White, and Forsyth, 1961). It is therefore not surprising to find bottomland-hardwood trees reported for this area, despite its higher elevations. North of Waverly, there is no evidence, at the surface, of the old Teays valley. The Teays River flowed to the north and so became lower in that direction; from Waverly north, younger stream deposits and glacial drift bury the ancient valley so completely that, farther north in Ohio, it is recognized only from well logs. Southeast of Waverly, though, the valley is high enough so that the old valley fill forms part of the present landscape and the local substrate (see also Beatley 1959).

*Vegetational Contrasts within the area of Wisconsin Glaciation*

One of the most striking areas on the vegetational map within the limits of the Wisconsin boundary is the large area of mixed oak and prairie lands (Region 23) in the west-central part of the state (the Springfield-Bellefontaine-Columbus-Washington Court House area). This was a region of the "wet" group of mixed oaks—pin oak and swamp white oak especially (and, according to Gordon (personal communication, 1968), hickory, so that much of the area is actually oak-hickory forest, one of the kinds of forest types included under "mixed oak"). The prairies here were wet (Sears, 1926, p. 145), bordered by stands of bur oak and surrounded by mixed ("wet") oak forests. Geologically this is an area of heavy clay soils (soils of the Miami 6A catena) (Forsyth 1965). Land is generally flat and drainage poor, resulting in wet, poorly aerated soils, the substrate characteristically associated with these "wet" oaks (and also with shagbark hickory and elm) (Sampson, 1930, p. 353). Gordon (1969, p. 40) also acknowledges this relationship: "Over the glacial till plains of western Ohio, . . . forests were mainly of the white oak-black oak-shagbark hickory type at the time of settlement . . . where soils were most subject to drought, especially in the late summer."

Farther south in this large area of mixed oak (in Greene, Payette, and northern Clinton and Ross Counties), some areas of more typical swamp forest occur. Swamp forest, "wet" mixed oak (oak-hickory), and wet prairie all occur in swampy areas. What determines which of these vegetational types will actually be present in any such area is not clear to me. Sampson (1930, p. 353) points out that both arboreal types occur in swampy, poorly aerated sites, but that "excessive abundance of pin oak and swamp white oak in the virgin forests . . . seems to have been . . . associated with the occurrence of heavy clay soils." He gives no explanation for this observation, nor have I found any other reason to account for which of the two swamp-inhabiting tree communities will be present. Braun (1960, p. 186) suggests that prairies occur where "climatic limitations (especially low precipitation-evaporation ratios, low relative humidity in summer, and high proportion of growing season precipitation) preclude development of mesophytic forests", but she does not elaborate. Actually, according to Gordon (1969, p. 54-61), the term prairie, as used in Ohio, covers several different kinds of tree-less settings, each distinguished by amount (depth) of standing water, pH of water, whether water dries up in late summer, and vegetational composition of the plants making up the prairie. Why the prairie was present initially is also explored by Gordon (1969, p. 55-61), who quotes a number of sources, and comes up with the ideas that some prairies were present since the retreat of the glaciers (drawn from Sears, 1967, p. 78) and that they were maintained, not by fire or by unusual decreased rainfall or dryer drainage characteristics, but as a result of exposure due to evaporation because of the treelessness (taken from Shimek, 1911). Additional studies on this subject should be of value, both to botanists and to geologists.

In that part of southern Logan County lying south and south-west of Bellefontaine, conditions are different, as acknowledged in a general way by Gordon (1969, p. 37-38). In this particular area, the mixed oaks are the "dry" oaks, which owe their presence to an extensive area of gravel kames and, along the Mad River valley, of gravel outwash (Forsyth, 1956). These permeable gravel deposits produce xerophytic conditions and therefore support the "dry" oaks. Locally, however, the kames are capped with a till cover ten to twenty feet thick, which holds more moisture and should support some of the more mesic oaks and sugar maple. Vegetational correlation with such localized geology, though, would only be revealed by more detailed mapping than is possible on a map of this scale.

Other, smaller area of mixed ("wet") oak, associated with wet prairies, swamp forests, and also oak-sugar maple forest, occur farther north, mainly in Marion and Wyandot Counties (Region 10). Here the prairies generally occur in the



bottoms of what were shallow postglacial lakes, held in on the east and west by low bedrock rises and on the north and south by end moraines. The mixed oaks here seem to occur around the low margins of these poorly drained lake bottoms, but also, in part, in higher areas of shallow limestone, a relationship which is repeated, on a smaller scale, north of Carey (Region 9). The old lake bottoms must have supported the "wet" oaks, but the habitat provided by such limestone "highs" is commonly xeric, because surface water is lost down through the rock along solution openings. Therefore at least some of the mixed oaks of this region are probably the "dry" oaks. It is also possible that the yellow, or chinquapin oak might have been among the species of oak on the bedrock highs where the shallow rock was limestone or dolomite (Braun 1961, p. 123).

The other most striking area on the vegetation map is that of the swamp forest (Regions 6 and 7) in the far northwestern part of the state. Here, extremely clayey soils combine with extremely flat land to produce wet, swampy ground. Before construction of the major drainage ditches about 1870 (Kaatz, 1955), the area was so swampy that it formed a real barrier to travel and settlement—the famous Black Swamp.

One part of the old Black Swamp has heavier soil than anywhere else, although no difference is shown on the vegetation map. This is in Paulding County (Region 7), an area that, at the time of the ancient postglacial lakes (especially Lake Whittlesey), was almost completely separated from the rest of the lake to the east by a ridge, which extended as two narrow promontories in from the north and from the south, almost meeting near Defiance. These promontories were the top of the Defiance End Moraine, most of which had been smoothed and flattened in this area by an earlier, higher stage of the lake (Maumee III), and which had been broken through at Defiance by erosion by an early Maumee River. Only the finest material in the waters of ancient Lake Whittlesey was carried in suspension through the opening near Defiance into this area of quiet water west of the end moraine. Although no difference in vegetation is recorded on the Ohio vegetation map for this area in Paulding County, as contrasted with the remainder of the Black Swamp, the soils are generally much higher in fine clay, a factor which may sometime be recognized, in more detailed vegetational studies in the future, as producing some slight differences in the original vegetation.

The entire Black Swamp area was submerged, before the time of the Black Swamp, by several high, late-glacial predecessors of Lake Erie (Forsyth 1959), held back by a dam of glacial ice in the northeastern end of the Lake Erie basin. Where these lakes flooded over northwestern Ohio, they helped to flatten even more the already glacially levelled land and they also left some local, but rather extensive sand-bar deposits. Most extensive of these sand deposits are those in western Lucas County and adjacent areas, the Oak Openings (Region 3). Similar extensive sand deposits occur in northern Fulton County (Region 2), where their accumulation was concentrated by the presence of the northern extension of the Defiance End Moraine, the till of which is almost completely buried by the cover of lacustrine sand. Less extensive ridges of sand are present farther south, notably near and west of Bowling Green, in Wood County. All the sand deposits south of the Maumee River are characteristically thinner, narrower, and more restricted than are the broad sand accumulations of the Oak Openings and northern Fulton County; Michigan was a better provider of sand than was Ohio, in the days of those ancient lakes.

Where the sand was particularly thick, small steep-sided hills, representing ancient dunes, are also present, formed when the level of the lake first lowered, permitting the sand to become dried out and vulnerable to wind erosion. At the present time, this variation in elevation has a pronounced effect on the soil moisture and therefore on the vegetation. Rain which falls on the sand soaks immediately into this very permeable material. Because the sand lies on a flat

base of impermeable clayey till, the water moves to the bottom of the sand and then remains there, saturating the lower levels of the sand. Where the surface on the sand stands high, as in a dune, the sand at the surface is very dry and xeric, so that the "dry" oaks are the usual tree vegetation. Where the surface on the sand is very low, the top level of the water saturating the sand (the water table) may extend up to or above the surface of the sand, forming a swamp or shallow lake. In places, these wet areas support no trees, only marsh-type herbaceous plants with a few shrubs; these are prairies—the "openings" of the Oak Openings, most of which are far too small to show on the scale of the Ohio vegetation map, though Gordon acknowledges this relationship by mapping "Oak Savannas" (1966) and discussing the oak-grass vegetation here (1969, p. 63-64). The contrasts produced by the variations in topography, thickness of sand, and depth to water table are so very small in scale that only with detailed vegetational mapping could any specific correlation be established here.

Near Bowling Green (Region 4), the buried surface of the underlying dolomite bedrock rises so high, it apparently made a shoal in that ancient lake, causing sand to be deposited around it and to extend as sand bars off to the west-southwest, in the direction toward which the major storm waves moved (especially at times of seiche-controlled high-water levels, produced by northeast storm winds. It is along the higher, dry parts of these ridges that the "dry" mixed oaks occurred. On the low clay flats to either side of the sand ridges was swamp forest, which commonly also included some of the "wet" oaks, especially pin oak. Locally on the flats around the ridges, the moisture pattern was of such a character that wet prairie was present. Why swamp forest was present in some places in this area and wet prairie in others is not clear to me. Some of the prairies seem to have occurred in areas that appear to be very slightly higher than the rest of the land, or where the sand blanketing the clayey till is somewhat thinner, but these relationships are not consistent nor predictable. Perhaps, at least under the conditions that existed when the virgin vegetation was present, these prairie areas were places where, though they were very swampy for most of the year, the soil became too dry during late summer drouths for swamp forest trees to persist, or at least to reproduce successfully. And, once trees were eliminated, the openness, coupled with high evaporation by the wind (and increased insolation) apparently maintained the prairie species (Gordon, 1969, p. 55, including material quoted by him from Shimek, 1911).

The dolomite rises of Wood and Ottawa Counties are mentioned by Gordon (1969, p. 89) as having a mixed oak forest of abnormal character. With the normal mixed oak species, Gordon lists trees commonly associated with shallow limestone or dolomite—chinquapin oak, blue ash, black walnut, and hackberry. None of these areas is large enough to show on the vegetation map (Gordon, 1966). This same combination of trees, together with a strong dominance of sugar maple, characterizes the Erie Islands (Hamilton and Forsyth, in prep.). As on the hills mentioned by Gordon (1969), beech is striking by its absence; apparently such a substrate is too xeric to support it. Another tree on the islands, with a modern dominance almost as great as that of sugar maple, is hackberry. Although this species is believed to be a successional form, it is extremely abundant today and makes up almost the entire tree population of one of the islands (West Sister) (Hamilton and Forsyth, in prep.).

East of Bowling Green are a number of other dolomite bedrock rises, each with an associated series of sand bars or sand beaches. Most of these are too small to show on a map of this scale, but one area, that south of Castalia, in western Erie County (Region 5), is even larger than the Bowling Green area and is shown in some detail. Here again, limestone bedrock stands high, so that the mixed oaks present were probably the "dry" oaks (plus chinquapin oak on this limestone substrate). Farther north, nearer Castalia, are springs (the "blue holes", of

which the south end of the Resthaven Wildlife Area is one), which represent the emerging ends of a buried complex of natural solution-formed pipe-like openings in the soluble limestone, and around which wet prairies occurred (true *fens*, according to Gordon—personal communication, 1968; and 1969, p. 66). The large triangle of prairie, shown extending southwestward from Huron on the vegetation map, is also in an area of sand, sand which was a delta, built out into the ancient high-level lakes (also referred to briefly by Gordon, 1969, on page 89).

On the narrow lake plains of northeastern Ohio, beech (-maple) forests are replaced by other types of vegetation. Mixed ("wet") oak forests on the low flats of the ancient lakes, in Cuyahoga, Lake, and Ashtabula Counties (Region 11), are present because of the poor drainage in the lacustrine silts and clays on that flat land. Just to the south of the areas of mixed oak are stands of mixed mesophytic forest (Region 12) on the north-facing edge of the Appalachian Plateau, which is held up here by resistant sandstone. Vegetation on these north-facing slopes, and in the deep north-going valleys which dissect these slopes, as well as on the large number of substrates available (sandstone, till, etc.), responds to a wide variety of environments, resulting in a mosaic of vegetational types, best represented on this map as mixed mesophytic forest.

Several bogs are shown on Gordon's map, all in the area of Wisconsin drift. This is expectable, for most bogs occupy depressions created by the melting out of blocks of ice buried in glacial deposits (kettle holes); only in the Wisconsin materials are the glacial deposits thick enough and sufficiently unmodified to have kettle holes preserved in them, thus providing sites for the evolution of bogs. Gordon (1969, p. 65 and p. 67-70) discusses some of these in a general way.

#### *General Comments*

From the foregoing discussion, it should be apparent that there is indeed a close relationship between the original vegetation of Ohio, as shown on the vegetation map (Gordon, 1966), and the underlying geology, a relationship that Gordon (1969, p. 83-89) acknowledges rather briefly. Existing knowledge does not yet, however, provide answers to all the differences in vegetation. Detailed studies, both by geologists aware of plant associations and by botanists acquainted with Ohio's geological materials, should provide many more individual correlations, which should, in turn, lead to additional general interpretations. And from these new interpretations may come new inferences about both vegetational distributions and as-yet-unrecognized variations in the geological deposits.

The study of these relationships is of value to both geologists and botanists. But, in order to obtain dependable data, it is essential that more geologists become better acquainted with Ohio's plants, and that more botanists develop a working knowledge of Ohio geology. The publication of this map showing the natural vegetation of Ohio is undoubtedly one of the most exciting steps forward toward this goal and it is hoped that the challenge of solving more of the relationships between the plants and their substrates, both at the scale of this map and in more detail, will be met by increasing numbers of Ohio's scientists.

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