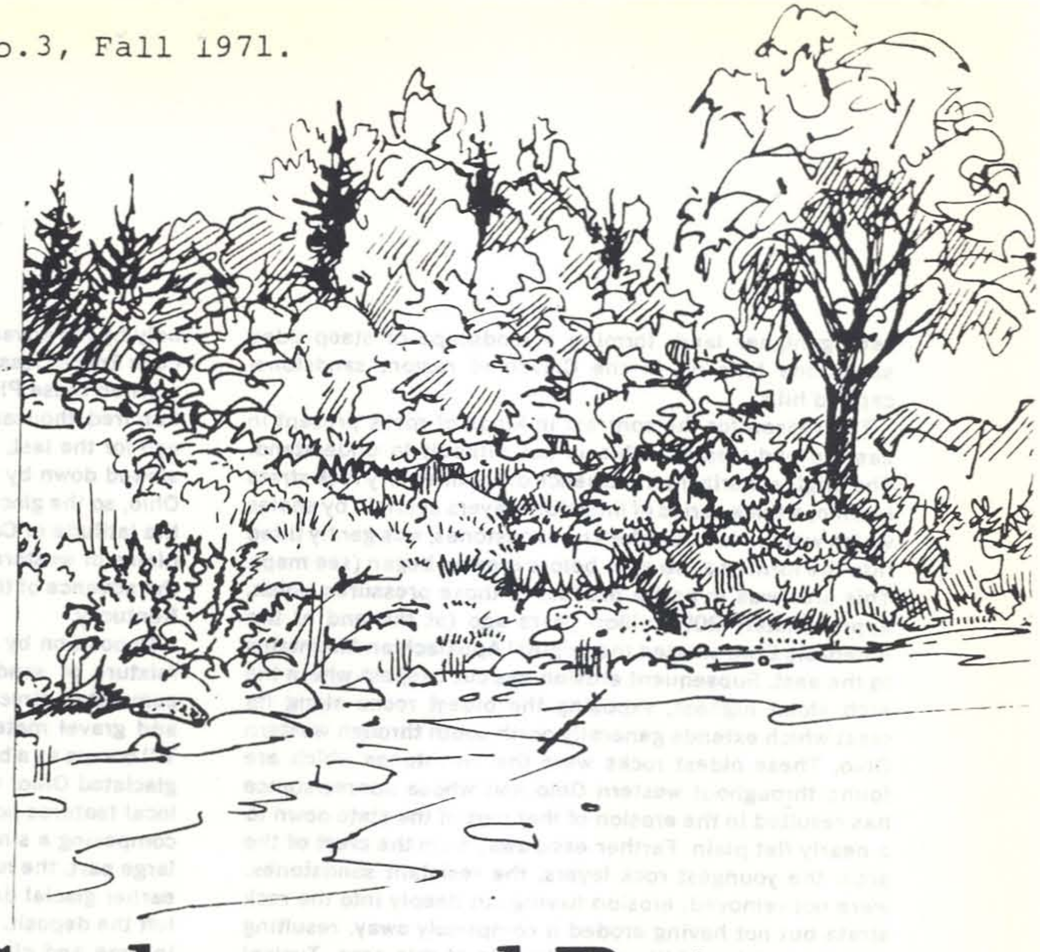
from The EXPLORER, v.13, no.3, Fall 1971.



Linking Geology and Botany ... a new approach

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THE BACKGROUND . . .

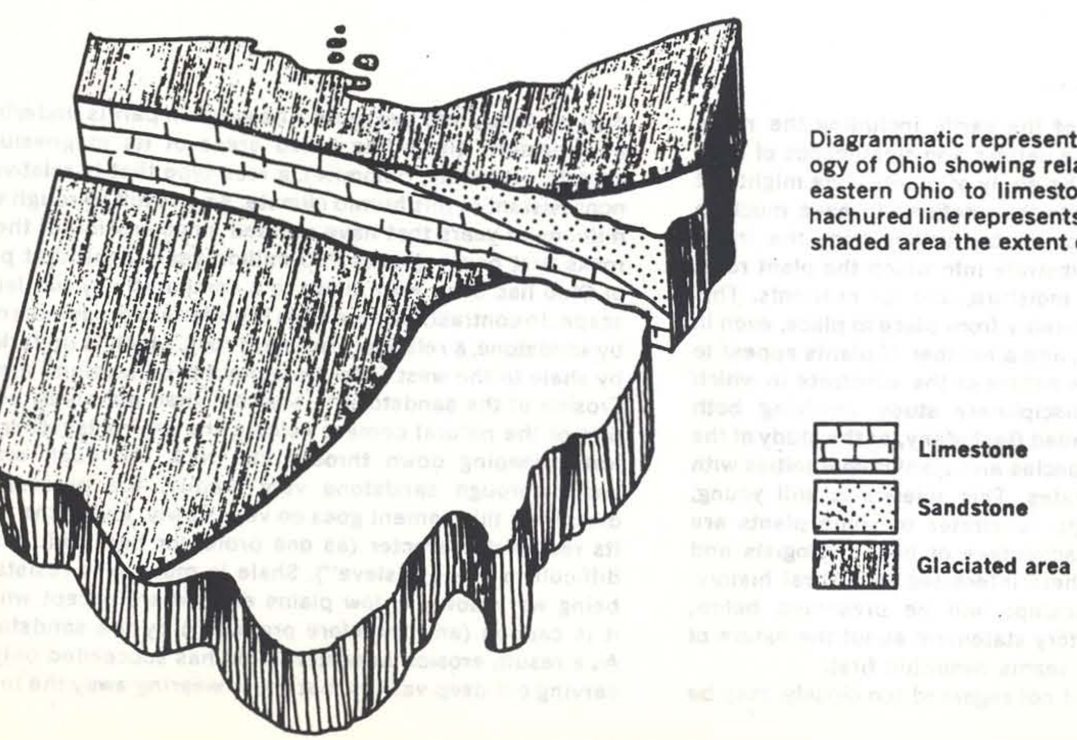
Geology is the study of the earth, including the rocks which compose it and the pattern and significance of their distribution. **Botany** is the study of plants. One might not expect these two subjects thus defined to have much in common, but nothing could be farther from the truth. Geology provides the substrate into which the plant roots extend for support, for moisture, and for nutrients. This substrate differs considerably from place to place, even in an area the size of Ohio, and a number of plants appear to be "choosey" about the nature of the substrate in which they grow. The interdisciplinary study involving both geology and botany is called **Geobotany,** or the study of the relationships of plant species and plant communities with their associated substrates. This science is still young, but already the geologic substrates of some plants are known, to the mutual advantage of both geologists and botanists as well as others interested in natural history. Some of these relationships will be presented below, though a brief introductory statement about the nature of Ohio's geologic setting seems desirable first.

The geology of Ohio, if not regarded too closely, may be divided neatly into two parts. The western part is underlain by limestone (including broad areas of its magnesium-containing variety, dolomite), a rock type that is relatively nonresistant in this humid climate. As a result, through the millions of years that have elapsed since erosion of these rocks first began (about 200 million years ago), that part of Ohio has been worn down to a comparatively flat landscape. In contrast, eastern Ohio is underlain predominantly by sandstone, a relatively resistant rock, which is underlain by shale to the west (and throughout the Cleveland area). Erosion of the sandstone is accomplished mainly by solution of the natural cement holding the grains together by water seeping down through the rock. Although water seeps through sandstone very readily, the process of dissolving this cement goes on very slowly, giving the rock its resistant character (as one professor has said: "It is difficult to erode a sieve"). Shale is much less resistant, being worn down to low plains everywhere except where it is capped (and therefore protected) by the sandstone. As a result, erosion in eastern Ohio has succeeded only in carving out deep valleys, but not in wearing away the intervening higher land, forming a landscape of steep-sided sandstone hills or, in the Cleveland region, sandstone-capped hills.

The reason for the contrast in kinds of rocks present in eastern and western Ohio is not difficult to understand. The original horizontal sequence of sedimentary rock strata in Ohio, a thick series of limestone layers overlain by shales which were in turn overlain by sandstones, was gently tilted into the form of a low arch before erosion began (see map). This arch was in part a product of those pressures which, approximately 200 million years ago (at the end of the Paleozoic Era), created the original Appalachian Mountains to the east. Subsequent erosion has cut deepest where the arch stood highest, exposing the oldest rocks along its crest which extends generally north-south through western Ohio. These oldest rocks were the limestones which are found throughout western Ohio and whose nonresistance has resulted in the erosion of that part of the state down to a nearly flat plain. Farther east, away from the crest of the arch, the youngest rock layers, the resistant sandstones, were not removed, erosion having cut deeply into the rock strata but not having eroded it completely away, resulting in the sandstone hills characteristic of this area. Typical of the Cleveland region, where the sandstone is underlain by shale, are the flat-topped uplands held up by sandstone, alternating with deep steep-sided valleys cut into the underlying shale. Most of this erosion of all the limestone in western Ohio and of the shale and sandstone in the east was accomplished by a famous preglacial stream, the Teays (pronounced "Taze") River. This river, together with its tributaries and contemporaries whose routes across Ohio are shown on a map in Bulletin 44 of The Ohio Geological Survey, was present in Ohio for a very long time—about 200 million years. As far as we know these streams continued to erode the land throughout the entire length of that long interval of time; their activities were curtailed only by the advance of the glaciers of the Ice Age (Pleistocene Epoch) less than a million years ago.

When these Pleistocene glaciers invaded Ohio only a few hundred thousand years ago or less (only 20,000 years ago for the last, or Wisconsin, advance), they were greatly slowed down by the steep-sided sandstone hills of eastern Ohio, so the glacial boundary there is no farther south than the latitude of Canton. In contrast, on the broad limestone plains of western Ohio, where there was nothing to hinder the advance of the ice, it extended as far south as northern Kentucky.

Deposition by the glacier was of two kinds: an unsorted mixture of sand, silt, clay, and boulders called *till*, accumulated directly by the melting of the ice, and the sand and gravel materials deposited by the glacial meltwater. Till occurs as a broad, continuous blanket over almost all of glaciated Ohio, whereas the sand and gravel deposits are local features occurring only within a single river valley or composing a single hill. The composition of till reflects, in large part, the nature of the geologic materials (bedrock or earlier glacial deposits) over which the glacier moved that left the deposit. Thus in western Ohio the glacial till is rich in lime and clay, products of the glacial abrasion of the limestone bedrock. In eastern Ohio, on the other hand, most of the till contains very little lime and clay, although near the margins of the area of sandstone hills, where the ice moved from limestone bedrock onto sandstone, the till is higher in both lime and clay than it is elsewhere in eastern Ohio. Glacial sand and gravel deposits representing mostly materials washed out beyond the glacial margin (*outwash*) also reflect the local bedrock in part, though limestone pebbles are found in diminishing numbers with increasing distance from the source area of limestone bedrock. Hills of gravel are also present locally, occurring in considerable numbers in some places such as the Massillon-Akron-Kent region.

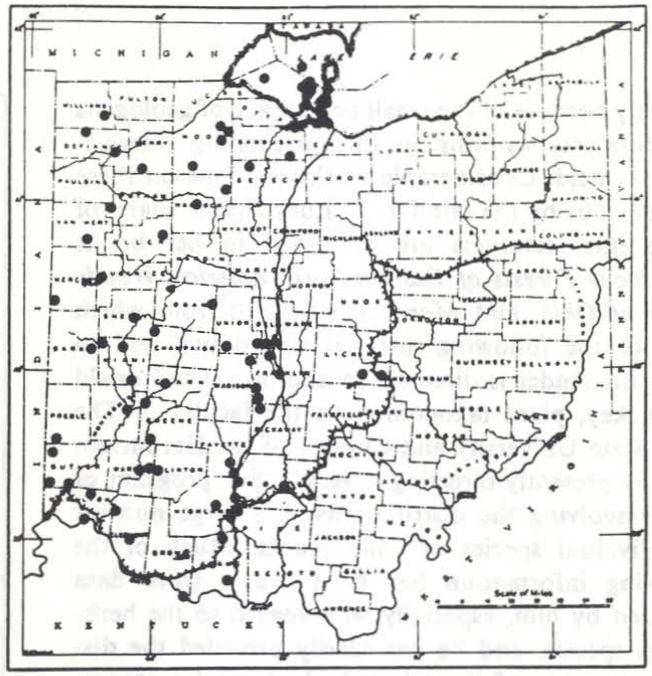


Diagrammatic representation of generalized geology of Ohio showing relationship of sandstone of eastern Ohio to limestone of western Ohio. The hachured line represents the glacial boundary, the shaded area the extent of glaciation.

Based on this rather cursory summary of Ohio's general geology, some basic substrates for plants become obvious. On the plains of western Ohio the most common substrate is limy, clayey till which provides a relatively impermeable soil, high in lime but poorly drained and inadequately aerated. On this soil, water does not soak in very fast but tends to remain on the surface, creating low oxygen availability during wet periods and bad drouths during dry spells. The supply of plant nutrients here is comparatively abundant. Where the glacial till is thin or absent, a condition encountered only locally, the soil on the limestone is generally very shallow, very high in lime, rich where it is not too thin, but very dry due to excessive drainage down through the natural solution openings (or "cavelets") in the soluble limestone.

In eastern Ohio on the other hand, the very permeable sandstone bedrock, where it is exposed, produces a very acid, low-nutrient substrate which is especially dry on the tops of the hills. Locally the sandstone crops out at lower elevations. Here, though it is also acid, it provides a supply of moisture that is continually both available and cool because it comes from springs, the water of which has percolated down through the permeable sandstone and emerged deep in the valleys without being sunwarmed. The shale present beneath the sandstone in some areas also produces a generally acid low-nutrient substrate. However, unlike the sandstone, it is impermeable. As a result surface water tends to run off rather than soak in, making it an especially drouthy substrate during prolonged dry spells. In addition shale may be present as layers within the sandstone; where this happens, the cool acid water moving down through the sandstone cannot extend deeper and emerges on the hillsides as springs. Where the sandstone is mantled by till, the amounts of clay and lime in the till result in less acid, more moist, and more nutrient-rich soils. The till which occurs near the margins of the sandstone area contains greater amounts of clay and lime, resulting in substrates more like those formed in the till of western Ohio.

Glacial gravels are the most permeable of all substrates so water availability is not determined by the composition of these materials, but by their relative elevation. Gravels at low elevations are commonly almost completely saturated, creating a high-moisture (and low-oxygen) substrate, whereas gravels at higher elevations are usually extremely dry (especially at the ends of long dry spells). Most Ohio gravel deposits contain abundant limestone pebbles providing a substrate high in lime; only far to the south of the glacial boundary and deep within the area of the sandstone hills is the increase in abundance of acid pebbles from local sources great enough to produce a really acid gravel substrate.



Distribution of blue ash (*Fraxinus quadrangulata*) in Ohio. Hachured line is glacial boundary and solid line separates area of limestone to west from area of sandstone and shale to east. Isolated records in eastern Licking and Ross counties occur in areas of thick till which probably contains more lime than other materials in these counties lying within the area of sandstone bedrock. Sources of data are specimens in The Ohio State University Herbarium and records compiled by E. Lucy Braun for her book, "The Woody Plants of Ohio."

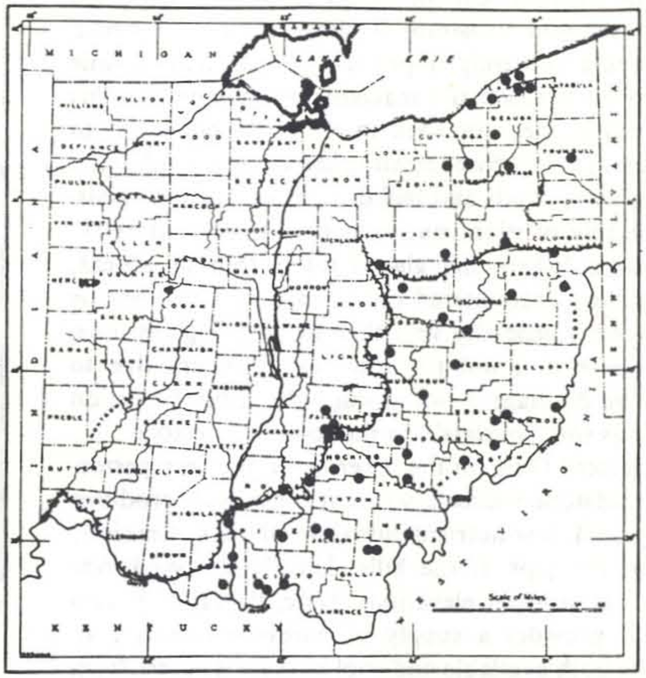
Plants vary greatly in their substrate requirements, and also in the range of their tolerances. Some plants—the "weeds"—have especially wide tolerances and will grow under almost any conditions, acid or limy, wet or dry. Other plants however have more narrow tolerances and therefore have distributions that are restricted, at least to some degree, by differences in substrate characteristics. A few occur only under extremely limited conditions. For a geologist wanting to use plants as keys to the recognition of certain geological conditions, or a botanist wishing to predict plant distribution on the basis of geological mapping, it is the latter group of plants that is the most useful and the most interesting.

Knowledge about which plants are so restricted in their substrate tolerances, and to exactly what substrate conditions they are restricted, is very incomplete, and reasons for these observed relationships are generally very obscure and little understood. This is mostly because of the small percentage of geologists and botanists working in this fascinating interdisciplinary field. Considerable work was done on these relationships by the late Dr. E. Lucy Braun, many of whose interpretations are preserved in her books (*Deciduous Forests of Eastern North America*, *Woody Plants of Ohio*, and *Monocots of Ohio*) from which some of the following material was drawn and to which the reader is directed. In addition, Dr. Ronald L. Stuckey, plant taxonomist on the faculty of The Ohio State University and Curator of the Herbarium there, is presently directing a very active program of study involving the distributions of a large number of individual species of Ohio plants. Much of the following information has been drawn from data provided by him, especially with regard to the herbaceous species, and he has kindly provided the distribution maps of the selected plant species accompanying this paper.

Substrates of course do not provide the only control on plant distribution. Climate, especially its rather restricted local variations (microclimate), and the past history of the land are also critical, although their influence is essentially ignored in this article. Actually

Distribution of *Sullivantia sullivantii* in Ohio. Hachured line is glacial boundary and solid line to west separates area of limestone to west from area of sandstone (and shale) to east. Solid line beginning in southwest Coshocton County and running south through Scioto County marks the separation between Mississippian rocks to the west and Pennsylvanian rocks to the east, both being sandstones with some shale. Sources of data are specimens in The Ohio State University Herbarium.

Distribution maps prepared by Ronald L. Stuckey.



Distribution of chestnut oak (*Quercus montana*) in Ohio. Hachured line is glacial boundary and solid line separates area of limestone to west from area of sandstone (and shale) to east. Sources of data are specimens in The Ohio State University Herbarium and records compiled by E. Lucy Braun for her book, "The Woody Plants of Ohio."

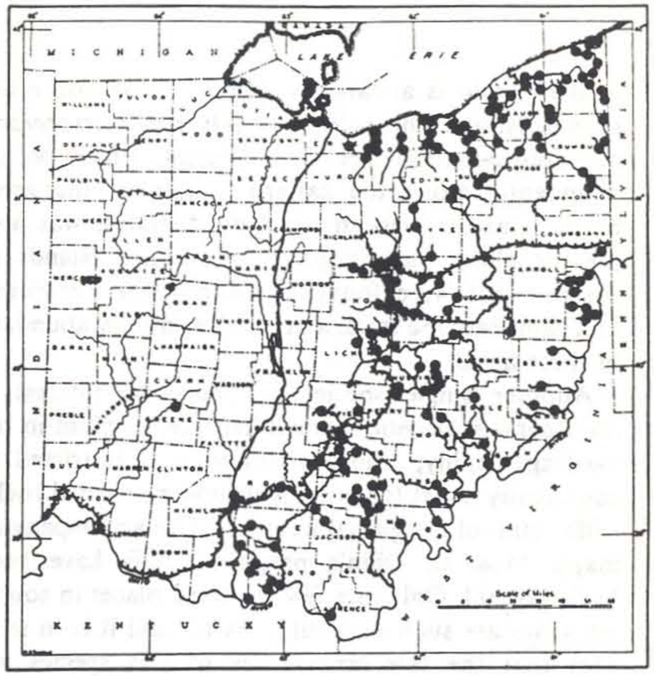
the geologic substrate also has an effect on the microclimate, and geologic history contributes a significant part of the past history of the land, so the importance of geologic factors in controlling plant distribution should not be underestimated.

Plants that have a distribution generally limited to limestone or limy substrates are perhaps best known. These include:

trees and shrubs	herbs
redbud (*Cercis canadensis*)	sedge (*Carex eburnea*)
red-cedar (*Juniperus virginiana*)	flat-stemmed spike-rush (*Eleocharis compressa*)
fragrant sumac (*Rhus aromatica*)	snow trillium (*Trillium nivale*)
hackberry (*Celtis occidentalis*)	two species of white bluets (*Houstonia nigricans* and *H. longifolia*)
blue ash (*Fraxinus quadrangulata*)	herb Robert (*Geranium robertianum*)
hawthorn (*Crateagus mollis*)	nodding thistle (*Carduus nutans*)
chinquapin oak (*Quercus muehlenbergii*)	cordate-leaved plantain (*Plantago cordata*)
hop hornbeam (*Ostrya virginiana*)	

Redbud, red-cedar, and fragrant sumac generally seem to occur on higher, drier sites where limestone is present at only very shallow depths below the ground surface (though there are a few unexplained sites in southern Ohio, near Pike Lake, where redbud is present apart from any limestone substrate, and red-cedar also occurs in non-limy places where the soil has been destroyed). Hackberry, although it occupies similar high, dry sites on limestone bedrock in the Erie Islands, is more common along floodplains in most of Ohio (perhaps because the water percolating through the relatively permeable floodplain deposits is high in dissolved lime). Blue ash occurs in greatest abundance on the limestone substrates of the Erie Islands, but is present throughout the area of high-lime tills of western Ohio (and locally in a few spots in east-central Ohio where the glacier transported lime-rich till farther east, as shown on the accompanying map showing the distribution of blue ash). This distribution of blue ash, extensive in the area of high-lime substrates in western Ohio but lacking in the acid substrates of eastern Ohio, is strikingly illustrated by the map showing the distribution of this species. The hawthorn listed above is an old-field species which occurs in very dry, disturbed (by man) sites, and which appears to be really abundant only in places where the limestone bedrock is quite shallow. The last two trees on the list, chinquapin oak and hop hornbeam, are species which are more common on limestone or limy substrates, but whose distributions are not limited to such sites. The herbaceous species listed above all have distributions closely related to

Distribution of sweet buckeye (*Aesculus octandra*) in Ohio. Hachured line is glacial boundary and solid line separates area of limestone to west from area of sandstone (and shale) to east. Sources of data are specimens in The Ohio State University Herbarium and records compiled by E. Lucy Braun for her book, "The Woody Plants of Ohio."



Distribution of hemlock (*Tsuga canadensis*) in Ohio. Hachured line is glacial boundary and solid line separates area of limestone to west from area of sandstone (and shale) to east. Single Greene County record is from Clifton Gorge, a cool moist valley; apparently the cool moist environment is more critical than any influence of the limy bedrock. Sources of data are specimens in The Ohio State University Herbarium, records compiled by E. Lucy Braun for her book "The Woody Plants of Ohio," and records from map showing "forest types with hemlock" prepared by E. N. Transeau, 1950, and published on page 31 in R. B. Gordon's book on "The Natural Vegetation of Ohio in Pioneer Days" (1969, Ohio Biological Survey 3(2):1-113).

the presence of shallow or exposed limestone bedrock, according to field data supplied by Dr. Stuckey.

Trees which characteristically are present on the high-lime, clay-rich substrates developed in the thick till of the western Ohio plains are not included among those in the list above, although blue ash is an occasional representative. Most common of the tree species occurring on these till plains are: sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), red oak (*Quercus borealis*), shagbark hickory (*Carya ovata*), together with white oak (*Quercus alba*) on somewhat drier sites, white ash (*Fraxinus americana*) in slightly wetter places, and swamp white oak (*Quercus bicolor*) and pin oak (*Quercus palustris*) where standing water may last for several days or weeks. These are the forms which make up the major species compositions of the common plant communities of glaciated Ohio as shown by Gordon on his map of the *Natural Vegetation of Ohio at the Time of the Earliest Land Surveys*.

Another tree that also occurs on the till plains of western Ohio is apparently there for a reason other than substrate. This is bur oak (*Quercus macrocarpa*), the prairie-margin tree. This species, which occurs abundantly along the eastern margin of the great prairies farther west in the United States, was also present along the margins of the small islands of prairies that were found in Ohio when Europeans first came into the state, and is still relatively abundant in these areas.

Another single species of particular interest is *Sullivantia sullivantii*, a small herbaceous plant in the saxifrage family, whose distribution is restricted to continually moist (commonly dripping), shaded rocky cliffs south of the glacial boundary (see accompanying map). Most of Ohio's preglacial cliffs have been buried by till. Only in a few scattered places in southern Ohio are such sites still present, and it is in such sites that the few occurrences of this species are located.

On the sandstone hills of eastern Ohio where acid, locally very dry substrates are characteristic, a totally different set of species is encountered. These include the following:

trees

- chestnut oak (*Quercus montana*)
- sourwood (*Oxydendrum arboreum*)
- scrub pine (*Pinus virginiana*)
- pitch pine (*Pinus rigida*)
- hemlock (*Tsuga canadensis*)
- mountain maple (*Acer spicatum*)

shrubs and other small woody plants

- mountain laurel (*Kalmia latifolia*)
- huckleberry-blueberry (*Vaccinium* ssp.)
- trailing arbutus (*Epigea repens*)
- greenbrier (*Smilax glauca*)

herbs

- pink ladies' slipper (*Cypripedium acaule*)
- ill-scented trillium (*Trillium erectum*)
- smooth Solomon's Seal (*Polygonatum biflorum*)
- bellwort (*Uvularia perfoliata*)

The tops of hills, which have the driest substrate, are where most of these plants—the first four trees (chestnut oak, sourwood, and the two pines); the two shrubs, and the three herbs—occur. Distributions of these species are thus restricted to areas of shallow or exposed sandstone bedrock, generally outside the glacial boundary (even within but near the glacial boundary there are many places where the till is so thin that sandstone bedrock is exposed and these plants are present). A good example is chestnut oak, whose distribution is shown in an accompanying map. This plant, whose occurrence is limited to the tops of high, dry sandstone hills, is predominantly a plant of the unglaciated hills. Its existence north of the

Distribution of rhododendron (*Rhododendron maximum*) in Ohio. Solid lines represent positions of trunk stream and tributaries of Teays River system. Sources of data are specimens in The Ohio State University Herbarium and records compiled by E. Lucy Braun for her book, "The Woody Plants of Ohio."

glacial boundary indicates the presence of such high, dry sandstone hills there, hills which must completely lack any of the till cover generally found elsewhere in glaciated Ohio.

Sweet buckeye is one of a number of species (like white basswood, *Tilia heterophylla*) which does not occur anywhere inside the glacial boundary, as demonstrated by its distribution on the accompanying map. The reasons for such restrictions in distributions are not known, but may have something to do with problems of repopulation, by these plants, of the clayey, high-lime glacial tills in the short time since the ice left Ohio. Why this plant does not extend even as far north as the glacial boundary in eastern Ohio (in Holmes, Stark, and Columbiana counties) is also not clear; perhaps climate is the controlling factor here, for no geologic discontinuity is known along the edge of its distribution (in Muskingum, Guernsey, and Belmont counties).

Hemlock is also present in unglaciated eastern Ohio, but its distribution extends far to the north, well north of the glacial boundary in that area, as shown by the accompanying map. The reason for this more extensive distribution appears to be its restriction to continuously cool, moist environments such as are found in the bottoms of deep valleys cut into sandstone and watered by cool spring water in the south, or such as occur in valleys in the north which contain some till but remain cool and moist because they are deep and open to the north. Apparently even though till thicknesses are generally greater north of the glacial boundary, resulting in somewhat less acidic soils, the cool moist north-facing valleys are adequate for hemlock to be present. The contrast in distributions of a plant restricted to unglaciated areas (sweet buckeye) and a plant occupying moist valley-bottom sites in sandstone (hemlock) is well demonstrated in the maps showing the distributions of these two species.

Tree species in unglaciated Ohio are not limited to those in the above list; these (except for mountain maple) are only those species characteristically present on high, dry sandstone hilltops, or in the perpetually moist cool valleys characteristic of sandstone bedrock (hemlock). More mesic conditions are abundantly present, made moist because of the presence of impermeable shale layers in the bedrock; because of cooler, north-facing slopes; or because of moist forest-induced microclimates. Here occur many different tree species, comprising the mixed mesophytic forest as characterized by Dr. E. Lucy Braun. This group of species owes its distribution mostly to past history—their evolution in the Appalachian highlands and their elimination inside the glacial boundary—and only in part to variations in the substrate. Mountain maple is an example of one plant found in the mixed mesophytic assemblage which has a distribution restricted to the areas of sandstone, though only to the more mesic sites.

Areas of shale bedrock are either steep, where capped by sandstone, or low and flat. Where they are steep, the hilltop species are those characteristic of the dry acid sandstone and the lower slopes are vegetated by species tolerant of dry acid substrates and prolonged drouths—many of the species listed above for the sandstone, but also including shingle oak (*Quercus imbricaria*). Where the shale is low and flat, it is generally covered by till, so the plant species present are those characteristic of a somewhat more lime-rich soil.

There are some plant species present south of the glacial boundary whose distribution might suggest that they belonged to the mixed mesophytic association in Ohio, even though they do not occur everywhere throughout the unglaciated area. An example of these is rhododendron (*Rhododendron maximum*). Only when its distribution is compared with the location of the valleys in the ancient Teays system (see map showing distribution of this species) does a possible explanation emerge. This species, according to Drs. E. N. Transeau and John N. Wolfe, represents one of several that lived (and still lives) in the Appalachian highlands and which migrated down through the preglacial Teays River system from that area north into southern Ohio. Subsequent glacial advance blocked the Teays River drainage and destroyed most of its valleys in Ohio, but the plants, whose distributions in Ohio were determined by this avenue of migration, still remain, living south of the glacial boundary and near the locations of some of the main valleys of that ancient river.

North of the glacial boundary, where till mantles the sandstone bedrock only thinly, most of the species in the above list persist. Where the till cover is thicker, however, especially near the margins of the area of sandstone and in the areas of shale, the substrate is more clayey and more limy, so that some of the same species of trees found on the till plains to the west are present: sugar maple, beech, red oak, white oak, and hickory. In the east, however, the number of species is greater, for poorly drained sites may also have white ash, red maple (*Acer rubrum*), or swamp white oak, and drier sites contain black oak (*Quercus velutina*) or shingle oak.

No list of species is presented for gravel substrates. This is mainly because of both the wide variation in acidity present throughout the areas of gravel and the great differences in available soil-water conditions when this substrate occurs at different elevations. Information about the plant-substrate relations here is also very inadequate. Indeed none of these lists is either complete or beyond question; there just has not been enough work done. In addition, as stated earlier, any attempt such as this to correlate plant distributions only with substrate ignores other important factors influencing the occurrence of plant species. The remarkable fact is that, in considering this one factor, there appears to be such good correlation with such a significant number of plants.

An important concept emerges from all this discussion: geologists and botanists now active in this area of research are needed, geologists who will learn enough about plants and botanists who will learn enough geology to make some real contributions. Once additional competent scientists are involved in collecting more information in this area of research, exciting new correlations may be made to extend greatly the already significant contributions of this new and challenging field of Geobotany.