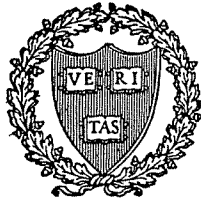


HARVARD FOREST

BULLETIN NO. 25

VEGETATION ADJACENT TO THE BORDER OF THE WISCONSIN DRIFT IN POTTER COUNTY, PENNSYLVANIA

By
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FOREWORD

The following paper on the forest vegetation of Potter County, Pennsylvania, prepared by Dr. John C. Goodlett, makes a twofold contribution. The first and most obvious is an exposition of the major features of the botanical landscape. Here are definitions of the forest communities that give variation to the landscape, and a description of the areal distribution of the communities. These more or less general facts are buttressed by studies of the distribution of individual species. Then there are statements of coincidence between the distribution pattern of forest communities, and the distribution of topographic features and soils. Finally there are the results of careful studies in the history of the forests of Potter County. Not only are there stated the coincidences that now exist among geographic patterns of soil, topography, and forest types, but also coincidences between existing forest patterns and patterns of change that have occurred in the forests over time.

The second contribution is in the field of methodology. The present paper presents primarily the botanical aspects of a collaborative research project. The nature of this collaboration is stated only in outline in Dr. Goodlett's introductory remarks, but it is worthy of somewhat greater emphasis.

We are in a period in the development of research techniques wherein much attention is being given to projects involving "teams" of investigators. These teams are usually assembled by gathering together individuals from the various disciplines that are likely to be of major importance in the research project as a whole. In some cases the assembled group assails the problem together, whether in field or laboratory. Frequent meetings are called to compare notes and keep everyone informed of general progress. In other cases the investigators do not go into the research as a group, but individually and separately, trusting to subsequent efforts at coordination to achieve the desired effects of collaboration.

Ideally such programs of collaboration are effective and productive. There is a tendency, however, to stress the effectiveness of their organization *per se*. There is a tendency to forget that the assembled group of investigators consists of individual human beings with the usual proclivities of human beings for finding more or less common ground with their

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associates. It is possible for the individuals in the research teams to become slaves to a sort of mechanically-derived objectivity which makes it difficult for them to find expression for their own personal contributions, which must come from their own thinking.

Fully productive collaboration involves a more spontaneous and sympathetic give-and-take among the people working together than is usually possible. This can only grow out of a genuinely common interest, common tolerance, and a common understanding of the basic problems in the various disciplines that are concerned. The present paper appears to be the result of such a collaboration. The geologist in charge was not only highly skilled in his own field, but had through study and association over a period of years acquainted himself with the basic problems faced by the students of soils and forests. Likewise, the latter two were well versed not only in their own disciplines, but were keenly aware of each other's fundamental problems as well as those of the geologist. Field operations under these circumstances became extremely stimulating to all concerned, for there was a true pooling of thought and inspiration while the physical and biological problems were immediately at hand.

Such collaboration as this is but rarely achieved. When it is, as in the present case, it makes a sound contribution to methodology and at the same time gives vitality to the simple exposition of scientific fact.

HUGH M. RAUP

INTRODUCTION

The effects of Pleistocene glaciation upon the distribution of plants outside the glaciated areas is a perennial problem to geographic botanists. That the glacier affected the vegetation beyond the ice margin is generally accepted as fact. The width of the area influenced, however, and the degree of modification, are difficult to determine.

The present ranges of many species of plants in eastern United States coincide roughly with the drift border. Determination of the age of these distribution patterns would contribute much to a solution of the problem of the effects of Pleistocene glaciation outside the glaciated region. Unfortunately, the botanical evidence is sketchy and controversial. Pre-Pleistocene fossils referable to living genera have not been found in the interior of the eastern United States. Stratigraphic relations of interglacial and postglacial pollen profiles seldom can be established to the satisfaction of all concerned, and dating of the various horizons is often uncertain. Evidence of tundra is scanty. Ecological interpretations of spruce and fir in pollen deposits in Louisiana, Texas, and Florida vary with the hypotheses of the authorities. In the same vein, the discovery of species characteristic of the eastern United States in the highlands of Mexico is considered to be both important and unimportant.

One of the more hopeful sources of aid to botanists floundering about in their distributional dilemmas, and a source that has been little employed, is the data unearthed by the so-called "periglacial" geologists. The importance of processes active in the region peripheral to an ice sheet was brought to the attention of American glacial geologists in 1928 by the late Professor Kirk Bryan of Harvard University, in his review of a book by Kessler, "Das Eiszeitliche Klima". Bryan became the head of a small group of glacial geologists who have been steadily collecting information about the cold frost climate that existed adjacent to the Pleistocene ice sheets in North America. This evidence is preserved in the surficial deposits and the landforms. During World War II these studies were extended to the Arctic, to areas where frost phenomena are actively shaping the landscapes at present. The Arctic studies show that modification of the landscape by deep freeze and thaw and related processes of mass movement (the process of cryoplanation¹) conditions and in turn is conditioned by the vegetation.

Geological investigations in areas peripheral to the glacial border pro-

¹ See Bryan, 1946, for terminology of frost processes and the results of frost processes.

vide evidence of the severity of the Pleistocene climate and the degree of disturbance of soil materials by processes related to severe frost action in the periglacial region. This is invaluable and concrete information for students of plant distribution. However, the effects of the periglacial climate and the indirect effects of soil instability upon the vegetation must be assessed by the botanist, and this is somewhat difficult. Argument by analogy with information derived from studies of arctic vegetation is subject to the same objections usually leveled at proof by analogy. In addition, as Raup (1951, p. 112) cautions, we must be very careful in interpreting "our modern vegetation in terms of the periglacial climates" because relationships between vegetation and cryoplanation in the Arctic are not fully known.

Evidence that Pleistocene frost action has influenced the distribution of the present vegetation in mid-latitudes was presented by Raup (1938) and Denny (1938) in their studies at the Black Rock Forest in New York. Denny showed that the mineral soil upon which the vegetation grows is composed of a disturbed layer derived from the underlying glacial till and bedrock. The formation of this layer was attributed to intense frost action during the rigorous periglacial climate that existed when the edge of the Wisconsin ice sheet was a few miles to the north. In areas where the bedrock was covered with thick surficial deposits, the disturbed layer was found to be underlain by unweathered, compact till. Certain forest types were found growing on the deep surficial deposits that were lacking in areas where the till was disturbed to its base.

Stout (1952) concluded that the local distribution of red oak and white ash in the Harvard Forest, in central Massachusetts, was determined by soil characteristics which resulted from the reworking of the glacial deposits and the addition of wind-blown materials in a periglacial climate.

During the summers of 1949 and 1950, investigations of the vegetation adjacent to the border of the Wisconsin drift in Potter County, Pennsylvania, were carried on by the author in informal collaboration with C. S. Denny of the U. S. Geological Survey and K. V. Goodman of the Division of Soil Survey of the U. S. Department of Agriculture.

The general method of attack has been: 1) To determine the present distribution of species in the region, with emphasis placed upon the trees of the upland forests; 2) with the help of the geologist and the soil scientist, to search for coincidences between the patterns of distribution of species and patterns of distribution of other components of the landscape, such as soils, surficial deposits, or bedrock; and 3) to attempt to determine the nature of the pre-settlement forest, and its relation to the present forest.

VEGETATION

The forests of Potter County are characterized by a pronounced variation over short horizontal distances, and a striking vertical uniformity although local relief ranges from 300 to more than 800 feet. There is no observable difference in the forests on either side of the border of the Wisconsin drift. The available evidence indicates that with few exceptions these distribution patterns were present in the pre-settlement forests, and that subsequent disturbances in the forests caused by man have had little effect upon the general distribution of species. Good evidence exists that the works of man since the time of settlement have produced less disturbance of the forest floor than natural phenomena in pre-settlement time, and that the present forests are undergoing a period of stability unknown in the primeval forest.

Potter County lies approximately at the midpoint of the northern tier of counties of Pennsylvania, occupying a part of the high Appalachian Plateaus. The irregularly concentric distribution of the tree species on the dome-like plateau permits the establishment of floristic regions. The high divide area in the central part of the county is covered with uniform forests of beech, sugar maple, yellow birch, black cherry, and hemlock. Away from the high central mass in all directions the number of tree species increases, resulting in stands containing as many as 15 species of canopy-forming trees. Here, in addition to the trees listed above, red oak, white ash, basswood, black birch, and red maple are common. Near the periphery of the county at points where the major streams penetrate the plateau, the forests consist predominantly of species of oak with occasional hickories. Here white oak, chestnut-oak, red oak, red maple, and beech are common. The oak forests show less vertical uniformity than the forests composed of other species, and this fact accentuates the difference between the forests of the central divide area and those at the margins of the county.

The forests of Potter County viewed by the first white settlers about 1810 differed in composition from the present medium-aged second growth forests chiefly in the abundance of white pine and chestnut. The white pines were cut during the remainder of the nineteenth century and did not regenerate themselves. Chestnut was killed by the chestnut blight early in the present century. During the last quarter of the last century and continuing through World War I the forests of Potter County were rapidly clear cut. Following the cutting, most of the southern two-thirds of the county was purchased for state forest land. The state forest land has been protected from fire and permitted to grow back to forest. Virtually no cutting has been permitted.

The forests are growing on soil materials derived from the underlying

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gently folded conglomerates, sandstones, siltstones, and shales. Roughly the northeastern quarter of Potter County is mantled by glacial drift, largely till, deposited by the Wisconsin ice sheet. The rest of the county is covered with unconsolidated debris, interpreted by Denny (1951) as being of periglacial origin. He believes that these unconsolidated deposits are the result of processes related to ancient frost action, active when the Wisconsin ice sheet was at or near the drift border. The glacial drift was reworked by frost action subsequent to its deposition, and it differs from the surficial deposits outside the drift border largely by its content of rounded, striated, and occasionally erratic stones.

Under the hypothesis presented here, 1) the mantle of surficial materials which occurs throughout Potter County, attributed to processes related to deep freeze and thaw in a cold frost climate adjacent to the Wisconsin ice sheet, is primarily responsible for the uniformity of vegetation on either side of the border of the Wisconsin drift, and for the general vertical uniformity of vegetation throughout the region; 2) forest vegetation was essentially absent or highly restricted during formation of the surficial deposits and throughout the period or periods when frost processes acted to create severe instability in the deposits; 3) the regional distribution of species is the result of climatic differentials, past and present, between the highlands of central Potter County and surrounding lower plateau surfaces; 4) local distribution of species is largely determined by variations in the physical composition of the surficial deposits, which bring about local variations in the depth to water tables, roughly in proportion to the abundance of rock fragments; 5) the restricted and discontinuous distribution of species is a reflection of expansions and contractions of ranges in the past, presumably in response to general climatic changes, local distribution at any point in time largely being determined by variations in the surficial materials; (6) disturbance of the upper parts of the surficial materials by windthrow of trees has affected in the past and continues to affect rates of erosion, processes of soil formation, and the development and composition of the vegetation.

Special appreciation is expressed to Dr. C. S. Denny and Prof. H. M. Raup for the opportunity to make the study, and for guidance and criticism through all phases of the work. Interpretation of the surficial deposits would have been impossible without the generous assistance of Dr. Denny and Mr. K. V. Goodman.

TOPOGRAPHY

Potter County is a high, dissected plateau interrupted by a series of slightly lower uplands trending generally northeast. Within the high central divide area rise the westward-flowing Allegheny River, the northward-flowing Genesee River, and streams flowing south and east to the Susquehanna River.

The higher ridges comprising the plateau remnants rise to altitudes of 2560 feet in the central part of the county, and local relief is generally 300 to 800 feet. Near the borders of the county the plateau remnants are somewhat lower, ranging from 2200 to 2400 feet in altitude. Here the plateau has been more deeply dissected by the major streams, and local relief is greater. Along Pine Creek and First Fork of Sinnemahoning Creek local relief reaches 1100 feet. The crests of the ridges are flattish, very irregular in outline, and generally less than half a mile wide. Ridge crests generally show a very sharp break in slope at their margins, accentuating their flat surfaces.

The hills comprising the slightly lower uplands are generally 100 to 200 feet lower than the adjacent plateau remnants. Local relief is also less, generally ranging from 200 to 400 feet. These lower hills slope smoothly from crest to valley floor, and lack pronounced flat tops.

The slopes of both the higher ridges and rounded hills are long, smooth, and uniform or slightly concave. The smoothness of the slopes is accentuated by a general absence of rock outcrops, except in the extreme southern part of the county. Along the upper reaches of streams, adjacent slopes meet sharply, with no intervening floodplain. Floodplains are absent or very narrow along all but the larger streams, where they are less than half a mile wide. The long, smooth slopes, absence of outcrops, and general lack of floodplains combine to produce a distinctive topography.

A mantle of surficial materials of varying thickness completely covers the bedrock of almost the whole region. These deposits are generally thicker on lower slopes. In the glaciated northern part of the county the smooth lower slopes are occasionally interrupted by thicker deposits of drift, locally producing a reduced ground moraine topography. A pronounced microrelief of 1 to 4 feet is seen throughout the unplowed areas of the county, the result of windthrow of living trees.

Rose Lake, on the divide between the Allegheny and Genesee drainage basins, is the only lake in the county. Many small bogs and poorly drained areas are seen in the glaciated part of the county.

ROCK FORMATIONS²

The bedrock of Potter County consists of gently folded sedimentary rocks, ranging from Upper Devonian to Pennsylvanian in age. Six major anticlines, six intervening major synclines, and various lesser folds trend northeast. The Chemung and Catskill formations are exposed in the anticlinal valleys, and constitute the rounded, slightly lower uplands. The Pocono and Pottsville formations cap the synclinal ridges and constitute the higher plateau remnants.

Separate, angular boulders of light gray, massive, fine-grained conglomerate or coarse-grained sandstone of the Pottsville or Pocono formations are present on many of the higher ridges. Conglomeratic boulders of various sizes, the largest as big as a small house, are abundant on slopes and valley floors. These often form blockfields, common at the heads of streams. The greenish-gray, thin-bedded, fine-grained sandstones and shales of the Pocono formation comprise most of the mass of the higher ridges, and occasionally cap the lower rounded hills in the anticlinal valleys.

The "redbeds" of the Catskill formation form the rounded hills in most of the anticlinal valleys and underlie the lower slopes of many of the higher ridges. They consist of a series of red sandstones and shales, interbedded with gray and green sandstones and shales.

The sandstones and shales of the Chemung formation closely resemble the thin-bedded sandstones of the Pocono formation in lithology. The Chemung formation is exposed occasionally in the anticlinal lowlands, and is of considerable extent in the northeastern and northwestern parts of the county. In the latter places it forms rather high, steep-sided ridges similar to those underlain by the sandstones of the Pocono formation.

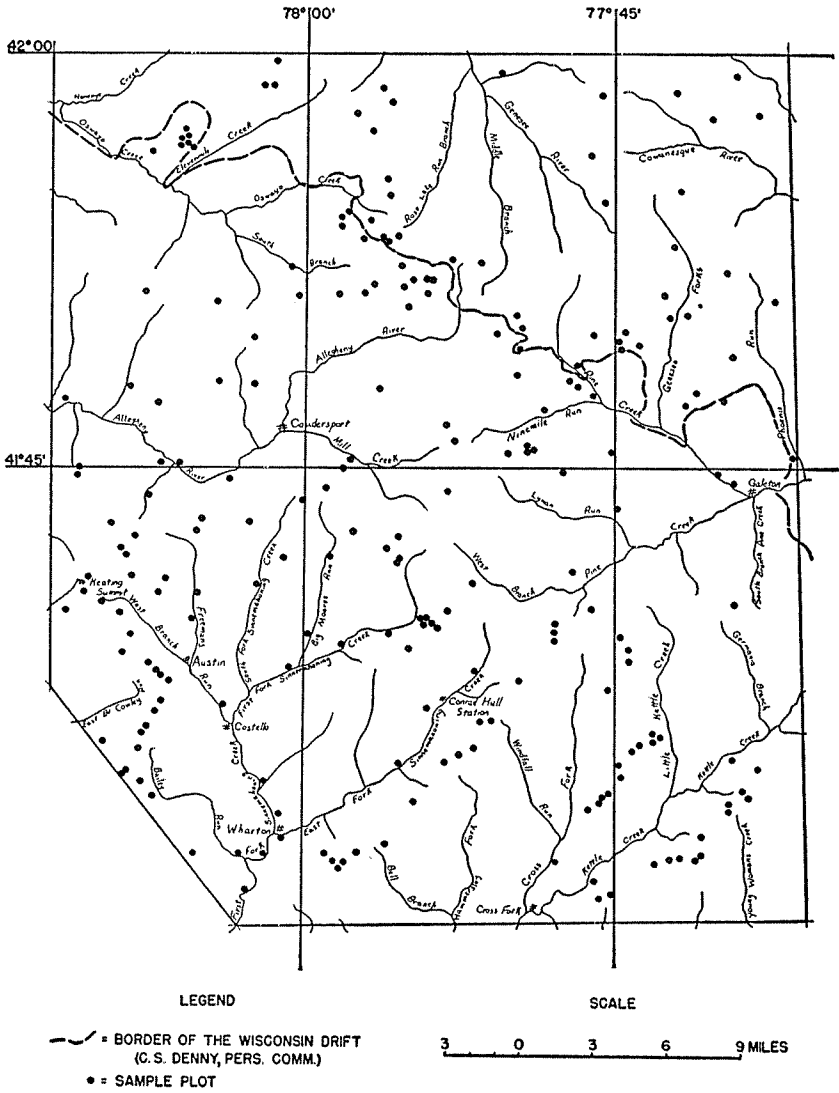
GLACIAL GEOLOGY

The border of the Wisconsin drift enters Potter County at its northwest corner and extends southeastward across the county to Pine Creek (Fig. 1). It is definable by the remnants of subdued morainal topography (Lewis, 1884), and more closely by the limit of igneous and metamorphic erratic stones (Denny, 1951). According to Denny (Geomorphology of Potter County, Pennsylvania, in preparation), the drift belongs to the Iowan or Tazewell substages of the Wisconsin, and is the same as the

² This section is compiled from Cathcart (1934), Ebright, et al. (1949), Sherwood (1880), Stose and Ljungstedt (1931).

VEGETATION

FIGURE 1. DRAINAGE MAP OF POTTER COUNTY, PENNSYLVANIA



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Olean drift mapped by MacClintock and Apfel (1944) in adjacent New York state.

The glacial materials of Potter County are derived predominantly from the sandstones, shales, and siltstones comprising the country rock. A few limestone pebbles are seen, presumably derived from lenses of impure limestone or calcareous sandstone occurring in the various formations. Erratic stones derived from igneous and metamorphic rocks make up less than one percent of the deposits.

The glacial till on upper slopes and summits is thin, but is often thicker on lower slopes. Morainal topography is rare, and when present is subdued. Stratified drift is scarce, although kame terraces are found at the edges of some of the stream valleys.

The upper part of the till has a very loose texture, and in general becomes more compact with depth. Angular rock fragments are abundant in the materials.

SURFACE FEATURES ATTRIBUTED TO PLEISTOCENE FROST ACTION

Soil structures similar to those forming at the present time in arctic and alpine regions (Antevs, 1932; Denny, 1940; Sharp, 1942; Troll, 1944) occur in Potter County, both within and outside the border of the Wisconsin drift. These consist of boulder rings, boulder stripes, and blockfields.³ Denny (1951) attributes these features to processes caused by the presence of the adjacent Wisconsin ice sheet. He suggests that they were formed at a time of more intense frost action, when the depth of frost penetration was greater than at present.

The soil materials mantling the bedrock outside the drift border strongly resemble the deposits of the glaciated region. Denny (1951, pp. 121-122) describes this material and discusses its probable origin:

The nonglaciated area peripheral to the Wisconsin drift border in Potter County is characterized by the widespread occurrence of a surficial mantle of unconsolidated debris, largely a rubble. Much of the material is an unsorted, heterogeneous mass that contains from 1 or 2 to almost 100 percent of rock fragments of all sizes from a fraction of an inch to tens of feet in diameter. Much of the material on the lower valley walls might be called colluvium. Many of the slab-shaped fragments or flagstones are oriented with their flat surfaces essentially parallel to the slope of the ground. Elsewhere the flagstones may be imbricated with their longest axis dipping toward the top of the slope at angles of a few degrees measured from the ground surface.

³ For detailed descriptions and discussion, see Denny, 1951, and Denny, *Geomorphology of Potter County, Pennsylvania*, in preparation.

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On ridge tops most rubbles do not show any preferred orientation of the fragments except where the fragments are grouped into circular or linear patterns (boulder rings and boulder stripes). Where the surficial mantle contains considerable fine material and only a subordinate amount of rock fragments, as in areas of fine-grained bedrock such as siltstone or shale, the material resembles till but does not contain erratics or striated rock fragments. The surficial mantle ranges from 1 foot to more than 10 feet in thickness.

It is suggested that this surficial mantle of debris is of Wisconsin age, that it was formed when the ice sheet was at or near the drift border, by processes active in a cold frost climate. On the uplands there is stratigraphic evidence that this mantle has moved down very gentle slopes, 1° to 5° , and in one place accumulated to a thickness of at least 10 feet. The soil profiles developed in the upper part of this mantle suggest that it has been relatively stable for at least 500 to 1000 years. Its degree of weathering is comparable with that on the adjacent Wisconsin drift. The author believes that these deposits can be best explained as the result of processes related to Wisconsin frost action. Most of the deposits on the uplands are probably congeliturbates (Bryan, 1946) or debris produced by frost-riving and moved by solifluction, the result of a deep seasonal freeze and thaw. The colluvial deposits on the lower slopes are interpreted as the result of a combination of slope wash, creep, and solifluction.

Small patches of ancient soils, believed to date from the last interglacial stage (Sangamon), are found in a few localities outside the border of the Wisconsin drift in Potter County. Pedologists believe these ancient soils belong to the Red-Yellow Podzolic great soil group, which is found throughout a large area in southeastern United States. These lenses of ancient subsoil may represent the soil materials that mantled the landscape prior to the advance of the Wisconsin ice. The nearly complete removal of this mantle or its mingling with quantities of fresh material derived from the underlying rock by processes associated with intense frost action in the periglacial region presumably resulted in the mantle of unconsolidated debris now present.

SOILS

Within Potter County are found soils belonging to the Podzol and Gray-Brown Podzolic groups. A detailed survey of the soils of the county is in progress. The field mapping units are too detailed for use in a reconnaissance study of the vegetation, and more generalized units employing the characteristics of the surficial deposits have been used in describing the substrata upon which the plants are growing.⁴ The surficial deposits

⁴ A detailed comparison of the soils as mapped by the Soil Survey and the distribution of the vegetation is planned following publication of the soils map of Potter County.

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can be defined in terms of color, texture, and the lithology, abundance, and shape of the included rock fragments. Occasionally thickness of the deposits can be determined by means of nearby outcrops of bedrock. Presence or absence of mottling and depth to mottled horizons, if present, give a rough measure of permeability and internal drainage of the materials.

CLIMATE

The northern tier of counties of Pennsylvania has a climate fairly typical of a true continental plateau. Summers are cool and short, and the winters are long and severe. Seasonal snowfall averages 54 inches, the snow lying on the ground for about three-fourths of the winter season (U. S. Dept. Agr. Yearbook, 1941, pp. 1097-1098).

Climatological maps of Pennsylvania (U. S. Dept. Agr. Yearbook, 1941, pp. 1096-1097) indicate a rather sharp division between the northern and southern halves of Potter County on the basis of the number of days without killing frosts. The northern half has less than 110, with a minimum of less than 100 in the northeast. The southern half has an increasing number of frost-free days, the extreme southeast corner showing 140 days. The northeast corner likewise has a smaller average annual precipitation, on the order of 36 inches. This increases steadily to the west, becoming 42 inches in the extreme southwest.

Data collected by the weather station at West Bingham, in the northeastern corner of the county (U. S. Dept. Agr. Yearbook, 1941, pp. 1088-1089), show an average January temperature of 22.3° F., and an average July temperature of 64.6° F. During the fifteen-year period covered by these records, the maximum temperature recorded was 98° F., and the minimum temperature was -31° F. Data covering a fourteen-year period show an average growing season of 77 days. The mean date of the last killing frosts of spring is the 17th of June, and the mean date of the first killing frosts of fall is the 2d of September. A fourteen-year record shows the average annual precipitation to be 35.79 inches. Average rainfall for the months April through October exceeds 3 inches per month. The maximum occurs in May, and the average for the remaining months exceeds 2 inches. These records indicate a relatively even distribution of precipitation throughout the year, with more than half falling during the spring and summer months.

VEGETATION

Present forests of the uplands

GENERAL CHARACTERISTICS

At the present time most of Potter County is forested. State forest and wooded state game lands occupy almost the entire southern half of the county. Here private lands are largely restricted to the major stream valleys. Within the predominantly agricultural northern half, many upper slopes and plateau surfaces still support forests. Most of the forests consist of 40- to 60-year-old hardwood stands that have grown up since the cutting of the pre-settlement woodlands. Scattered remnants of the pre-settlement forest are occasionally seen.

The forests of Potter County are characterized by the presence of two major assemblages of tree species, differing from each other in so many characteristics as to be readily distinguished by persons untrained in plant science. Many species of trees are restricted to a single vegetative assemblage. Furthermore, the relative abundance of some tree species that are common to both assemblages differs markedly. The form of the trees comprising the forests is different, and the nature of the understory and ground cover is distinctive.

PREVIOUS WORK

Most of the county lies within the "Beech-Birch-Maple" forest region as mapped by Illick and Frontz (1928), who designated the forests in the extreme southern part of the county "Oak-Chestnut type." Hough and Forbes (1943) included most of Potter County in the "Allegheny Hardwoods-Hemlock" forest type. Part of the Pine Creek drainage basin and a small area in the southern part of the county were designated "Oak-Chestnut-Yellow Poplar" forest type. Braun (1950) considers the "Allegheny Hardwoods-Hemlock" forest type as part of the "Northern Appalachian Highland Division of the Hemlock-White Pine-Northern Hardwoods" region, in contact along its southern margin with outliers of the "Ridge and Valley Section of the Oak-Chestnut Forest region."

Other workers included the entire region in one category of vegetation. Sargent (1884) mapped the area in his "Northern Pine Belt," Frothingham (1915) as part of the "Northern Hardwood" region, and Nichols (1935) as part of the "Hemlock-White Pine-Northern Hardwood" region.

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METHOD OF STUDY

The varying number of categories of vegetation mapped and described in Potter County along with the diversity of names applied to them have resulted not only from changes that have occurred in the forests since settlement, but also from the highly subjective nature of plant ecology. The present distribution of the species comprising the forests can be mapped, and by use of data derived from old stumps and historical records an incomplete picture of the past composition and distribution can be obtained. If the present distribution in Potter County of a single tree species is plotted in the form of a spot map, each spot representing the occurrence of one or more trees, the area occupied by the species can be outlined by drawing a line around the peripheral spots. Superposition of spot maps of the various species may or may not show a degree of coincidence of range.⁵ The coincidence of range among species is probably the best criterion for the delineation of plant assemblages.

In the following sections the present distribution of species, chiefly the tree species, will be outlined, the evidence for separation of major floristic regions will be presented, and concrete forest types will be defined. The present distribution of species will be compared with their distribution in the pre-settlement forests. Geobotanical relationships will be presented and, finally, hypotheses advanced to explain the development of present distribution patterns and the important changes in composition that have taken place since settlement.

DISTRIBUTION PATTERNS OF TREE SPECIES

The present forests are composed of approximately 25 species of trees (Table 1). The basic data for determination of the areas of the different species were obtained in the field at 217 localities (Fig. 1). The location of these points was determined primarily by the presence of obvious variations in composition of the forest stands. No attempt was made to establish a regular grid system in the area.

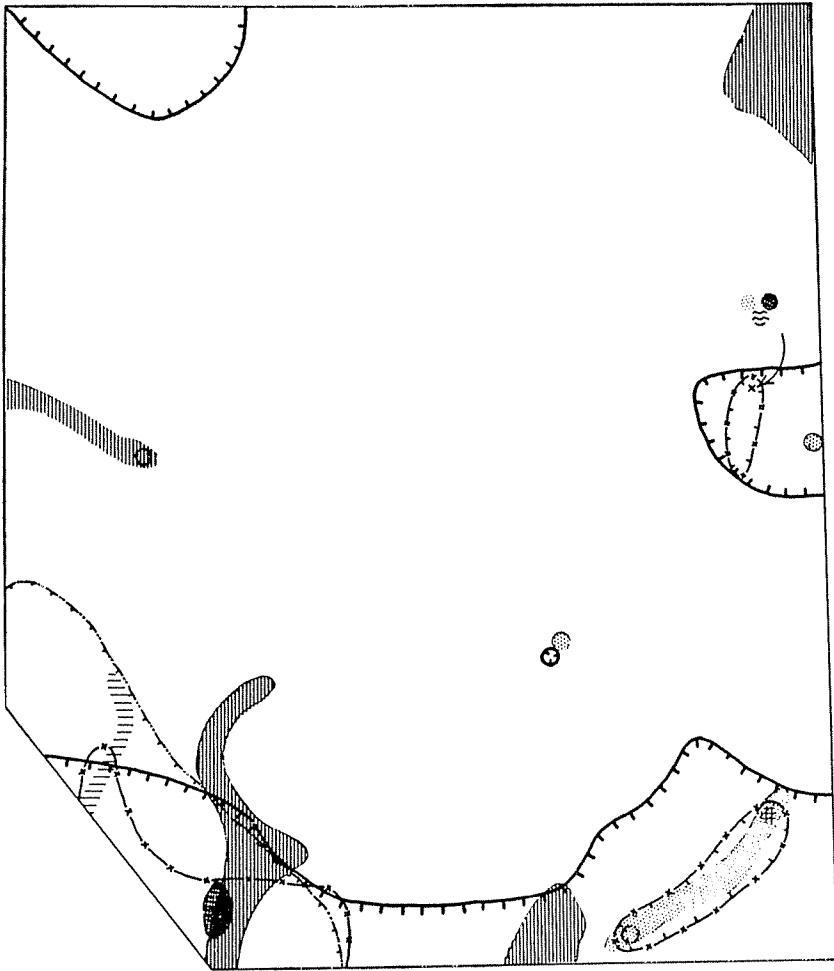
The superposition of the spot maps prepared for each species of tree reveals four general distribution patterns:






- 1) Species found throughout the county: beech, sugar maple, and hemlock.
- 2) Species having highly restricted distribution: white oak, chestnut-oak, black oak, cucumber-tree, tulip-tree, pitch pine, red pine, pig-nut, shagbark hickory, and paper birch (Fig. 2).





⁵ This is the method of Gaussen as described by Cain (1947) and employed by Raup (1947).

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FIGURE 2. TREE SPECIES OF RESTRICTED DISTRIBUTION



-  • QUERCUS ALBA
-  • QUERCUS PRINUS
-  • MAGNOLIA ACUMINATA
-  • PINUS RESINOSA
-  • PINUS RIGIDA

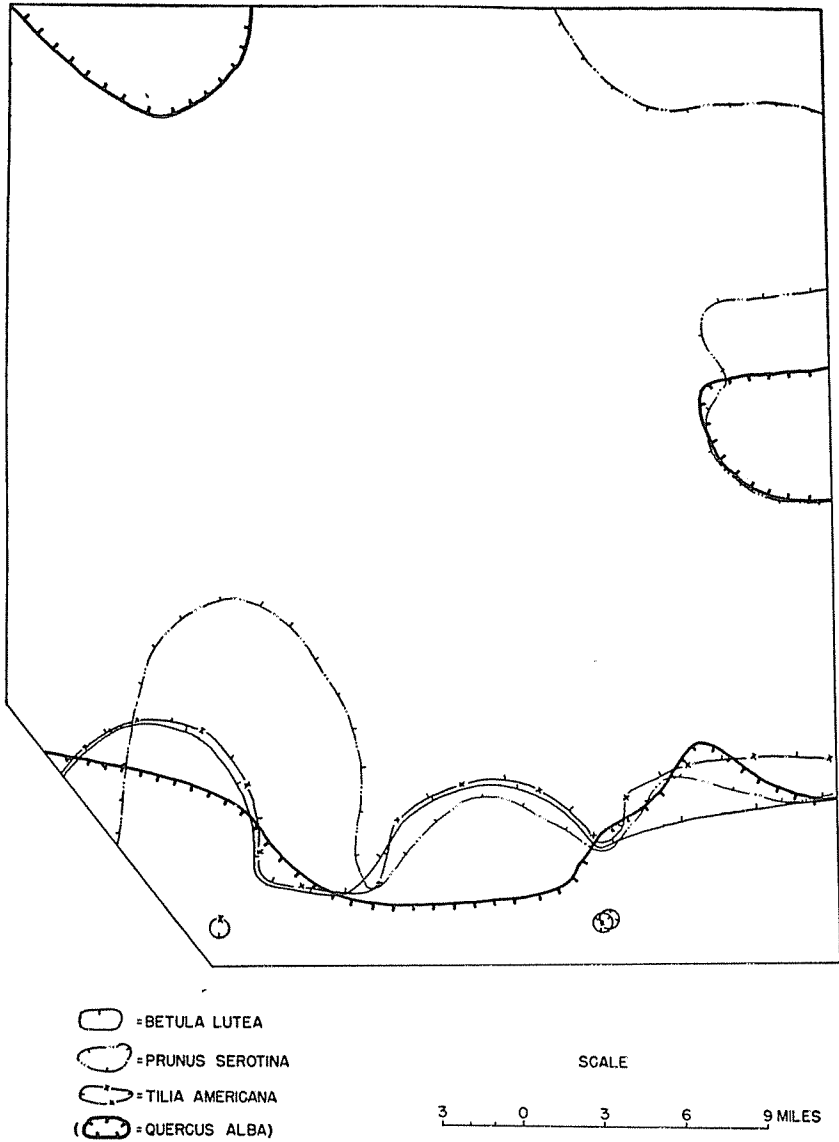
-  • QUERCUS VELUTINA
-  • BETULA PAPYRIFERA
-  • CARYA GLABRA & C. OVATA
-  • LIRODENDRON TULIPIFERA

SCALE

3 0 3 6 9 MILES

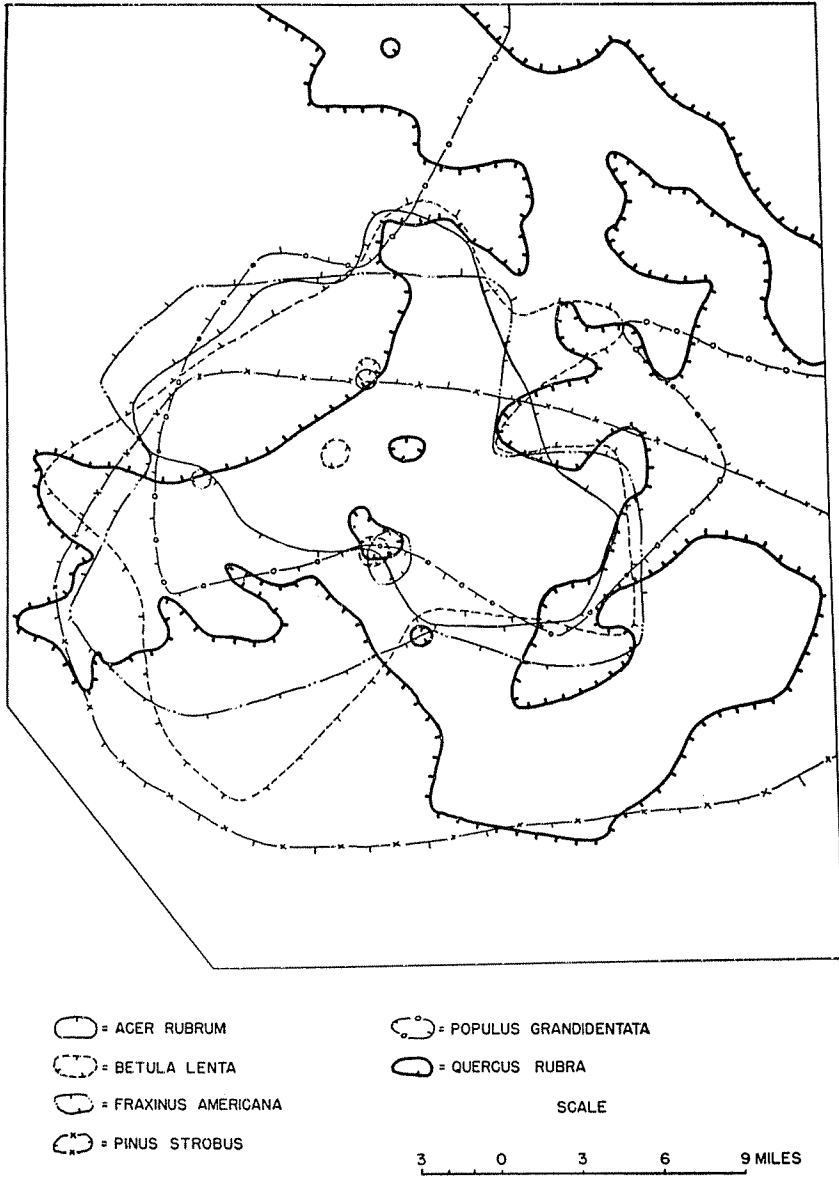
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FIGURE 3. WIDE-RANGING TREE SPECIES ABSENT FROM THE EXTREME SOUTH



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FIGURE 4. WIDE-RANGING TREE SPECIES ABSENT FROM PARTS OF THE CENTRAL HIGHLANDS



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- 3) Species essentially absent from the southernmost part of the county, but wide-ranging throughout the rest of the county: yellow birch, black cherry, and basswood (Fig. 3).
- 4) Species found throughout the county but essentially lacking in the high central divide region: red oak, white pine, white ash, large-toothed aspen, red maple, and black birch (Fig. 4).

These four patterns of species distribution may be grouped into two forest regions, which have long been recognized by plant ecologists. In this way, the synthetic forest regions are presented as subjective, but on the whole distinct, aggregates of tree species whose present ranges have been mapped on the ground.

FOREST REGIONS

OAK FOREST REGION

The forests at the periphery of Potter County, particularly the southernmost parts, are characterized by the presence of a group of species that have a highly restricted distribution (category 2 above). Of this group of species, white oak occupies the largest area. Furthermore, most species having restricted distribution are confined to the area occupied by white oak. In addition, species "essentially absent from the southernmost parts of the county" (category 3 above) are found almost without exception only outside the area of white oak. In other words, their southern limits coincide very closely with the northern limit of white oak. They are also generally absent from the Pine Creek area of white oak in the eastern part of the county.

The presence of a group of species whose area, in general, lies within the range of white oak, together with the virtual absence of other species that are wide-ranging in the county, strongly suggests that the area occupied by white oak is part of a distinct floristic region, which will be referred to in this paper as the Oak Forest region (Fig. 5). The author believes that this area is a part of the "Oak-Chestnut Forest" region of Braun (1950).

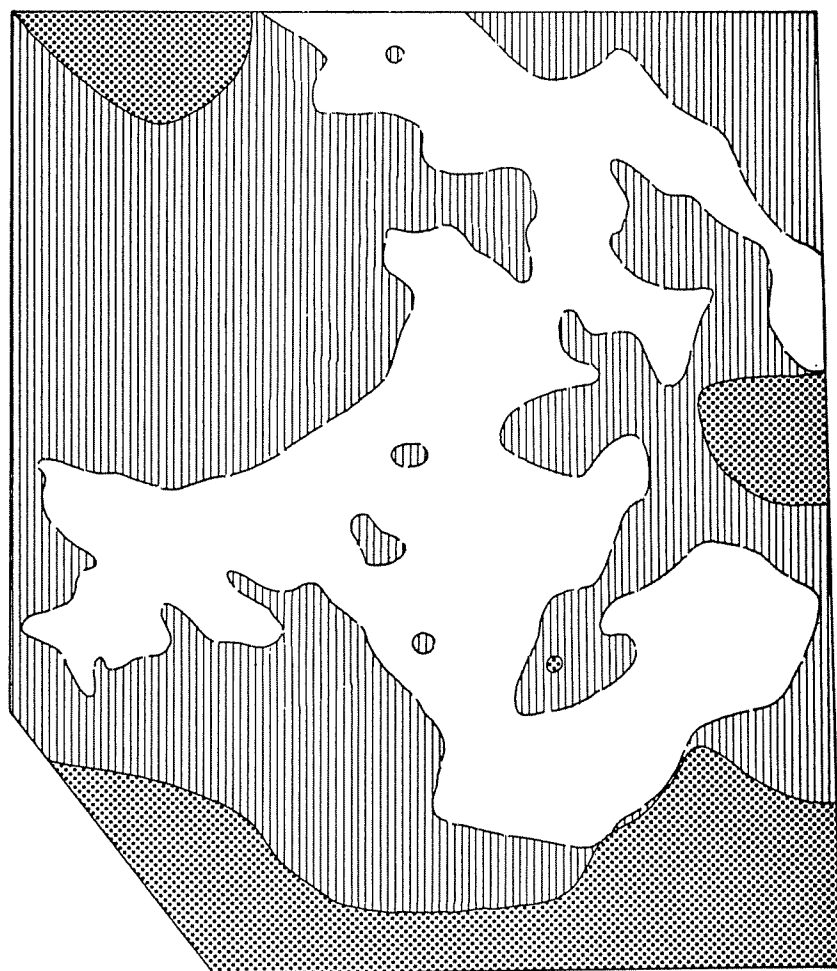
NORTHERN HARDWOOD REGION

The remainder of Potter County constitutes a second floristic region, which will hereinafter be called the Northern Hardwood region (Fig. 5). This region represents a part of the "Hemlock-White Pine-Northern Hardwoods" region of Braun (1950).

However, species distribution as shown by the spot maps indicates

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FIGURE 5. FOREST REGIONS OF POTTER COUNTY, PENNSYLVANIA



NORTHERN HARDWOOD REGION

CENTRAL HIGHLANDS
(LARGELY BEECH-BIRCH-MAPLE
FOREST TYPE) ■ □

"TRANSITION ZONE"
(LARGELY RED OAK FOREST
TYPE) ■ □□□

OAK FOREST REGION
(WHITE OAK, CHESTNUT OAK, AND
RED OAK FOREST TYPES) ■ □□□□

SCALE

3 0 3 6 9 MILES

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two rather distinct parts within the Northern Hardwood region: 1) a "central highlands zone," and 2) a peripheral or "transition zone".

CENTRAL HIGHLANDS ZONE

The forests of the central divide area of Potter County consist of species placed in categories 1 and 3 above. The principal components of the stands are sugar maple, beech, yellow birch, black cherry, and hemlock.

TRANSITION ZONE

The forests in the Northern Hardwood region of Potter County peripheral to the central highlands zone contain species placed in categories 1, 3, and 4 above. The stands in the transition zone contain many more species than those in the central highlands zone, but consist largely of sugar maple, beech, red maple, red oak, black cherry, basswood, white ash, and hemlock.

Of the wide-ranging species "essentially lacking in the high central divide area" red oak shows the most complex distribution pattern. Red oak is universally present in the Oak Forest region, widespread in the region peripheral to the central highlands, and completely absent from large parts of the central highlands (Fig. 2). The discontinuous distribution of red oak became apparent early in the course of the field work. For this reason the area occupied by red oak was worked out in greater detail than that of any other species found in the Northern Hardwood region. The range of red oak as shown in Figure 2 is much more nearly accurate than the ranges of the other species, because its occurrence has been plotted between the localities shown on the spot map (Fig. 1).

Within the range of red oak are found other species of trees lacking from the central divide area. White pine, now almost completely absent but abundant in the pre-settlement forest, is found only within the area of red oak. Furthermore, the white pine stump remnants are almost completely restricted to the present range of red oak. Hickory and chestnut-oak, species characteristically found in the Oak Forest region, are present within the range of red oak.

The distributional evidence suggests that the forests peripheral to the central divide area in the Northern Hardwood region, roughly contained in the range of red oak, represent a floristic transition zone between the forests of the central highlands zone of the Northern Hardwood region and the Oak Forest region to the south.

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STATISTICAL EVIDENCE OF REGIONAL VARIATION IN FOREST COMPOSITION

A central highlands zone and a transition zone within the Northern Hardwood region, and the differences between these two subdivisions of the Northern Hardwood region and the Oak Forest region can be demonstrated by arranging the distribution data for all tree species into three classes: 1) species found in the forests outside the range of red oak; 2) species found in the forests outside the range of white oak, but within the range of red oak; and 3) species found within the range of white oak (Fig. 6). Comparison of the first and third classes shows that several species vary widely in frequency⁶ and that the second class usually shows a frequency intermediate between the two. Red maple, black birch, large-toothed aspen, butternut, witch-hazel, and cucumber-tree show highest frequencies within the Oak Forest region, lowest in the forests of the central highlands zone, and intermediate in the forests of the transition zone. Conversely, sugar maple, beech, yellow birch, and black cherry show highest frequencies in the forests of the central highlands zone, lowest in the Oak Forest region, and intermediate in the forests of the transition zone. White ash, tulip-tree, hop-hornbeam, trembling aspen, basswood, and elm show maximum frequencies in the transition zone.

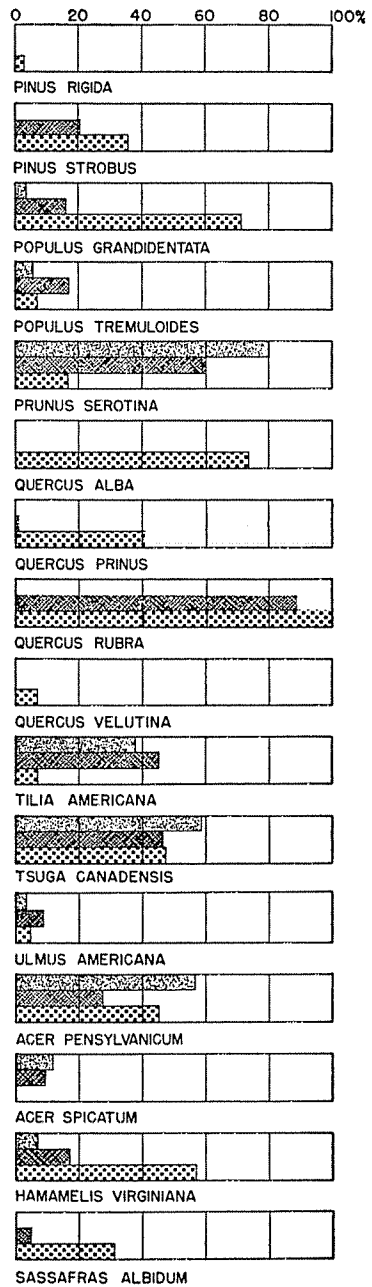
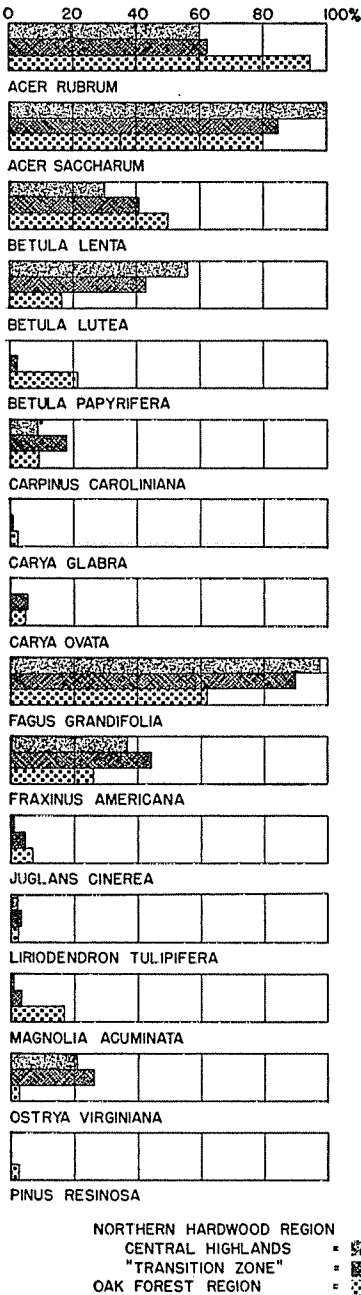
Similarly, the distribution data for the principal non-tree species (Fig. 7) indicates that sweet-fern, blueberry, and maple-leaved viburnum, common in the Oak Forest region, are absent from the central highlands zone of the Northern Hardwood region. Maidenhair fern, marginal shield fern, New York fern, Christmas fern, and the club-mosses are present in the central highlands zone of the Northern Hardwood region, but are essentially absent from the Oak Forest region. All these species are present in the transition zone of the Northern Hardwood region in varying frequencies.

Several non-tree species found throughout the county show intermediate frequencies in the transition zone of the Northern Hardwood region, as did the tree species. Hay-scented fern, mountain laurel, and bracken are most common in the Oak Forest region, less common in the transition zone, and rarest in the central highlands zone. The frequency of marginal shield fern shows the reverse order.

⁶ Frequency, as used here, is the number of localities in a single class at which a species is found, compared with the total number of localities examined in that class, expressed in percent.

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FIGURE 6. FREQUENCY OF TREE SPECIES

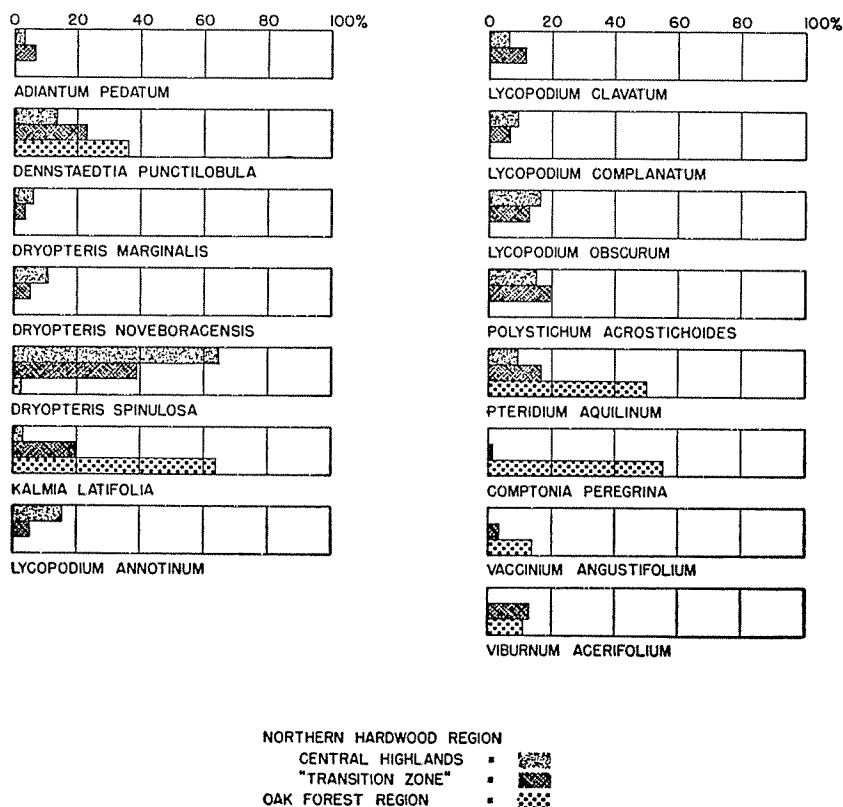


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PHYSIOGNOMIC DIFFERENCES IN THE FOREST

Differences in species composition in the Oak Forest region and the two parts of the Northern Hardwood region result in differences in the life forms represented, and lead to differences in the over-all appearance of the forests.

FIGURE 7. FREQUENCY OF NON-TREE SPECIES



In the central highlands zone of the Northern Hardwood region the beech, birch, and maple trees comprising the bulk of the stands have straight boles and upsweeping branches, forming an even-surfaced canopy. The dense canopy produces a heavily shaded forest floor, accentuated by the fern and club-moss mat. The open nature of the forests in the Oak Forest region is in strong contrast to the forests of the central divide area. The more widely spaced oaks with their somewhat heavier, more diver-

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gent branches form a discontinuous, irregular-surfaced canopy. Dense tangles of laurel and other shrubby plants, along with heavy stands of bracken and hay-scented fern appear in the open places. In the transition zone, of the Northern Hardwood region, the forest more nearly resembles that of the central highlands. However, the red oaks scattered through the stands rise above the general canopy level, and spread laterally. Viewed from a distance, their irregular, somewhat globose crowns, quite different in texture from the surrounding trees, stand out sharply as a supercanopy. Occasionally concentrations of red oaks produce stands quite similar in appearance to the forests in the Oak Forest region. This is pronounced in the stands that have a shrubby layer in the understory.

FOREST TYPES

DEFINITION

The areal differentiation of the forests of Potter County provides a foundation for the establishment of three somewhat arbitrary, but concrete, forest types. A fourth forest type is proposed, to recognize the distinctive characteristics of stands containing chestnut-oak. Chestnut-oak has a restricted distribution, and its presence is usually accompanied by other changes in composition of the stands (Fig. 8). These stands consist largely of red maple, red oak, white oak, chestnut-oak, large-toothed aspen, and black birch. Blueberry, mountain laurel, sweet-fern, sassafras, and striped maple comprise most of the ground cover and understory.

The four-way subdivision of the forests is summarized in the following key:

- Oak present
 - Chestnut-oak present chestnut-oak type
 - Chestnut-oak absent
 - Red oak the only oak present red oak type
 - Both red and white oak present . . . white oak type
- Oak absent beech-birch-maple type

Delineation of concrete forest types is desirable so that marked variations in the forests within a floristic region may be briefly described. The species that characterize a region seldom occupy all habitats within that region. Thus, forests can be found in each region that most nearly resemble those characteristic of other regions. For example, within the range of red oak there are stands lacking red oak that most nearly resemble the forests of the central divide area. A further reason for segregating forest types within the floristic regions is that the local distribution of

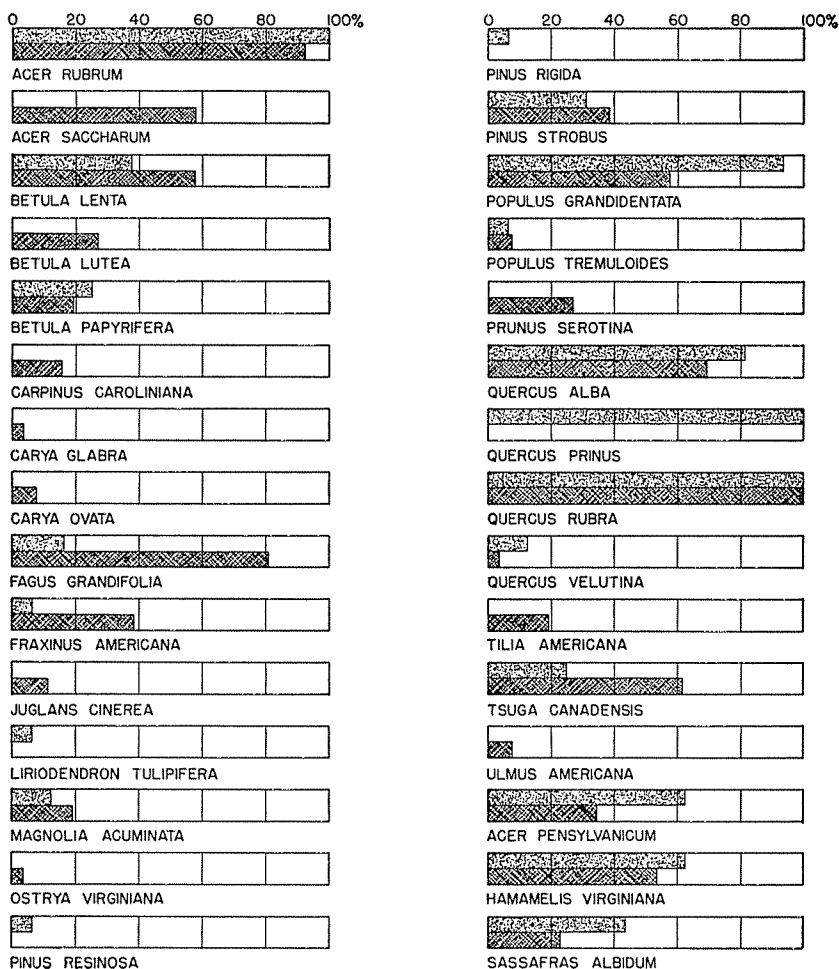
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species and groups of species can be predicted, with some degree of accuracy, if the characteristics of the surficial materials are known.

GENERAL DISTRIBUTION

Within the Northern Hardwood region most of the high plateaus support forests of the beech-birch-maple type that cover the landscape from

FIGURE 8. FREQUENCY OF TREE SPECIES IN CHESTNUT-OAK TYPE FORESTS COMPARED TO OTHER STANDS WITHIN THE OAK FOREST REGION LACKING CHESTNUT-OAK



▨ = OAK FOREST REGION, CHESTNUT OAK PRESENT

▩ = OAK FOREST REGION, CHESTNUT OAK ABSENT

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ridge crest to valley bottom. The largest continuous forest of the beech-birch-maple type occupies an area approximately 12 miles in greatest dimension on the broad plateau in the central part of the county that divides the Allegheny, Genesee, and Susquehanna watersheds (Fig. 5). This central mass has three main branches. One narrow branch extends northward on the plateau to the Genesee-Cowanesque River divide where it forks, one branch extending northwestward between the Genesee River and Owayo Creek, the other branch occupying the narrow plateau between the Cowanesque River and Pine Creek to the southeast. A second branch extends southeastward on the uplands to a point approximately five miles north of Cross Fork, where it turns northeast on the plateau dividing the Pine Creek-Kettle Creek drainage systems. The third branch extends westward on the Allegheny River-Sinnemahoning Creek divide to a point approximately four miles southeast of Keating Summit.

Red oak type forests within the Northern Hardwood region occupy most of the watersheds of the Allegheny River-Owayo Creek system, Sinnemahoning Creek and its branches, the Cowanesque River, and Pine Creek and its branches (Fig. 5). Parts of the Kettle Creek drainage basin lying between the beech-birch-maple type forests of the high plateaus and the Oak Forest region to the south support red oak type forests. The red oak type forests of the West Branch of Pine Creek extend a long finger up on the divide between Pine Creek and Kettle Creek, almost splitting the beech-birch-maple type forests of the high plateaus into two parts (Fig. 5). Scattered, isolated stands of red oak type forest are found in the beech-birch-maple forests of the high central divide area.

The Oak Forest region (Fig. 5) is most extensive in the southern part of the county where white oak, chestnut-oak, and occasional red oak type forests form a continuous cover. A tongue of the Oak Forest enters the county from the east along Pine Creek and occupies a small area in the vicinity of Galeton. A second small area of white oak type forest is found in the Owayo Creek drainage basin in the northwestern part of the county. This is an eastward extension of the Oak Forest region of the Allegheny River valley.

FOREST TYPES AND SURFICIAL GEOLOGY

The distribution of the forest types of Potter County shows some relationship to the distribution of the geologic formations and the surficial deposits that overlie them. The evidence suggests that the mantle of loose, heterogeneous surficial materials which occurs throughout the county is primarily responsible for the uniformity of the forests on either side of the border of the Wisconsin drift, and for the vertical uniformity of vege-

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tation within the Northern Hardwood region. Local concentrations of fragments of sandstone in the surficial deposits bring about local variations in the depth to water tables, roughly in proportion to the abundance of fragments. These variations are reflected in the vegetation by the appearance of forest types that are more xerophytic than those on adjacent less stony surficial materials.

In general, the Pottsville formation⁷ is overlain by yellowish-brown sands and loamy sands that contain and are overlain by large blocks of sandstone or conglomerate.

The Pocono formation underlies yellowish-brown sandy loams or silt loams that can be divided into those that are "rubbly" or contain an abundance of rock fragments, and those that contain essentially no rock fragments or only a small percentage. The rubbly areas often show a wide variation in stone content within short distances, the result of the presence of boulder stripes. Denny (1951, p. 122) describes boulder stripes as follows:

In some places, both within and outside the glaciated area, surficial concentrations of boulders on slopes of 2° to 10° are arranged in roughly parallel stripes. Irregular boulder bands 2 or 3 feet to more than 10 feet wide are separated by relatively stone-free areas 10 to 50 feet wide. Excavations across these stripes show a mass of rock fragments that are packed tightly together and extend to depths of 2 to 3 feet. At comparable depths the material between the stripes is relatively free of rock fragments.

Other rubbly deposits do not show a sorting of fragments into boulder stripes, but appear as broad sheets of rock concentrations, or rock fans. Still other deposits classed as rubbly may appear as very channery and flaggy⁸ sandy loams or silt loams. The coarse skeleton of these deposits generally constitutes more than 35 percent of the soil volume.

The Catskill formation or "redbeds" are overlain by reddish silt loams that generally are not rubbly. The soil materials overlying the Chemung formation are similar to those overlying the Pocono formation.

The relationships between forest types and surficial deposits differ in the two floristic regions.

⁷The fine-grained conglomerates and coarse-grained sandstones that cap some of the ridges in Potter County will be referred to as the Pottsville formation in this paper.

⁸Channery: "soils contain fragments of thin, flat sandstone, limestone, or schist up to 6 inches along the longer axis. A single piece is a *fragment*" (Soil Survey Manual, 1951, p. 215).

Flaggy: "soils contain relatively thin fragments 6 to 15 inches long of sandstone, limestone, slate, or shale, or, rarely, of schist. A single piece is a *flagstone*" (Soil Survey Manual, 1951, p. 216).

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NORTHERN HARDWOOD REGION

GENERAL FIELD RELATIONS

The general character, structure, and distribution of bedrock and surficial deposits in the Northern Hardwood region of Potter County are shown in Figure 9. The surficial deposits are divided into two classes: 1) rubbles or those that contain an abundance of rock fragments; and 2) non-rubbles, or those that are dominantly silt loam, sandy loam, or loamy sand. Across the top, the diagram shows the forest types that are associated, in most areas, with the geologic bodies that lie directly below.

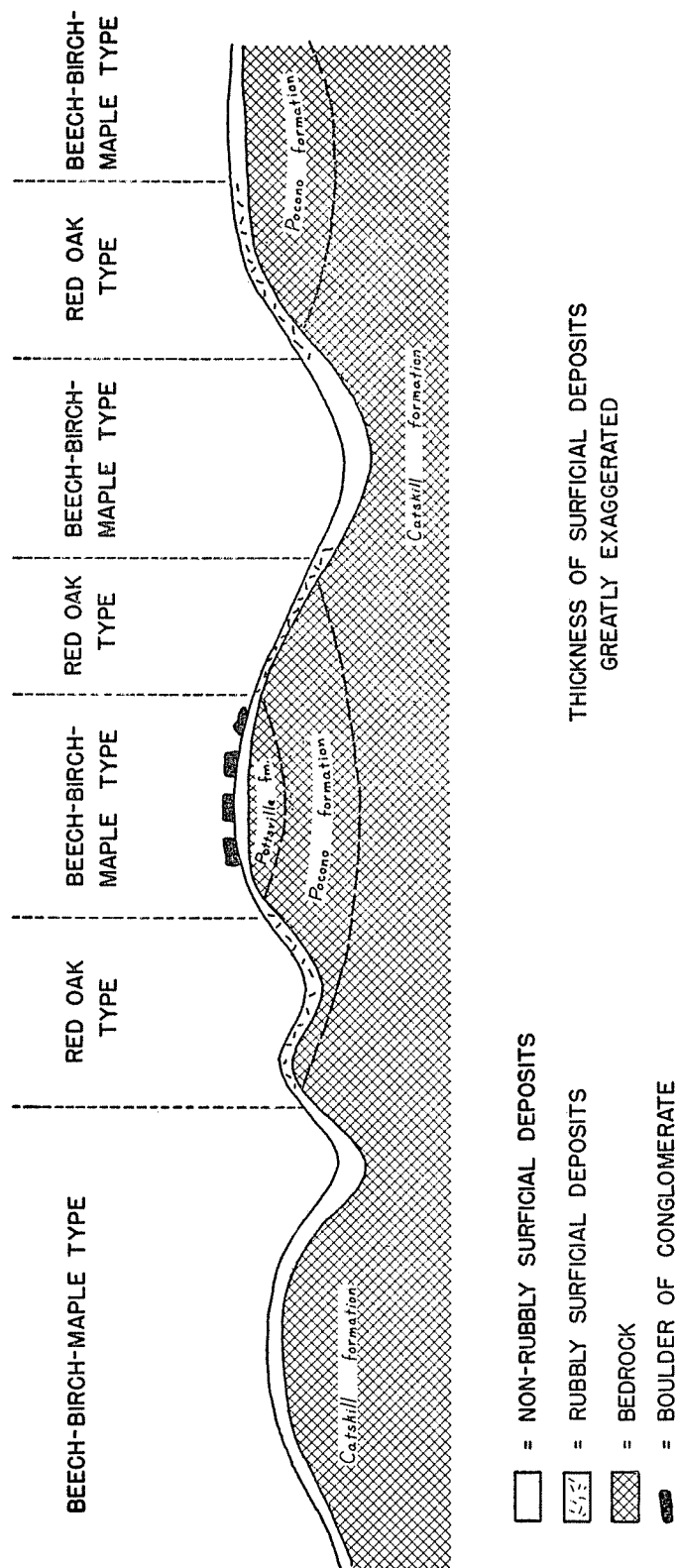
Figure 9 is a broad generalization based upon detailed field work. It shows that the beech-birch-maple and red oak forest types overlie both the Pocono and Catskill formations. The red oak type grows on rubbles, whereas the beech-birch-maple type is found on non-rubbly surficial deposits. There are many exceptions to these generalizations. Two relationships that have almost no known exceptions are, first, the occurrence of the beech-birch-maple type on ridge crests underlain by coarse sandstone and conglomerate of the Pottsville formation and, second, the occurrence of the red oak type on rubbles. However, it is not a fact that all rubbles support the red oak forest type.

LOCAL DISTRIBUTION

Plateau surfaces underlain by sandy soils derived from the Pottsville formation support forests of the beech-birch-maple type. Forests growing on the Pocono formation show a wide range of variability. On most broad essentially level plateau tops that are covered with thick deposits of non-rubbly sandy loams to silt loams grow forests of the beech-birch-maple type. Plateau tops with a thin covering of rubbly materials generally support forests of the red oak type, although forests of the beech-birch-maple type, composed largely of beech, also occur on these materials.

Steep upper slopes covered with a thin mantle of rubble generally support the red oak type. In general the mantle of surficial materials is thicker toward the valley floor, and the forest may change to the beech-birch-maple type. Forests of the beech-birch-maple type are also found on gentle upper slopes near the heads of streams where the surficial deposits are thick. Most lower slopes are covered with surficial materials derived from the Catskill formation or from both the Catskill and Pocono formations and also support beech-birch-maple type forests. Rubbly deposits on lower slopes may support forests of the red oak type. Hills mantled with non-rubbly materials derived from the Catskill formation support forests of the beech-birch-maple type.

FIGURE 9. IDEALIZED PROFILE SHOWING FOREST TYPES, SURFICIAL DEPOSITS, AND BEDROCK GEOLOGY IN THE NORTHERN HARDWOOD REGION OF POTTER COUNTY, PENNSYLVANIA



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OAK FOREST REGION

GENERAL FIELD RELATIONS

The general character, structure, and distribution of bedrock and surficial deposits in the Oak Forest region of Potter County are shown in Figure 10. Rubbly and non-rubbly surficial deposits are distinguished, as in the Northern Hardwood region. However, the mantle of surficial deposits in the Oak Forest region is, in general, thinner and more rubbly than in the Northern Hardwood region. Surficial materials on lower slopes are only 2 to 3 feet thick in many places, and outcrops of bedrock are more numerous. In general, in the Oak Forest region, the chestnut oak forest type grows on very rubbly materials derived largely from the Pocono formation, whereas the red oak forest type grows on the Pottsville formation and on the thicker and less rubbly materials derived from the Catskill formation. The white oak forest type grows on surficial materials that are in general thicker than those beneath the chestnut oak type, but are more rubbly than those beneath the red oak type. There is a suggestion, therefore, that there is a coincidence between the sequence, chestnut-oak-white oak-red oak forest types and a change from thin, rubbly surficial deposits to thick non-rubbly surficial deposits.

LOCAL DISTRIBUTION

The relationships between forest types and surficial deposits vary to some extent with topography, whether the stand is on a hill top, a steep slope, or a gentle slope. However, the chestnut oak type forest grows on thin, very rubbly deposits derived from either the Pocono or Catskill formations, regardless of topographic position. Some thin rubbles support forests of the white oak type.

On plateau surfaces the red oak type forest grows on sandy materials derived from the Pottsville formation, and on relatively thick, non-rubbly materials derived from the Pocono and Catskill formations. The white oak type forest is found generally on moderately stony sandy loams and silt loams overlying both the Catskill and Pocono formations.

Gentle slopes often are mantled with somewhat thicker or less rubbly materials than adjacent steep slopes. A change in slope, therefore, is often accompanied by a change in forest type. Non-rubbly deposits on steep slopes generally support forests of the white oak type. Non-rubbly deposits on gentle slopes, particularly if derived from the Catskill formation, often support red oak type forests. Forests of the red oak type are uncommon on steep slopes.

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POSSIBLE EXPLANATIONS OF GEOBOTANICAL RELATIONSHIPS

The surficial deposits of Potter County are closely related to the underlying bedrock and, within each of the two floristic regions, the forest types are related to variations in the surficial deposits. The most significant variation in the surficial deposits is in the degree of stoniness of the materials, whether they are rubbly or non-rubbly. Rubbles are derived from both the Pocono and the Catskill formations. The more xerophytic forest types, or the red oak type in the Northern Hardwood region, and the chestnut-oak type in the Oak Forest region grow almost without exception on rubbles. However, all rubbles do not support these forest types.

Surficial deposits derived from the Pottsville formation are non-rubbly, and are found only on the crests of the higher ridges. Within the Northern Hardwood region, surficial deposits derived from the Pottsville formation almost without exception support forests of the beech-birch-maple type. In the Oak Forest region the red oak type generally grows on these materials.

Non-rubbly surficial deposits derived from the Catskill and Pocono formations support forests of the beech-birch-maple type in the Northern Hardwood region. Forests of the red oak and white oak types, in the Oak Forest region, grow on the less rubbly surficial deposits derived from the Catskill and Pocono formations. Whether red oak or white oak types occur seems to depend largely upon the thickness of the deposits and the degree of slope. However, thick non-rubbly deposits derived from the Catskill formation generally support forests of the red oak type.

A working hypothesis to explain these changes in forest types is that they are related to the permeability of the surficial deposits. The thinner, more rubbly surficial deposits are very permeable and support the more xerophytic forest types. The occurrence of such types may be related, therefore, to the presence of highly permeable surficial materials where the permanent water table is doubtless at a greater depth than in the less rubbly deposits. It is probably also true that in rubbles, a temporary high water table caused by heavy rains or melting snow will exist for only a short time and will disappear much faster than similar temporary water tables in less permeable non-rubbly surficial deposits.

Most changes in surficial materials occur with changes in altitude (Figs. 9 and 10) because the bedrock is essentially flatlying. The accompanying changes in vegetation might be due, therefore, to changes in altitude or slope. However, on a few ridge tops a change in surficial deposits without change in altitude or exposure shows the same change in forest type, indicating that the relationship is primarily between surficial

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deposit and forest type, rather than between slope, exposure, or altitude, and forest type. The occurrence of one forest type from the summit to the base of a hill that has uniform surficial materials further suggests such a relationship.

Pre-settlement forests of the uplands

HISTORY OF EXPLOITATION ⁹

The dense forests of Potter County were viewed by the early settlers as a tremendous obstacle to the development of agriculture. Within a hundred years the pre-settlement forests were completely destroyed. The supposed latent wealth of the soil is only now becoming available as a result of modern farming methods, and once again more than half of the county is covered with considerably less valuable examples of that old enemy, the forest. During the dark days of the recent Great Depression, Beebe (1934, p. 163), the local historian, told the story of this largely wasted opportunity:

Our timber was, as we now realize, our most valuable natural resource. The opinion was often expressed two generations ago, that no true prosperity would ever be attained by our people, till the timber should be exhausted, and attention turned to farming and other pursuits. It is now only too apparent that this was not the truth. It is a fact that the methods then used in lumbering were wasteful, and that the floating population of lumber camps and sawmill towns was not equal in solid worth to that class of our citizens who were engaged in less transient pursuits. But this condition, as we now realize, is one of the ever present evils of brisk industrial growth, and is a part of the price that must always be paid for material prosperity. The only mistake was made in the too early and too rapid removal of the timber, entailing much waste, because the value of the timber at the time it was cut had not increased to the point that would make close conservation profitable. This posthaste removal of the timber was brought about by the excessive taxes imposed on the large landholders, forcing them to cut their timber to escape the payment of an enormous annual tribute to the scattered population of the timbered districts. The advice was often given at town-meetings and gatherings of local officials to "lay the taxes right on; in a few years the timber will be gone, and we shall have no unseated taxes." This short-sighted policy speedily brought about the destruction of our primeval forests, and exhausted our most valuable resource. No development can now be predicted that will restore our population to the figure it once reached, or bring back the time when any man who wished to work could find employment on the nearest log job. Those

⁹ Unless otherwise noted, the information upon which this section is based is derived from Beebe's *History of Potter County, Pennsylvania*.

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days are gone forever; and the future progress of Potter must follow another course.

For many years the only tree of economic importance in the forests was white pine, which was generally rafted down the major streams to city markets. Shortly before the pine supply was exhausted, the exploitation of hemlock and hardwoods began. The period of most rapid removal of the forests followed, largely due to the development of a railroad net throughout the county connected with the major markets. Gigantic saw-mills were constructed in the county, and many wood-using industries moved into the area. Thus the lumbering operations fell roughly into two phases: 1) the pine era, building up slowly from the time of settlement to a peak about the time of the Civil War and essentially closed by 1890; and 2) the hemlock-hardwood era, beginning about 1870, reaching its peak between 1900 and 1905, and virtually over by the end of World War I.

North central Pennsylvania, including that part now known as Potter County, was almost unknown to the white race prior to its purchase from the Iroquois Confederation in 1784. The first permanent settler probably did not arrive in Potter County until 1808. Sweden Township, in the central part of the county, is assumed to be the site of the first permanent settlement. The population grew very slowly; the census of 1810 lists only 29 inhabitants in the whole county, and the census of 1820 lists only 186.

Before 1820, some white pine was being rafted to Pittsburgh from the Allegheny region, and possibly from the Oswayo. At this time, pine lumbering was carried on by individual settlers only along the major streams. The timber was sawed in small water-powered mills, and rafts of sawed lumber or square timber were floated downstream. The first large company was organized in 1837, and began operations in the Oswayo valley.

Lumbermen operating on the Sinnemahoning and Pine Creek rafted down the Susquehanna River to the head of navigation, where the timber was loaded on vessels for New York, Philadelphia, and other cities on the eastern seaboard. This was a better market than Pittsburgh, and much pine was later hauled over the divide to Pine Creek from the central part of the county. Some pine was hauled overland to Dansville, N. Y. after the opening of the Erie Canal in 1825. The opening of the New York and Erie (Erie) Railroad in 1851, connecting the Hudson and Lake Erie, gave the lumbermen of the northern half of the county a better outlet for their product. Lumber was then hauled overland by wagon to Wells-ville, New York.

Just prior to the Civil War the use of rafts was sharply reduced. Booms

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were constructed on the Allegheny at Olean, and on the Susquehanna at Williamsport to catch loose logs, and the lumber companies ceased the practice of rafting. As a result, pine logs that formerly were converted into lumber in the county were processed in other mills adjacent to the booms.

In 1851 Potter County had 83 sawmills, with an estimated yearly output of 20¾ million feet of pine lumber valued at seven dollars per thousand. More than half of this amount came from the 15 mills in the Oswayo valley. The Potter County Journal of March 15, 1860¹⁰ gave the following production figures for white pine by streams:

	<i>Logs</i>	<i>Square Timber</i>	<i>Lumber</i>	<i>Shingles</i>
Pine Creek	4,000,000		2,500,000	200,000
Youngwomans Creek	2,000,000		1,000,000	200,000
Kettle Creek	4,000,000		1,000,000	200,000
Sinnemahoning	4,000,000	2,000,000	2,000,000	2,000,000
Hunt's Run			3,000,000	
Portage Creek		500,000	400,000	
Allegheny Portage	5,000,000			
Allegheny	5,000,000		2,000,000	1,000,000
Oswayo	15,000,000		12,000,000	12,000,000
Honeoye	5,000,000		6,000,000	3,000,000
Eleven Mile			5,000,000	2,000,000
Genesee			3,000,000	
Total board measure, 100,300,000				
Aggregate value, \$802,400				

These figures indicate that the pine in the northwestern quadrant of the county was being harvested at a terrific rate, although the operations were becoming general throughout the county.

Pine lumbering was still active in parts of the northern half in the 1870's, although the emphasis had shifted to the southern part. The end of the pine era is described by Beebe (1934, p. 174):

After 1880, the pine timber began to be exhausted in this county. The earlier lumbering had been very wasteful, and for many years a profitable business was done in manufacturing shingles, with occasionally a little lumber, from the fragments of pine timber remaining in the old cuttings. . . The last pine on the Sinnemahoning was being cut in 1886, and the last pine logs were run down the Oswayo in 1889. The last large tract of pine timber in the county stood on the west branch of Dingman Run in Eulalia Township. . . Another smaller

¹⁰ As quoted by Beebe (1934, p. 169); not available to author.

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tract of pine was . . . in Bingham Township on the road from Hickox to West Bingham.

The Dingman Run stand was cut about 1893, and the stand in Bingham Township was cut in 1896.

The following statement is quoted at length because of its vivid description by contemporary writers (Haskell, et al., pp. 980-981) of conditions and feeling in Potter County at the end of the pine era:

The mountain sides and valleys of Potter County were formerly covered with a luxuriant growth of timber, pine and hemlock greatly predominating. This timber, were it upon the stumps today, would yield a wonderful capital; but at this date [1887] the last straggling pines are being gathered. This year will probably finish up the pine lumbering of our section, and the hemlock is beginning to fall rapidly beneath the woodman's axe, more for its bark than for its lumber. It would naturally be supposed by those who know nothing of the history of the county that the marketing of this great mass of timber would have made at least a few of our citizens very wealthy, and have greatly improved the financial standing of many more, but this is not the case. We know of no Potter citizen who has been made wealthy by the pine of Potter, and very few who have been benefited even to a moderate degree therefrom. On solution of this problem we will advance the first and most important reasons, and this is that the bulk of the land in the county has been and still is owned by capitalists living without the county — in Philadelphia, New York, Williamsport and elsewhere. In an early day, when a piece of land was sold to an actual settler, there was little chance of marketing, and the forest was chopped down and the logs burned in the log heaps of the fallows, many of the fine pines being cut into rails. Later, as the pine became more valuable, when a piece of land was sold the pine was reserved, as is still done, giving the settler so much for preparing it for market, or the land was held until the pine was taken off of it. There were no large mills in the county to manufacture the lumber, and thus bring money into the community. The logs were peeled by gangs of men, and rafted or driven along the streams into the great booms beyond the borders of the county. Many logs went to Pittsburgh, down the Allegheny, in an early day, but of late years the pine has found its way to the boom at Williamsport, to be manufactured in the giant sawmill at that city, either by way of Pine Creek or the Sinnemahoning and Susquehanna. A great majority of the men working in the lumber camps of the county came from beyond the limits of the county. Some camps were made up entirely with loggers from Maine, and even from Canada and other remote points. It was necessary to the prosperity of the owners and jobbers that this should be so, for Potter could not supply the men to do the work. There has ever been sufficient work in the woods for all of the citizens of Potter. But aside from the wages of the rough men, there has been comparatively little of the great profits of the business which has remained in the county. An evil this system has brought is that farms were neglected, and

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that tracts of land have been left unimproved. One can realize this in an instant when entering a section where a little pine is left, and where lumbering has not yet ceased to tempt the settlers from their homes. A great part of the farms lay in old slashings, with the tree stems lying where they fell. The houses are very primitive, small and uncomfortable. The cattle have a lean, half-starved look, and the people you meet are more or less costumed in the bizarre fashion of the backwoods. Their language overflows with coarse slang, and with the men it is mingled with much profanity. The fences about the farms are tumble-down affairs constructed of mossy rails, logs or brush, slashed in windrows. A general air of dilapidation crowns the whole of the landscape. It is not until this section is entirely cleared of its lumber camps that we may begin to expect improvements upon the farms, whilst a more civilized manner of dressing, and a more Christian-like use of language would be desirable. This same lumbering business which invaded Potter at an early day, and has bound it in slavery down to the present time, is to blame for the uncultivated condition of the greater portion of our county today. It has kept us fifty years in the rear of sections unhampered thereby. Many have been ruined by attempting to work as contractors in a business they did not thoroughly understand. Others have lost their year's work by working for unscrupulous contractors or those who were unlucky and insolvent also. Men have been made rich by dealing in the pine of Potter County, but they were foreigners, and they took their money with them to spend elsewhere. Whatever others may have done, our county has been made poorer in every way by the pine forests which at one time beautified its mountain slopes. Could the pine have belonged to our citizens, it would not have been so bad, and even this, we doubt not, would have been cut and sold, with more or less of the demoralizing influences at work, the effects of which we now deplore. Potter has been despoiled of her pine, while where it stood are vast barrens to remind us of what once was our pride.

Of the hemlock, much land has been cut over for the bark for tanning purposes, and this has been nearly as demoralizing to the denizens of the hemlock districts as the cutting of the pine. Thousands of acres have been slashed for this purpose, and the timber left to rot and the ground to grow up to fire cherries and briers. At present the prospect is more cheering, as mills are rapidly being built to manufacture the hemlock lumber, with now and then a giant in its way like the great saw-mill at Austin, capable of manufacturing 1,000,000 feet every ten days; the colossal mill at Galeton, and the large mill to be built at Nelson by the Lackawanna Lumber Company. Millions of feet of hemlock logs are now being cut every year, and the advantage to us is that we shall reap some benefit from the industry of home manufacture. Beyond the immediate earnings from the lumber business we shall probably have more railway facilities, and be brought nearer en rapport with the vast world of life and action which lies beyond our borders.

The large quantity of hemlock timber in Potter County was considered of little value during the first half of the nineteenth century, and was

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used for construction locally only when pine was not available. The primitive transportation system discouraged the cutting of hemlock for bark. Except for the movement of logs and rafts down the streams when they were in flood stage, all materials had to be hauled by wagon to the nearest water or rail head outside the county.

In 1873 the Western New York and Pennsylvania Railroad was opened between Buffalo and Emporium, and passed through Keating Summit, in the western part of the county. This railroad provided an outlet for hemlock bark, which was becoming valuable, and hemlock operations commenced. A railroad network was rapidly constructed throughout the county, connecting with the main eastern roads. Narrow-gauge railroads, connecting with the main rail net, permitted access to any part of the forest.

After 1880 the stage was set for the rapid exploitation of the hemlock. White pine was being exhausted throughout the north central states, and building materials were still in great demand. The transition from pine to hemlock lumbering was smoothly made. While pine was still available, hemlock logs were burned or left to rot in the forest after the bark was removed. As pine became scarcer, the logs became valuable, too. In 1880 hemlock logs were worth \$2.50 per thousand on the Allegheny or the Sinnemahoning. Very few industries in the county were dependent upon pine timber; and after the practice of rafting ceased about 1850, few sawmills were cutting pine.

The hemlock operations soon came under the control of giant lumber companies that purchased most of the unsettled lands of the county. The rail network encouraged the development of wood-using industries, many of which required large quantities of hardwoods. For the first time, hardwoods as well as softwoods could be sold in quantity, and the efficiency of the lumber companies, encouraged by the tax policies, insured the rapid removal of the forest. Efficient, large capacity sawmills were erected near centers of logging operations where they were fed by the rail net. A giant mill at Austin was cutting more than 7 million feet of lumber a month in 1887 and employed 175 men (Haskell, et al., 1890, p. 1113).

The Goodyear Lumber Company owned great tracts of forest in the southwestern and central parts of Potter County. The cutting of these holdings was begun in 1885, and completed in 1909. By 1890 the annual output was 60,000 tons of hemlock bark and 100 million feet of lumber (Haskell, et al., 1890, p. 1118). The hardwoods on the Goodyear lands were cut by the Emporium Lumber Company, which began operations

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in 1892 and ceased to be active about 1917. The Lackawanna Lumber Company began cutting hemlock and hardwoods along the Allegheny and its tributaries west of Coudersport about 1877. It later shifted to the southeastern part of the county, cutting timber in the Kettle Creek and part of the Hammersley Fork drainage basins. Sometime after 1900 the Central Pennsylvania Lumber Company began cutting its scattered holdings, and cut the last stands of hemlock in the county in 1920.

Between 1877 and 1886 six large tanneries were built in Potter County to utilize hemlock bark. Several factories sprang up to kiln-dry and bind fragments of the hemlock slabs discarded at the mills for kindling wood. A pulp mill later used most of the hemlock waste from the Austin mills. After 1880 many plants were built in the county to utilize hardwoods, which formerly had little value. Some hardwoods, such as ash and black cherry, had been shipped outside the county during the early days of lumbering, but never in any quantity. At least seven plants made barrels or barrel components. The stave and heading plant at Hulls employed 150 men and used 8 or 10 million feet of hardwood per year. Six chemical plants made wood alcohol, acetate of lime, and charcoal from any available hardwoods. Other plants made hubs, veneer, baskets, mangle rollers, brewery chips, butter dishes, and other wood containers. A clothespin factory in Coudersport, reputed to be the world's largest, used 2 million feet of beech a year. Almost all of the wood-using industries ceased their activities or moved out of the county during or shortly after World War I, as the timber became exhausted.

In 1897, the logging operations reached their maximum, with a recorded cut of approximately 600 million feet of lumber. The population reached its peak between 1900 and 1905, when the hemlock-hardwood industry employed hundreds of people in factories, mills, and tanneries, and required an army of woodsmen to "mine" the raw materials. Almost all of the timber, both softwoods and hardwoods, had been removed by 1915. The cutting of the last important tract of timber, a stand of hemlock near Costello, was completed in 1920.

A few settlers were attracted to the cleared land resulting from the intensive logging operations in the south, but most of them later abandoned their holdings. As early as 1891, the Goodyear Lumber Company offered cutover land for sale, and a large area was sold to a short-lived land company, which was forced to sell much of the land for taxes. Most of the land owned by the large lumber companies was eventually made a part of the state forest lands.

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COMPOSITION AND GEOGRAPHIC DISTRIBUTION

METHOD OF RECONSTRUCTION

The history of the lumbering era in Potter County indicates that large quantities of white pine were removed from the forests. Later the hemlocks and hardwoods were essentially clear-cut. Although the presence of numerous pines in the pre-settlement forests is well established by the historical record, and its geographic distribution roughly outlined, local distribution and relationships to present forest types are not clear.

The classification of forested land during the lumbering era was highly practical, and roughly divided the forests into pine, hemlock, and hardwood stands. Little can be determined of the species composition from this classification. Some of the species of hardwoods present in the county can be determined by compiling a list of the kinds of wood used in the wood fabricating plants, but their geographic distribution cannot be fixed.

Therefore, the establishment of the distribution patterns of tree species in the pre-settlement forests must rest upon other lines of evidence. These consist of stump remnants, occasional patches of forest containing a few old trees, and a pre-settlement land survey of the county which employed "witness trees" to mark boundaries. From this fragmentary evidence, something of the distribution of tree species in the pre-settlement forests can be learned and a comparison made with the distribution of the tree species in the present forests.

DISTRIBUTION OF WHITE PINE AND HEMLOCK

EVIDENCE FROM POST-SETTLEMENT RECORDS

The white pine production of Potter County for the year 1860, cited previously, indicates that pine was present in quantity in the drainage basins of all the major streams of the county except the Cowanesque River. However, the presence of a shingle mill, and a sash, door, and blind factory in the Cowanesque valley suggests that white pine was present (Beebe, 1934, pp. 173-174). Beebe (1934, pp. 163-164) carefully delineated the area of white pine in his reconstruction of the forest at the time of settlement:

Let us consider briefly the kind of timber that covered our lands before any of it had been removed. By far the most valuable item was the white pine. It is hard for us now to realize the original extent of our pine forests. Only a few stumps remain; even most of these have been eradicated. The last stand of virgin pine was cut in 1892. The original acreage of pine timber in the county probably equaled that of the hemlock, or at least would have cut as many board

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feet of lumber, as the pine trees were both larger and taller than the other timber. The best of the pine was that great forest that covered the whole of the valley of the Oswayo and its tributaries, the Honeoye, the Eleven Mile, Clara Creek, the South Branch, extending over the divide to the headwaters of the Genesee and the Cowanesque. The boundary line of this tract of pine was the edge of the continental divide that separates the valley of the Allegheny from that of the Susquehanna, beginning in Ulysses township and extending across Sweden, Summit, Homer, and Keating. There were several patches of pine along the north side of the Allegheny River, in some cases extending up the hillside. . . At some points, these patches were continuations of the pine forest of the Oswayo, extending over the watershed. . .

A second tract of pine covered the southern and southeastern parts of the county, occupying the tops of the ridges and many of the hillsides in the country drained by Pine Creek, Young Woman's Creek, Kettle Creek, and the Sinnemahoning, also Hunt's Run, a tributary of Driftwood Creek, which was included in Potter County at the time the pine was cut. This timber was probably not quite equal in quality to that of the Oswayo valley, but its location was more favorable, since it could be readily run down the Susquehanna to the eastern markets. The top of the great continental watershed was timbered chiefly with hardwood, with some admixture of hemlock, and originally contained groves of the finest cherry and ash; oak and chestnut were also found in certain localities. There was considerable hemlock over the whole county, mingling more or less with the pine, but the tallest and finest hemlock trees stood on the steep hillsides sloping from the Continental Divide.

In effect, Beebe recognized three general forest regions: 1) a central divide area occupied by hardwoods with lesser amounts of hemlocks; 2) a concentration of hemlocks in the forests on the steep slopes peripheral to the central divide area; and 3) pine forests containing admixtures of hemlock in the remainder of the county. He implies that the pine was more uniformly distributed and more continuous in the northwestern pine tract than in the southern and southeastern tract.

EVIDENCE FROM STUMP REMNANTS

A more nearly exact delineation of the area of white pine in the old forests can be made by mapping the stump remnants (Fig. 13). A large number of white pine stumps remain, even though many were removed for agricultural reasons or for the manufacture of shingles. Although the last pines were cut more than 50 years ago, most pine stumps are still in a fair state of preservation. They range from about 24 inches to 60 inches in diameter, most of them being from 30 to 40 inches in diameter. Most of the stumps are hollow, with a firm outer shell, and samples of the wood usually contain enough resin to yield the characteristic pine odor. The old

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sawline is generally evident. Many stumps in the northern part of the county have been reduced to a rude circle of upright slabs of firm wood, all that remains of the outer rind. Most of the stumps in the southern part of the county are not hollow, and the growth rings are still visible, often to the core.

Concentrations of pine stumps are common, particularly in the northwestern part of the county where many pastures are full of them. Pine stumps, presumably collected in the immediate vicinity, are often piled thickly along field borders to form fences. Numerous pine stumps are seen in the forests in the Oswayo drainage basin and in the southern part of the county.

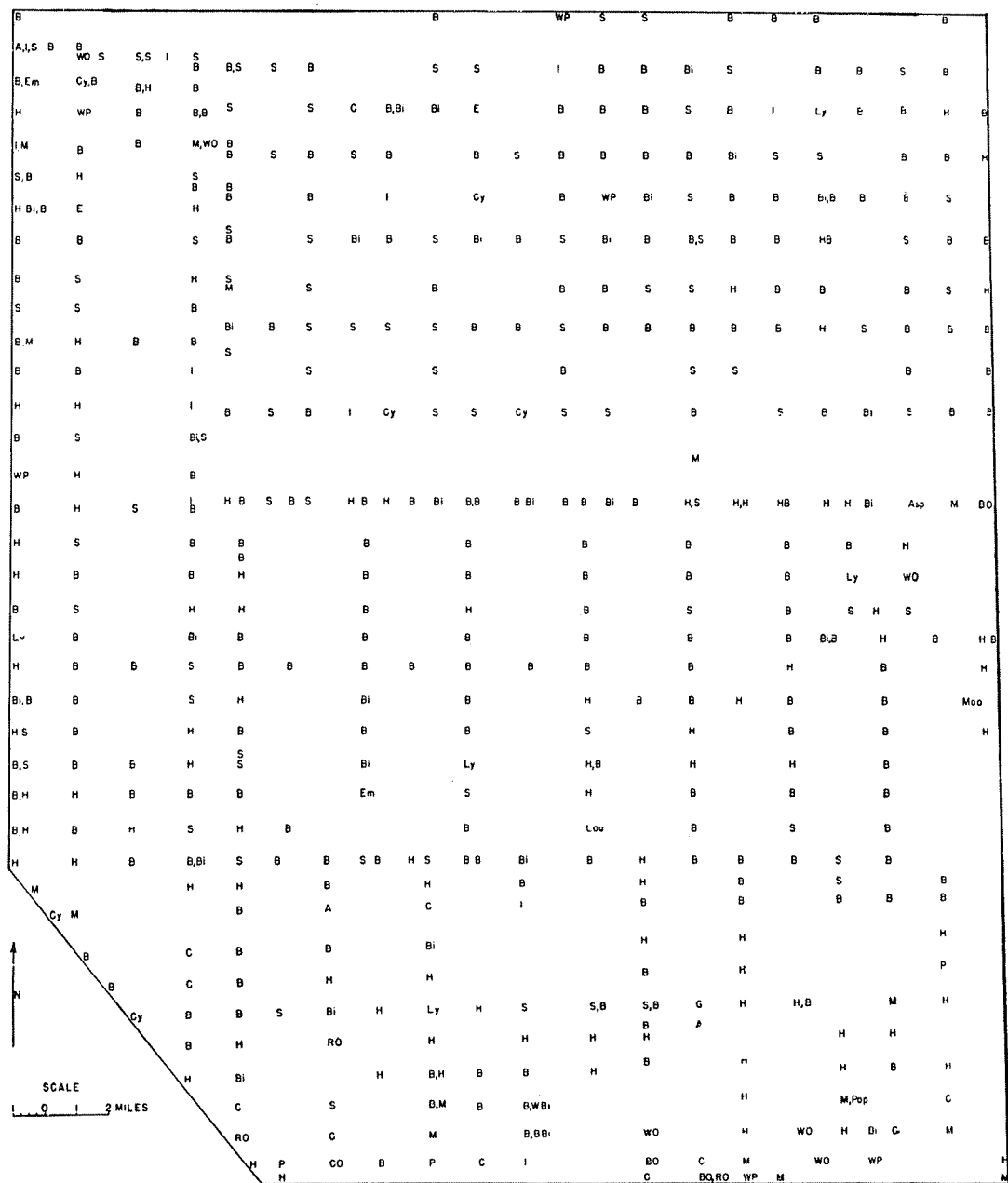
Hemlock stumps are not nearly as well preserved as those of pine, although most of the hemlock logging followed the pine logging. They range from about 20 inches to 38 inches in diameter. Most of the stumps show a considerable amount of decay, and the wood is quite punky. The outer part disintegrates first, leaving a somewhat cone-shaped central portion of loose, tindery, decayed wood. The stumps of more recently cut hemlocks show a sawline, and these, though appearing firm, can often be torn apart with the hands. Hemlock stumps are abundant in the forests of the central divide area, where pine stumps are very rare. Hemlock stumps also are found in other parts of the county mixed with those of pine.

HARDWOOD SPECIES AND THEIR DISTRIBUTION EVIDENCE FROM A PRE-SETTLEMENT LAND SURVEY

The most complete information concerning the species and geographic distribution of hardwood trees that grew in the pre-settlement forests is provided by the "witness trees" used in the pre-settlement land survey. The first survey of Potter County was completed prior to 1793 (Beebe, 1934, p. 20), at least 15 years before the arrival of the first permanent settler, and subdivided the area into 1000-acre blocks of land (warrants).

The warrants established in the original survey are still employed in land transactions in Potter County. Maps of the county by township indicating the location of the warrants, presumably derived from the original survey, can be seen in the County Commissioners' Office in Coudersport. Many of the corners of the warrants were identified by means of trees, and 24 tree species and 2 shrub species were used (Fig. 11). The large number of species utilized by the surveyors tends to rule out the possibility that certain selected, and possibly non-merchantable tree species were preferred as witness trees. White pine and hemlock, trees that later became the foundation of the lumber industry, marked many corners.

FIGURE 11. MAP OF POTTER COUNTY SHOWING "WITNESS TREES" DESIGNATED IN THE FIRST LAND SURVEY OF THE COUNTY.



- | | | | |
|--------------------|-------------------|-----------------|--------------------|
| A — ash | CO — chestnut oak | I — ironwood | RO — red oak |
| Asp — aspen | Cy — cherry | Lau — laurel | S — sugar tree |
| B — beech | E — elkwood | Ly — lynn | W Bi — white birch |
| B Bi — black birch | Em — elm | M — maple | WO — white oak |
| Bi — birch | G — gum | Moo — moosewood | WP — white pine |
| BO — black oak | H — hemlock | P — pine | |
| C — chestnut | HB — hornbeam | Pop — poplar | |

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Most of the common names of the trees used by the surveyors can be translated into binomials, but several unfamiliar names appear. Furthermore, some generic common names make exact identification impossible. In the following list of "witness tree" species a knowledge of the present vegetation has been employed in matching the common names and their probable binomial equivalents:

ash	<i>Fraxinus americana</i>
aspen	<i>Populus tremuloides</i>
beech	<i>Fagus grandifolia</i>
birch	<i>Betula lutea</i>
black birch	<i>Betula lenta</i>
black oak	<i>Quercus velutina</i>
chestnut	<i>Castanea dentata</i>
chestnut-oak	<i>Quercus Prinus</i>
cherry	<i>Prunus serotina</i>
elkwood	<i>Magnolia acuminata</i>
elm	<i>Ulmus americana</i>
gum	<i>Nyssa sylvatica</i>
hemlock	<i>Tsuga canadensis</i>
hornbeam	<i>Ostrya virginiana</i>
ironwood	<i>Carpinus caroliniana</i>
laurel	<i>Kalmia latifolia</i>
lynn	<i>Tilia americana</i>
maple	<i>Acer rubrum</i>
moosewood	<i>Acer pensylvanicum</i>
pine	<i>Pinus spp.</i>
poplar	<i>Populus grandidentata</i>
red oak	<i>Quercus rubra</i>
sugar tree	<i>Acer saccharum</i>
white birch	<i>Betula papyrifera</i>
white oak	<i>Quercus alba</i>
white pine	<i>Pinus Strobus</i>

The specific mention of black birch and white birch suggests that "birch" refers to yellow birch, although the possibility exists that this word refers to any species of birch. Similarly, most "maple" is probably red maple, because "sugar tree" refers to sugar maple. Because striped maple often attains a size that would permit its use as a witness tree, it is suggested that "moosewood," a term applied to several plant species, refers to this tree. Small (1933, p. 536) gives "elkwood" as a common name for *Magnolia tripetala*, and this name may have been applied to *M. acuminata* by the surveyors.

About half of the witness trees are beech, and they occur throughout

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the county. Hemlocks and sugar trees each mark about one-third as many corners as beech; "birch" (yellow birch?) appears about one-third as often as hemlock and sugar maple, and "maple" (red maple?) appears about one-half as often as "birch." These five trees combined mark about three-fourths of the corners.

Chestnut and species of oak are shown in the southern part of the county, along Pine Creek in the vicinity of Galeton, and in the north-western part of the county. Pines, both "white pine" and "pine" are concentrated in the oak and chestnut areas.

EVIDENCE FROM OLD FOREST REMNANTS

Stands containing a few old, large hardwood trees are occasionally seen in Potter County. They usually occur on remote divides, and almost always contain evidence of lumbering activity. These rare, scattered trees indicate the intensity of the lumbering operations, which resulted essentially in a county-wide clear-cutting operation.

On the plateau east of Wildcat Creek (Coudersport quadrangle) grows a stand of old trees, consisting of beech, sugar maple, white ash, basswood, and hemlock. The largest individual tree is a sugar maple 31 inches in diameter. One large sugar maple, recently cut, showed approximately 250 growth rings. The trunk of a chestnut tree, approximately 36 inches in diameter, lies on the forest floor. Decayed beech and hemlock stumps are common.

Beeches in excess of 24 inches in diameter, and sugar maples up to 30 inches in diameter are common on the plateau between Cross Fork and Kettle Creek (Oleona quadrangle). Beech, sugar maple, white ash, and black cherry trees whose average diameter is 18 to 20 inches are abundant. Scattered through this forest are numerous decayed beech, sugar maple, and hemlock stumps.

The forest growing on the plateau between Prouty Run and Borie Branch of First Fork of Sinnemahoning Creek (Ayers Hill quadrangle) consists of closely spaced beech, sugar maple, white ash, and black cherry trees, ranging up to 40 inches in diameter. No hemlock or pine stumps are present. Recently cut stumps of beech, sugar maple, and ash trees are numerous along the state forest trail that traverses the plateau. One 40-inch sugar maple stump showed approximately 100 growth rings to the large, hollow core, with no releases evident. Absence of softwood stumps, elsewhere abundant, the large size of the trees, and the spacing of the trees suggest that this stand is a relatively undisturbed remnant of the pre-settlement forest.

Along State Highway 44, on the plateau forming the divide between

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the heads of Prouty Run of First Fork of Sinnemahoning Creek and the West Branch of Pine Creek, are many giant sugar maple, beech, and black cherry trees. Well-decayed hemlock stumps are common on this ridge.

Comparison of pre-settlement and present forests of the uplands

COMPOSITION

The available information concerning the pre-settlement forests of Potter County is sufficient to permit a rough comparison with the present forests.

Of the tree species comprising the present upland forests, only hickory and tulip-tree do not appear as witness trees in the pre-settlement survey. These species have a very restricted distribution and occur in small numbers in the present forest. Failure of these species to appear among the witness trees probably indicates that they were rather rare in the pre-settlement forest, as they are at present, and not that they were lacking entirely.

The map of the witness trees (Fig. 11) indicates that chestnut was a common component of the forests in parts of the county. Chestnut trees are absent in the present forests, presumably destroyed by the chestnut blight. However, many living chestnut sprouts, as much as 25 feet tall, are found in the oak-containing forests. The larger sprouts almost invariably show diseased stems, and are usually accompanied by dead sprouts arising from the same root system.

The pre-settlement forests contained a greater number of conifers than are present in the forests today. The historical record and the stump remnants indicate that white pine was formerly abundant in pure stands and as individual trees scattered through much of the forests. Where found today, white pine constitutes a fraction of one percent of the stand. Hemlock was probably more abundant in the pre-settlement forest, and certainly was more abundant in the canopy. At the present time hemlocks are common in the young second growth hardwood stands, especially in the understory. The hemlock logging operations were not completed until after World War I, and scattered hemlocks of merchantable size have been removed continuously since that time.

FLORISTIC REGIONS

The pre-settlement land survey, supplemented by the rather meagre data from the historical record and the softwood stump remnants, indicates that floristic regions similar to those of the present forests existed in the pre-settlement forests. In other words, 150 years of occupation by man,

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during which the forests were clear-cut, has not altered the geographic distribution of the tree species to any great extent. However, man has severely modified the numerical relationships of the tree species within their ranges. Thus, the space in the forest formerly occupied by chestnut and pine must have been filled by individuals of other species growing in the same area, increasing their relative abundance in the stands.

The difficulties inherent in an attempt to delineate the range of a species from a map that records one tree of the stand at a single locality is obvious. Nevertheless, the map of witness trees in the early survey of Potter County strongly suggests that the distribution of tree species in the uncut forests was essentially the same as at present.

White oak, which grows only in the forests of the extreme southern part of the county and in parts of the Oswayo Creek and Pine Creek watersheds (Fig. 2), had a similar distribution in the forests of the 1780's (Fig. 12). Chestnut-oak, and black oak are even more restricted in area than white oak, and are found only near the southern margin of the county and in the Pine Creek watershed in the vicinity of Galetton. The pre-settlement survey shows black oak in both of these areas, but chestnut-oak appears only in the southwest corner of the county.

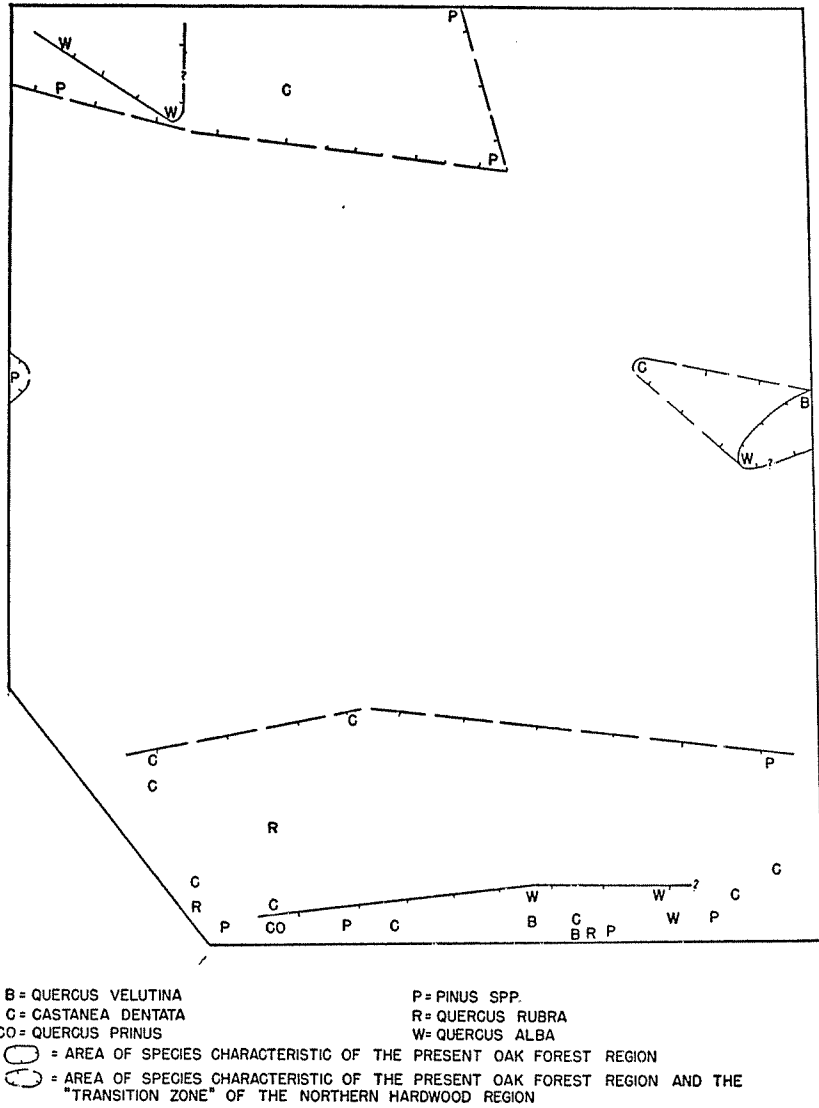
Chestnut marked corners of warrants in the same three general areas in which white oak occurred, but occupied a somewhat larger area. The distribution of chestnut sprouts in the present forests has not been mapped, but they are common in stands that contain species of oak.

If the locations of the pine stump remnants are plotted against the locations of young white pine trees in the forests, and the present range of red oak is superimposed (Fig. 13), it will become apparent that the white pine, both in the pre-settlement forest and at present, is found only within the range of red oak. Furthermore, the range of white pine is more restricted today than it was in the pre-settlement forests. It is absent not only from the central divide region as formerly, but also from a wide area peripheral to the central divide.

The difficulty of using survey witness trees to reconstruct species areas in the uncut forests is clearly evident if red oak is considered. At present, red oak is found in all parts of the county outside the high central divide. It is most abundant within the range of white oak, but present in varying amounts in a much larger area. However, the old survey map shows red oak only in the southern part of the county. The fact that many of the red oaks now seen in the forests are of sprout origin indicates that they were present in the previous stands. Similarly, observation shows that the former range of chestnut was much larger than shown on the survey map.

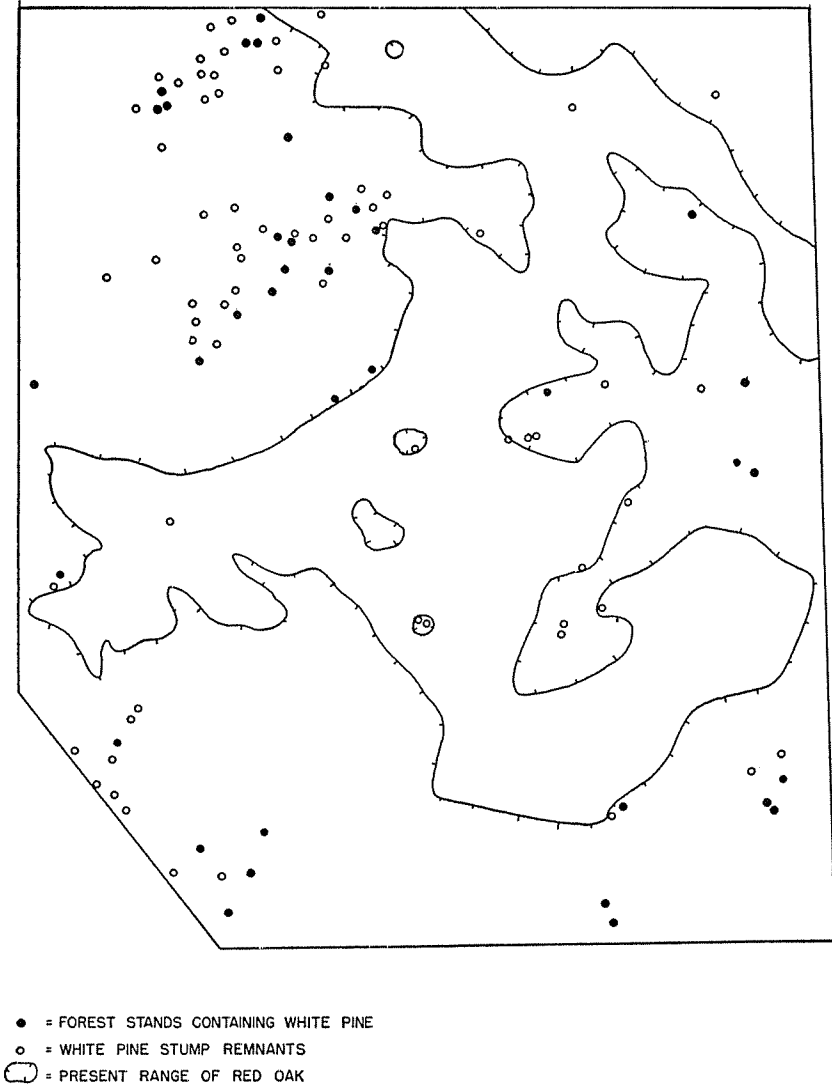
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FIGURE 12. DISTRIBUTION OF SOME "WITNESS TREE" SPECIES HAVING RESTRICTED RANGES IN THE PRESENT FORESTS



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FIGURE 13. DISTRIBUTION OF WHITE PINE



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Where a species was present in a stand in small numbers, the odds against its selection as a witness tree were very high. The high frequency of beech, hemlock, sugar tree, birch, and maple on the old survey map indicates their abundance, and not that the forest was uniformly composed of these species.

White oak, black oak, and chestnut-oak, are characteristic of the present Oak Forest region. These tree species were found in the same general areas in the pre-settlement forest, as indicated by the old land survey. This strongly suggests that the Oak Forest region occupied essentially the same area in the forests of 1780 that it occupies at the present time, and that the activities of man have not drastically changed the distribution of its component species.

In the remaining parts of the county, in the present Northern Hardwood region, the rather well-defined distribution of white pine in the pre-settlement forests provides justification for a subdivision into central divide area and transition zone. The absence of white pine, red oak, and chestnut from the high central divide region, and the widespread occurrence of sugar maple, beech, birch, hemlock, and black cherry suggests that the pre-settlement forest in this region was essentially the same as at present. The transition zone was characterized by the presence of white pine. Red oak and chestnut were probably present also, but little evidence is available. Determination of the extent of these two species in the Northern Hardwood region would require an intensive study of stump remnants and possibly stem and root age analyses of the trees comprising the present forests.

Similar patterns of species distribution over a period of two generations of forest separated by clear-cutting provides a degree of substantiation for the establishment of natural floristic regions in the present forests. This must be modified to the degree that the present trees are stump-sprout descendants of the older trees. Many trees have the appearance of stump sprouts, but most of the individuals seem to be of seedling origin. An unknown number of these may be of seedling-sprout origin. In many cases the cutting of the pre-settlement forest may have resulted only in the development of new and younger stems on old root systems, without breaking the continuity of life of the individual trees.

Development of the upland forests

LIMITATIONS RESULTING FROM INADEQUATE DATA

Reliable information concerning the forests of Potter County prior to about 1780 is not readily available. Intensive examination of stump and

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root fragments¹¹ would permit a degree of reconstruction of the forests as they existed in a still earlier period, probably well into the seventeenth century. Beyond the limits of this material, forest composition must remain inferential because fossil plant remnants of post-Carboniferous age have not been found.

This vegetational hiatus exists throughout the interior of the eastern deciduous forest, extending from the time of the earliest angiosperms of the Mesozoic to the pollen deposits of Pleistocene age. During this long period, plants referable to genera and species now found in the eastern forests are preserved only in the peripheral parts of the deciduous forest region, in the Arctic, and in western United States.¹²

In the face of such a dearth of fossil evidence, a thorough and accurate reconstruction of the past vegetation is impossible. The only substantial body of evidence available consists of the geologic history of the forest substrata. Utilization of this information for botanical purposes must rest upon the assumption that the life processes of plants during the recent geologic past were similar to those of modern plants. This assumption, probably valid for higher plants in general, becomes somewhat tenuous when applied to the relationships of individuals of a particular species to their total environment. Genetic variation within species makes ecological prediction dangerous in space, and just as likely dangerous in time.

PRE-PLEISTOCENE DECIDUOUS FOREST

A discussion of the hypothetical vegetation of Potter County in pre-Pleistocene time is beyond the scope of the present work. The most comprehensive reconstruction of the pre-Pleistocene vegetation of the eastern United States is that of Braun (1950). She relies chiefly upon a detailed knowledge of the present forests, organized according to the tenets of American physiographic ecology. By extrapolation this framework, modified by the fossil record, is applied to the physiographic development of the eastern United States since late Mesozoic time. The disjunct distribution of species, the genetic evidence of complexities within species, and the climatic inferences are carried back to pre-Pleistocene time. At the close of the Tertiary, according to Braun (1950, p. 510) the "mixed Tertiary forest . . . continued to occupy the areas where the ancient Schooley peneplain, although dissected, was not replaced by a later peneplain (Appalachian Plateaus . . .)." The species composition of the "mixed Tertiary

¹¹ E. P. Stephens' work at the Harvard Forest, still in progress, is an example of this intensive method of forest reconstruction.

¹² For a recent review of the paleobotanical record, see Braun, 1950, Chapter 14.

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forest" is not clear, but presumably it contained some of those species preserved as fossils in other parts of the United States.

INFLUENCE OF PLEISTOCENE EVENTS

EFFECTS OF PERIGLACIAL CLIMATE UPON THE VEGETATION

The evidence indicates that any forests growing in the unglaciated parts of Potter County during the Olean substage would have been destroyed or highly restricted. This conclusion is based upon 1) the geologic history as inferred from the surficial deposits outside the border of the Wisconsin drift, and 2) an analogy with conditions in the Arctic where processes presumably similar to those which led to the formation of the surficial deposits in Potter County take place in essentially treeless areas.

The surficial materials that mantle the bedrock in the unglaciated parts of Potter County and the associated soil structures suggest an origin by mass movements caused by frozen subsoils. In brief, the geological evidence indicates that the area in Potter County outside the border of the Wisconsin drift was a very unstable habitat for plant growth. The periglacial debris underwent considerable downslope movement, producing thin deposits on gentle upper slopes and thicker deposits on steeper lower slopes. This material concealed the bedrock, buried pre-existing floodplains, and formed smooth, uniform slopes. In the absence of proof that the soil materials were perennially frozen, Denny (1951, p. 124) suggests that the formation of the surficial deposits was accomplished by processes related to a seasonal freeze and thaw to a depth of at least 6 feet.

An assessment of the probable effects of this instability upon any existing forest vegetation depends upon a study of the influence of modern frost action and related soil movement upon vegetation. Recent studies in the Arctic and Subarctic provide a mass of information about frost phenomena and relationships between frost action and vegetation.¹³ Geomorphologists studying arctic land-forms have found that frost action is a primary geomorphic process, and that vegetation and the frost phenomena are so closely related as to form an inseparable, mutually interacting complex.¹⁴

Significantly, areas now undergoing frost action of sufficient intensity to modify the topography are covered with tundra.¹⁵ According to Raup (1951, p. 112), the boundaries between forest and tundra in the Arctic may reflect the change from "relatively stable to relatively unstable soils,"

¹³ For a general discussion of frost-vegetation relationships, see Raup, 1951.

¹⁴ Hopkins, 1949; Hopkins and Sigafos, 1951.

¹⁵ Tundra, "assemblages of shrubs and herbaceous plants" (Sigafos, 1951, p. 283).

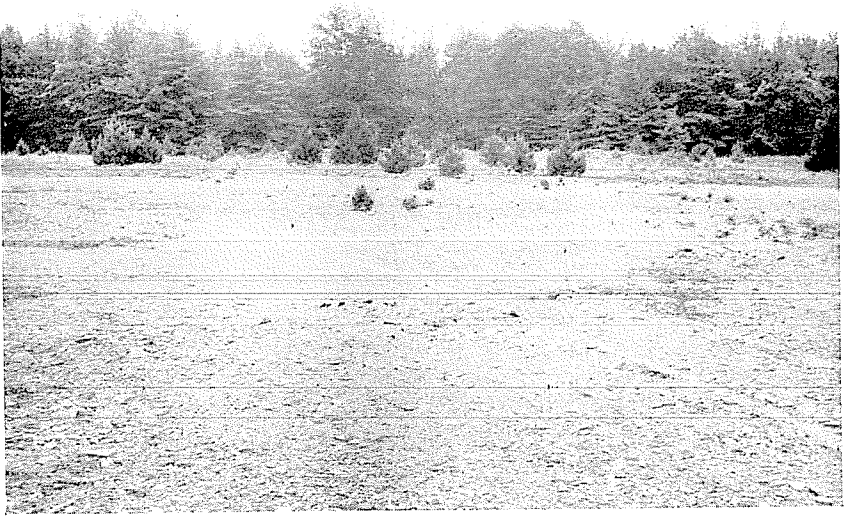


PLATE 1. Bare area covered with pavement of small fragments of sandstone. Note scattered pines in middle foreground. Scattered patches of grass, as seen in right side of photograph, occur on the material, as well as small birches. Parallel diagonal lines are auto tire prints. View southwestward from south side of State Highway 44, Olona-Lee Fire Tower quadrangles, Potter County, Pa.

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a function of the intensity of frost action. Denny (1952, pp. 906-920) describes the effects of intensive frost action along the Alaska Highway, and concludes that elimination of the original topographic forms of the glacial deposits and production of long cryoplanation slopes indicates a degree of frost action that could not have been attained on tree-covered surfaces. Sigafoos' (1952, p. 487) studies of frost action in tundra led him to believe that land surfaces modified by Pleistocene frost action and resultant mass movement in mid-latitudes¹⁸ supported vegetation "similar at least in form to that in present day tundra regions." It should be noted that these ancient mid-latitude frost forms may not have been underlain by permafrost at the time of their development.

Present day frost action in mid-latitudes influences, and in turn is influenced by, the vegetation. Miniature stone nets, stone stripes, and turf-banked terraces are forming at present in essentially bare areas above the "continuous scrub forest line" on Mount Washington (Antevs, 1932). According to Antevs (1932) formation of these soil structures is initiated by a disruption of the continuous vegetation mat by such agents as the ripping action of rolling or sliding frost-rived rock fragments, upfreezing of stones, or wind action. Exposure of the underlying soil leads to frost heaving which may enlarge the break by destroying the adjacent vegetative cover. Scars once formed will not become covered with vegetation until the frost activity diminishes.

Denny (1940) believes that the presence or absence of modern miniature stone rings on the mountain summits of central New England is determined by the vegetation, provided a source of small rock fragments exists and suitable ground water conditions are present. The treeless summits of Monadnock, Kearsarge, and Cardigan show miniature stone rings and stone stripes. Absence of modern frost phenomena from the tree-covered summit of Mount Graylock, higher than Monadnock, and presence of "probable stone rings" on the shores of Lake Champlain are advanced as substantiating evidence for this hypothesis.

The present climate of Potter County is sufficiently rigorous to produce miniature stone rings, stone stripes, and earth hummocks by frost action if the forest cover is removed and the organic litter on the forest floor is disturbed. The local distribution of plants is affected by the frost action and resulting microtopographic features.

A bare area approximately 150 yards long and 50 yards wide, covered with a pavement of small sandstone fragments, is located 1.4 miles east of the boundary between Potter County and Lycoming County on State

¹⁸ For examples, see Smith, 1949a, 1949b; and Judson, 1949.

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Highway 44 (Plate 1). Many of the small rock fragments lie with their long axes perpendicular to the ground surface. On the essentially level central part of the area the fragments form irregular miniature stone rings, showing distinct sorting of the fragments according to size (Plate 2). On the gently sloping western edge of the bare area the fragments form miniature stone stripes.

The bare area occupies the higher parts of an old field, which is surrounded by medium-aged hardwood forests. A few red pines, white pines, and small birches are growing on the pavement, and tufts of curly grass (*Danthonia* sp.) are scattered over it. Many of these tufts of grass are dead, and are lying loose on the pavement surface. Although no old stumps are present, the bare area presumably was covered with forest prior to the settlement of the region. Removal of the trees from this area, probably followed by cultivation or maintenance as a pasture, brought about conditions favorable for the concentration of the small rock fragments on the surface of the ground. Presumably this was the result of the upfreezing of the fragments under the present climatic regime, possibly aided by the removal of fine material by rainwash and wind. The continued instability of the materials mantling the area apparently has prevented the establishment of a continuous vegetative cover on the pavement, as suggested by the dead tufts of grass.

Further evidence of frost activity and its relation to the vegetative cover is provided by earth hummocks (Plate 3), which are present throughout the glaciated part of Potter County.¹⁷ Earth hummocks consist of low mounds of loose, porous, mineral soil, 2 to 3 feet long, 1 to 2 feet wide, and 1 to 1.5 feet high. They are characteristically covered with a dense mat of moss (*Polytrichum* sp.) which is sparingly present or lacking in the areas between the hummocks. The basal parts of the hummocks and the areas between them support a dense growth of grasses and sedges. The surficial materials underlying areas of earth hummocks usually consist of dense, silty till. Small bogs, wet spots, and ancient boulder rings often are associated with earth hummocks. The characteristic tree species growing in areas of abundant earth hummocks is hawthorn.

The old fields studded with earth hummocks and hawthorn trees were formerly covered with forests, as indicated by the presence of old stumps. Earth hummocks have not been seen in the young second-growth forests. This suggests that removal of the forest cover by clear-cutting does not

¹⁷ A closely related phenomenon has been described by Sigafoos and Hopkins (1951). Their study of grass and sedge tussocks growing in fresh water marshes in eastern Massachusetts showed that a part of the height attained by the tussocks was a result of frost activity in the present climate.



PLATE 2A. Close-up of part of area shown in Plate 1, showing small stone rings composed of fragments of sandstone. The knife lies across the center of one of the rings. Numerous "on-end" fragments are evident. Note the tufts of curly grass.



PLATE 2B. Slightly larger stone rings showing sorting of fragments. The cigarette package lies in the center of the ring where the finer materials are concentrated.



(C. S. Denny, U. S. Geol. Survey)

PLATE 3A. Earth hummocks in old pasture field within the glaciated area. View looking southward across Turner Creek approximately 0.4 miles southeast of Bingham Center, Genesee quadrangle, Potter County, Pa.



(C. S. Denny, U. S. Geol. Survey)

PLATE 3B. Close-up of earth hummocks showing characteristic cover of *Polytrichum*. Locality same as above.

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initiate hummock formation without disturbance of the organic litter on the forest floor. Cultivation or use as a pasture destroys the insulating layer of litter and probably results in frost heaving sufficient to produce the earth hummocks. The trampling of grazing animals may initiate hummock formation by providing surface inequalities that permit deeper penetration of frost, and lead to differential heaving. Furthermore, surface irregularities result in differences in snow depth. A thin mantle of snow, lying deeper in the depressions than on the elevations, insulates the depressions against frost and permits frost activity on the elevations. Well-developed hummocks probably are most severely disturbed in early spring, when melting of the snow cover exposes the moss-covered mounds of mineral soil while the troughs remain filled with snow. Diurnal temperature fluctuations around the freezing point would cause cycles of freezing and thawing, and result in frost heaving. Frost heaving acts to maintain the observed looseness and porosity of the soil material.

There is little evidence of invasion of hummocky areas by tree species from the adjacent forests. Perhaps the instability of the hummocks during the colder parts of the year, in combination with their extreme droughtiness during the summer, prevents the establishment of the forest trees. The troughs between the closely spaced hummocks, while not subject to severe disturbance, are poorly drained, and probably are full of meltwater during the early growing season. The poorly-drained, earth hummock-hawthorn old fields may represent an arrested development of the vegetation that will be maintained for some time.

Evidence from the northeastern United States, including Potter County, shows that forest vegetation inhibits frost action of an intensity capable of producing miniature stone rings, stone stripes, and microtopographic features in the present cool temperate climate. Local distribution of plants is affected, and the natural renewal of a tree cover may be inhibited. The surficial deposits in Potter County show evidence of intense frost activity in the past, but at present are essentially stable. In the Arctic, areas undergoing active cryoplanation are essentially treeless. By analogy, it is reasonable that forests were absent or extremely restricted in the periglacial region of Potter County when the Olean ice sheet was at or near the drift border.

The nearly complete removal of the pre-Wisconsin soils and the presence of the universal mantle of periglacial debris indicates that the entire periglacial region was subjected to intense congeliturbation, but the stirring and movement of materials probably did not take place simultaneously. Comparatively stable areas existed adjacent to areas undergoing disturbance. In the Arctic, deposits on stream banks and flood plains,

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glacial outwash, or other well-drained deposits undergo little or no congeliturbation. The varying intensities of frost action are reflected in the vegetation. Spruce (Raup, 1951, p. 113) and poplar (Sigafoos, 1951, p. 283) often grow on these relatively stable sites. In the periglacial region of Potter County, similar areas of relative stability probably supported trees.

Congeliturbanation, according to Sigafoos (1951, p. 284), "affects plants by: (1) burying them beneath soil; (2) damaging roots and stems by breaking or bending them; and (3) changing soil-water relations by moving the plants with respect to water table or by blocking surface-water flow." Variation in depth to water tables affects local distribution of plants, as illustrated perhaps in Potter County by the vegetation in areas of earth hummocks. Probably the most important effect of soil movement upon plants is displacement and damage to the root system. Raup (1951, p. 111) attributes the high mortality of spruce forests growing on moving soil materials to a separation of the root systems from their "intimate soil contacts." The trees may be killed or merely suppressed in growth, and many that survive assume a characteristic leaning position, creating a "drunken forest."

Materials subjected to congeliturbanation show differential movement, and in many instances small patches of soil only a few feet in diameter move as a unit. Presumably this favors the survival of plants that have shallow roots extending over a small area. Such root systems are, in general, characteristic of herbaceous and shrubby plants. The differential movement of soil materials would also act to "root prune" plants having tree form and result in a degree of dwarfing. Short stature would further minimize the tendency of plants to fall when their roots were displaced.

The foregoing analysis suggests that the vegetation in Potter County peripheral to the Olean ice sheet consisted largely of tundra, or of plants having the herbaceous and shrubby form characteristic of tundra. In the absence of pollen deposits or macrofossils, no useful purpose is served by speculations as to its species composition. However, the most conservative hypothesis holds that it was composed of species now found in the Northeast, and not of species comprising the present arctic tundra (Raup, 1951, p. 113). Perhaps some of the species now found in the forests of Potter County were able to survive the cold climate, the short growing seasons, and the active stirring and movement of the soil materials by frost action.

AMELIORATION OF THE CLIMATE

Melting and retreat of the Olean ice sheet must have been followed by a spasmodic, but on the whole steady, amelioration of the climate in the

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area outside the border of the Wisconsin drift. In the glaciated parts of Potter County soil structures, abundance of angular rock fragments in the drift, general lack of morainal topography, and the long smooth slopes indicate that the drift also was subjected to frost disturbance during Olean time. Frost action may have again disturbed the surficial deposits in Potter County during Binghamton time, when the margin of the ice sheet lay 30 to 40 miles to the north in southern New York (MacClintock and Apfel, 1944). MacClintock and Apfel believe that the Olean ice retreated far to the north prior to the advance of the Binghamton ice sheet. If this hypothesis is correct, the surficial materials in Potter County may have become stable during the Olean-Binghamton interval, with the accompanying development of continuous forest cover.

Variations in the intensity of the cold frost climate presumably resulted in alternating expansion and contraction of areas undergoing congeliturbation, along with alternating increase and decrease in severity of disturbance. During periods when large parts of the surficial materials were essentially stable, areas of forest vegetation probably expanded, only to be destroyed or converted into "drunken forests" during a cycle of instability. That such fluctuations in vegetative cover actually existed is suggested by the "drunken" spruce forests on slopes in British Columbia (Denny, 1952, pp. 915-916). The soil materials are somewhat active at the present time, but show evidence of more active mass movement in the past. The spruce grows on frozen soil, and Denny (1952, pp. 918-919) believes that once established, spruce forests may reduce the intensity of congeliturbation by keeping the ground in shade and decreasing daily freezing and thawing, even though they might "act as an insulator and preserve permafrost." He suggests that lodge-pole pine, which does not grow on frozen soil, may not appear until the permafrost is destroyed by climatic amelioration.

The glacial and periglacial deposits of Potter County probably were subjected to varying degrees of disturbance by frost action, greater than that going on at present, during most of Wisconsin time. Periods of intense congeliturbation probably alternated with periods of less active frost action in poorly-drained areas while much of the land surface was essentially stable. The expansion of relatively stable areas during periods of reduced frost action probably permitted the increase of forested areas and a corresponding reduction in tundra-like vegetation. Climatic deterioration would reactivate frost action and convert many forested areas into "drunken forests" or tundra. Thus a steady advance of forest into Potter County following retreat of Olean ice seems unlikely. A long period of

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vegetational instability, similar to that seen in parts of the Arctic today, may have endured throughout Wisconsin time.

* * * * *

The above hypotheses concerning the vegetation of Potter County during Wisconsin time have been presented only after much hesitation. The account is based upon no fossil evidence, but absence of data seldom deters plant ecologists from flights of fancy resulting in showers of hypotheses, too often presented as irrefutable fact. Having joined this group, the author would like to plead (perhaps paradoxically), with Deevey (1949), for an "economy of hypothesis," and a closer examination of the ever-growing body of geological information concerning Pleistocene and post-Pleistocene events.

POST-PLEISTOCENE FOREST DEVELOPMENT

The amelioration of the climate of Potter County at some point in post-Olean time brought an end to active congeliturbation and mass movement, the mantle of surficial materials attained its present relative stability, and presumably supported a continuous forest cover.

No direct evidence of the nature of this forest cover is available prior to about 1780. A comparison of the pre-settlement forests and the present forests strongly suggests that the ranges of the component species have remained essentially unchanged. Therefore, the present distribution of species may provide indirect evidence of the nature of the forests that grew in Potter County prior to 1780.

No difference has been observed in the forests growing on either side of the border of the Wisconsin drift except for the change from the Northern Hardwood region to the Oak Forest region near Galeton (Fig. 5). There is apparently no direct connection between species distribution and the distribution of the Wisconsin drift.

The highest plateau surfaces occur in central Potter County, in the Northern Hardwood region, and they support uniform forests of the beech-birch-maple type. Surrounding this high divide area, and still in the Northern Hardwood region, is a broad band of red oak type forest. This is transitional to the white oak and chestnut-oak type forests characteristic of the Oak Forest region, which are found on the generally lower plateau surfaces at the periphery of the county. Within each of these forest regions, rather well-defined relationships exist between the forest types and the surficial deposits. The surficial deposits, though somewhat more rubbly in the Oak Forest region, possess essentially the same character-

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istics, and were formed by similar processes. A working hypothesis to explain the change from Northern Hardwood to Oak Forest region postulates a climatic differential between the highlands of central Potter County and the surrounding regions. Doubtless this relationship originated in the past, and might go back to the thermal maximum when perhaps the Oak Forest region covered a larger proportion of Potter County than at present.

Isolated stands of red oak type forest are present in the central mass of beech-birch-maple type forest (Fig. 5). The large southwestward extension of red oak type forest up the West Branch of Pine Creek from the Oak Forest region in the vicinity of Galeton occupies part of the high central plateau in the vicinity of Cherry Springs, and is almost completely surrounded by beech-birch-maple type forests. White oak, a species characteristic of the Oak Forest region, occurs in this extension. The surficial deposits that support these isolated and attenuated oak forests are rubbly, and are surrounded by non-rubbly materials that support beech-birch-maple type forests. These isolated stands of oak forest can be explained as relics of an expanded Oak Forest region that occupied the high central plateaus, relics that persisted on rubbly deposits during and after the contraction of the Oak Forest region to its present limits.

Forests in the Northern Hardwood region, particularly the central mass of beech-birch-maple forest, show pronounced vertical uniformity, although local relief ranges from 300 to more than 800 feet. This phenomenon is present both within and outside the border of the Wisconsin drift. These forests grow on a mantle of surficial materials that conceals the bedrock and produces long, uniform slopes. According to Raup (1951, p. 112), in the arctic the vertical and lateral uniformity of the vegetation growing on slopes that have been shaped by cryoplanation is pronounced. This feature he attributes to the uniformity of soil texture and water tables.

In the southern part of Potter County, in the Oak Forest region, outcrops of bedrock are more numerous, and the surficial deposits on lower slopes are only 2 to 5 feet thick in many places. The forests show more variability than is found in the Northern Hardwood region. With increasing distance from the drift border the mantle of surficial materials on slopes appears to become thinner and more rubbly. Within about 10 miles of the drift border outcrops of bedrock are essentially lacking, and lower slopes are covered with deposits as much as 15 feet thick. Presumably this thinning of the surficial mantle is related to the decrease in the intensity of frost action with increasing distance from the ice margin.

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Disturbance of forest stands and surficial materials by windthrow

GENERAL DESCRIPTION OF MOUND AND PIT MICRORELIEF IN POTTER COUNTY

The unplowed areas of Potter County are characterized by a pronounced microrelief of mounds and pits (Plate 4). The mounds are circular to oval in outline, 10 to 20 feet long, 6 to 15 feet wide and 1 to more than 4 feet high. In cross section they are triangular to somewhat rounded. The pit may be rectangular, oval, crescent-shaped, or irregular in outline, and from 6 inches to 24 inches deep. Mounds and pits are found on ridge crests, steep slopes, and gentle slopes, both within and outside the border of the Wisconsin drift, on rubbly and non-rubbly soil materials. They may be lacking in areas having very abundant boulders.

The soil material comprising the mounds is loose and porous. Bare mineral soil is exposed on the crests of mounds, although some mounds are capped by a thin organic mat less than 1 inch in thickness. A trench dug through a mound will reveal disturbed soil horizons, and usually masses of buried organic matter. Pits are usually partially filled with organic matter, often underlain by a pavement of small rock fragments, in turn underlain by mineral soil. Areas between mounds and pits show more or less well-developed podzolic soil profiles.

Most of the mounds are old, and have resulted from the fall of trees that grew in the pre-settlement forest. The present forests are growing on this microrelief produced by past vegetation, and occupy all parts of the "blow-down landscape" except the bottoms of the pits, where they are almost universally absent.

The medium-aged trees comprising the forest stands are occasionally uprooted at the present time. The mounds and pits that result are not as large as many of those formed in the past.

SIGNIFICANCE OF WINDTHROW

The evidence indicates that windthrow has disturbed the soil materials to a depth of 2 to 3 feet throughout the past 200 to 300 years, and probably since reoccupation of the region by forest trees. Lutz and Griswold (1939) made a study of the influence of tree windthrow in southern New Hampshire, and suggested that "all soils which bear, or in the past have borne, forest stands have been more or less disturbed."

Disturbance of the upper parts of the surficial deposits by windthrow over long periods of time probably produces the high degree of variability observed in soil profiles over short horizontal distances. Existing soil



(C. S. Denny, U. S. Geol. Survey)

PLATE 4A. Large mounds composed of loose silt loam. View is northward on mapped area (Fig. 14). Mound 1 is at left foreground, and mound 2 is at right background. Note decayed hemlock trunk projecting from the base of mound 1.



(C. S. Denny, U. S. Geol. Survey)

PLATE 4B. View southward on mapped area (Fig. 14). Mound 3, supporting a 17-inch white ash, is in the left foreground. Mound 1 can be seen in the right background.

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Lutz and Griswold (1939) made exhaustive studies of the effect of windthrow upon soil morphology in southern New Hampshire, and Lutz (1940) further examined the effects of windthrow upon the physical and chemical properties of the disturbed soil materials.¹⁸ The general effect of the uprooting of trees upon soil morphology is described by Lutz (1940, p. 5):

. . . as a result of disturbance, horizons may be very irregular, occasionally with long tongues from the upper layers penetrating deeply into the layers below. Further, horizons may be discontinuous and masses of soil material may be translocated to positions above or below those normally occupied. Frequently, material from upper and lower horizons is rather intimately mixed. The vertical and horizontal movement of rocks two or more feet in diameter is evidence of the tremendous forces involved. In short, disturbance of the upper three or four feet of the soil body by tree roots may be manifested in exceedingly diverse ways.

Lutz reported that pore volume, air capacity, and permeability to water were significantly greater in disturbed soil in mounds produced by windthrow, ranging from 80 to possibly 300 years in age, than in undisturbed soil. The higher base saturation, greater buffer capacity, and significantly higher heavy mineral content of disturbed soil as compared with undisturbed soil he considered as modifications favoring vegetation.

WINDSTORMS IN POTTER COUNTY

At the present time, seasonal high winds occasionally overturn medium-sized trees on exposed plateau surfaces in Potter County and presumably have done so in the past. At least twice since settlement, Potter County has experienced wind storms of hurricane force. These are described by Beebe (1934, pp. 79-80, 118):

On March 21, 1834, occurred the most terrific wind storm that Potter County has ever known. The town of Lymanville was almost completely demolished, the water blown out of the mill pond, and logs bedded in the road torn up. At Roulet, some damage was done, but it was not so great as at Lymanville. Large areas of timber were blown down, as the storm swept in a northeasterly direction across the county. Boards and debris from Lymanville were found in New York State, thirty miles distant. At Ulysses the damage was nearly as great as

¹⁸ See Lutz and Griswold (1939, pp. 389-392) for a review of the literature pertaining to the disturbing effects of tree roots upon soil materials. Lutz (1940, p. 3) reviews European literature dealing with the effects of windthrow upon tree regeneration.

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at Lymanville. Mrs. Lavinia Lewis tells us that the track of the storm was from half a mile to a mile and a half in width. There were several hairbreadth escapes. . . . Traces of the windfalls then made in the timber may be seen even at the present day [1933]. Trees that sprouted on the upturned roots of fallen timber which long ago rotted away, knolls and hollows resulting from the uprooting of the original evergreen timber, and the like, still bear testimony to the great wind storm of 1834.

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The windstorm of September, 1856, was second only to that of 1834 in the amount of damage done. Large areas of timber were blown down, and fires were started by embers borne from burning fallows by the terrific gale. . . . This storm was a gale, not a twister or cyclone, like that of 1834, and seems to have covered the greater area of the two.

DESCRIPTIONS OF WINDTHROW IN THE 18TH CENTURY FORESTS OF PENNSYLVANIA

Journals and diaries of explorers, soldiers, traders, and missionaries who traveled west of the Allegheny Mountains in the 18th century, prior to the period of exploitation of the forests, disclose evidence of severe wind damage to the forests.

One of the French soldiers (Harpster, 1938, p. 30), journeying to the Forks of the Ohio in 1754 to construct Fort Duquesne, had this comment on French Creek:

The twenty-fifth of March we left the fort of the riviere aux Boeufs in bateaux and pirogues all loaded with supplies and munitions. We were obliged to navigate by short stages on this river, because it was obstructed by many trees that had fallen in, either through decay or by hurricanes that are rather frequent in these parts, where eddies of wind often uproot the trees.

In 1766 the Rev. Charles Beatty (Hanna, 1911, vol. 1, p. 249) traveled the Juniata Path on his way to Ohio, where he was to be an Indian missionary. He left the present site of Mexico, Juniata County, August 25, 1766, and traveled west on the path along the Juniata:

We traveled up the Juniata River eight miles, through a bad road, to a place called the Narrows (now Lewistown Narrows), where a rocky mountain bounds so close upon the river as to leave only a small path along the bank for the most part; and this, for about ten miles, very uneven; at this time also greatly encumbered by trees fallen across it, blown up from the roots some time ago by a hard gale of wind; so that we were obliged to walk some part of the way, and in some places to go along the edge of the water.

In 1784, Arthur Lee (Craig, 1848, vol. 2, p. 335), who had been ap-

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pointed commissioner to treat with the Indians, made the following note in his journal while travelling the Frankstown Path:

Leaving Bedford, we again crossed the Juniata, and traversed the Allegheny Mountain to Stony Creek. On the road we saw the marks of a most tremendous whirlwind which happened last year and in its course tore up by the roots or twisted off every tree, however large. Numbers of the largest were laid down by each other, as if strewn by the whirlwind with as much ease as so many straws scattered by a light wind.

The builders (Faris, 1919, p. 305) of the Susquehanna and Waterford Turnpike (1796-1822) encountered difficulties when they approached Reynoldsville, east of Brookville:

Trees were found lying about everywhere. The limbs had completely rotted away and the trunks had nearly disappeared. "They were so thick that it was almost impossible to go a couple of rods without coming across one or more." The trunks were so rotten they would not bear a man's weight. It was thought that they had been blown down by some storm a century or two before, for a forest of gigantic trees was growing above the prostrate trunks.

Other parts of the Old West had severe windstorms. George Washington (Craig, 1848, vol. 1, p. 423), on his trip down the Ohio in 1770, noted hurricane damage between Steubenville, Ohio, and Wheeling, West Virginia. General Richard Butler (Craig, 1848, vol. 2, p. 454) observed severe wind damage near the junction of the Licking and Ohio Rivers in 1785. David Zeisberger's diary (Bliss, 1885) kept while he lived in various locations in the vicinity of Lake Erie (1781-1798) records at least ten violent windstorms, with severe damage to the forests.

WINDTHROW IN THE PRESENT FORESTS

Four black cherry trees, presumably windthrown, were seen immediately north of State Highway 44 on the gently sloping plateau between the heads of West Branch of Pine Creek and Prouty Run (Ayers Hill quadrangle) in the fall of 1950 (Plate 5). The wilted leaves on these trees indicated that the "blowdowns" were produced during the growing season of 1950. The maximum diameter of the fallen trees was 18 inches. At least six sugar maples and beeches, of equal or greater diameters, growing in the same area, were undisturbed. The mass of soil material retained by the root systems was 12 to 15 feet wide and 5 to 6 feet high. The average thickness of the root masses was 2 feet, and the maximum thickness was about 3 feet. The ball of earth retained by one uprooted tree contained a concentration of sandstone fragments suggestive of a boulder stripe (Plate 6).



PLATE 5A. Two recently windthrown black cherry trees. The root system to the leeward has not been torn from the ground. Diameter of the trees is approximately 18 inches. Located near State Highway 44 at the head of West Branch of Pine Creek, Ayers Hill quadrangle, Potter County, Pa.



PLATE 5B. Windthrown black cherry tree showing formation of a "hinge-type" blow-down mound. Note the large mass of earth torn from place by the roots. Location as above.

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An 18-inch sugar maple blowdown, probably not more than two years old, was seen on the same plateau. The soil mass retained by the root system was about 12 feet wide, 5 feet high, and 2 to 2.5 feet thick. This material consisted of silt loam, almost free of stones, which still adhered closely to the roots. A 1-inch layer of needle ice was present (November, 1950) in the bottom of the pit, and the uprooted soil mass was covered with a thin (less than 1 inch thick) rind of frozen soil. Beneath this thin rind the soil material was very loose and porous. A weak rainwash sculpture was apparent on the surface of the ball of soil material.

MICRORELIEF PRODUCED BY ANCIENT WINDTHROW

RIDGE ROAD

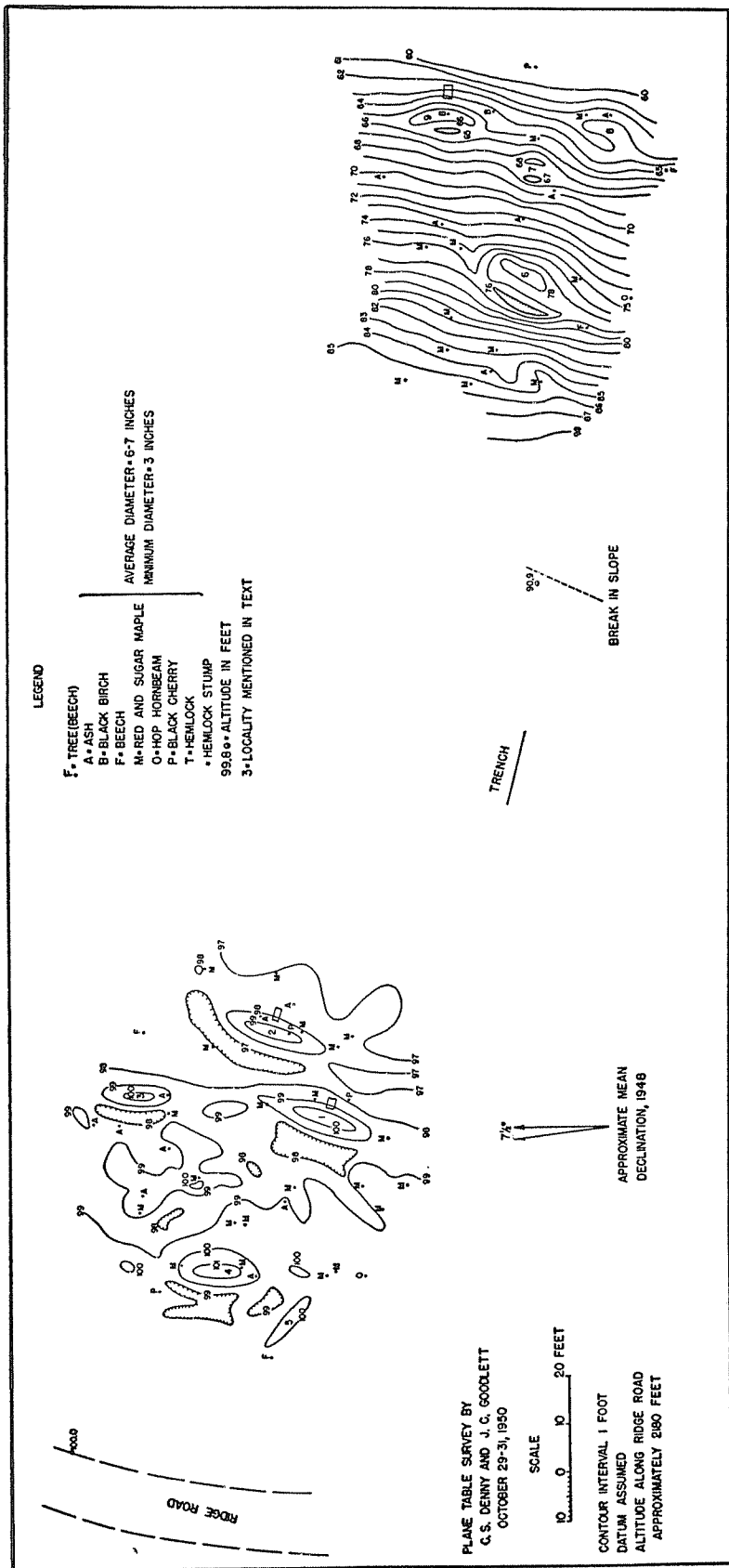
Large mounds and pits can be seen on the ridge that forms the divide between Little Portage Creek and East Branch of Cowley Run (Wharton quadrangle), and on the steep east slopes leading to Big Carlson Hollow (Fig. 14).

The long axes of the mounds on the plateau trend generally north-south, roughly at right angles to the prevailing winds. Four large mounds occur within an area 50 feet square immediately east of Ridge Road, which traverses the plateau (Fig. 14). These mounds appear to fall into two classes. The long axes of mounds 1 and 2 trend N. 20° E., while the long axes of mounds 3 and 4 trend N. 2° E. This difference in orientation may be due to two separate winds of considerable velocity.

Mounds 1 and 2 are approximately 24 feet long and 6 feet wide, with a maximum relief of about 3.5 feet from the bottom of the pit to the top of the mound. The pit side of the mounds slopes at about 40°, and is somewhat steeper than the side away from the pit. Remnants of hemlock stumps protrude 3 to 4 feet from the material comprising the mounds. Both stumps are more than 20 inches in diameter. On the tops of the mounds bare mineral soil consisting of very loose, yellowish-brown silt loam underlies a layer of leaves. The pits contain 2 to 3 inches of partially decayed leaves underlain by a thin pavement of sandstone fragments, in turn underlain by loose, yellowish-brown silt loam. The close similarity of these mounds as to size, shape, angle of slope, absence of soil profiles, degree of preservation of the protruding stumps, and orientation of their long axes suggests that they are of essentially the same age, and probably were formed as the result of a single gust of wind.

Mounds 3 and 4 are approximately 15 feet long and 7 feet wide, with a maximum relief of about 3 feet. The pit side of the mounds slopes at

FIGURE 14. MAP OF MOUND AND PIT MICRORELIEF ALONG RIDGE ROAD, NEAR HEAD OF BIG CARLSON HOLLOW, WHARTON QUADRANGLE, POTTER COUNTY, PENNSYLVANIA



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approximately 40°. Mound 3 supports a 17-inch white ash, whose age, as determined by borings, is approximately 70 years. The trees growing on the basal parts of mound 4 are of the same general diameters and height as those comprising most of the forest stand at this point. Several random borings indicated that the stand is approximately 40 years old. No trunk remnants project from mounds 3 and 4. However, fragments of wood later identified as sugar maple were removed from the center of mound 3, presumably part of the tree that formed the mound when it fell. The similar size and shape and the similar orientation of mounds 3 and 4 suggest similar ages. The top of mound 3 shows essentially no black organic matter, and no evidence of development of a new profile in the disturbed soil material. The pit contains 4 to 6 inches of organic matter, underlain by a 1-inch pavement of sandstone fragments, underlain in turn by slightly mottled yellowish-brown silt loam. At a depth of 1 foot, the material is grayer and less mottled. The mottled horizon underlying the stone pavement may represent an early stage of soil profile development.

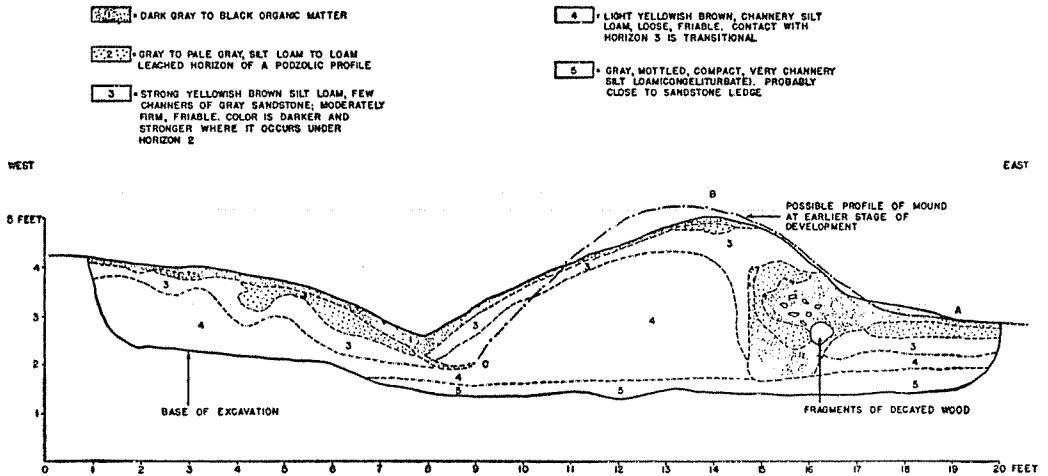
The second-growth hardwood stand on the plateau consists largely of sugar maple, red maple, ash, black cherry, and beech, and most of the trees are about 40 years old. These trees are growing on the flanks of the larger mounds and in the space between mounds. Trees are completely absent from the bottoms of pits, and are seldom found on the crests of mounds. This absence of trees in pits is seen even in the depressions where the microrelief is less than 1 foot, and mound-pit relationships are obscure.

Because trees of the present forest stand are growing in the disturbed material comprising the mounds, the mounds must be older than the trees they support. The 70-year old white ash growing on mound 3 indicates that the mound is at least 70 years old, and the tree that formed the mound must have fallen sometime prior to that. The length of time required for the slumping of the soil material retained by the root mass to form the mound is not known. Likewise, the time interval between mound formation and establishment of the ash seedling is not known. A conservative guess would place the time of tree fall approximately 100 years ago. The more rounded outline of mound 3, and the deeper organic layer and evidence of profile development in the pit suggest that it is older than mounds 1 and 2. The sizable hemlock stumps protruding from mounds 1 and 2 show clear sawlines indicating a salvage operation, probably carried out within 10 years after the blowdown. According to Beebe (1934, pp. 182-183), the hemlock in this region was cut for timber between 1888 and 1902. Therefore, the blowdowns that produced mounds 1 and 2 probably occurred at a minimum of 50 years ago, and perhaps more than 70 years ago.

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One of the smaller mounds on the plateau was trenched at right angles to its long axis to show its internal structure (Fig. 15). This mound is approximately 13 feet long and 9 feet wide, with a maximum relief of 2.5 feet from pit bottom to mound crest. Maximum slope is approximately 20° , on the pit side. The east end of the trench, at point "A" beyond the edge of the mound, exposes a Podzol profile. That portion of the trench west of the pit exposes a discontinuous Podzol profile. Underlying the east slope of the mound is a quantity of dark gray to black organic matter, containing decayed fragments of beech wood, partially surrounding an

FIGURE 15. PROFILE OF TRENCHED BLOW-DOWN MOUND



irregular mass of grayish silt loam similar to the bleached layer at "A". This bleached material presumably is a remnant of the soil profile displaced by the roots of the fallen tree that formed the mound. A layer of organic matter extends from the top of the mound from point "B" to the bottom of the pit, increasing slightly in thickness toward the pit. A slight soil profile development is seen on the west slope of the mound.

The buried finger of organic matter underlain by a pavement of sandstone fragments at "C" may mark the bottom of the pit at an earlier stage in the reduction of the mound. Since that time the pit has been partially filled by material from the mound. This filling may have taken place quite rapidly, because one would expect slow filling to result in a deposit of mixed mineral soil and organic matter. The suggestion of a new soil profile on the west slope of the mound, a feature that is lacking

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On the pit side slopes of mounds 1, 2, 3, and 4 described above, may indicate that the trenched mound is of greater age.

Local relief in areas between the large mounds ranges from about 6 inches to 24 inches. The elevations and depressions are occasionally identifiable as mound and pit microrelief where the maximum relief is no greater than 1 foot. Presumably the low, rounded mounds are the result of erosion of older, and probably larger, mounds. Pits dug in the area of low relief between the larger mounds show a pronounced difference in soil profiles, not only between the elevations and the depressions, but also between adjacent pairs of elevations and depressions. Bleached layers are very discontinuous, even in the intermound areas. One must search for a good Podzol profile.

The rather steep (20°) slope immediately east of the ridge has almost no microrelief except that provided by the numerous mounds and pits. Four well-defined mounds and pits are found in an area 50 feet square on the upper slope (Fig. 14). The slightly crescent-shaped mounds are 7 to 20 feet long and 5 to 8 feet wide. All are asymmetric in cross-section, apparently the result of downslope fall of the uprooted soil material. The pits are 9 to 16 feet long and 2 to 4 feet wide. Broad, shallow troughs extend upslope from the pits.

All of the mounds are downslope from their pits. The long axes of mounds 6 and 8 trend slightly downslope in a northerly direction, the axis of mound 9 trends slightly downslope in a southerly direction, and the axis of mound 7 trends approximately at right angles to the slope. Slight gullies are present at one end of these mounds that do not lie at right angles to the maximum slope. These gullies are a result of the direction of fall of the trees that formed the mounds, and are not the result of erosion. Pits indicate that the slope is covered with loose, rubbly, sandy loam to silt loam, and rain water presumably percolates down through this material instead of running downslope on the surface.

The present stand growing on the slope consists of beech, red maple, white ash, and occasional black birches and sugar maples. A few red oaks grow at the break in slope at the edge of the plateau. The average diameter of the trees is 6 to 7 inches, and the stand is approximately 40 years old. A black birch is growing on the summit of mound 9, the base of its trunk flush with the top of the mound. The diameter of this tree is approximately 8 inches.

The presence of medium-aged trees on mound crests, lack of evidence that the present stand is subject to windthrow, and the large size of the mounds indicate that the mound and pit microrelief was formed under a forest of larger trees at some period in the past.



(C. S. Denny, U. S. Geol. Survey)

PLATE 6A. Mass of earth retained by roots of overturned black cherry. Note the concentration of slabs of sandstone in the upper right. Pit is evident at base of the earth mass. Photographed November, 1950. Location same as Plate 5.



(C. S. Denny, U. S. Geol. Survey)

PLATE 6B. Same tree, November 1952, showing slow initial rate of reduction of earth mass retained by root system.

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pine on the South Branch of Oswayo Creek was begun extensively about 1845 (Beebe, 1934, p. 175). Assuming that the 30- to 40-inch pine trees on Ford Hill were 150 to more than 200 years old at the time of cutting, the mounds upon which they grew are at least 200 years, and probably as much as 300 years, old. The reduced, circular mounds, presumably 200 to 300 years old, closely reflect the configuration of the root systems of the old pine trees whose stumps are still present atop the mounds. This suggests that the decay-resistant roots are largely responsible for maintaining the identity of the mounds.

FORMATION AND REDUCTION OF MOUNDS

These observations, substituting space for time, suggest a general sequence of events in the formation and reduction of microrelief in the northeastern United States.

Shaler (1891, pp. 273-274) described the windthrow of trees and its effects upon the soil materials which support them:

When a forest is overturned by a strong wind the trees, unless they be tap-root species, are commonly torn from the ground or uprooted, and thus it occurs that the soil about the base of the bole is rended away so that it lies at right angles to its original position. This mass of uprent roots is often as much as ten feet in diameter, and contains a cubic yard or more of soil. The pit from which it has been torn is often two or three feet in depth. This cavity quickly becomes filled with vegetable waste, and as the roots decay the earth which they interlock gradually falls back upon the surface whence it came, burying, it may be, a thick layer of leaf mold to the depth of a foot or two below the surface. In certain parts of the country where hurricanes are of frequent occurrence the amount of vegetable waste thus buried is considerable.

The immediate results of tree fall are 1) the wrenching from place and lateral displacement of a mass of soil material 2 to 3 feet thick, having a radius dependent upon the size and lateral extent of the roots, and 2) the opening of a gap in the forest canopy equal to the diameter of the crown of the fallen tree.

The time required for the slumping of soil material retained by the root systems of overturned trees to form mound and pit microrelief is conditioned by the form, size, and rate of decay of the root system, and the texture of the displaced soil material. Reexamination in November, 1952, of the black cherry blowdowns described above indicates a very slow initial rate of slumping (Plate 6). Rock fragments of distinctive shape at the periphery of the soil mass can be identified in both photos. A small accumulation of rock fragments and finer material was present in the

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Ridge Road indicates that the initial relief of a mound may be reduced very slowly

The preservation of mound outlines, preservation of the loose texture of the material comprising the mounds, and the absence of soil profiles on the surface of mounds for periods of several hundred years may be the result of continuing disturbance of the material by freezing and thawing. The miniature boulder rings and boulder stripes, the hummocks in cleared areas, and the breakup in place of individual stones in ancient boulder rings are evidence that frost action occurs at the present time on a relatively small scale. Frost may act upon the mounds as follows: During the period of time when ground frost is present, the depth of penetration of frost in the mound material is considerably greater than the depth of penetration in the pits or intermound areas. Furthermore, the organic matter which accumulates in the pits probably acts as insulation. This differential in depth of frost penetration would be increased during periods when intermound areas and the pits are filled with snow and the mounds are bare. During the spring and fall when temperatures fluctuate diurnally about the freezing point, lenses of needle ice similar to those seen in pits of the recent blowdowns may form in the mound material. Masses of needle ice forming in the moist soil material, initially very loose as it dropped from the roots of the overturned tree, may grow by the addition of moisture from below. Repeated freezing and thawing of the material would destroy any incipient soil profiles and counteract the packing effect of rain on the surface of the mound. The porosity of the mound material would be maintained, rain water would filter down through the material instead of running off its surface, and the rate of erosion of the mound by rainwash would be reduced.

The location of trees on large, unreduced mounds may be conditioned by continuing disturbance of the loose mound material by freezing and thawing. Trees generally grow on the sides of mounds, and in the saddles between mounds and pits. With the exception of the perched birches, trees are generally absent from mound crests. Perhaps disturbance due to frost activity prevents the continued growth of most seedlings that germinate on mound crests. The growth of trees on the flanks of mounds probably reduces both frost activity and rates of erosion, retarding the rate of mound reduction. Both the medium-aged trees of the present forests and the old stumps are almost universally absent from the bottoms of pits, even where the microrelief is less than 1 foot and mound and pit relationships are obscure. The thick organic mat that slowly accumulates in pits probably inhibits the establishment of seedlings.

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As reduction of the mound proceeds, the slopes become flattened, the size of the pit decreases as it becomes filled with a mixture of leaf litter and soil from the mound, and a thin layer of organic matter accumulates on the flanks of the mound. Gaps in the forest canopy produced by the fall of the tree that initiated mound formation are filled by the lateral expansion of the crowns of adjacent trees and/or by the growth of trees that become established on the disturbed soil material. Canopy closure probably results in the elimination of many seedlings growing on the mound material through the processes collectively known as "competition." Many mounds in various stages of reduction support no trees, and canopy closure is effected solely by the lateral extension of the crowns of trees adjacent to the disturbed area.

Still more reduced mounds that support large trees appear essentially round in outline, with relief ranging from 18 to less than 12 inches. Dark organic layers often cover the mound surface, and thin soil profiles may be present. Pits may be completely filled.

The slow reduction of mounds may be interrupted by the overthrow of trees growing in the mound material after they have attained considerable size, initiating a new cycle of mound formation and reduction.

POSSIBLE SOLUTION TO THE PROBLEM OF WHITE PINE IN POTTER COUNTY

The absence of white pine from a region formerly possessing an abundance of pine is an important vegetational problem. Any explanation of the absence of pine from the present forests must also contain an hypothesis to explain its abundance at the time of settlement.

At the present time most workers believe that the appearance of pure stands of white pine in the pre-settlement forests of eastern United States has been the result of catastrophic events. Fisher (1933) believed that the recurrence of fire in the pre-Colonial forests of central New England resulted in the heavy concentrations of pine that were found in some localities by the early settlers. Nichols' (1935, pp. 410-411) conclusions regarding white pine provide a brief summary of the peculiar position it occupies in the deciduous forest:

. . . White pine, throughout a large part of its geographical range is a normal, although minor, constituent of the climatic climax forest. (2) As such, it occurs not as pure stands but in varying admixtures with hemlock and hardwoods. (3) Where represented in such mixed growth by numerous trees of approximately even age, the origin of the pine characteristically dates back to a forest fire or to some other more or less widespread calamity; but (4) where represented here only by scattered specimens of uneven age, or only very locally,

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the pine in all probability has originated in relatively small forest openings brought about by windfall or by some other purely local influence. Openings due to windfall and the like are to be looked upon as a normal incident in the life of the forest. (5) Once established in openings of any description, the pine may or may not grow to maturity; to a varying degree, depending on local and seasonal conditions, it does so. Germinating in the forest, under favorable conditions of moisture and soil, the white pine may be able to hold its own in competition with more tolerant trees by virtue of its persistent growth, its large size, and its great length of life.

The importance of fire in the development of vegetation has long occupied a prominent position in the literature of plant ecology. Previous workers in northern Pennsylvania have emphasized the importance of fire in attempting to explain the formation of the forests. Jennings (1928), discussing the pure stands of white pine in the Cook Forest, suggests that creation of an open area in the mixed forest by wind, fire, or clearing the land would often result in its occupation by white pines. Lutz (1930a), using old land survey notes to reconstruct original forest composition in northwestern Pennsylvania, suggests that the 23 windfalls or areas of fallen timber noted by the surveyors were really old burns. In his study of the Heart's Content tract (1930b, p. 20), he came to the following conclusion: "It seems highly probable that the even-aged white pine which occurs in the stand at present came in following a destructive fire about 250 years ago." Hough and Forbes (1943) speak of the great fire of 1644 in northwestern Pennsylvania, and the later but less destructive tornado of 1811.

Good evidence of pre-settlement fires in Potter County would be very difficult to obtain. Throughout the county, old fire-scarred stumps are seen, and fragments of charcoal in the loose, upper parts of the surficial deposits further indicate extensive fires. According to Beebe (1934, p. 189) cutover lands of most of the county were burned repeatedly, but "few fires of major proportions" occurred in the county between the time of settlement and 1880.

However, evidence of pre-settlement windthrow is abundant on the ground, and accounts of travels west of the Allegheny Mountains during this period commonly mention wind damage in the forest.

Pinchot and Graves (1896) studied the white pine in north central Pennsylvania and reported that it seldom occurred in pure stands. The species most commonly mixed with white pine was hemlock. They believed that hemlock might gradually replace pine because of its capacity to survive shade, and suggested that stands of white pine growing on land "which the Hemlock would tend to occupy to its exclusion is often

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to be explained by the fact that, although it may once have been driven out, the Pine has returned in the windfall clearing made by a storm" (1896, p. 23). They also suggested that "the same result would follow a devastating fire" (1896, p. 23). This order is the reverse of that used by most authors, and is perhaps significant because Pinchot and Graves made their studies during the last part of the white pine lumbering era in north central Pennsylvania. In other words, this is not a reconstruction but a contemporary analysis by America's pioneer forester.

The evidence suggests that most of the white pines in the pre-settlement forest of Potter County became established in bare areas created by windthrow. Old pine stumps in all parts of the county present essentially the same appearance as those on Ford Hill. Many stumps surmount well-defined mounds, most are seen on low, circular mounds lacking pits, and a few appear on level ground.

If this hypothesis is correct, the pines must have become established on the mound material at a rather early stage in mound reduction, before breaks in the canopy produced by windthrow had been closed. This is suggested by the noted "intolerance" of white pine in the Northeast. Evidence of intolerance is presented by the old mounds which have a large pine stump on one end and a smaller hemlock stump at the other end. No mounds have been seen bearing more than one pine stump. However, the absence of perched white pine stumps indicates that pines did not become established on a new blowdown until most of the soil had fallen from the root system of the fallen tree.

The abundance of large white pine stumps atop mounds in various stages of reduction indicates that blowdown mounds provide conditions favorable for the germination and survival of white pines. Recent studies of eastern white pine (D. M. Smith, 1951; L. F. Smith, 1940; and Stevens, 1931) provide information concerning seedbed conditions that favor germination and survival of the seedlings. Windthrow creates many of the conditions that have been found, by direct observation and experiment, to favor white pine regeneration.

It will be recalled that windthrow 1) admits light to the forest floor by breaking the canopy, 2) disrupts and overturns the organic litter on the forest floor, and 3) displaces soil materials to depths of two to three feet which, falling from the overturned root system to the ground surface, create a mound of bare mineral soil. Furthermore, the soil materials comprising the mound are initially free of roots of living plants — isolated from the surrounding root-infested, undisturbed soil materials.

Overhead shade encourages germination of pine seeds, but leads to damping-off or inhibition of growth (D. M. Smith, 1951, and L. F. Smith,

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1940). According to D. M. Smith (1951, p. 55), side shade provided by trees, herbaceous ground cover, or debris on the forest floor provides "nearly optimum conditions" for the growth of very young seedlings. L. F. Smith (1940, p. 413) reported that pine seedlings that survive full sunlight were "larger and more vigorous than those in part shade." Windthrow provides direct sunlight in areas where many trees are felled, and side shade in areas where a few individual trees in a stand are overturned. Growth of herbaceous plants is encouraged in the sunny openings, and the fallen trunks provide a certain amount of side shade. Thus windthrow produces light conditions that favor germination and survival of white pine seedlings.

White pine litter is a poor seedbed for germination of white pine seed. In open areas pine litter does not retain moisture as well as mineral soil (L. F. Smith, 1940), falling seeds do not penetrate the litter, and high temperatures resulting from slow heat dissipation kill the germinating seeds (D. M. Smith, 1951). Organic litter from hardwoods also appears to inhibit white pine regeneration (D. M. Smith, 1951). On the other hand, bare mineral soil encourages the establishment of white pines. A standard silvicultural technique is the scarification of the forest floor to expose bare mineral soil. D. M. Smith (1951, pp. 47-48) summarizes the characteristics of bare mineral soil as a seedbed for white pines:

They [seedbeds of mineral soil] are very favorable to white pine regeneration, unless subject to extreme desiccation. There are no barriers to penetration of seed and the radicles of germinating seedlings quickly establish contact with the substratum, except in occasional instances when they are eroded from sandy soils by heavy rains. Bare, insulated mineral soil conducts heat downward so efficiently and has such a high specific heat that lethal surface temperatures occur only when the soil is very dry. Mortality from other causes is negligible. Growth of seedlings on mineral soil is generally good, although there is evidence that the removal of litter may induce detrimental nutrient deficiencies. Such deficiencies are not likely to be long-enduring if the litter is renewed by subsequent leaf-fall or if the exposed patches are no more than a few inches in size.

The soil which falls from the roots of a windthrown tree is initially loose and porous. Root growth is encouraged by well-aerated, loose soil material (Stevens, 1931), bettering chances of seedling survival. Absence of living roots from mound material eliminates root competition. According to Stevens (1931, p. 47), seedlings growing in a mature stand suffer greatly from root competition with the older trees.

Scattered pines must have been present in parts of the forest to provide seed for the occupation of bare areas. A seed source would permit a grad-

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ual increase in the percentage of pines in the stands, as occasional windthrows produced open, disturbed areas.

Perhaps the pine stumps abundant on ridge crests in southern Potter County are remnants of white pines that became established on bare areas resulting from occasional windthrow of a few trees by seasonal high winds. At the present time seasonal high winds are overturning individual trees on exposed ridge crests, and this presumably has taken place in the past. The white pines in the southern part of the county, in general, were cut at a later date than those in the northern part, and complete ring counts often can be made. The ages of individual trees thus determined range from 150 to 225 years, suggesting a slow build-up in the numbers of white pines.

However, the dense stands of white pine that grew in the northwestern part of Potter County may have had a slightly different origin. Here closely spaced stumps cover many acres, and are found on ridge crests, slopes, and valley floors, particularly in the Owayo drainage system. Although decay of the stumps prevents age determinations, their density and close spacing suggests that the stands were essentially even-aged. This suggests, in turn, establishment of white pines following widespread destruction of the forest such as results from hurricanes or gales. In 1834, Potter County suffered a tornado, whose path was 0.5 to 1.5 miles wide. Again in 1856, a "gale" was recorded, which covered a wider area. The large stands of white pine in northwestern Potter County may have resulted from similar tornadoes and gales in pre-settlement time that caused widespread destruction in the forests by windthrow, and produced a high density of blowdowns that became occupied by white pine.

The white pine lumbering era closed, with the exhaustion of the pine supply, approximately 60 years ago, and white pines are essentially absent from the present forests. The rapid cutting of the pre-settlement forest may have been responsible for the loss of the white pine. Almost all of the seed trees were removed, and windthrow was essentially eliminated. Although cutting operations, like windthrow, opened the forest canopy, the soil materials remained relatively undisturbed. The cutover areas were rapidly occupied by hardwood species.

From the time of settlement until roughly 1870, white pine was virtually the only species removed from the forest. During this period the northern half of Potter County, which contained the largest pure stands of white pine, was essentially stripped of pine. Many cutover white pine stands were brought under cultivation or maintained as pasture; others grew up to second-growth hardwoods. After 1870 the hemlock and hardwoods were clear-cut throughout the county. The intensive logging opera-

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tions were followed by severe fires which burned over most of the clear-cut areas.

The removal of white pine during the early period of logging 1) eliminated or drastically reduced the source of white pine seed, and 2) left seedbeds of pine litter unfavorable for the germination of white pine. Areas of bare mineral soil exposed by burning of slash and other mechanical disturbances associated with the logging operations, and by occasional windthrow in the remaining stands, probably received little seed. Furthermore, after 1880, the widespread fires in the cutover areas would have destroyed any young pines that had become established during the early stages of pine lumbering.

During the period of hardwood logging operations a further bar to reestablishment of white pine was created. The clear-cutting of the hardwoods presumably resulted in a marked increase in the number of hardwood trees of sprout origin in the ensuing stands. The vigorous growth of sprouts inhibits the growth of white pine in mixed stands, and generally results in suppression or death of the pines (Lutz and Cline, 1947).

White pines are occasionally seen in old fields. At the eastern edge of the stand of old pine stumps immediately south of Hebron, a narrow belt of medium-sized white pines is present. Adjacent to this group of pines is a group of young white pines that are growing in the old stump-filled pasture field. Approximately three miles north of Colesburg, on the Colesburg-Andrews settlement road, a solitary medium-sized white pine, growing in an old field, is surrounded by several dozen young pine seedlings.

Since the settlement of the agricultural northern half of Potter County in the early nineteenth century, there has been no widespread abandonment of farmland that might lead to the establishment of old field white pine stands. At the present time the shortage of seed trees may account for the scarcity of young pines in the semi-abandoned pastures.

SUMMARY

During early Wisconsin time the northeastern quarter of Potter County was covered by the continental ice sheet, which destroyed the existing vegetation and left deposits of glacial drift, largely till. The rigorous periglacial climate that existed along the ice margin almost completely removed the old weathered soils from the plateau surfaces, and mantled the landscape with unconsolidated debris derived from the bedrock and the old soil. The extreme instability of the surficial materials in the periglacial region at this time probably resulted in the essential absence of

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forests from large parts of the upland, although some species of the present forests may have survived in dwarfed form. The glacial drift in the northeast was subjected to a period of intense frost action subsequent to its deposition, which largely destroyed the differences in the nature of the surficial materials within and for a few tens of miles outside of the border of the Wisconsin drift.

Amelioration of the climate in post-Wisconsin time presumably led to the reestablishment of forests on the uplands. The uplands, both within and outside the glaciated area, were mantled with loose, heterogeneous surficial deposits which essentially concealed the bedrock and produced smooth, uniform slopes. A major variation in the surficial deposits was provided by the widespread occurrence of rubbly materials derived from thin-bedded sandstones.

With the development of forests of large trees on the loose surficial deposits, seasonal high winds and occasional tornadoes presumably began to topple the large living trees. This not only perpetuated the disturbed nature of the upper parts of the surficial materials, retarding soil profile development and decreasing surface erosion, but it provided openings in the forest canopy and a changing series of site characteristics making any long-continued biological succession impossible over large areas.

Stratigraphic evidence in the form of pollen profiles is lacking, and the species composition of the forests in prehistoric time is not known. Assuming that the forests at the time of the xerothermic period were composed of essentially the same species that comprise the present forests, the oak forest probably occupied more extensive areas in the county than at the present time, and all species of oak may have had a wider distribution. With the more recent general climatic deterioration, the range of oaks was probably reduced, resulting in the pattern of distribution to be seen at present. The scattered appearance of species of oak in the Northern Hardwood region may be a result of the xerothermic period, oaks persisting in certain favorable sites.

The forests of Potter County as seen by the first settlers (circa 1810) consisted of essentially the same species, grouped in essentially the same assemblages, as those comprising the present forests. Forest types typical of the Northern Hardwood region covered most of the county, roughly centered in the high plateau south of the border of the Wisconsin drift. Away from this central mass of northern hardwoods, toward the periphery of the county, were found scattered areas of forest typical of the Oak Forest region. The transition from Northern Hardwood forest to Oak Forest was pronounced and abrupt across the extreme southern part of the county.

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One hundred years of lumbering operations following settlement resulted in the clearcutting of almost the entire area, and the proportions of the various species comprising the forest types were markedly changed in the ensuing stands. Second growth stands contain virtually no white pine. Other components of the types supplanted white pine, and chestnut was lost to the chestnut blight. The evidence suggests that the white pine population was slowly built up over the centuries preceding settlement by local and wide-spread cataclysms in the forest, largely the result of wind of hurricane force. Windthrow of large trees, singly and in large groups over considerable areas, opened the forest canopy and exposed bare mineral soil, creating conditions favorable for the establishment of white pine. Rapid cutting of the forest eliminated the normal means by which the forest floor is disturbed, thus encouraging the growth of suppressed hardwoods and hemlock as well as the establishment of hardwoods of sprout and seedling origin.

The present upland forests of Potter County, particularly in the Northern Hardwood region, show a marked uniformity from ridge crest to valley floor, although local relief ranges from 300 to more than 800 feet. Variations in the vegetation are generally accompanied by variations in the nature of the surficial materials, and the more xerophytic forest types grow on rubbly materials. No apparent change in the vegetation is seen upon crossing the border of the Wisconsin drift.

The evidence suggests that the layer of loose, heterogeneous surficial materials that mantle the bedrock of the region, is primarily responsible for the uniformity of the vegetation on either side of the border of the Wisconsin drift, and the vertical uniformity of the vegetation throughout the region, probably by reason of the establishment of relatively uniform water tables from valley floor to ridge crest. Local concentrations of rubbly materials consisting of slabs of thin-bedded sandstone presumably bring about variations in the levels of water tables, roughly in proportion to the abundance of fragments. These variations in the nature of the surficial deposits are reflected in the vegetation by the appearance of forest types that are more xerophytic than those growing on adjacent non-rubbly soil materials.

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TABLE

SCIENTIFIC NAMES OF SPECIES MENTIONED IN TEXT

TREES

<i>Common Name</i>	<i>Scientific Name</i>
American Elm	Ulmus americana L.
Basswood	Tilia americana L.
Beech	Fagus grandifolia Ehrh.
Black Birch	Betula lenta L.
Black Cherry	Prunus serotina Ehrh.
Black Oak	Quercus velutina Lam.
Blue Beech	Carpinus caroliniana Walt. var. virginiana (Marsh.) Fern.
Butternut	Juglans cinerea L.
Chestnut	Castanea dentata (Marsh.) Borkh.
Chestnut-Oak	Quercus Prinus L.
Cucumber-tree	Magnolia acuminata L.
Hawthorn	Crataegus spp.
Hemlock	Tsuga canadensis (L.) Carr.
Hop-Hornbeam	Ostrya virginiana (Mill.) K. Koch
Large-toothed Aspen	Populus grandidentata Michx.
Mountain Maple	Acer spicatum Lam.
Paper Birch	Betula papyrifera Marsh.
Pignut	Carya glabra (Mill.) Sweet
Pitch-Pine	Pinus rigida Mill.
Quaking Aspen	Populus tremuloides Michx.
Red Maple	Acer rubrum L.
Red Oak	Quercus rubra L.
Red Pine	Pinus resinosa Ait.
Sassafras	Sassafras albidum (Nutt.) Nees
Shagbark Hickory	Carya ovata (Mill.) K. Koch
Striped Maple	Acer pensylvanicum L.
Sugar Maple	Acer saccharum Marsh.
Tulip-tree	Liriodendron Tulipifera L.
White Ash	Fraxinus americana L.
White Oak	Quercus alba L.
White Pine	Pinus Strobus L.
Witch-hazel	Hamamelis virginiana L.
Yellow Birch	Betula lutea Michx. f.

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SHRUBS AND HERBS

<i>Common Name</i>	<i>Scientific Name</i>
Bracken	<i>Pteridium aquilinum</i> (L.) Kuhn
Christmas Fern	<i>Polystichum acrostichoides</i> (Michx.) Schott
Club-moss	<i>Lycopodium annotinum</i> L. L. <i>clavatum</i> L. L. <i>complanatum</i> L. L. <i>obscurum</i> L.
Hay-scented Fern	<i>Dennstaedtia punctilobula</i> (Michx.) Moore
Low Sweet Blueberry	<i>Vaccinium angustifolium</i> Ait.
Maidenhair Fern	<i>Adiantum pedatum</i> L.
Maple-leaved Viburnum	<i>Viburnum acerifolium</i> L.
Marginal Shield-Fern	<i>Dryopteris marginalis</i> (L.) Gray
Mountain-Laurel	<i>Kalmia latifolia</i> L.
New York Fern	<i>Dryopteris noveboracensis</i> (L.) Gray
Spinulose Wood-Fern	<i>Dryopteris spinulosa</i> (O. F. Muell.) Watt. var. <i>intermedia</i> (Muhl.) Underw.
Sweet-fern	<i>Comptonia peregrina</i> (L.) Coult.

Nomenclature follows that of Gray's Manual of Botany (8th edition).

