

THE UPROOTING OF TREES: A FOREST PROCESS

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For many years the uprooting of trees has been recognized as a natural phenomenon. As such, it has usually been regarded as one of freakish occurrence noted for its direct and catastrophic results upon the trees immediately affected. Uprooting, it seems, has seldom been considered with enough perspective to reveal its basic relationship to the forest.

A form of very detailed descriptive research was instigated in 1948 to document the developmental trends of the forest stands which had occurred on a one-acre area. Uprooting was established conclusively as an important factor in the development of the area during the last 500 years.

When uprooting is observed and interpreted on a limited area with the perspective afforded by 500 years, its role becomes that of a natural forest process, rather than a single event in the life history of a forest stand. As a process, it must be considered along with reproduction, growth, podsolization, and other generally recognized processes. Similarly, the series of actions and subsequent reactions associated with uprooting can be described quantitatively, qualitatively, and chronologically.

More extensive research has indicated that uprooting is a general forest process in eastern North America. Its influences have many ramifications, and like most other natural processes, are highly variable. The soil is one of the components of the forest greatly affected by the process of uprooting.

THE UPROOTING OF TREES: A FOREST PROCESS

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For many years the uprooting of trees has been recognized as a natural phenomenon (Shaler, 1891), (Holmes, 1893), (Van Hise, 1904), (Lutz and Griswold, 1939). The most comprehensive treatment of the subject to date has been that of Lutz (1940). A review of the literature at that time, as stated by Lutz, brought out three principal facts:

1. That uprooting of forest trees is of widespread occurrence.
2. That uprooting results in drastic disturbance of forest soils.
3. That such disturbance is of ecological importance.

The investigations of Lutz were devoted primarily to the influence of uprooting on various soil properties believed to have ecological and pedological significance. However, the importance with which he regarded the phenomenon as a whole can be expressed best, perhaps, by quoting a portion of his conclusions.

"Windthrow, with the generally attendant uprooting of trees, is a universal phenomenon in forest regions. Occasional violent storms of hurricane intensity may operate over extensive areas and cause entire stands to be uprooted. Less spectacular, but more common, is the windthrow of scattered individuals or groups of trees which occurs during normal years. Over long periods of time the soil under forest stands may repeatedly be subjected to disturbance when trees are uprooted. This type of natural disturbance of the soil body is peculiar to land bearing forest stands; it may be likened to plowing by the agriculturist."

Seldom since Lutz's study has uprooting been considered with the amount of perspective required to reveal its basic relationship to the forest.

A form of very detailed descriptive research was instigated at the Harvard Forest in 1948 to document the development of the forest stands that

had occurred on an area slightly less than one acre in extent. The original objective was to trace the development of the forest to pre-colonial time, about 1730.

The first procedure was to construct a 10-foot grid, which permitted the accurate location of any object on the area. Next, a series of maps was made to the scale of 10 feet to the inch which described:

1. All live and dead tree elements ranging from less than $1\frac{1}{2}$ inches in diameter inside bark at breast height to the smallest recognizable seedling.
2. All stumps, dead tree boles, and large fragments of wood lying on the present forest floor.
3. All live tree elements $1\frac{1}{2}$ inches and larger inside bark at breast height.
4. Contours of the present forest floor to an interval of 6 inches.
5. Boulder concentrations and all individual boulders on the present forest floor to a minimum diameter of 6 inches.
6. Present forest canopy.

In conjunction with map construction, other general procedures were followed:

1. Specimens of all stumps and wood fragments were collected for species identification and age determination.
2. As the tree elements less than $1\frac{1}{2}$ inches in diameter were described, a section for age determination was removed from the base of each coniferous seedling and from the base of the stem and primary root of each sprout hardwood.
3. The mounds and pits of uprooted trees were sectioned at right angles to their long axes to depths of from 2 to 5 feet. Ten sections, the ages of which could be most closely determined,

were profiled to the scale of one foot to the inch. Only the gross aspects of the sections were recorded: color, texture, consistency, and arrangement of the horizons. The remaining sections were profiled diagrammatically to the same scale and described. Coincident with sectioning, specimens were collected of buried wood from the trees that had been uprooted, buried organic layers of the pre-disturbed forest floor, and charcoal. The wood and charcoal were collected for species identification, as was the pollen content of the organic layers.

4. The remaining trees were felled, and sections for height and diameter growth reconstruction were removed from each at 4-foot intervals.

The application of the historical-development approach (Stephens, 1953) to a small area of forest permitted the documentation of the stands that had grown there since pre-colonial time. In addition, this approach made it possible to observe the cumulative effects of several hundred years of forest processes. As an immediate result, many of the gross trends in the life histories of the stands were exposed. The uprooting of trees was established conclusively as one of the important influences. Uprooting may be defined as the toppling over of a tree with the result that some or all of its roots are wrenched from their anchorage in the soil. The influences of uprooting on the forest in general are many and varied. The soil is one of the components of the forest which shows the results of uprooting most vividly.

When uprooting is observed and interpreted on a limited area of forest with the perspective afforded by 500 years, its role in the development of the area becomes that of a natural process rather than simply an event in the life history of a stand. The 6-inch contours of Figure 1 delineate the microrelief of at least 62 pairs of mounds and pits that are known to have been directly related to the uprooting of trees. Evidence both above and below the present

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surface of the forest floor indicates that the area has been subjected to four periods of major uprootings. Further interpretation of the evidence on the ground supplemented by written historical records places the dates of three of these disturbances as 1938, 1815, and 1635. The fourth and oldest was estimated to have occurred between 1400 and 1500 from evidence existing solely on the ground.

An overlay of the 6-inch contour map, Figure 2, shows the area, distribution, and chronology of the mounds and pits on the current research area. The area of each age class is as follows: 1938: 958 square feet; 1850: 183 square feet; 1815: 707 square feet; 1730-1750: 113 square feet; 1635: 1802 square feet; and 1400 to 1500: 1379 square feet. The total area of the mound and pit surfaces is approximately 5100 square feet. Almost 14 per cent of the surface of the present forest floor is composed of mounds and pits.

Most natural processes are characterized by the influence that they have upon the media or areas in which they are active. Their expressions change over time, and the developmental morphology and anatomy of the forms thus produced can be described qualitatively and quantitatively.

The mounds and pits on the research area were sectioned at right angles to their long axes, or parallel to the direction of tree fall. Figure 3 represents four such sections of mounds and pits which are typical of the different age classes and which occurred on relatively level surfaces. The ages of the sections are as follows: Mound and Pit No. 1, 14 years old; No. 35, 137 years old; No. 17, 317 years old; and No. 4 is between 450 and 550 years old. The gross characteristics of the profiles can be delineated when color, texture, consistency, and arrangement of the horizons are used as criteria. In Mound and Pit No. 1, the youngest of the four, these gross characteristics can be grouped to form four major anatomical features:

I. Region of deposition: the pit side of the uprooting where a

large portion of the mineral material picked up by the roots is destined to fall.

- II. Region of pivot: the mineral mass which either provided the anchorage for that part of the root system which acted as the fulcrum in the uprooting, functioned as the fulcrum itself, or both.
- III. Region of overburden potential: that mineral and organic mass on the mound side of the uprooting which is held in suspension by the roots and is destined to fall upon the relatively undisturbed surface of the forest floor.
- IV. Relatively undisturbed region: the extremities of the section occurring at both ends and at depths beyond the regions of general disturbance.

These four anatomical features in the youngest profile may be found in the older mounds and pits, and their development traced over time. They may be considered as ^{homologous} ~~analogous~~ parts.

The profile of Mound and Pit No. 1 has a generally disrupted appearance, the four regions having a blockwise arrangement along the length of the section. Color, texture, and consistency of the soil are extremely variable across this section, but quite consistent within each region. Only at the ends and depths beyond the regions of disturbance is there any resemblance to valid horizons. These characteristics prevail in Mound 35. All four of the anatomical features which occurred in the youngest section are still apparent in the 137-year-old one. The overburden potential, however, has changed to actual overburden by having fallen upon and buried a small part of the pre-disturbed forest floor.

When the older profile of Mound and Pit No. 17 is compared with the profile of No. 35, marked differences appear. The four major regions are still present, but they are beginning to lose their identity. The "blocky" effect is

no longer so pronounced in the older section. A more nearly uniform appearance has been created by the changes in color, form, and arrangement of the regions. The colors are more nearly comparable, the forms have become elongated, and a horizontal relationship of the regions is being approached.

The cross section of the oldest mound and pit, No. 4, presents a profile which is almost uniform in its general appearance. Color, texture, consistency, and arrangement of horizons break down as criteria to differentiate the four major regions which characterize the younger sections. The regions are no longer present as individual entities. The soil-forming processes appear to have had almost enough time to erase the gross expressions of uprooting and to develop a "normal" soil profile. Figure 3 represents, in many respects, the development of a soil profile over time. Only the gross aspects of the individual stages have been described here. However, this approach, coupled with a detailed investigation of the physical and chemical properties such as that of Lutz (1940), would permit comparative analyses.

More extensive research, involving over 30,000 miles of traveling, was conducted to determine the occurrence of uprooting in other forest regions. The area included the United States east of the Continental Divide and the Maritime Provinces of Canada. Almost without exception, the evidence of uprooting was apparent throughout the naturally timbered regions of this area. The micro-relief of mounds and pits was observed to be as much a characteristic of the forest as the trees. The uprooting of trees may well be considered a general natural process of the forests in eastern North America.

Since the process of uprooting is based upon a series of natural phenomena, its causes, expressions, and influences are highly variable and have many ramifications. Fifty-nine of the 62 mounds and pits on the present research area have been attributed to uprootings resulting from winds of hurricane origin. The more extensive the observations of uprootings, however, the more significant

becomes the realization that the uprooting process cannot be successfully rationalized if based solely upon winds of hurricane and tornado force. Before uprooting can be placed in its proper perspective as a general forest process, a broader basis of knowledge must be employed.

The causes of uprooting are many and varied. Basically, all uprootings are dependent upon the force of gravity. Likewise, wind is probably a key factor in most uprootings, whether of hurricane and tornado force or of the seasonal variety. The forest which has developed and grown up in a perfectly calm atmosphere is difficult to imagine. In this light, all uprootings may be considered as mechanical. However, other factors, agents which are not inherently mechanical forces, can be instrumental in uprooting. They tend to create the circumstances which are favorable for uprooting, and may be considered as physiological causes. The factors of uprooting may be classified as follows:

<u>Mechanical</u>	<u>Physiological</u>
wind	pathogens
ice	insects
snow	fire
	senility

Mechanical uprooting is usually associated with a direct physical force other than that exerted by gravity. Physiological uprooting, in contrast, is dependent generally upon the force of gravity acting upon the mass provided by a tree that is in a weakened physical condition. Actually, the uprooting of trees is ordinarily the result of a combination of factors. Therefore, it is extremely difficult to ascertain the primary agent that was responsible for a particular uprooting. The blowdowns or windthrows resulting from hurricanes and tornadoes are perhaps the most spectacular of mechanical uprootings. They also demonstrate the most clearly definable primary cause. Even the healthiest of trees are uprooted if subjected to winds of extreme velocity and duration. Ice and snow likewise appear to function as sole agents of uprooting if the

accumulations are heavy enough. Ordinarily, however, uprooting is the expression of a combination of factors. Trees in various stages of senility are seldom totally sound. Occasionally, even the slightest wisp of wind will topple them over under certain circumstances. Rarely, if ever, does the aerial portion of a tree develop so that it is perfectly balanced. The force of gravity coupled with root-specific pathogens, fire-weakened root systems, insects, water erosion, seasonal winds, or a combination of any or all, result in the uprooting of uncountable numbers of trees.

Even though the primary causes of uprooting are extremely difficult to differentiate, it is basic to further reasoning that at least the gross variables be recognized and considered. Extensive field observations indicate that the frequency, occurrence, and principal causes of uprooting vary from place to place and from time to time. Nevertheless, the variations tend to be related fundamentally to the geographical characteristics of the region: location, topography, vegetation, and past land use history, to cite only a few. The eastern coast of the United States and the Maritime Provinces of Canada are recognized as a general region of hurricanes. There has been sufficient evidence in both the historical and recent past to justify this designation. The meteorological components of the hurricanes that pass over this region admittedly are extremely variable. Nevertheless, the manner in which the forest, as one of the principal constituents of the landscape, reacts to the forces involved can be related directly to the species, ages, physiological condition of the trees, and even to the past practices of land use imposed by the vagaries of society. On the other hand, physiological uprooting may be more significant in some regions than the mechanical. Even the cursory research that has been devoted to uprooting reveals the existence of distribution patterns of characteristics that are mappable.

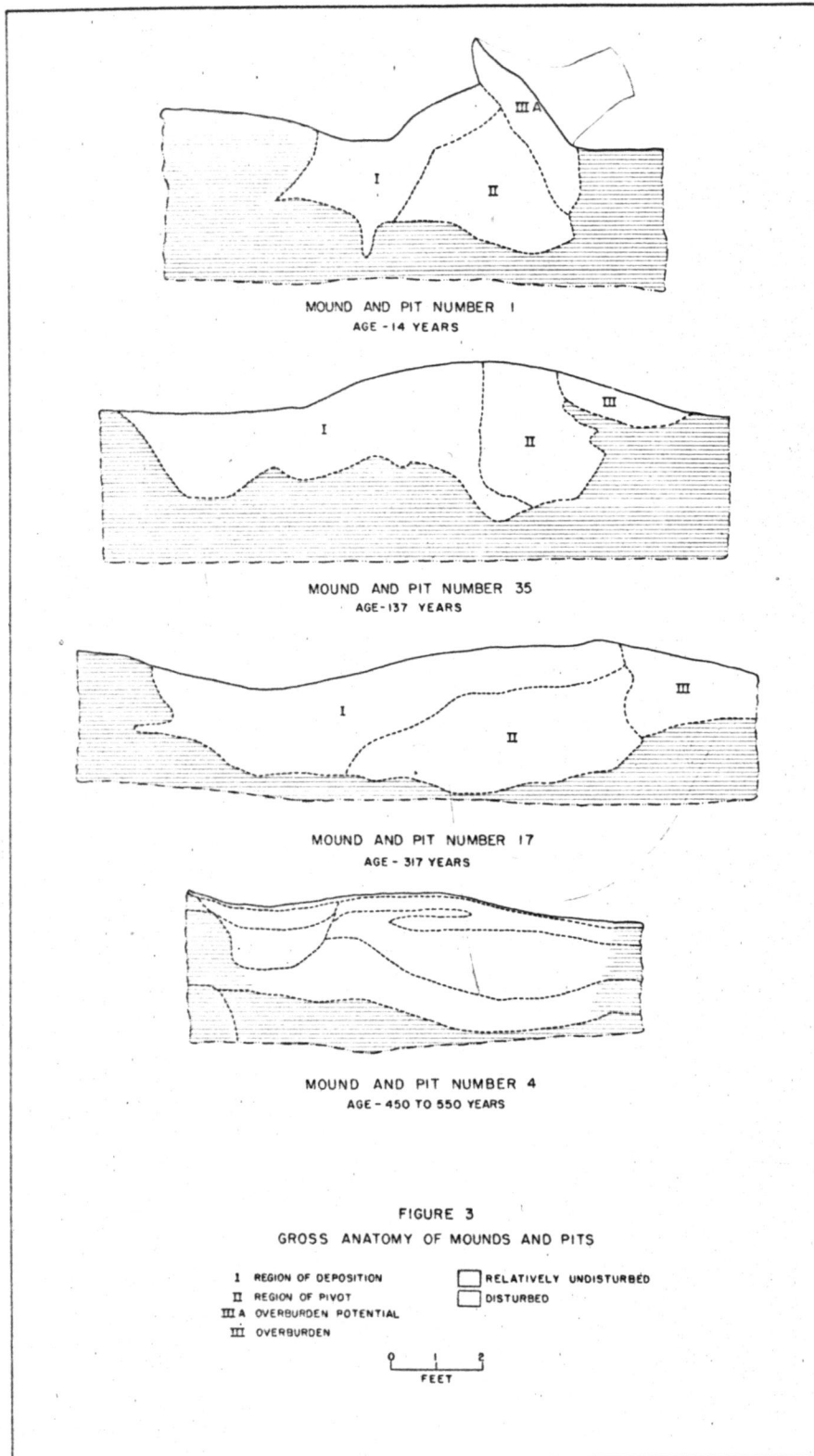
The trees of the "primeval forest" (Hartshorne, 1939) had two general destinies: uprooting, or piece by piece disintegration in place. It is impos-

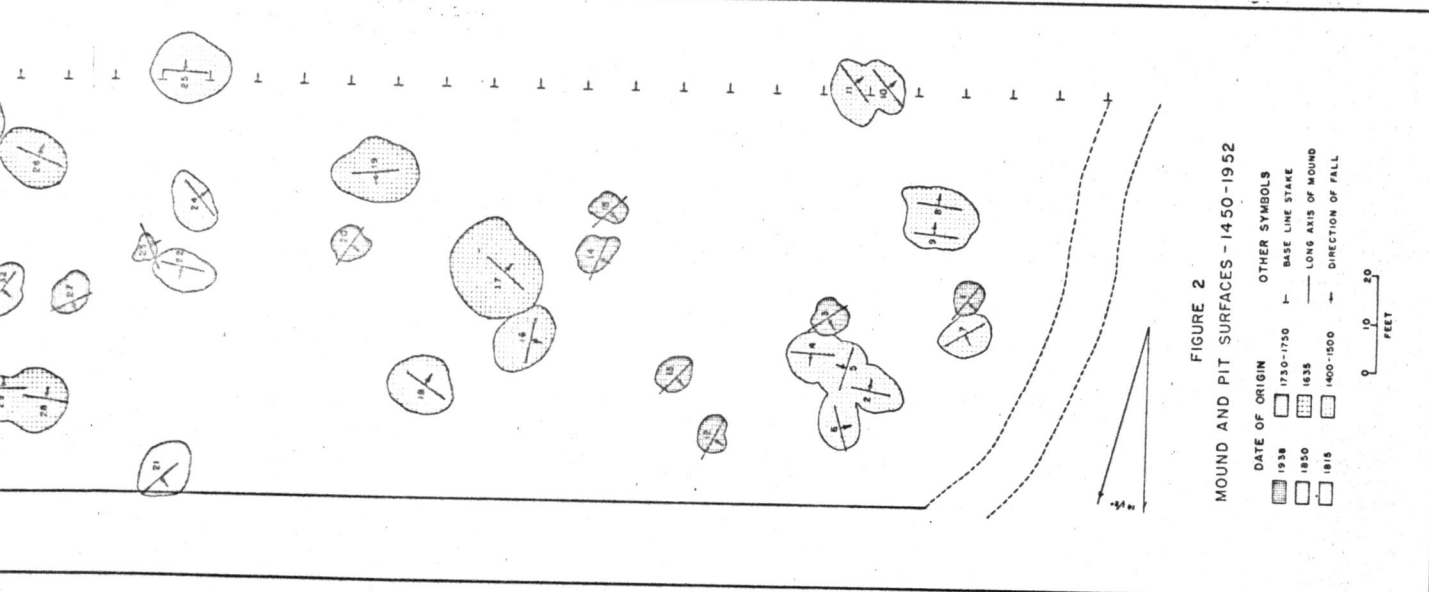
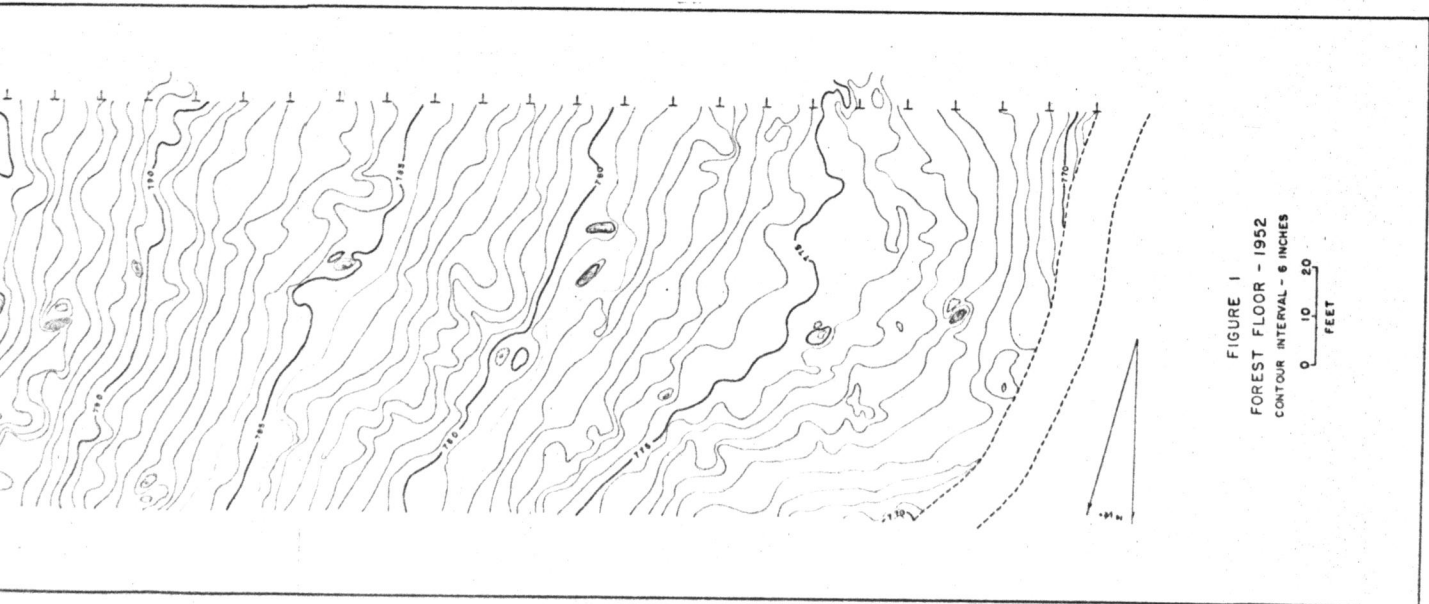
sible to conceive of any forest in the past that has not been influenced in some manner by the process of uprooting. The trees of today's forests have an additional possible fate: to be felled by logging. Nevertheless, the uprooting process plays an important role in the development of the forest as a whole.

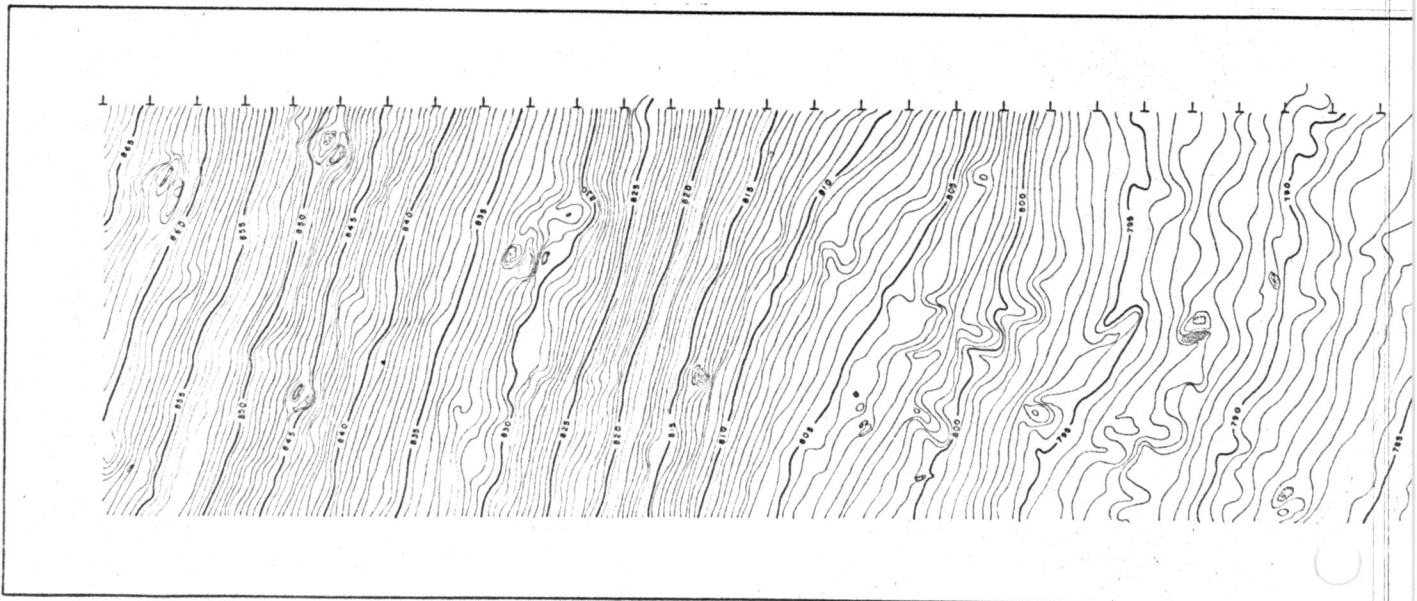
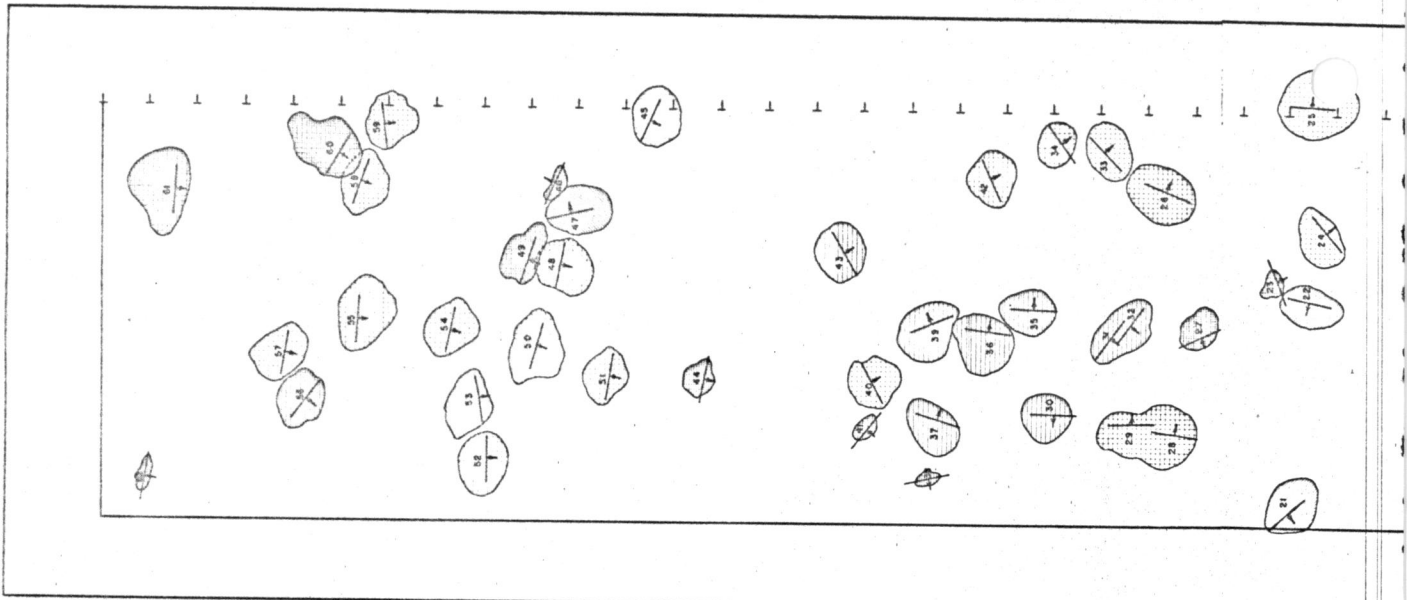
With this degree of perspective, uprooting assumes the proportions of a general process of the forest; and as a process, it can be considered in the same way as other generally recognized forest processes, such as growth, reproduction, podsolization. The recognition of uprooting as a process, therefore, is essential to a better understanding of the development of the forest.

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Research in the Biological Aspects of Forest Production¹

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WHETHER we like to admit it or not, forest production is a highly speculative proposition. The degree of speculation in the future will be related to the demands that society places upon the forest potential and the rate at which silvical knowledge is accumulated. One of the greatest deficiencies in the production aspect of forestry today is our general lack of ability to predict the species, form, and volume of the trees that will be growing on a particular area at a given time. This deficiency stems from the fact that we as foresters are working with a wild crop, and we simply do not have the degree of control which permits accurate prediction. Modern industry, the bond between forest potential and society, requires realistic predictions in order to function properly. Ultimately, sound decisions as to production policy must rest upon a firm foundation of knowledge; a knowledge which inevitably will be basically biological due to the inherent characteristics of the forests themselves.

Many problems of forest production have become apparent, although a great number remain to be generally recognized before they can be delineated and rationally approached. Our difficulties seem to originate from two major sources. When one views the first source with an extremely broad perspective, it emerges as the myriad of imponderables involved in the forester's attempt to evaluate the sum total of the reactions between the genotypes of the forest trees and their environments. This is what the forester is trying to do when he predicts the site quality of a wooded area. The second source of difficulties is as specific as the first is general. It involves the factor of time, an element which can be measured precisely and the requirement of which is consider-

able for the life cycles of most of our native tree species. The influence of time in the biological research of forest production has no parallel in any comparable area of investigation.

Methods of Approach

Research in the biological aspects of forest production can follow several methods of approach.

Experimental.—The one which will ultimately provide the major framework for scientific silviculture is often referred to as fundamental experimental research. Here, elaborate equipment and intricate techniques are employed to break down the physiological processes of plants into their physico-chemical reactions, isolate them, and measure their variations under controlled conditions. Control is essential. The major efforts of plant physiology have been devoted to the lower plants and the herbaceous members of the higher plants. The application of similar experimentation on trees creates a whole set of problems of considerable magnitude. The highly trained plant physiologist in this country who concerns himself primarily with trees is rare indeed. One might even say that the science of plant physiology has not developed to the stage where trees as individuals, let alone in the form of forests, can be observed efficiently. One could probably state further that the basic problems related to the reactions of a tree with its environment are not in the hands of the forestry profession as such. This is not an admission of failure on the part of the forester but one of realism, of challenge. Here, then, lies a whole area of research responsibilities, a part of which could be shouldered by the "forest physiologist," if for no other reason than to assist in the recognition and description of the basic problems.

Empirical.—Another mode of research is as old as man and is the trial-and-error or empirical method. This manner of learning was largely responsible for the changes wrought in man's existence from one of a gatherer of wild plants and animals to one of a cultivator of domestic crops. Our whole civilization rests upon it. The primary difference between this mode of investigation in silviculture and in agriculture is the time factor that is so strongly in favor of the latter. The agriculturist also has at his command the advantages of over three thousand years of experience with a comparatively few food plants. The silviculturist has as his backlog of experience a few hundred years with a multitude of tree species.

Empirical investigation in forest production has been primarily descriptive chiefly because of the difficulties in achieving an adequate degree of control. Its motivation has been the pressure of practical problems. Plantations and sample plots of differently treated areas generally fall within this realm of research. The value of such research will be related to the manner in which it was originally conceived, and the amount and quality of the observations recorded during the many years of its continuous maintenance. When one considers the complexity of the problems involved, it would appear that a multitude of these projects will produce nothing more than a crop of trees, and many of these at great expense. The trial and error approach is very apt to defy accurate description, interpretation, and duplication.

Historical.—The third avenue to the biological problems of silviculture can be referred to as the historical method. This mode of investigation also has been employed for a long time. It is no accident that the major wheat belt in North

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America occupies the area which only a century ago was dominated by the mid-grass prairies. Trial and error, environmental manipulation, and genetics have altered the boundaries, but the outlines of the original vegetation still are almost intact. In this approach, the plants are considered as integrators of the total environment. Investigators attempt to reconstruct and interpret the expressions or trends in the development of the vegetation in the light of what has gone on before. With an historical background in hand, they can be more intelligent about what to expect in the future. The reasoning is primarily inductive.

Climate has often been defined as the succession of weather. A forest might be referred to as the product of a series of "nature's experiments." In this respect, a forest might also be compared with a technical library. The experiments are not cataloged but they are there just the same and need only to be recognized, interpreted, and evaluated.

One should be very conservative in appraising this means of deriving information. The method is chiefly one of fundamental description. No basic quantitative data regarding physiological processes or facets of the environment will result. The whys and wherefores of plant distribution will not be solved. However, definite facts of presence and absence of tree species will be exposed. Major fluctuations in the environment and the gross expressions of the tree vegetation to related changes can be observed. The time factor, always so influential, can be telescoped by meticulous application of simple techniques and judicious observation. The results of many years of "nature's experiments" can be scrutinized within a comparatively short time. New problem areas can be exposed and subjected to more elaborate experimentation.

The experimental, trial-and-error, and historical approaches to the biological aspects of silvicultural research cannot stand alone. All three, particularly the first, must of necessity take into consideration

the principles of genetics. Eventually, all silvical knowledge must have genotypic qualification. Genetics can provide an impetus to forest production. The recognition, selection, and creation of particular genotypes will not only make it possible to grow better trees faster, but also assist in the analysis of the environmental complex.

Silvics, commonly defined as the biological foundation of silviculture, is in its embryonic stage of development. It is destined to become a science of synthesis, dependent upon the contributions of the allied disciplines for its foundation. The nature of the problems demands the application of the experimental sciences for ultimate solutions. As a result, answers will be a long time in coming. One might rationalize the situation by considering experimental research as the long-term approach, and descriptive research in the form of trial-and-error and historical methods as short-term approaches. Of the three, the historical is perhaps the least time-consuming. When one considers the present status of the development of silvics, the complexity of the problems, and the importance of time, it would also appear that the historical approach could be employed to the greatest advantage *now* toward the contribution of partial solutions for the silviculturist in the woods.

Application of Historical Approach

For a period of two years the historical approach was applied to an area slightly less than one acre, situated on the Harvard Forest in Petersham, Massachusetts.

The original objective was to trace the development of the vegetation to precolonial time, about 1730. The area was chosen because it supported a stand of trees, and it was accessible. The first procedure involved the construction of a 10-foot grid which permitted the accurate location of any observation one cared to record.

A series of maps was constructed to the scale of 10 feet to the inch which described:

1. All stumps, dead tree boles and large fragments of wood lying on the forest floor.
2. All live tree elements to a minimum d.b.h. of 1½ inches.
3. All live tree elements ranging from 1½ inches in diameter to the smallest recognizable seedling.
4. Contours of the forest floor to an interval of 6 inches.
5. Boulder concentrations on the surface of the forest floor and all individual boulders to a minimum diameter of 6 inches.
6. Present forest canopy.

Along with map construction other procedures were as follows:

1. Specimens of all the stumps and wood fragments were collected for identification and age determination.
2. As the tree elements less than 1½ inches in diameter were described, a section for age determination was removed from the base of each coniferous seedling and from the base of the stem and primary root of each sprout hardwood.

The 6-inch contours vividly delineated the microrelief of the area which included over 60 mounds and pits created by the uprooting of trees. The next major effort concerned the mounds and pits exclusively. Each was sectioned at right angles to its long axis, to depths of from 2 to 5 feet. Ten sections, the ages of which could be most closely determined, were profiled to the scale of one foot to the inch. Only the gross aspects of the sections were observed: color, consistence, texture, and arrangement of horizons. The remaining sections were diagrammatically profiled to the same scale and described. Coincident with sectioning, specimens were collected of buried wood from the trees that had been uprooted, buried organic layers of the pre-disturbed forest floor, and charcoal. The wood and charcoal were collected for identification, as was the pollen content of the organic layers.

The final stage in the field consisted of clearcutting the area. Sections for height and diameter growth reconstruction were removed at 4-foot intervals from each tree. So much for the general pro-

cedures except to say that the laboratory analyses involve a terrific volume of labor. Approximately 10,000 individual specimens were collected.

Findings

One of the first facts to be revealed was that in spite of at least two major logging operations, four periods of wind disturbance, and fires, the area had supported trees continuously since precolonial time. This fact has a significance which perhaps is so elementary that its real meaning is forgotten: that in this general region of the United States the developmental trends of the vegetation are climaxed by trees. This is the basic premise upon which our present-day silviculture and forest management are founded. The concept of plant succession was derived from the discipline of plant ecology, and provides the forester in New England with the basis for a reliable prediction: that any area in New England—those of obvious environmental extremes excluded—will produce a crop of trees if given enough time.

The majority of the trees whose uprooting had caused mounds and pits had been alive and quite large when uprooted. The individual characteristics of the mounds and pits indicated that at least four major periods of wind disturbance had occurred over approximately the last 500 years. Recently I had the opportunity to travel over 5,000 miles to the Cumberland and Smoky Mountains, south through the Piedmont Region, then west across the Mississippi Delta to the Ouachita and Boston Mountains, and back to Massachusetts. Practically everywhere one looked mounds and pits of uprooted trees were found. One has no difficulty finding the same phenomena in New England. The evidence on the ground is substantiated by accounts in the literature of innumerable storms of varying intensities since colonial time. I have come to the conclusion that the mound and pit microrelief is as much a characteristic of the forests as the trees themselves. The question that I am

forced to ask myself is: how does disturbance of this magnitude and frequency affect the climatic climax concept of vegetational development, a concept upon which much of our silvicultural and management practices are based? The climatic climax concept is founded upon a degree of stability that appears never to have existed in many forested regions. What adjustments do we have to make in our silvicultural reasoning to accommodate the influence of uprooting, of instability? Can the disturbances be predicted with reliability? Can the regions most affected be mapped?

The insertion of a disturbance or instability concept forces one to ask the same question about the development of soils. On the area under investigation it is possible to ascertain three different ages of soil surface within a horizontal distance of 20 feet. Over the area in general it is impossible to select one profile that can be designated as "typical," "normal," or "mature." The influence of instability upon soil genesis would appear to be an important consideration.

The stem analyses vividly revealed the height growth of the trees as individuals and of the stand in general. The hardwoods of one age class showed a period of pronounced decrease in height development. Further observation indicated that about 70 years ago the crowns of this age class were mechanically damaged. A severe ice or glaze storm was probably the agent involved. Regions of frequent and severe glaze storms are recognized by the electric power companies throughout the United States. So aware are they of this phenomenon that critical areas have been mapped, and in these regions adjustments have been made in the equipment employed to accommodate the weight of ice accumulation. What influence do ice storms have upon tree height growth and consequently upon the development of clear log length? Is clear log length actually limited by ice in certain regions? Can the frequency and occurrence of ice storms be predicted?

Had a forester cruised this particular area periodically every hundred years starting in 1650, his tally sheets would have shown quite different totals in regard to composition, dominance, and, of course, volume. The chances are that he would have assigned a different forest type designation to the stand that he found there each time. Which one of these "forest types" was real? Which one represented the true biological potential of the area? One might ask the same questions concerning the many different forest types now recognized in New England.

I have attempted to describe my concept of the historical approach to forest production research. I have cited only a few of the gross expressions of the vegetation to its environment and the simple techniques involved in their observation. It would appear that this approach could be applied very advantageously at this stage in the development of scientific silviculture. Its major objectives could be the determination of the "natural" biological production potential of forested areas and the degree of flexibility they present to environmental manipulation. Admittedly, most of the information derived would be descriptive in nature and would undoubtedly fall by the wayside as the experimental sciences came into play. Regardless of the nature of the knowledge, it is needed now, and much of it is destined not only to provide a framework for further investigation but also to contribute to the basic foundation of scientific silviculture in the future.

A basic question involves the degree of accuracy with which one should expect to predict the biological potential of an area. There are innumerable agricultural areas in the Midwest, for example, that have not experienced a crop failure in 50 years. I do not imagine that the proprietors of these acreages would have any difficulty financing improvements through a bank loan. However, move these same areas west near the margin of the 30-inch annual precipitation zone and observe the degree of

speculation mount. The inherent characteristics of our forests will never permit the degree of prediction exercised in agriculture. However, a forest industry should be able to undertake a land procurement program with reasonable certainty that the acreage they obtain will meet the demands which are to be placed upon it. A silviculturist should be able to realize the risks involved and the chances of attaining his objectives when he attempts to grow trees with two clear logs of a particular species and size in a prescribed length of time. As we learn to manipulate the environment to coincide with the silvical requirements of a plant, or to ad-

just the genotype to the environment, we shall be able to predict results more accurately.

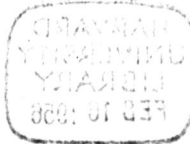
Conclusion

In the future, I believe that we should be very realistic about our research in forest production. Not necessarily practical, but realistic. All scientific investigation consists of accumulating observations. The subjects being scrutinized vary tremendously as do the techniques employed. Nevertheless, the first objectives are the same: the recording of accurate observations. Ultimately the data are synthesized. Conclusions are derived which lead to a partial solution. Another facet

of knowledge has been exposed, and an additional plane has been established on which further reasoning can be based for an approach to another set of unknowns.

During the initial stages in the development of silviculture, the description and empirical methods of research could probably be employed to the greatest advantage. After these have been exploited to reveal the gross biological phenomena of forests, the application of the experimental method will come into full play. It would also appear that the forester could accept more of the research responsibilities pertinent to the biological aspects of forest production.





THE HISTORICAL-DEVELOPMENTAL METHOD
OF DETERMINING FOREST TRENDS

A thesis presented

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1 INTRODUCTION

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INTRODUCTION

The dynamics of vegetation were recognized by Theophrastus (370-285 B.C.). Plant succession is now a widely accepted principle. The developmental trends of vegetation, however, are difficult to document, especially when the plants involved are long-lived trees. One of the common approaches to the study of vegetational trends relies upon the periodic description of permanent quadrats (Clements, 1905). Since the research worker must wait for the vegetation to develop, the factor of time is a serious hindrance. Another method is based upon the comparative analysis of several quadrats, each of which represents a genetically related, sequential stage in the development of the vegetation of an area. This technique, though it does avoid the time factor, rests upon the assumptions that the stages selected for description are valid, and that they will develop as expected. The first approach to the study of vegetational trends takes time, several hundred years in the case of trees, while the second is based largely upon deductive reasoning.

Another method of studying forest trends was employed in the current investigation. This approach considers the forest as a product of Nature's experiments, a long-term series of reactions between the trees and their environments. The investigator endeavors to describe and interpret these experiments as objectively as possible, tracing them into the past as far as the available evidence will permit. The method is primarily inductive. By its judicious application, the student may be able to observe on a single area, in a relatively short time, the major trends of several hundred years of forest development.

As a product of Nature's experiments, the forest might be compared to a technical library. The experiments in the forest, however, are not catalogued; nevertheless, the results are there, and need only to be observed and interpreted.

The evidence of vegetational change that is present in the forest is highly diverse. As stated by Bailey and Spoehrer (1929):

"The forest is an exceedingly complex biological unit. It comprises not only a more or less diversified aggregation of trees, but numerous species of shrubby and herbaceous plants, fungi, insects, herbivorous animals, and a complex soil fauna and flora. In other words, it consists of a very large number of mutually interacting organisms which are affected by, and themselves affect, a complex of environmental factors."

The current method is based upon the most conspicuous evidence in the forest: that furnished by the trees. Trees have the inherent capacity of providing directly and indirectly two general kinds of evidence that reveal forest trends: concrete and implied. Examples of concrete evidence are the trees themselves, alive or dead; stumps; fragments of wood; charcoal; and mounds and pits resulting from uprooting. The implied evidence is founded upon known silvical characteristics and recognizable reactions of trees to the complex of environmental factors. Such evidence includes the general ability of hardwood trees to sprout from cut stumps, the influence of foliage-eating insect epidemics upon radial growth, and the occurrence of trees growing in perched positions above the general level of the forest floor.

These two general kinds of evidence provide not only basic quantitative and qualitative data pertinent to developmental trends, but also a chronology of the major sequences. Thus, the student is able to visual-

ize the forest as it has developed over time.

This paper is a description of the historical-developmental method applied to a forested area of slightly less than one acre¹ on the Harvard Forest, Petersham, Massachusetts

1. 0.89 of an acre.

METHODS OF STUDY

Mapping

A 10-foot grid 460 feet long and 84 feet wide was established on the research plot (Fig. 1, Plate 2). With the grid as a base, a series of maps 10 feet to the inch was constructed of the following:

1. All trees and stumps 1.5 inches and larger in diameter inside bark at breast or stump height (Figs. 2, 3, 4). A number was assigned to each live tree, dead tree, stump, and multiple clump.
2. All large fragments of wood lying on the forest floor (Fig. 5). A fragment was considered that portion of a tree which could not be related definitely to a specific tree or stump. Four kinds of fragments were recognized: boles, bolts, branch spikes, and nondescript masses. They ranged in length from one to several feet.
3. Incidence of charcoal (Fig. 6).
4. Contours of the forest floor to an interval of 6 inches (Fig. 1, Plate 3).

A total of 689 numbers were assigned: 444 to live trees, 122 to dead trees, and 123 to stumps. Included in the multiple clumps were 22 live boles, 43 dead boles, and 221 stumps, making a grand total of 975 boles and stumps on the research plot (Table 1). Thirty fragments and the locations of 23 occurrences of charcoal were mapped (Tables 3, 4).

Description of Trees, Stumps, and Fragments

Each tree, stump, and fragment was considered an individual case. The descriptions were as objective as possible, and included any observation that might contribute to the determination of the forest stands that had grown on the research plot (Table 2).

As the trees, stumps, and fragments were numbered and mapped, they were described as to:

1. Species
2. Average diameter inside bark at breast and stump heights
3. Physiological condition (alive; dead)
4. Crown classification (live trees)¹
 - a. Dominant
 - b. Codominant
 - c. Intermediate
 - d. Suppressed
 - e. Leaning -- partially uprooted
5. Form of bole and crown (live and dead trees)
 - a. Open-grown (Plate 22)
 - b. Forest-grown (Plate 21)
6. Position on the ground²

a. Stump (Plate 15)	d. Pit
b. Log (Plate 6)	e. Boulder (Plate 8)
c. Mound (Plates 40,41)	f. Forest floor
7. Origin
 - a. Seedling
 - b. Stump-sprout. Parental stump 1.5 inches or larger in diameter (Plate 5).
8. Number of generations represented by each stump-sprout clump and the diameter of the stumps (Plate 42).
9. Incidence of charcoal at bases (Plate 8)

1. Hawley, 1937.

2. Where the seed had germinated and the tree originally had become established.

1. Many of the stumps were too rotten for sectioning. In these instances the largest, soundest pieces obtainable were collected.

2. All notes were recorded in Record notebooks No. 389, 8 x 10 inches. The descriptions of trees, stumps, and fragments required 170 pages, approximately 200 words per page.

#555 Live black birch tree, 20 inches D.B.H., dominant, growing on edge of mound close to white pine stump #553 (plate 19). Hole is well pruned to a height of about 22 feet, but headed-over branch scars 2 to 4 inches in diameter persist to within a few feet of the ground. The crown has extended over the old white pine stump. Loose pebbles are on ground around the base of this tree.

#554 Live hemlock tree, 2 inches D.B.H., suppressed, growing on top of white pine stump #553. A section of a root was excavated. The roots are not as large as some of the white pine roots collected earlier. Growth rate near perimeter was about 18 rings per inch, while toward center it was 7 rings.

#553 White pine stump, 29 inches in diameter. Had grown on upper slopes of a mound. The stump is very much disintegrated, having rotted practically to ground level.

#554 Live hemlock tree, 2 inches D.B.H., suppressed, growing on top of white pine stump #553. The following are examples of notes recorded in the field.

Each tree and stump was exposed at its base by shallow excavation to determine its origin and the incidence of charcoal. Quite often the gross features of the soil were described in general terms: depth of organic accumulation, degree of incorporation of organic matter with mineral material, degree of leaching, and resistance to excavation (Plate 7). And finally, a cross section or portion thereof¹ was removed from each stump and fragment, and its age determined (Plates 9-14, 16, 17, 18). While all of the trees, stumps, and fragments were observed with extreme care, the amount of detail in their descriptions varied considerably. The following are examples of notes² recorded in the field.

#331 Live hemlock tree, 21 inches D.B.H., dominant, has large lateral branches extending to within 10 feet of the ground. Crown is very broad, 50 to 60 feet in diameter. Could indicate that this tree grew most of its life under open-grown conditions. Branches are sparse on northern side up to about 40 feet. There are two red maples growing to the north about 15 feet away, but it is difficult to imagine that they could have influenced the crown development of the hemlock to this extent. Were there other trees nearer at one time, and evidence of them has disappeared?

Digging around the base of this tree exposed the following:

Loose boulders and cobbles are underneath this tree. Around the base, on the south, east, and northern sides, are heavy accumulations of organic matter. However, immediately under a rather thin layer of organic debris on the western and northwestern sides, the soil is a light yellowish brown, shows hardly any evidence of leaching, and has very little incorporated organic matter, somewhat the same characteristics that are associated with the C horizon of the area. Under this mineral soil and under the roots of the hemlock is a sizable amount of wood. One piece, quite sound, is white pine. The question is, how did the fresh-looking mineral soil get on top of the old wood? The grain of the wood is practically parallel to the forest floor, and its configuration suggests that the wood came from the base of a tree. About the only way to account for this phenomenon is by the uprooting of a tree. This large hemlock could have grown on an old white pine stump, as many do, but practically unweathered mineral soil on top of the wood could not be accounted for in this manner.

There is a lot of charcoal present directly under the roots of the hemlock. The charcoal is in small pieces. The tops of the boulders, upon which the hemlock is growing, can be exfoliated readily in small pieces. Would a fire have made these surfaces more subject to disintegration?

Tree #330, a 4-inch hemlock, is growing within 2 feet of #331. One of its larger roots has grown upward at a very perceptible angle and into the side of the slight elevation on which the large hemlock is growing. The root is now suspended in mid-air with

no organic or mineral matter touching it from a few inches where it originates until it enters the ground almost a foot and a half away.

Question: Did fire or fires occur before or after uprooting of tree, or both? Observations:

1. No indication of fire on present tree boles or roots.
2. Charcoal directly under roots on surfaces of boulders.
3. Present organic accumulations show no evidence of having been burned.
4. Old wood under tree shows no signs of fire.

Fragment 32 E - 34 H

Chestnut bole lying diagonally across the plot near trees #492 and #506. The bole is about 30 feet long. The larger or northern end is approximately 2 feet in diameter, while the other end is about one foot. The diameters are difficult to determine because the bole has flattened out due to decay. The big end still has a saw line on it.

Directly in line with the bole, about 51 feet to the northeast and off the plot, is a huge chestnut stump 5-1/2 feet in diameter. The chestnut was cut as indicated by the saw line. No other chestnut stumps in the local area are of proportions similar to the prostrate bole. The evidence suggests that the bole belongs to the large stump. If so, almost 50 feet of logs were removed from between the part of the bole that is lying on the ground and this stump. Approximately 80 feet of tree could be represented here, plus 20 feet more that might have extended beyond the small end of the bole. The total height could have been about 100 feet.

One hundred twenty-four annual rings were counted on the large end of the bole, including about 7.5 inches of its radius. What proportion of the total radius it included is not known. How old could this tree be at the stump? -

Description of Mounds and Pits Resulting from Uprooting of Trees

There were 62¹ perceptible mounds and pits on the research plot that had resulted from the uprooting of trees (Fig. 26). Seven of these mounds and pits, plus three² others that occurred off of the area but in the immediate vicinity, were selected for intensive investigation.

(Figs. 8-16). Each uprooting was treated as follows:

1. Record made of magnetic bearing of tree fall.
2. A cross section was excavated through the mound and pit approximately at right angles to their long axes or parallel to the direction of tree fall.
3. The profile and gross anatomical features of the cross section were plotted to the scale of one foot to the inch. Color, consistence, and texture of the soil were described under field conditions as the cross section was being dug or immediately after. The colors were measured by comparison with a Munsell³ color chart. Consistence was determined by the degree of resistance offered by the soil to excavation and deformation with a pick and shovel, knife, and hands. Texture was determined by rubbing the soil separates between the fingers.

1. Evidence of another uprooting was found. The mound and pit were obscured by the presence of hemlock #391 (See p. 7).

2. These three mounds and pits were selected because their dates of origin could be determined very closely from the ages of the live trees that were perched on them (Plates 32, 38, 39, 40, 41). They were designated as "A," "B," and "C."

3. Munsell Color Company, Inc., 10 East Franklin St., Baltimore 2, Md.

As the cross sections were excavated, specimens were collected of the wood, remnants of the pre-disturbed forest floor,¹ and charcoal that had been buried by the mound and pit.

Thirty-nine mounds and pits were investigated in a manner similar to the first ten, except that the anatomical features of their cross sections were plotted diagrammatically (Figs. 19-24). The remaining 16 uprootings obviously were the result of the 1938 hurricane. Only the profiles of their cross sections were plotted (Figs. 17-19).

Stem Analysis

There were 566 numbered live and dead trees involving 631 boles on the research plot. They were felled and treated as follows:

1. Three hundred and twenty-two boles were sectioned for stem analysis. Cross sections were sawed from each at points directly above the root collar, 4.5 feet from the butt, and every 4.0 feet thereafter along the entire length of the bole² (Plates 23, 24, 25; Table 5).
2. A cross section was sawed from directly above the root collar of as many of the remaining 209 boles as possible.
3. The total height of each bole was measured to the nearest 0.5 feet.

1. The buried organic layers are apt to contain pollen and spores of the plants that were present at the time the uprootings occurred (Plate 28).

2. A few of the larger hemlocks were sawed into 8- and 12-foot logs. Average diameters inside bark were recorded where the sections ordinarily would have been removed.

4. The cross sections were taken to the laboratory and air dried. The average diameter of each was cut out on a table saw.¹
5. The surface of each section was polished² with sandpaper (Plate 26).
6. The average diameter³ of each cross section was measured, and its age determined.⁴

The clearcutting and sectioning of the trees involved the processing of approximately 4,400 cross sections.

Reconstruction of Forest Stands That Had Grown on the Plot

Concrete evidence was found and analyzed of at least 1038⁵ boles 1.5 inches D.D.H., i.b. and larger that had grown on the plot (Table 1). The chronological order in which the trees had grown is illustrated by Figs. 32-42. The procedure employed to reconstruct the stands was as follows:

-
1. A 12", hollow-ground planer saw blade was used. This type of saw provides a very smooth cut surface.
 2. Preliminary sanding was done with either a belt or rotary sander and 3/0 paper, depending upon size of cross section. Final finishing was done with a small electric vibrator sander, using a series of papers ranging from 5/0 to 14/0, depending upon the species of wood and the degree of finish desired. The small sander vibrates in a short arc at a speed of 14,400 strokes per minute.
 3. Diameters of sound cross sections were measured to the nearest 0.1 inch; otherwise to the nearest inch. Diameters of the sections removed at 4.5 feet were measured both inside and outside of bark; all others inside bark.
 4. The ages were counted of both radii of cross sections at 4.5 feet. The age of only one radius was determined for the other sections.
 5. 975 boles plus 63 uprootings. Some of the mounds and pits could have resulted from the uprooting of more than one tree.

Live Trees, Dead Trees, Stumps

Construction of Dendrograms

The radial increments of the following cross sections were transferred¹ to narrow strips of paper.

1. All sections of trees and stumps that had been removed from directly above the root collar.
2. All sections of roots and branch whorls that had been removed from stumps.

The radial increments were transformed into dendrograms by plotting the annual radial growth of each cross section on a horizontal line. The radial increments were plotted on 10 x 10 = 1 inch cross-section paper with a sharp 6H lead pencil. Every tenth of an inch along the horizontal equals one year of age. The height of each segment is the actual radial growth for that year. Figs. 32-42 have been reduced to approximately one third of their original size.

A total of 606 dendrograms was constructed.

Plotting the Dendrograms

The dendrograms of the live trees were plotted in a vertical column, in an order approximating the actual location of the trees on the area. Graph paper approximately 16 feet long and 4 feet wide was used. Spaces were left between the dendrograms of the live trees for the dead trees, stumps, roots, branch whorls and mounds and pits to be inserted later.

-
1. A narrow strip of paper was placed along the radius of the cross section and held in place with drafting tape. With the aid of a microscope, the width of each annual ring was marked on the paper with a sharp 6H lead pencil.

Once the dendrograms had been plotted, developmental trends of the current stand became apparent ¹ (Fig. 43).

1. The coincidence between ages, especially of the stump sprouts, and dates of marked increases in radial growth rates indicated that the plot had been logged several times. The most prominent dates of logging were 1939,² 1890,³ 1864³ and 1854.³ Several minor operations were indicated between 1864 and 1890, and another in 1935.
2. The dates of origin of the oldest trees, the locations of which were generally confined to the eastern half of the plot, suggested the occurrence of another major event about 1800, probably a logging.
3. The incidence of sudden decreases in radial growth rates during 1944 and 1945, most pronounced in the oaks, suggested an epidemic of an insect, a pathogen, or both.⁴

1. The dendrograms, when plotted in a vertical column and considered collectively, constitute a "silvagram."

2. The evidence on the ground, as well as Harvard Forest records, indicated that the logging operation of 1939 was conducted to salvage the trees that had been uprooted and otherwise damaged by the hurricane of 1938.

3. The actual loggings could have been conducted during the year preceding each of these dates, during the growing season of the dates designated, or both.

4. Gypsy moth outbreaks of epidemic proportions were described in the town of Petersham for 1944 and 1945 (Bess, Spurr, and Littlefield, 1947).

4. A series of successive growth rate increases between 1908 and 1920, primarily in the under-story hemlocks, suggested an important environmental influence at work.¹
5. The areal distribution of the effects of logging, pathogens, insects, and the 1938 hurricane could be mapped. Some affected the whole plot, others only portions of it.²

The information derived from the dendrograms of the live trees was used as a basis for determining the proper chronological niches for the dead trees and stumps. First, the stands were reconstructed to 1854, the earliest important date of logging indicated by the live trees. After plotting the dendrograms and estimated ages³ of the trees that had

1. The dates of these increases did not coincide with dates of logging or tree origin. Furthermore, the distribution of the dates formed essentially a normal curve, quite unlike those resulting from logging, hurricane, or insect depredation.

The chestnut blight was gaining a foothold in Massachusetts as early as 1911. Its incidence was quite general by 1912. In 1916, the prediction was correctly made that the chestnut would be eliminated as a tree of commercial importance within a short term of years (Rane, 1911, 1912, 1916).

2. When the vertical column of live tree dendrograms is scanned from beginning to end, the major dates of tree origin and growth rate fluctuations differ from one part of the plot to another. The oaks throughout the length of the plot tend to decrease sharply in radial growth during 1944 and 1945. In contrast, the influences of the logging operations of 1890 and 1854 are most pronounced on the western half of the plot.

3. Diameter-age relationships at stump height were determined for most of the species present (Tables 22-28) (Bruce and Schumacher, 1942).

2. Evidence on the plot, in the immediate vicinity, and in other parts of the town of Petersburg substantiates the occurrence of a hurricane in 1815. This storm is described by Perley (1891) and Brooks (1945).

1. Approximate date. Minor cutting could have begun 5 to 10 years earlier.

1. 7.3 inches D.B.H., 1.b.
2. Dominant crown class.
3. 97 years old.
4. Seeding origin.
5. Growing against aspen stump #4 which is 9 inches d.i.b.
6. Aspen stump has been logged; the saw line is still evident.
7. The bole of the oak leans away from the probable position once occupied by the crown of the aspen.
8. Radial growth rate:
 - a. Marked increase in 1890 and 1935.
 - b. Sudden decrease in 1944.

A. Basic data:

Tree #5 - Live white oak

evidence.

and how long it had grown. The following are typical examples of such of evidence was exploited to determine when each had become established. As each tree and stump was considered an individual case, every source terms that had been traced into the past.

had grown on the area was practically dictated by the developmental possibilities. The chronological order in which the majority of the trees In general, the reconstruction of the stands met with only minor difficulties. The reconstruction of the stands that had existed prior to 1854.

comprised the stand in 1854, additional developmental trends became apparent (Fig. 44). A major logging operation had been conducted in 1803¹, a minor one in 1841, and another event was suggested to have occurred in 1815.² These earlier events then were used as a basis for reconstructing the stands that had existed prior to 1854.

comprised the stand in 1854, additional developmental trends became

9. Pertinent features of the local area:
- a. Four major age classes of trees:
 1. 97-98 years old
 2. 60-63 " "
 3. 17 " "
 4. 14 " "
 - b. Live trees had marked radial growth rate increases during 1889-90 and 1935-36.

3. Interpretation:

Since the oak was alive and had been felled in 1952 when it was 97 years old, its dendrogram was plotted to show that it originated in 1856.

Stump #4 - Aspen

A. Basic data: (Refer to Tree #5)

1. 9 inches d.i.b.
2. Stump appears as a hollow cylinder standing on end. Bark is still intact, while wood has decomposed (Plate 43).
3. No cross section or age available. Sections were obtained from two other similar aspen stumps.
4. Pertinent features of the local area:
 - a. Concentration of similar aspen stumps.
 - b. Numerous small stump sprouts of other species that are 17 years old.
 - c. Other trees show marked increases in radial growth rates during 1935-36.

B. Interpretation:

When the distributions of the aspen stumps were mapped, the 17-year-old sprout hardwoods, and the trees that demonstrated marked growth increases in 1935-36, all were confined to a small area, on the western edge of the plot. The aspen stumps had resulted from a minor logging operation in 1935¹. The estimated life span of the aspen stump was plotted so that it terminated in 1935. Its date of origin was not known, but ages of two other aspen stumps indicated that they had originated between 1890 and 1854. Therefore, all aspen stumps were plotted to originate between these two dates.

1. Harvard Forest records describe such logging operations during 1935 to remove the aspen.

Tree #263 - Dead chestnut

A. Basic data:

1. Two boles, 5 and 6 inches D.B.H., i.b.
2. Each bole 25 years old.
3. Stump-sprout origin.
4. Parental stump is 20 inches d.i.b.
5. Stump is at least 75 years old.
6. Stump is the result of a logging operation. The saw line is still evident.
7. Pertinent features of the local area:
 - a. Four other clumps of dead chestnut trees and stumps, all within a few feet of one another.
 - b. No large live trees present. The closest large tree is #268, a 15-inch hemlock, which increased suddenly in radial growth during 1890-91.
 - c. Two hemlocks, #264 and #265, each 3.9 inches D.B.H., i.b., are growing within 3 feet of this clump. They show marked radial growth increases in 1891 and 1892 respectively.
 - d. Live trees surrounding the area are predominantly one age class: 60-63 years old.

B. Interpretation:

The date of death of the chestnuts is known to be between 1908 and 1920. The dendrogram of one sprout was tentatively inserted into the vertical column of the other dendrograms with its terminal end falling between 1908 and 1920. Since the parental stump had undoubtedly been logged in 1890, the ensuing sprouts probably originated the same year or shortly afterward. Therefore, the dendrogram was replotted to the right until its date of origin coincided with the operation of 1890. When the life span of the parental stump¹ was plotted, its date of origin nearly coincided with the logging operation of 1890. The parental chestnut might well have been of seedling-sprout or root-sucker origin.

1. A cross section was not cut from the parental chestnut stump. Its age was determined in the field.

Stump #208 - Hemlock

A. Basic data:

1. 24 inches d.i.b.
2. Protrudes about one foot above the ground. Exposed part too rotten for sectioning.
3. Root section is at least 105 years old.
4. Cross section shows extremely pronounced growth increase approximately 50 years before tree was logged.
5. Tree had grown on the side of a mound.
6. Pertinent features of local area:
 - a. A 15-inch white oak stump, #209, within a few feet, had rotted practically to ground level.
 - b. Trees preponderantly of two age classes: 62-63 and 97-98 years old.
 - c. Many trees increased radial growth in 1890 and 1891.

B. Interpretation:

The hemlock stump appeared too rotten to have resulted from the logging of 1890. It also appeared to have been cut more recently than white oak #209, which probably dated back to 1803. Therefore, the dendrogram of the hemlock was oriented tentatively so that its terminal end was located between 1854 and 1803. When a few years were allowed for decay, the date of the sudden increase in growth rate practically coincided with the logging date of 1803. As a result, the dendrogram was moved back until the two dates did coincide. The hemlock almost surely was cut in 1854.

Stump #553 - White pine

A. Basic data:

1. 29 inches d.i.b.
2. At least 87 years old.
3. Had grown on upper slopes of a mound.
4. Had deteriorated to ground level.
5. Root section was at least 87 years old. Growth toward perimeter was about 18 rings per inch, while toward center it was about 7 rings. Hemlock tree #554, 35 years old, and 2.0 inches D.B.H., i.b., growing on top of it.

6. Live black birch #555, 17.8 inches D.B.H., i.b., and at least 120 years old, is growing on side of same mound within a few feet. Black birch has straight bole, clear of branches for about 22 feet. However, healed-over branch scars, 2 to 4 inches in diameter, persist to within a few feet of the ground. Birch could have grown under quite open conditions during its earlier years. Only one marked fluctuation in its radial growth rate, and that is a sudden decrease in 1866.
7. Crown of black birch has developed directly over stump. No evidence that crown of the white pine had ever occupied the same space.
8. Pertinent features of local area:
 - a. Oldest live trees on the plot occur on this eastern end. Their dates of origin range between 1799 and 1806.
 - b. Major logging took place in 1803, with several minor operations later.

B. Interpretation:

White pine stump #553 was highly deteriorated, much more so than stumps of the same species, and similar size and growth rate on the western part of the plot. The pine and birch were never contemporaries. Since the eastern third of the plot had been practically clear cut in 1803, this stump probably was the result of that operation. No dendrogram could be made. However, the pine was at least 87 years old. Therefore, its estimated age, 141 years plus or minus the standard error of estimate of 21 years, was plotted.

Uprooted Trees

Relative Ages of the Mounds and Pits

The cross sections of the mounds and pits were compared. The relationship between profile form and internal characteristics was very pronounced. This coincidence between form and structure indicated that four¹ major relative age classes existed (Figs. 8-24).

Relative age class	Number of mounds and pits
I	18
II	2
III	8
IV	1
V	15
VI	18

Form and Structure of the Major Relative Age Classes

Each age class of mounds and pits was characterized by a set of form and anatomical features that was related to its stage of development (Table 6).

Age Class I

Type specimen — Mound and pit #1

Mound and pit #1 (Fig. 8) resulted from the uprooting of red oak #25. Two boles, approximately 10 and 7 inches D.B.H. and 53 years old, were partially uprooted. The disturbance occurred on relatively level ground, the boles falling in a N 36° W direction. The soil is a Jaffrey gravelly fine sandy loam of glaciofluvial origin (Simmons, 1939). The oak was salvaged in 1939.² The cross section intersects the western two-fifths of the mound and pit.

1. Profile:

The maximum relief between the mound and pit is very pronounced, 2.2 feet vertical distance over a horizontal span of 2.0 feet. The profile is decidedly angular.

1. Two of the relative age classes present involved only three mounds and pits: two in one class, and one in the other.

2. Date of salvage determined from evidence on the plot. Corroborated by Harvard Forest records.

2. Arrangement of soil horizons:

The cross section has the general appearance of having been greatly disturbed. The soil horizons are discontinuous, and their contact with the disturbed regions is very abrupt. The long axes of the disturbed regions deviate sharply from the horizontal.

3. Pit:

The amount of litter accumulation and the degree of organic incorporation with mineral material is negligible.

4. Buried soil horizons:

None present.¹

5. Buried wood² of the uprooted tree:

None present.

Age Class III

Type specimen -- Mound and pit B

Mound and pit B resulted from the toppling of a tree to the south at a right angle to a 40 percent slope (Fig. 9). The soil is Brookfield stony loam (Simmons, 1939). Two large trees were growing on the mound. One, a black birch 18 inches D.B.H. and 136 years old, was perched on columnar roots so that its root collar was almost 4 feet above the crest of the mound (Plate 40). The other, a 12-inch hemlock 105 years old, was growing on a lower level within 2 feet of the birch. The cross section intersects the lower third of the mound and pit.

1. Profile:

The maximum relief between the mound and pit is 1.0 feet vertical over 4.0 feet horizontal distance. The profile is a series of abrupt curves.

1. Buried horizons of the pre-disturbed soil were present in many of the mounds of this age class that resulted from the toppling of trees downhill (Fig. 16).

2. Those remains of the uprooted trees which have become buried by mineral material and ordinarily cannot be seen without excavation. In many instances, whole trees were still present that had been uprooted to form the mounds and pits of age class I (Plates 36, 37; Fig. 16).

2. Arrangement of soil horizons:

The cross section has the appearance of unconformity. The horizons are discontinuous. The boundaries between the relatively undisturbed and disturbed regions are clear. The relative positions of the disturbed regions are decidedly askew. The development of organic layers on the surface is very irregular, with accumulations that are deep in the pit and merely a film on the mound crest.

3. Pit:

The depth of organic accumulation is very pronounced. The degree of organic incorporation with mineral material is slight and irregular, as is the degree of leaching.

4. Buried soil horizons:

Buried horizons are present, the most conspicuous of which is a layer of highly decomposed organic matter.¹

5. Buried wood of the uprooted trees:

Large quantities present.²

Age Class V

Type specimen -- Mound and pit #17

Mound and pit #17 (Fig. 10) occurred on relatively level ground, the direction of the tree fall being S 55° W. The soil is a Brockfield stony loam (Simmons, 1939). The remains of two stumps, #208 and #209, were present on the mound. #208, a hemlock 24 inches in diameter with a minimum age of 105 years, had resulted from the logging operation of 1854. #209, a white oak 15 inches in diameter and at least 127 years old, had been felled in 1803. Two live trees were growing on the mound and pit surfaces. A beech tree, #210, 6 inches D.B.H. and 91 years old, was on the mound. A red oak, #220,

1. In regions where podzolization is a dominant process, the A₂ horizon is a conspicuous feature of buried soils.

2. Had the cross section been excavated near the center of the mound (usually prohibited by the presence of live trees), more buried wood than that indicated by Fig. 9 would have been apparent. The wood of the uprooted tree is ordinarily concentrated in the leeward side of the mound. Enough wood was removed from each of the mounds of age class III to fill a bushel basket.

8 inches D.B.H. and 63 years old, was on the edge of the pit. The cross section intersects the western two fifths of the uprooting.

1. Profile:

The maximum relief is 1.1 feet over 7.5 feet. The profile consists of a smooth, very elongated S-shaped curve.

2. Arrangement of soil horizons:

The distinction between the disturbed and undisturbed regions is not highly contrasting. The horizons, though discontinuous, merge gradually across the length of the cross section. The long axes of the disturbed regions are approaching the horizontal, and are practically parallel with the surface of the forest floor. The accumulation of organic matter is rather uniform, about equal amounts being present in the pit and on the mound surfaces. The degree of leaching is irregular, the least occurring on the crest of the mound.

3. Pit:

The depth of organic incorporation is very pronounced. One of the most conspicuous anatomical features.

4. Buried soil horizons:

A buried soil is present, the most conspicuous part of which is the upper portion of the B horizon.¹ Next to the pit region, this feature is the most pronounced internal constituent of the cross section.

5. Buried wood of the uprooted trees:

None present.

1. The buried organic matter has disappeared. In its stead is a horizon that resembles the B₂ more than it does any of the A horizons. Some of the buried soils of age class V were very conspicuous due to their charcoal content. Others contained remnants of A₂ horizons.

Age Class VI

Type specimen -- Mound and pit #4

Mound and pit #4 (Fig. 11) occurred on a relatively level surface. Direction of tree fall is $N 18^{\circ} E$. The soil is a Jeffrey gravelly fine sandy loam of glacioluvial origin (Simmons, 1939). A 9-inch aspen stump, #83, was located on the western edge of the mound. The cross section intersects the center of the uprooting.

1. Profile:

The maximum relief is 0.3 feet over 3.3 feet, only a slight elevation and depression in the forest floor.

2. Arrangement of soil horizons:

The horizons are practically continuous along the length of the cross section. The major unconformity is the pit, and even here the boundaries are very diffuse. The horizons are essentially horizontal. Their boundaries are rather smooth and regular, the most apparent exception occurring where the C horizon undulates¹ perceptibly. Horizons of organic concentration and of incipient leaching are quite evenly developed across the surface of the ground.

3. Pit:

Extremities of the pit are outlined by the degree of organic incorporation. The most pronounced anatomical feature.

4. Buried soil horizons:

None apparent.²

5. Buried wood of the uprooted tree:

None present.

The form and anatomical features that characterized each relative age class of uprootings are summarized in Table 6.

1. Perceptible dip in the C horizon, and consequently of the one above, is due primarily to the thrust and gouging effect of the roots at the time of uprooting. Practically all of the cross sections showed this feature.

2. Occasionally a plane consisting of charcoal was present in this age class.

Direction of Tree Fall

The directions of tree fall were compared by age classes (Fig. 25). In each class, the directions of tree fall were concentrated in one or parts of two 90-degree quadrants: the northwest and southwest. This group-wise distribution indicated not only that the mounds and pits could be separated logically into age classes, but also that they had resulted from storms, probably hurricanes, comparable to the one of 1938.

Actual Ages of Mounds and Pits

The actual ages of all but the oldest of the relative age classes, number VI, were determined from the dates of origin and the relative positions of the trees that had grown on the surfaces of the mounds and pits (Table 8). The date of each uprooting could not be fixed directly from the trees that had grown on it. Nevertheless, the ages of typical specimens of each class of uprootings could be determined.

A preponderance of evidence indicated that the mounds and pits of age class I had resulted from the hurricane of 1938 (Plates 29, 30, 31 and 33). Perched live trees dated precisely the uprootings of classes II and III as 1851 and 1815 respectively (Figs. 12, 14; Plates 38-41). The single uprooting of class IV was estimated to have occurred between 1730 and 1750. The oldest tree on its surfaces was a 147-year-old live white oak growing approximately midway up the slope of the mound. The position of the oak in relation to the crest and shape of the mound indicated that about 50 to 70 years had elapsed after the uprooting before the oak became established. In a similar manner, several of the mounds and pits of age class V were dated to the first half of the seventeenth century.

A survey of the literature¹ indicated that central Massachusetts was

in the paths of several hurricanes that had passed through New England within historic time. Their dates of occurrence coincided very closely with the dates of origin that had been computed for three of the major age classes of mounds and pits.

Class I	1938
Class III	1815
Class V	1635

The age of class VI could not be determined directly from concrete evi-

dence on the plot. The only certainties were that class VI comprised

the oldest perceptible mounds and pits on the plot, and that all four

major age classes of uprootings occurred throughout the general vicinity.²

Whenever the oldest two or three age classes occur in the same vicinity,

the minimum ages and diameters of the largest stumps practically demand a

period of growth of 300 years or more to have attained such proportions.

These probably were exceptional trees, however, while most of the forest

was composed of trees dating back 150 to 200 years. Many of the trees

that were felled in Peterham during the first quarter of the nineteenth

century, the era of land clearing (Kemp, 1941), must surely have originated

as early as 1500 or before, especially the white pine (Lutz, 1930). It

is difficult to conceive how any catalysms of the violence indicated by

1. Perley (1891), Brooks (1939, 1945), and Tammehill (1944).
2. Uprootings resulting from these hurricanes have been observed throughout northern New England, the Maritime, and the Gaspe Peninsula. Their occurrence is influenced highly by former land use. Locally, the area to the east and contiguous with the research plot had been cleared about 1800 and abandoned. There were no trees of any consequence on the area in 1815 to be uprooted. As a result, only three of the major age classes of mounds and pits are represented: I, V, and VI.

the number of mounds and pits of age class VI could have occurred without influencing the developmental patterns of the precolonial forest. Therefore, the uprootings of age class VI were estimated to have occurred between 1400 and 1500 as the result of a major hurricane.

Species of Uprooted Trees

Only 10¹ of the 62 mounds and pits contained valid buried remnants of the trees that had been uprooted: the two mounds of age class II and the eight of class III (Table 7; Plates 36, 37). The species of the wood indicated that 9 of the 10 mounds and pits resulted from the uprooting of white pines, while one was due to the toppling of a white oak.

Only two² of the mounds contained charcoal that definitely could be related³ to the trees that had been uprooted (Table 7). The species were white pine and hemlock.

The species could not be determined of the trees that had formed the remaining mounds and pits of classes IV, V and VI.

1. Actually 13 of the 62 mounds and pits contained wood. Not included is the uprooting described under hemlock #331. This uprooting was placed in age class III since it contained large quantities of wood, occurred in the same local area with the other uprootings of this class, and had on its surface a 121-year-old hemlock, as did several of its associates. The buried wood was white pine.

2. Altogether, 18 of the uprootings contained charcoal.

3. Large concentrations of charcoal occurred in the leeward sides of the mounds above the buried horizons of the pre-disturbed soil, where ordinarily wood of the uprooted tree occurs; as though the bases of the trees had burned in place after uprooting. #43 contained both wood and charcoal.

Diameters of Uprooted Trees

The diameters could be determined directly for only those trees that had been uprooted in 1938. With the known variables taken into consideration, a comparison of the 1938 mound and pit dimensions showed several relationships. The factors of soil, physiological condition of the tree, and the direction of fall in relation to slope appeared to have more influence on the degree of disturbance than the diameters of the trees. Large dead trees created less disturbance around their immediate bases than considerably smaller live trees. Those uprooted on bouldery soils produced small mounds and pits regardless of diameter, condition, and direction of fall. When these factors were held constant, the uprootings of trees of quite different diameters resulted in essentially the same degree of disturbance. Uprootings 49, 56, 60 and 61 (Figs. 16, 18, 19) are practically the same size, while the trees responsible are 15, 10, 14 and 24 inches respectively.

With a few exceptions,¹ the dimensions of the uprootings comprising the five oldest age classes are remarkably uniform. Furthermore, the degree of disturbance that resulted from the uprooting of trees of known diameters, specifically Nos. 49, 56, 60 and 61, suggests that most of the mounds and pits of the five oldest age classes probably resulted from trees 12 to 24 inches in diameter.

Diameters of uprooted trees were estimated from the degree of disturbance indicated by the general proportions of the resulting mounds and pits (Figs. 8-24). The estimates were based on the uprootings of 1938, with due consideration given to factors of soil, slope, direction of tree fall in relation to slope, and physiological condition of the tree (Table 7).

-
1. Nos. 17, 19, 25 are considerably larger than the rest.
 2. 6-inch diameter classes.

Species composition could be determined readily for any forest stand that had grown on the plot since precolonial time. The trees present at a specific date had only to be recorded from the vertical column of dendrograms.

The composition was computed at 13 different periods, beginning with the stand of 1803, which had developed in precolonial time, and ending with the current one of 1952 (Tables 9-21). Diameters inside bark at breast height¹ for the selected periods were measured from the cross sections that had been removed from the trees at 4.5 feet above the ground.

Forest trends became apparent when the species composition of the stands was compared (Fig. 45; Tables 35, 36). The stand was predominantly white pine, chestnut, and white oak when the town of Peterham was settled in 1733.² In 1803, the date of the first major logging operation, these three species comprised over 90 percent of the basal area: white pine, 50 percent; chestnut, 38 percent; and white oak, 9 percent. The largest trees ranged from 10 to 32 inches in diameter and were probably from 80 to 120 feet in height.³ The stand was practically clear-cut, especially the eastern half. About two thirds of the pine and

1. The diameters inside bark at breast height of stumps and decayed trees were computed from the relationships between diameters at stump and breast height. This relationship was determined for most of the species present (Tables 29-34) (Bruce and Bohmeyer, 1942).
2. The chestnut that occurred on the plot was also preponderantly of white pine and chestnut. All evidence indicated that most of the chestnut originated in precolonial time.
3. Height estimates were based upon the dimensions of prostrate boles that occurred on the plot and in the immediate vicinity.

almost all of the chestnut and white oak were felled. Only 17 percent of the total basal area was left, and this was white pine confined largely to the western half of the plot.

Almost half of the remaining pines were blown over by the hurricane of 1815. The uprootings occurred on a small area near the center of the plot.

In 1854, the stand was essentially one of white pine standards towering over a coppice of chestnut and red maple sprouts. The area was operated again; this time the logging was concentrated on the western half. Most of the pine and over half of the chestnut, red maple, and white oak were felled. About three fourths of the basal area was cut.

A series of four minor loggings followed during the next 35 years. Those of 1864, 1872, and 1878 were fuelwood operations which removed primarily small chestnut and red maple sprouts 3 to 8 inches in diameter. The occasional larger chestnut, hemlock, black birch, red maple, or white oak was not cut. In 1882, a sawlog operation was conducted to harvest the few remaining larger white pines and about half of the chestnut.

By 1889, the stand had developed a definite three-storied structure. Scattered over the area, especially the eastern half, were occasional hemlocks, chestnuts, white oaks, red maples, and black birches ranging in diameter from 10 to 21 inches. They constituted the upper canopy. Sprouts of chestnut and red maple, 2 to 6 inches in diameter, dominated the intermediate story, while smaller hemlocks and black birches provided a conspicuous understory only a few feet high. The logging operation of this year, in effect, removed most of the intermediate story of sprout hardwoods and a large proportion of the chestnut which comprised the

upper canopy. The western portion was logged the heaviest, the eastern part only slightly, while the central portion, which had been uprooted in 1815, was scarcely disturbed. About 40 percent of the basal area was removed during this operation, the last major logging to be conducted.

Between 1889 and 1909, the chestnut sprouted and grew with such vigor that it more than regained its former status as a major element in the intermediate canopy of the three-storied stand. When the chestnut blight hit the stand, approximately in 1909, over one third of the basal area was made up of chestnut. This species had more than quadrupled its basal area since 1889. By 1915, most of it was dead. From 1889 to 1915, hemlock and black birch developed at a rate almost comparable to that of the chestnut. Their basal areas were practically trebled, and in general, the understory which they had previously provided became even more pronounced. The death of the chestnut and the accelerated development of the hemlock and black birch altered the three-storied structure of the stand to one of two canopies. Hemlocks, black birches, red maples, and red and white oaks 10 to 20 inches in diameter overtopped a general understory of smaller trees of the same species, but predominantly hemlocks, of from 2 to 5 inches in diameter. A small group of large-tooth aspen occurred on the extreme western end of the plot.

A minor operation was conducted in 1935 to remove the small group of aspen. In the process, a few small maples and oaks were felled. Since 1915, the hemlock again had increased its basal area significantly. It now comprised 35 percent of the basal area, and with black birch made up over 50 percent of the stand.

The hurricane of 1938 was responsible for the destruction of over 70 trees. Eighteen were uprooted directly, while the rest were damaged so severely that they either were salvaged in 1939 or died shortly afterward. The most severe damage occurred on the eastern half of the plot where the largest trees were most abundant. Uprooting was generally distributed over the area, however. About one fourth of the basal area was destroyed.

The composition of the 1945 stand was essentially the same as that of the 1938 stand before the hurricane. Hemlock comprised 44 percent of the basal area, black birch 19, red maple 14, and red and white oak 9 percent each. Even though the hemlock and black birch had regained their basal areas lost by uprooting, the basal area of the entire stand was still below that of 1938. During 1944 and 1945, the stand was subjected to gypsy moth defoliation. Suppressed white and red oaks were affected most. About one fourth of the white oaks 2 inches and larger in diameter were killed, while approximately one fifth of the red oaks succumbed. Only about 3 percent of the basal area of the stand was lost, however.

The stand of 1952 was essentially of hemlock and mixed hardwoods. Hemlock was the primary species by far, both from the numerical and the basal area standpoints. It comprised almost 47 percent of the stand. Black birch and red maple were represented by nearly the same number of trees 2 inches and larger in diameter, but the birch made up the larger percentage of the basal area, 19 percent. Red oak was next in importance with 10 percent of the basal area, followed by white oak with 8 percent. White pine and paper birch comprised slightly over one percent each. The abundance of small, suppressed hemlocks resulted in a definite two-story structure in over half of the plot. In general, the largest

and oldest trees occurred on the eastern half of the plot. The largest trees were hemlock, 20 to 21 inches in diameter and 70 to 80 feet tall.¹

1. The absence of fire scars on the trees plus the spotty distribution of charcoal, indicate that the plot had not been severely burned, at least during the last 500 years. Fire is about the only ordinary disturbing agent, however, to which the area was not subjected during this time. The spotty distribution of the charcoal suggests that it is the result of small fires built by Indians and loggers for cooking.

ROLE OF THE HISTORICAL-DEVELOPMENTAL METHOD IN FOREST ECOLOGICAL RESEARCH

The historical-developmental method is extremely simple. It is based upon the evidence that exists in the forest. As a method, its degree of application can be altered to meet the desires of the research worker and the characteristics of the area to be investigated.

Only a part of the data accumulated in the present study have been used in the preceding discussion. The investigation here described was designed principally to trace the developmental trends of the forest composition on a small plot. All trees less than 1.5 inches in diameter have been arbitrarily excluded from the discussion. Had the discussion included all of the trees down to the smallest recognizable seedling,¹ a better understanding of the future compositional trends could have been achieved.

The evidence afforded by the trees larger than 1.5 inches in diameter was not fully utilized either. Only the species, numbers, ages, radial growth, and diameters of the trees that had comprised the stands were determined at this time. The characteristics of height and volume growth could have been considered as well.²

1. The trees less than 1.5 inches D.B.H., i.e. down to the smallest recognizable seedling were analyzed. Each was located and described in a manner similar to the larger trees. A cross section for age determination was cut from each seedling at a point directly above the root collar. Sections were also collected of both roots and stems directly below and above the root collars of sprout-origin trees. A map of the small trees is illustrated by Fig. 27. A belt transect of milacre plots was established to sample the herbaceous and shrubby components of the plot (Fig. 28).

2. This phase of the project is in progress. Stem analyses of the live and dead trees will permit accurate determination of height and volume growth. The heights and volumes of the trees represented by stumps and uprootings can be reasonably estimated from the relationships that exist between D.B.H., height, and volume of the live and dead trees. At least the minimum volume of wood that the area has produced over the last 150 years can be computed.

The exploitation of the mounds and pits was confined to the determination of what kinds of tree had grown where and when. Once the background of information had been derived to determine their dates of origin, the evidence inherent in uprootings could have been analyzed further. The quantitative and qualitative influences of the soil-forming processes upon soil genesis could be evaluated over documented periods of time.

Likewise the buried pollen and spore content could be analyzed.¹

Of the major forest components, the stumps were the most intensively considered. The fragments and charcoal were regarded primarily as sources of substantiating evidence.²

Once an area has been subjected to an intensive historical-developmental approach, a wide range of alternatives for study is available to the student. In effect, the developmental morphology of the current stand can be reconstructed.³ Changes in its form, structure, composition, and growth can be documented over time. Subsequently, the relative influences of the major factors responsible for the dynamics of the forest can be

1. The pollen and spore content of one mound were analyzed. The pollen of mound and pit #35 included white pine, hemlock, holly, oak, and traces of another pine. Spores of ferns and at least three species of lycopods also were present.

2. The width of the annual rings in the charcoal could be interpreted to suggest the conditions under which the trees had grown (Table 7).

3. A series of profiles constructed of the stand to show the height relationships of the trees at various stages may be used in conjunction with stand maps as a basis for diagrammatic perspective drawings. The development of the microrelief of the forest floor can be illustrated by a series of contour maps.

1. The roles of wind, fire, insects, pathogens, and ice storms can be appraised. 2. The influences of man upon the forest can be evaluated more intelligently. 3. And finally, an approach can be made to the relationships of the major forest components and their reactions with the environmental complex. 4. These phenomena may be revealed by map superposition. 5. The study of relationships, such as the indicator value of herbaceous plants, can be carried further.

1. The great extent of each mound and pit was planimetered (Fig. 29). At least 14 percent of the forest floor is comprised of mounds and pits due to uprooting.

Age Class	Area (sq. ft.)
I	958
II	183
III	707
IV	113
V	1,802
VI	1,279
	<u>5,142</u> sq. ft.

2. When the occurrences of uprooting, fire, insect depredations, catbarkings of pathogens, and ice storms are considered over a period of several hundreds of years of forest development, they assume the role of forest processes. 3. The current area was subjected to three major and five minor logging operations during the last 150 years.

4. Fig. 30 illustrates the relationship between the distribution of the small tree component and the forest canopy in 1952. Boulder and cobble distribution is shown by Fig. 31. Approximately one half of the live trees 1.5 inches and larger in diameter had become established originally on some surface other than the immediate forest floor.

Surface	Trees
Logs	28
Stumps	23
Boulders	112
Mounds	50
Pits	11
	<u>224</u>

5. At this time, any consideration of the indicator value of herbaceous plants would have to include as a variable the extreme differences that exist in the stages of soil development due to uprooting.

In contrast to the areal approach, the development of individual trees can be analyzed. Juvenile characteristics, established through repeated observations, can be evaluated as factors in the success or failure of a species to compete with the ever-changing environment.¹ Trees of the same species, the forms of which are known to have developed under radically different conditions, can be compared to show the range of reaction in specific characteristics that can be expected.² The genotypes of some trees can be traced successively to the precolonial forest.³ They have persisted by vegetative reproduction, and represent the third or fourth generation of sprouts in the same clones.

The historical-developmental method lends itself also to extensive application. One or several of the forest components may be investigated over a large area. Experience within a forest region enables the identification of stumps and the age determination of uprootings by cursory examination. An investigation could be conducted over extensive areas

1. Oak seedlings were observed repeatedly to have tap roots (Plate 47). Such roots were present also on 50- to 60-year-old trees (Plate 48). However, they were not evident on stumps of oak 100 to 125 years of age (Plate 13). Birches and hemlocks developed very fibrous, matty root systems, apparently capable of conforming to the media in which they were growing. This type of root could be instrumental in the success of these latter species to become established on the extremely unstable surfaces provided by young mounds. The preponderance of the trees that had become established on stumps and boulders were hemlock and black birch.

Sprouting ability is related to age of parental stump. This factor could account in large measure for the abundance of chestnut at the time of the blight.

2. Hemlock #673, Plate 22, developed under open-grown conditions due to logging. Hemlock #107, Plate 21, grew as a part of an intermediate canopy where competition for crown space was severe.

3. Red maples especially, and chestnut before the advent of the blight.

that might include, for example, only the analysis of stumps or the pollen content of the mounds.

The historical-developmental method of forest ecological research is basically one of fundamental description, comparable in many respects to the purely objective dissection-description of a plant or animal. No basic quantitative data regarding physiological processes or facets of the environment will be derived from its application alone. Neither will the whys and wherefores of plant distribution be solved. However, the definite chronological sequence of compositional trends can be documented. Major fluctuations in the environment and the primary expressions of the forest vegetation to related changes can be observed. And the time factor, so influential in the development of forests, can be telescoped by the meticulous application of simple techniques and judicious observation. The results of many years of "Nature's experiments" can be scrutinized within a comparatively short time. The problem areas can then be subjected to experimental techniques through a "team approach," and many problems carried to their logical solutions. It would appear that up to this time we have neglected to dissect our major subject of study, the forest.

All scientific research consists of accumulating observations. The subjects examined vary tremendously as do the techniques employed. Ultimately the data are synthesized. Conclusions are derived which lead to partial solutions. Additional facets of knowledge have been exposed, and more advanced planes have been established on which further reasoning can be based for an approach to another set of unknowns.

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<u>Latin Name</u>	<u>Common Name</u>	<u>Abbreviation</u>
Amelanchier canadensis (L.) Medic	amelanchier	Am., Amel
Populus grandidentata Michx.	large-toothed aspen	Asp.
Fagus grandifolia Ehrh.	beech	Ba
Betula lenta L.	black birch	BB
Betula papyrifera Marsh.	paper birch	BB
Castanea dentata (Marsh.) Borkh.	chestnut	Ch
Larix canadensis (L.) Carr.	hemlock	Hom., L
Carya glabra (Mill.)	hickory	Hic
Acer rubrum L.	red maple	RM
Quercus rubra L.	red oak	RO
Quercus alba L.	white oak	WO
Pinus strobus L.	white pine	WP

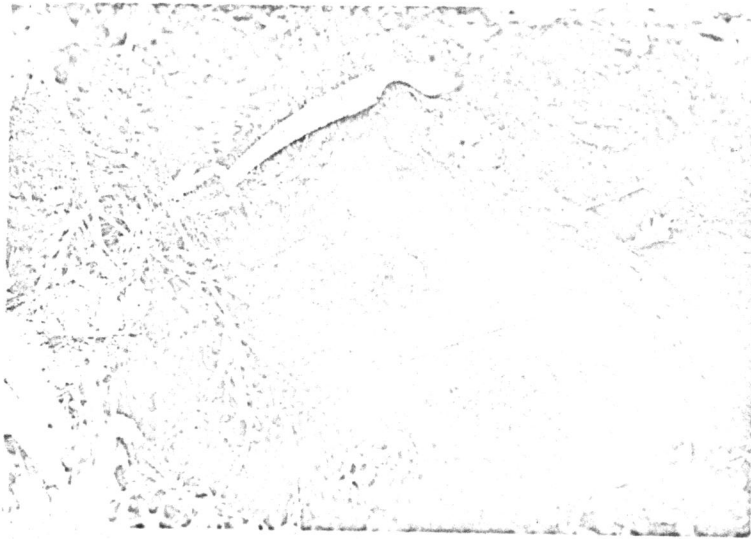


Plate 8. White pine stump #95. Stump is 20 inches in diameter and at least 45 years old. Stump is on a boulder, the surface of which is covered with charcoal. The stump and roots show no evidence of having been burned. When stump was removed, charcoal was observed under the roots. Also, the bark was still intact where the roots rested upon the boulder. Evidence suggests that a fire occurred before the white pine became established. Blade of saw is 14 inches long. Measuring tape is 2 inches in diameter.

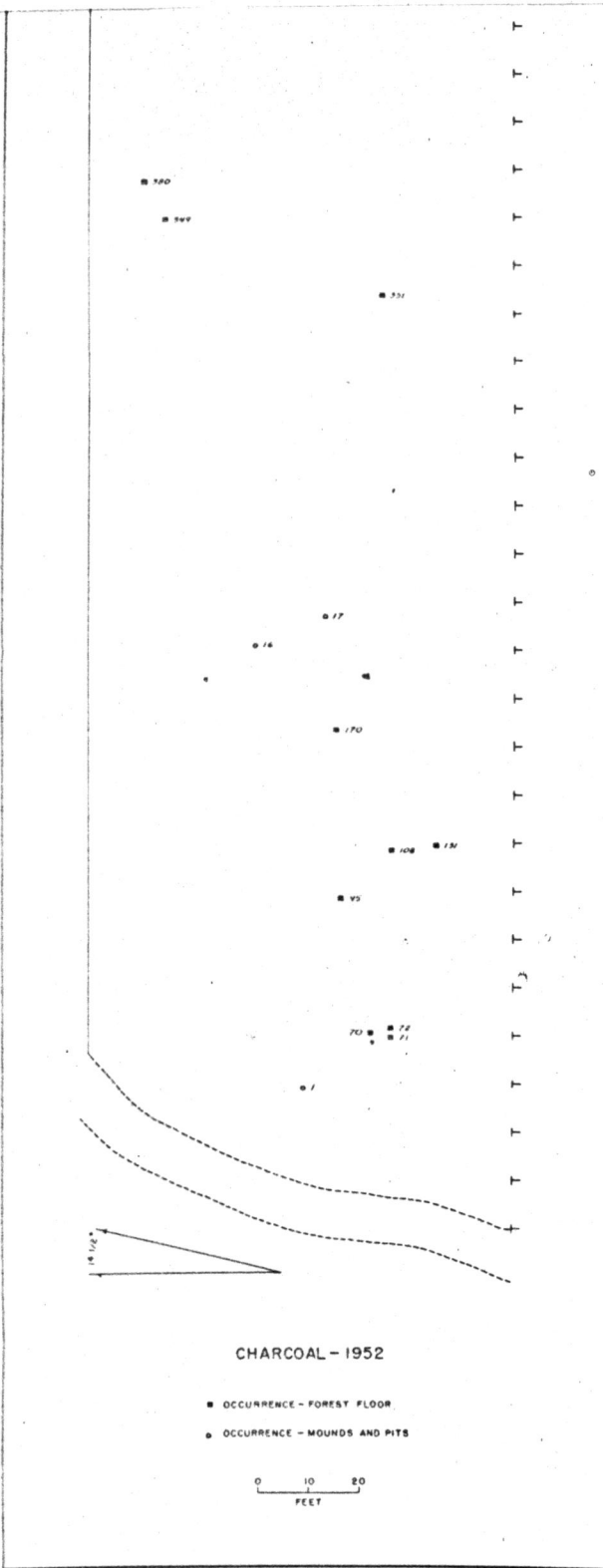
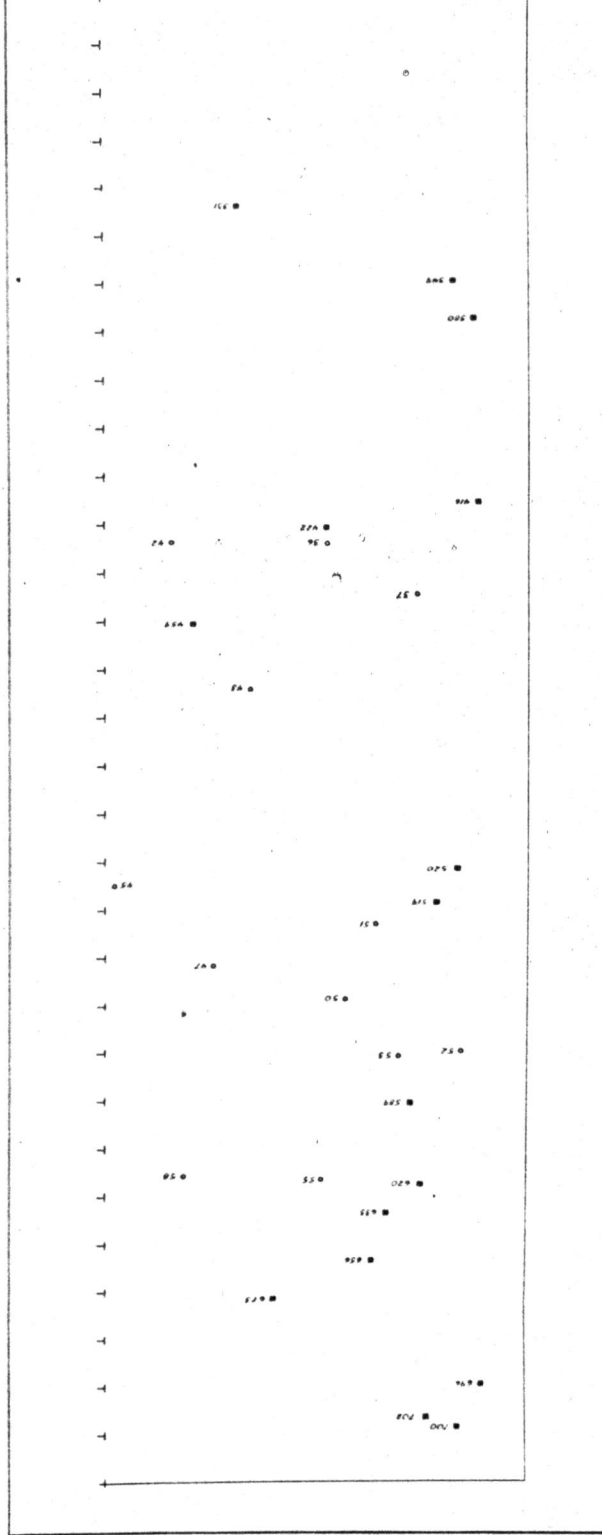


Figure 6



1 Associated: holes and stumps as parts of stump sprout clumps.

	Numbered	Associated ¹ Live Holes	Associated Dead Holes	Associated Stumps	Totals
Live Trees	444	22	9	127	
Dead Trees	122	--	34	71	
Stumps	123	--	--	23	
Uprootings	63	--	--	--	
Totals	752	22	43	221	1038

Trees and Stumps 1.5 inches and larger D.B.H., 1.0. or Stump.

TABLE No. 1

Explanation

Live trees, dead trees and stumps 1.5 inches and larger inside bark at breast height or stump.

TABLE NO. 2

1. Grown Class:
 D - dominant
 CD - codominant
 I - intermediate
 S - suppressed
 L - leaning
2. Position on Forest Floor: Forest floor proper unless designated otherwise:
 L - log
 ST - stump
 M - mound
 P - pit
 B - boulder
3. Origin:
 S - seedling
 SS - seedling sprout: parental stump less than 1.5 inches in diameter.
 SSS - stump sprout: parental stump 1.5 inches in diameter and larger.
4. Additional Live Stems: Figures refer to D.B.H. 1.5. of boles present of the same Generation and in addition to the one numbered. Additional Dead Stems or Stumps: Figures refer to D.B.H. at p.h. or stump of boles and stumps present of the same Generation and in addition to the one numbered. If a numbered element is a stump, the additional elements are stumps. If numbered element is a stump, the additional elements are stumps.
5. Additional Generations Represented: Figures refer to diameters inside bark of stumps of generations which have preceded the numbered trees or stumps.
6. Diameters of trees, except a few of the larger hemlocks, are of all divided cross sections. Diameters of stumps are measured in the field.
 Table includes 26 trees that are less than 1.5 inches D.B.H. 1.5. Four are hemlocks which, due to shrinkage while drying, are less than 1.5 inches. The remainder are small sprouts from parental stumps 1.5 inches or larger in diameter.
7. Trees Nos. 371 and 372 are considered dead boles of No. 370. All belong to the same sprout clump.
8. There is no number 483.

TABLE No. 4

Charcoal - Surface of Forest Floor

<u>Location</u> ¹	<u>Species</u>
70	WP
71	WP
72	WP
95	--
108	--
131	--
170	--
331	WP
349	WP
380	WP
416	--
422	WP
459	WP
519	--
520	--
589	WP
620	WP
633	WP
656	WP
673	--
696	Ch
700	Ch
702	--

1. Location: Numbers refer to tree or stump under or near which charcoal was found.

TABLE No. 6

Major Form and Anatomical Features of the
Mounds and Pits

Map Number	Age Class	Form - $\frac{1}{4}$ / $\frac{1}{4}$ (feet)	Buried Wood	Buried A Horizon	Buried B Horizon	Unincorporated Organic	Incorporated Organic	Relationship of Horizons	Direction of Area Hill (Magnetic bearing)
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1	I	1.10							N 38° W
3	I	0.52		x					N 19° W
12	I	0.21							N 46° W
13	I	0.91							N 30° W
14	I	1.35		x					N 53° W
15	I	0.53		x					N 28° W
20	I	0.75							N 42° W
23	I	1.13		x					S 79° W
27	I	2.15		x					N 9° W
38	I	3.00		x					N 30° E
41	I	0.82		x					N 37° W
44	I	0.80		x					N 65° W
46	I	0.15							S 50° E
49	I	0.86							N 57° W
56	I	0.74		x					N 37° W
60	I	0.80		x					N 44° W
61	I	0.65		x					N 73° W
62	I	0.50							N 68° W
21	II	0.51		x	x			\\	N 26° W

Map Number
Age Class
Norm - V/R^1 (feet)
Disturbed Wood
Disturbed A Horizon
Disturbed B Horizon
Unincorporated Organic
Incorporated Organic
Relationship of Horizons
Direction of Tree Fall (Magnetic bearing)

N260E	//	X	X	X	0.60	II						22
N160E	//	X	X	X	0.40	III						30
N390W	//	X	X	X	0.40	III						31
N390W	//	X	X	X	0.40	III						32
N390W	//	X	X	X	0.20	III						35
S160W	//	X	X	X	0.40	III						36
S220W	//	X	X	X	0.40	III						37
S310W	//	X	X	X	0.40	III						39
S70E	//	X	X	X	0.48	III						43
S740W	//	X	X	X	0.24	III						47
S10W	//	X	X	X	0.20	IV						16
N650W	//	X	X	X	0.27	V						17
S550W	//	X	X	X	0.15	V						18
S480W	//	X	X	X	0.24	V						19
N100E	//	X	X	X	0.23	V						26
S360W	//	X	X	X	0.14	V						28
S230W	//	X	X	X	0.20	V						29
S130W	//	X	X	X	0.13	V						34
S670W	//	X	X	X	0.09	V						42
S790W	//	X	X	X	0.11	V						45
S710E	//	X	X	X	0.16	V						52
N590E	//	X	X	X	0.13	V						50
S760W	//	X	X	X	0.13	V						52

Remnants of buried A horizon in form of A₂ and charcoal.

Horizontal distance involved.

1. V/H Difference in elevation between the mound and pit divided by the

Map Number	Age Class	V/H	Form - V/H ₁ (feet)	Buried Wood	Buried A Horizon	Buried B Horizon	Unincorporated Organic	Incorporated Organic	Relationship of Horizons	Direction of Tree Fall (Magnetic bearing)
53	V	M ₂	0.11			M		X	///	
55	V	M ₂	0.11			M		X	///	
2	VI		0.13							
4	VI		0.10							
5	VI		0.15							
6	VI		0.12							
7	VI		0.05							
8	VI		0.10							
9	VI		0.10							
10	VI		0.08							
11	VI		0.10							
24	VI		0.15							
25	VI		0.12							
33	VI		0.12							
40	VI		0.08							
51	VI		0.15							
54	VI	M ₂	0.11							
57	VI	M ₂	0.05							
58	VI	M ₂	0.09							
59	VI	M ₂	0.09							