The Uprooting of Trees: A Forest Process[1]

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ABSTRACT

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 1-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.

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 1 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 1½ 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 1½ 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 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.
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 1 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 com-

[1]Presented before Div. V–A, Soil Science Society of America, St. Paul, Minn., Nov. 11, 1954. Received Oct. 23, 1954.

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ponents 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 be-

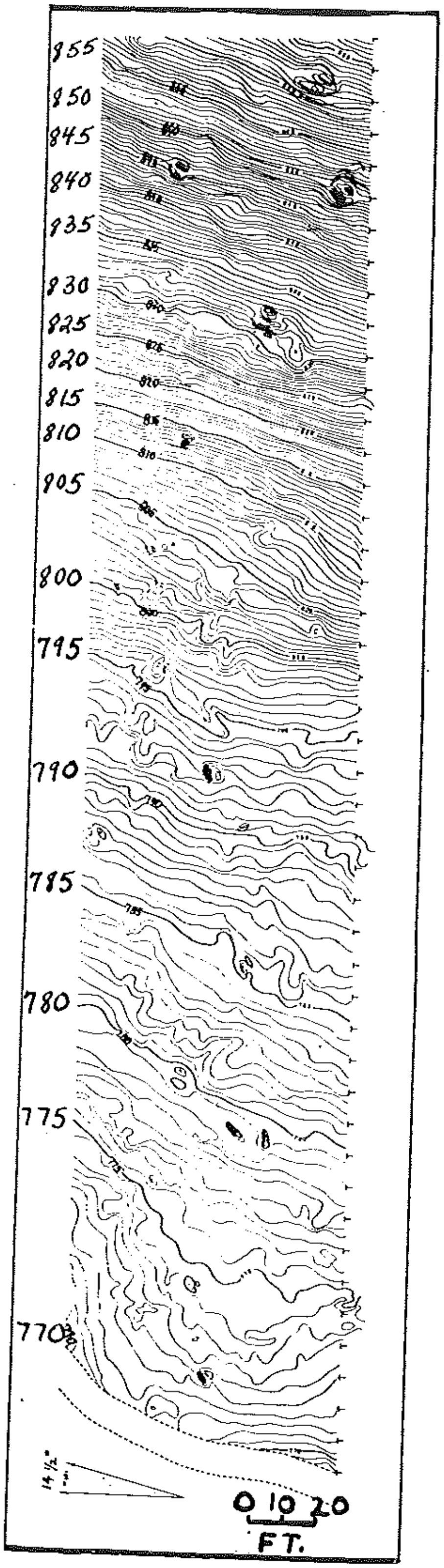

FIG. 1.—Forest floor, 1952. Contour interval, 6 inches.

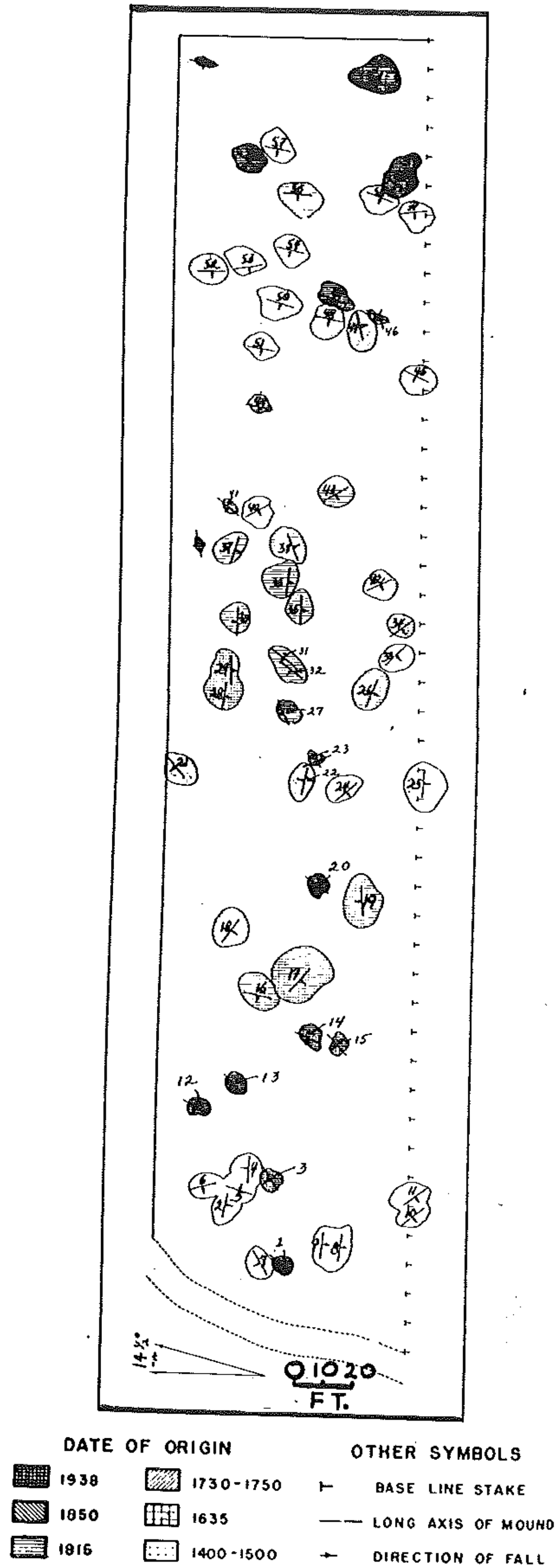

FIG. 2.—Mound and pit surfaces, 1450 to 1952.

comes 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 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 3 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 5,100 square feet. Almost 14% 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 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

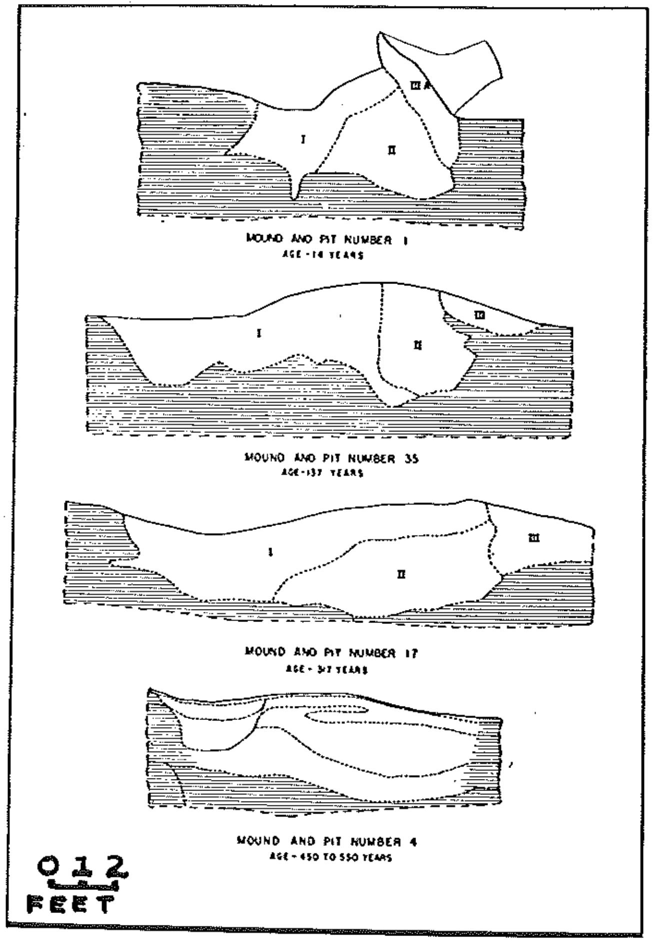

FIG. 3.—Gross anatomy of mounds and pits. I—Region of deposition; II—Region of pivot; III-A—Overburden potential; III—Overburden.
Shaded area—relatively undisturbed
Unshaded area—Disturbed.

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 microrelief 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:

Mechanical.—wind, ice, snow.

Physiological.—pathogens, insects, 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 impossible 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 processes, such as growth, reproduction, and podzolization. The recognition of uprooting as a process, therefore, is essential to a better understanding of the development of the forest.

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