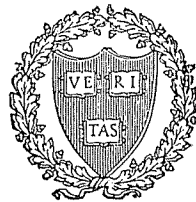


MOUND AND PIT MICRORELIEF IN  
RELATION TO SOIL DISTURBANCE  
AND TREE DISTRIBUTION IN  
NEW BRUNSWICK, CANADA

*By*

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ABSTRACT

About 500 mounds and 600 pits per acre occur on representative forested areas studied at the Acadia Forest Experiment Station in New Brunswick, Canada. These mounds and pits have a distinctive microrelief and are the result of the uprooting of trees by wind. Disrupted, irregular soil horizons resulting from the disturbance by windthrow are obvious in cross sections made through mound-pit sequences. Age of mounds could not be determined by observation of the soil but mounds of low relief tend to have continuous horizons and this may be an indication of older age. The largest trees, both in natural stands and plantations tend to be on mounds. There are essentially no trees in pits. The implications of this relationship should be considered in any silvicultural program.

INTRODUCTION

Mound and pit microrelief, caused by tree throw, characterizes all forested areas in Northeastern North America except where the surface has been leveled by cultivation. Trees fall as a result of many different causes but conspicuous mound and pit microrelief generally occurs only when live trees are uprooted by wind. Toppling of trees by wind is a continual process in forests. In Northeastern North America it occurs frequently in small areas on a more or less tree-by-tree basis as a result of winds in line squalls or thunder showers. It occurs over much broader areas at intervals of 50-100 years as a result of hurricanes or tornadoes.

The purpose of the study reported here is to indicate the distribution and character of mounds and pits in relation to the forest management. The study was conducted in New Brunswick in an area thought to be representative of much of the forested area of Northeastern North America.

Especially thanks are given personnel at the Acadia Forest Experiment Station, Canada Department of Forestry, who helped in many ways; B. C. Wile - Superintendent, H. E. Munn, W. Evans, J. A. Flanagan - technicians and D. A. MacGregor - student assistant. Also to W. R. Murison, C. T. Youngberg and W. R. Sise who at the time of the study were connected with the Harvard Forest and to K. K. Langmaid, Canada Dept. of Agriculture who identified the soils. Funds for this publication have been supplied from generous gifts by the Friends of the Harvard Forest.

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## REVIEW OF LITERATURE

Mound and pit microrelief (commonly known as cradle-knolls or hillocks) in forests is often overlooked because it is so common, but both foresters and soil scientists have described this feature many times.

As early as 1847 Dawson described cradle-knolls in the forest of Nova Scotia and attributed them to windthrow. In the same year Gesner writing about New Brunswick describes them as follows, "The surface of the land is frequently very uneven from the presence of cradle hills which should be plowed lengthwise rather than across. The soil in the hollows is very rich and care should be taken in plowing to keep it on the surface as much as possible." In a footnote Gesner states that the cradle hills "are small eminences produced by the roots of the trees and frost." In another footnote Gesner describes a tornado accompanying a thunder storm July 5, 1842, on the Tobique River. The width of this tornado did not exceed one-half mile but it "tore up the trees and levelled the forest to the ground."

Shaler (1891) described the process of windthrow and Pinchot (1901) spoke about the plowing of forest soil by wind and mentioned that "once the attention has been called to it, the frequency of the little mounds, which remain long after the tree itself has entirely rotted away, is seen to be very great."

Lutz (1940) was one of the first to make detailed studies of the cross sections of mounds and pits resulting from uprooting of trees. He called attention to some of the pedological and ecological implications of the process.

Stephens (1956) at the Harvard Forest in Massachusetts studied mounds and pits both in relation to their extent (14% of the surface in the one-acre area he studied in detail) and their age. From the character of the soil horizons and the shape of the mounds he thought some of the faintly expressed mounds were at least 500 years old. Stephens concluded as a result of 30,000 miles of travel in the United States east of the Continental Divide and in the Maritime Provinces of Canada that the presence of mounds and pits is as much a characteristic of the forest as the trees themselves and that uprooting of trees is a natural process in the forests of eastern North America.

Schubert (1954) supplemented the work of Stephens at the Harvard Forest by studying the relation of red pine trees in plantations to mounds and pits. He found consistently larger diameter growth of red pine on elevations than on level areas or depressions but the differences were not statistically significant. He found no trees in pits.

Denny and Goodlett (1956) studied the microrelief resulting from fallen trees in Northern Pennsylvania. They found that most forested areas in Potter County have a microrelief of at least a foot and concluded that most of the land surface of the County has been disturbed by the toppling of trees during the last 300 to 500 years and that most of the existing podzolic soil profiles probably are not more than 500 years old. Judging from the size of the mounds they thought that many of the older ones were made by trees larger than those now growing in the second growth forest. They discussed the importance of the process of uprooting to geomorphology, soil science and plant ecology. Earlier Goodlett (1954) discussed the possible importance of tree throw in the establishment of white pine trees in the presettlement forest of Potter County.

Further studies relating to the microrelief of the forest were made by Dixon and Place (1952) at the Acadia Forest Experiment Station in New Brunswick. They called attention to the importance of microtopography to the survival of spruce and fir reproduction and showed that best survival occurred on the lower slopes of the mounds.

Hart *et al.* (1962) studied the variation in thickness of organic matter in relation to microrelief in New Hampshire. They found roughly twice as much humus depth on slopes of mounds as on tops of mounds and three to four times as much in depressions as on tops of mounds. In depressions organic matter averaged 4-7 inches thick compared with 1.4 - 2.0 inches on top of mounds.

Apparently microrelief developed from uprooting of trees is common in the USSR. Rode (1955) discusses its importance in relation to surface runoff and presents a detailed scale diagram of the microrelief showing location of trees in relation to mounds and pits. Many trees are shown on the mounds whereas there are none in the pits.

### PROCEDURE

All studies were made at the Acadia Forest Experiment Station Canada Dept. of Forestry, located about 16 miles east of Fredericton, New Brunswick. Loucks (1962) classified the forest here in the red spruce-hemlock-pine zone of the Maritimes Lowlands Eco-region. Red spruce and balsam fir are major components of the present forest and the stands date from two major fires about 1875 and 1900 that together burned over the whole 37 square miles of the Acadia Station.

The well-drained soils are Podzols (Spodosols) developed on acid, sandy, red glacial drift derived principally from red sandstones of Mississippian or Pennsylvania age.

Seven 30 x 100 foot plots, (Table 1) were selected for study, primarily on the basis of kind of forest rather than kind of soil. All seven plots have mount-pit microrelief and are

Table 1.

Characteristics of Soils and Forest Stands on Seven 30 x 100 Foot  
Wide Study Plots at the Acadia Forest Experiment Station,  
New Brunswick, Canada

Plot No.	Soil Catena	Overall Natural Drainage	Parent Material	Character of Stand	Principal Trees
1	Harcourt	Good	Red sandy till	Natural	Paper birch, Red maple, Balsam fir
2	"	Imperfect	Red sandy till	Natural	Red spruce, Balsam fir
3	Unnamed	Good	Red sandy glacial stream deposits	Natural	Balsam fir, Red maple, Paper birch
4	Harcourt	Good	Red sandy till	Plantation	Red pine (6' x 6' spacing)
5	"	Good	Red sandy till	Plantation	Douglas fir (6' x 6' spacing)
6	"	Good	Red sandy till	Plantation	Red pine (5' x 5' spacing)
7	"	Imperfect	Red sandy till	Plantation	White spruce (5' x 5' spacing)

thought to be representative of enormous areas in northeastern North America. Three plots are in natural stands and four are in plantations planted about thirty years ago.

Following are the common and latin names of the tree species mentioned in this paper. Nomenclature follows Gray's Manual of Botany 8th Edition.

<u>Common Name</u>	<u>Latin Name</u>
Balsam fir	<i>Abies balsamea</i> (L.) Mill.
Black spruce	<i>Picea mariana</i> (Mill.) BSP.
Douglas fir	<i>Pseudotsuga menziesii</i> (Mirb.) Franco
Hemlock	<i>Tsuga canadensis</i> (L.) Carr.
Paper birch	<i>Betula papyrifera</i> Marsh.
Red maple	<i>Acer rubrum</i> L.
Red pine	<i>Pinus resinosa</i> Ait.
Red spruce	<i>Picea rubens</i> Sarg.
White pine	<i>Pinus Strobus</i> L.
White spruce	<i>Picea glauca</i> (Moench) Voss.

Location and areal extent of mounds and pits in relation to trees were mapped visually using a 10 foot grid. Trees were mapped by species and one-inch diameter classes. Initially attempts were made to distinguish between faint, distinct and prominent mounds but these attempts failed and the mounds finally shown on the maps are only those which are distinct or prominent. Similarly it was difficult to distinguish simple depressions between mounds from "true" pits that would hold water when the soil was saturated. The pits shown on the map are thought to be concave enough to hold water and this was determined by actually stepping in them. Because of these difficulties in mapping the authors feel the mound-pit maps show extremes. Especially is this true for the pits and certainly there are many faint mounds not mapped. Detailed maps showing all mounds could be made if the forest floor were removed. Two-inch contour maps based on a two-foot grid were made of each of the seven plots. These were found to be more useful in determining relief than in determining the outline of the mounds and pits. On maps made in this manner, the general slope of the plots tends to confound the outline of mounds and pits.

The three plots with natural stands were visited several times during the spring of 1965 and the location of the pits with standing water, ice or snow was mapped.

Eight soil profile diagrams were made to scale in trenches dug across representative mounds and pits in the three natural stands. Mounds with low, medium and high relief were selected for study in each plot.

Root distribution on the profile faces of these trenches was also mapped using a broad three-way classification of many, common, and few or none. Essentially the maps show the distribution of nonwoody roots smaller than about 2mm in diameter.

## RESULTS

Mounds are elliptical for the most part and, at a maximum, are about 10 feet long, 5 feet wide and 2-3 feet high. Pits are much smaller being 6-7 feet long at a maximum, 1-2 feet wide, and 1 foot in depth. Some idea of the distribution and character of the microrelief can be obtained from Figures 1 and 2.

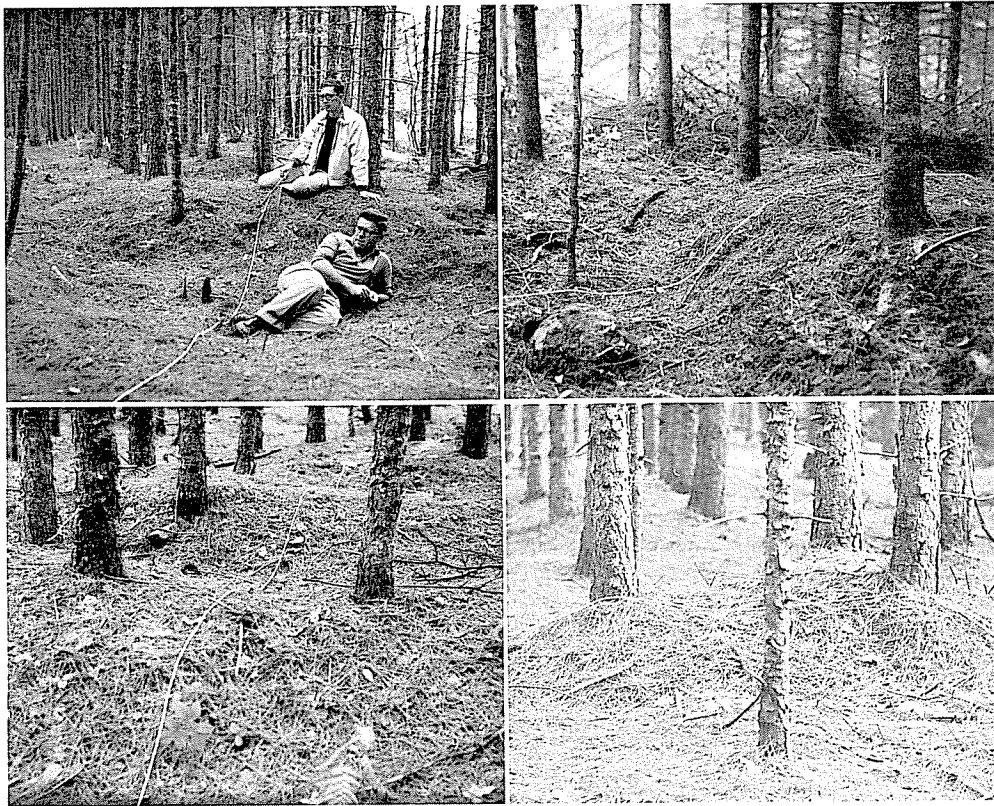


Figure 1 Mound and pit microrelief in red pine (Plot 6) and white spruce (Plot 7) plantations. Some idea of the size and shape of the mounds can be obtained by observing the white string. The mound shown with the two persons (W.R. Sise, top; D.W. MacLean, bottom) is large, but not unusually large. Note the larger trees on the mounds and the smaller trees, or stumps of former trees, in the depressions.

Numbers of mounds and pits and percentages of areas they occupy are shown in Table 2. There is an average of about 500 mounds and 600 pits per acre. About 35 per cent of the area is occupied by mounds and 10 per cent by pits. In other words roughly half the area is occupied by conspicuous mounds or pits.

#### Relationship of trees to mounds and pits.

Location and size class of trees in relation to mounds and pits on three of the plots are shown in Figure 3. Cross sections along a 100 foot line in these same three plots are shown in Figure 4. Per cent of live trees on mounds and pits is shown on Table 3, and distribution by size class in Figure 5. There are very few live trees in pits, and in general trees are larger and more numerous on mounds than in intermediate areas that are neither mounds nor pits. Predominance of trees on mounds takes an added significance when allowance is made for the fact that generally less land is occupied by mounds than by intermediate areas.

#### Periodicity of water in pits.

The observations of periodicity of water, ice and snow in pits showed water accumulation in some but not all pits. During the winter of 1946-65 the amount of precipitation was less than the regional normal and so in the spring there was less likelihood of water for long periods in the pits than in most years. The standing water has implications in terms of de-oxygenation, low temperatures conducted to the plants by ice and submersion of tree stems and seedlings.

Table 2.

## Number and Area of Mounds and Pits

Plot	No. of Mounds per Acre	% Area Occupied by Mounds	No. of Pits per Acre	% Area Occupied by Pits
1	726	42	261	7
2	566	40	682	12
3	770	37	668	14
4	247	44	537	13
5	261	24	552	8
6	378	39	581	12
7	610	29	842	15
Average	508	36	589	12

Table 3.

Distribution of Live Stems 1 Inch or More d.b.h.  
(30 x 100' plots) in Relation to Location on Mounds and Pits.

Location	Per cent live stems			Total No. Stems
	Mounds	Intermediate	Pits	
Plot 1 - Natural Stand	74	26	0	47
" 2 - " "	80	20	0	94
" 3 - " "	58	38	4	153
" 4 - Plantation -Red pine	65	31	4	74
" 5 - " -Douglas fir	35	63	2	68
" 6 - " -Red pine	64	36	0	105
" 7 - " -White spruce	47	49	4	125



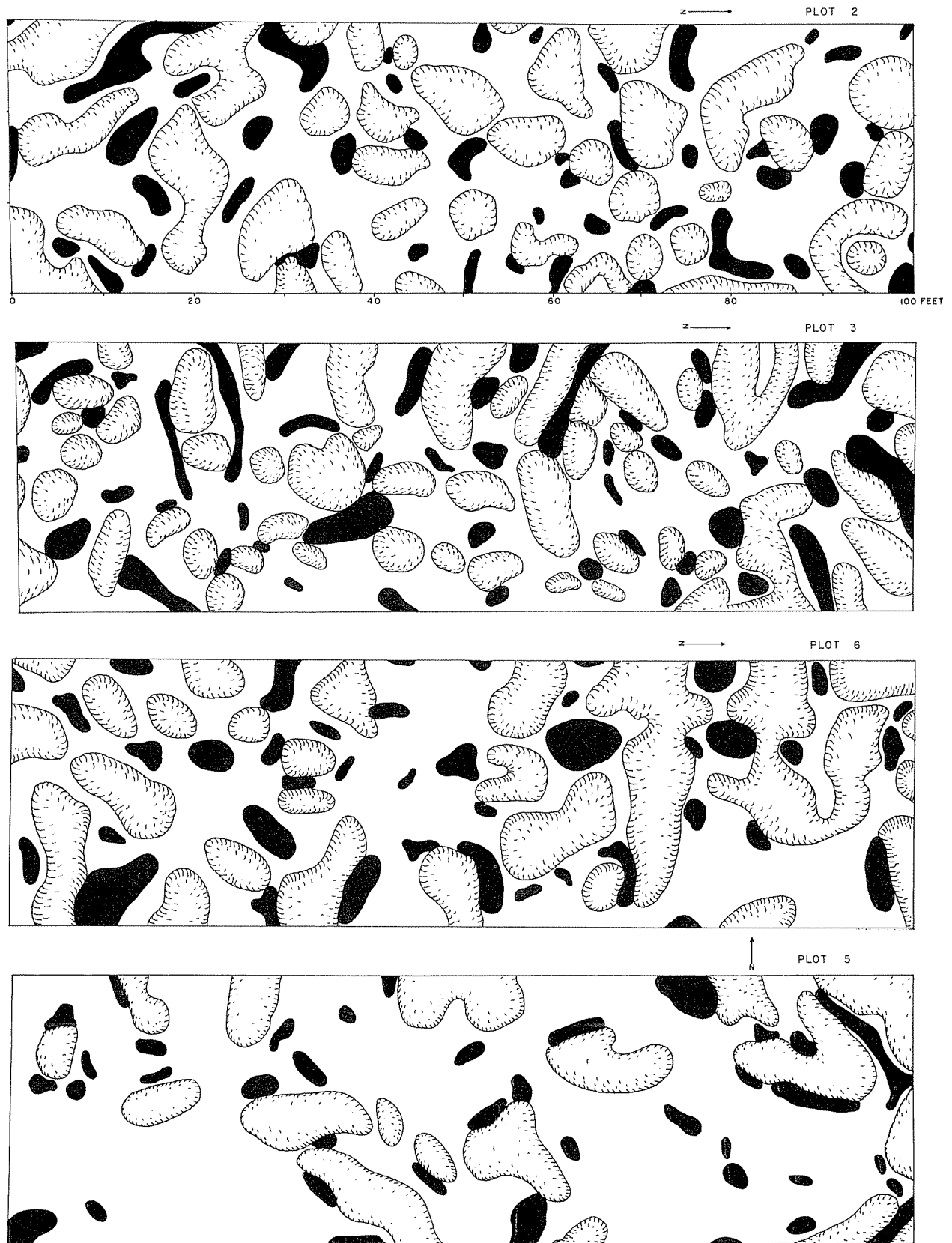


Figure 2 Areal distribution of mounds and pits on four 30-100 foot plots. Stippled areas are mounds, darkened areas are pits. Mound and pit distribution on three other plots is shown in Figure 3.

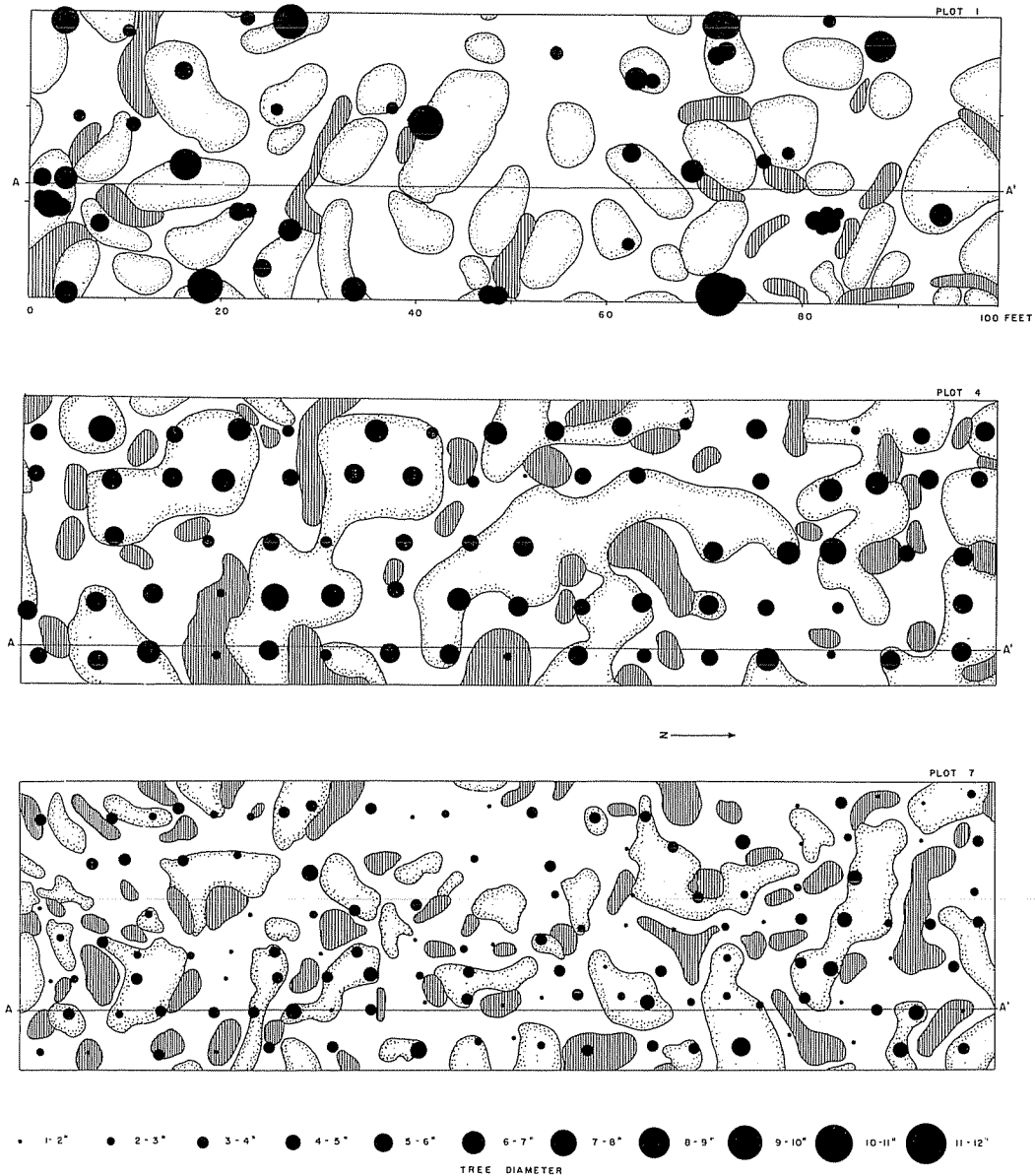


Figure 3 Location and diameter size class of live trees in relation to mounds and pits in a natural stand (Plot 1) and in red pine (Plot 4) and white spruce (Plot 7) plantations. The size class of the trees is exaggerated with respect to the mounds and pits for emphasis. Stippled areas are mounds, vertically lined areas are pits.

#### Soil characteristics in mounds and pits.

Representative soil profiles showing the horization in trenches across mounds and pits are shown in Figures 6 and 7. Several features of these profiles are noteworthy.

Forest floor thickness and weight is less on the mounds than in the pits. The following data were obtained from C. T. Youngberg (personal communication) who collected samples from these same plots at the time our studies were made.

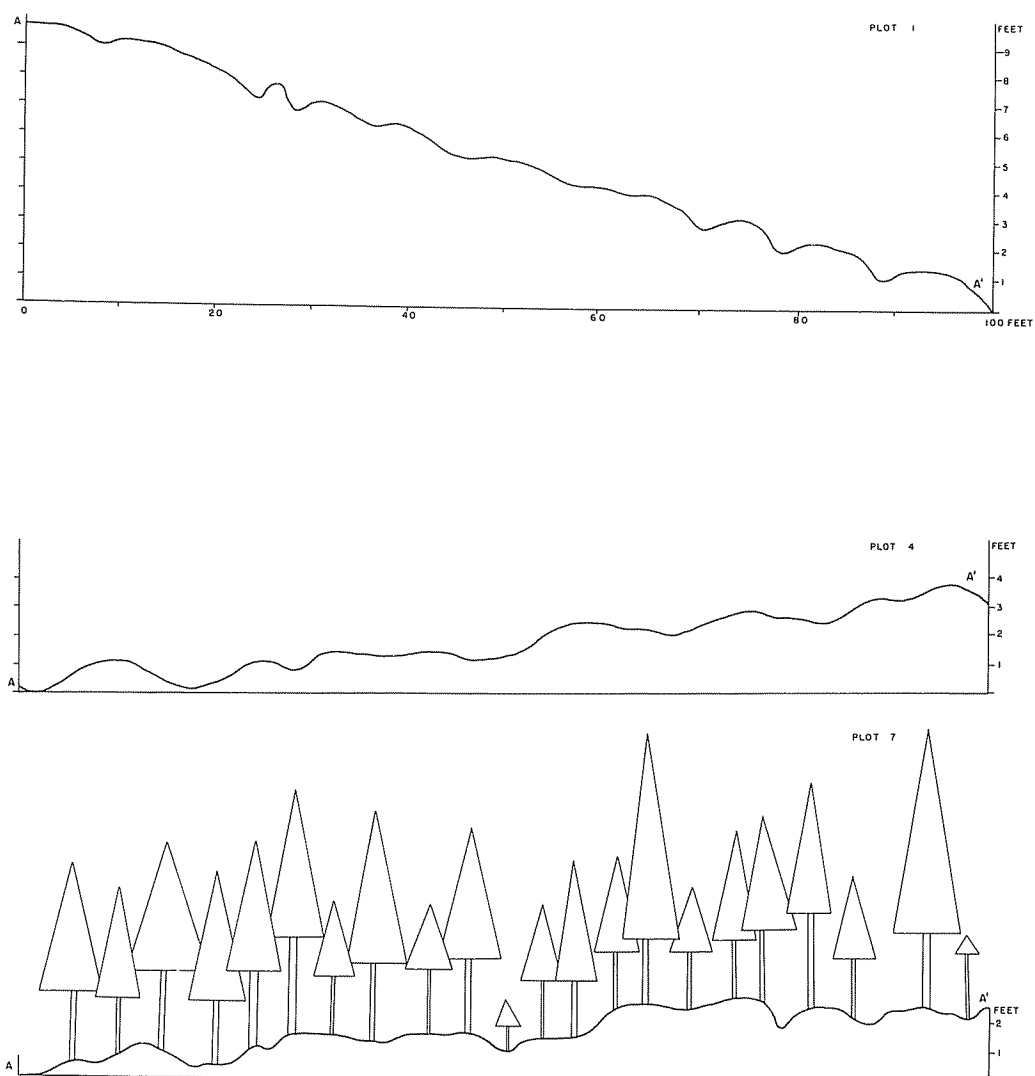


Figure 4 Vertically exaggerated cross sections along lines A-A shown in Figure 3. In the bottom diagram only the vertical scale of relief is exaggerated. Scale of crown diameters, crown heights, heights and diameters of the white spruce trees is the same as the horizontal scale.

	<u>Mounds</u>	<u>Pits</u>
Average thickness of F and H layers	1 3/4 inches	4 3/4 inches
Average air dry weight of litter	24100 pounds/acre	54000 pounds/acre

Mound-pit sequences vary in relief. This variation may be the result of age, as described by Stephens at the Harvard Forest, the result of uprooting of trees or clumps of trees of unlike size or species, or by uprooting of dead trees. The following observations have a bearing on this question.

All mounds show some inversion or disruption of A and B horizons and this supports the view that mounds are formed as a result of tree throw. But in the two mound-pit sequences with low relief (Plot 1-1, Figure 6 and Plot 3-2, Figure 7) the A2 and B2 horizons

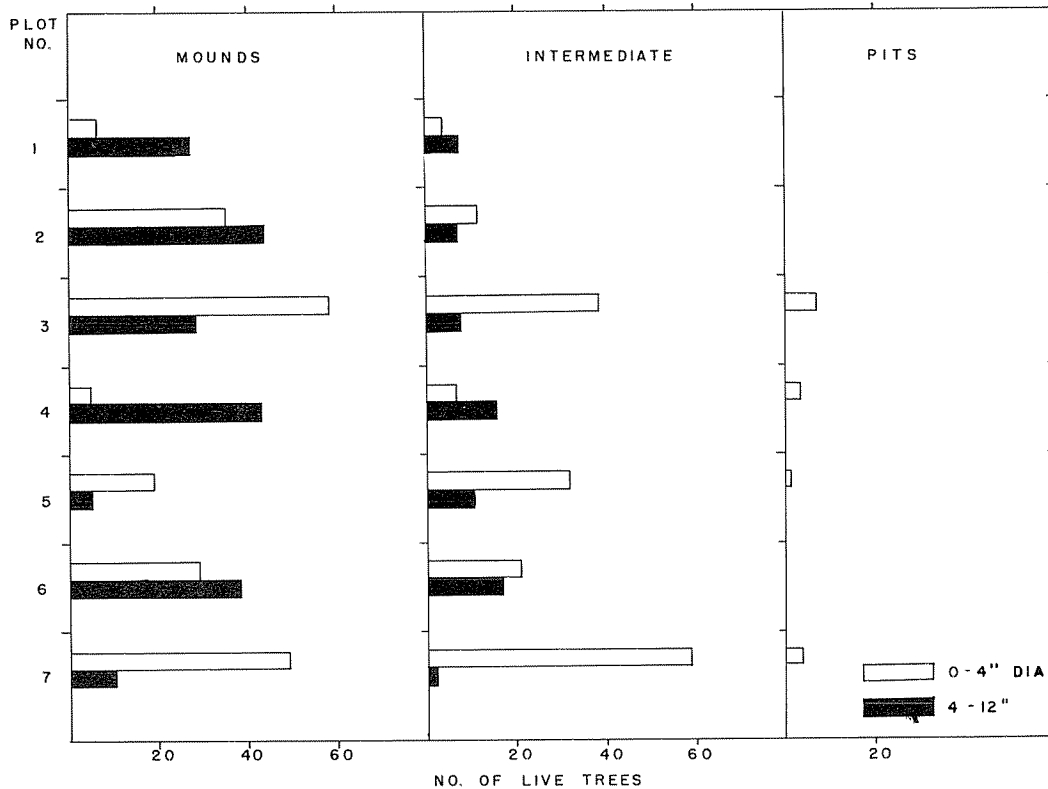


Figure 5 Distribution of live trees on mounds and pits by broad size classes.

are noticeably more continuous than in the mound-pit sequences with higher relief. Also there is a thin nearly continuous Bh horizon in mound-pit sequence 1-1. Then too there is a yellowish A3 horizon in three of the pits and this seems to be a former nearly white A2 horizon that is partially changed to a B horizon.

Where over-all drainage is slightly impeded the mottled soil in the pits provides evidence of a periodically high water table. This is illustrated in the mound and pit sequence 2-1, Figure 7. In such soils the wetter conditions of the pits contrast greatly with the drier conditions on the mounds, especially during the growing season and this is likely to be reflected in the vegetation.

#### Root distribution in mounds and pits.

Root distribution in three representative trenches is illustrated in Figure 8. Roots are most numerous in the forest floor, the fluffy very friable B2ir horizon and the intermixed A1-B21 horizons at the bottoms of the pits. Fewer roots occur in the A2 horizons but this is not especially noticeable unless these horizons are more than 3-4 inches thick. There are essentially no roots in the fragipan (Bx) and C horizons.

In general the non-woody roots are localized in the mounds except in those instances where the soil in the bottoms of the pits is disturbed sufficiently to mix the A1 and B2 Horizons.

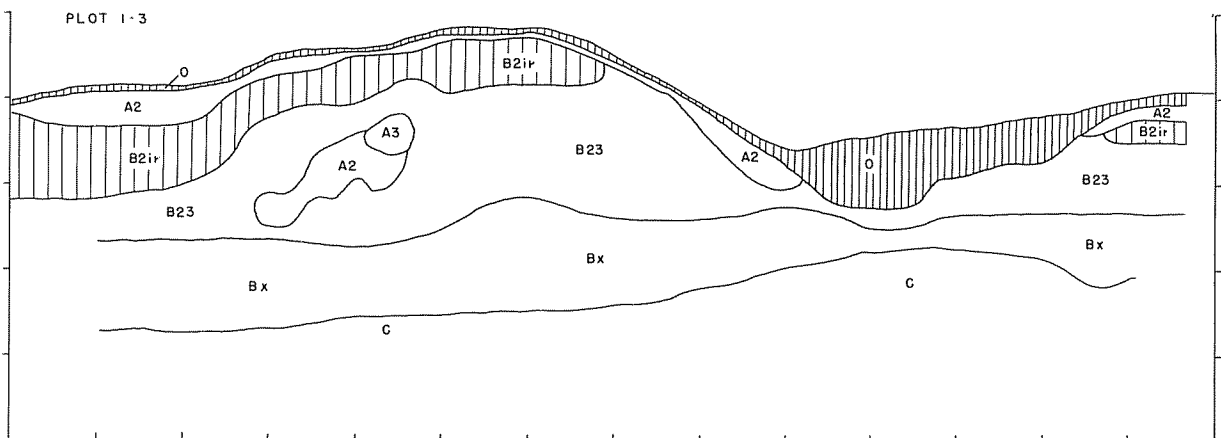
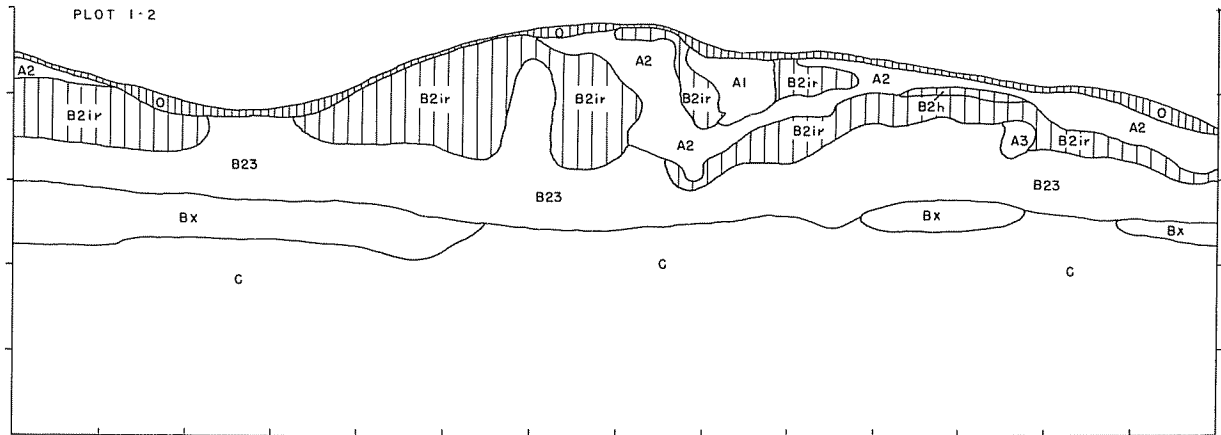
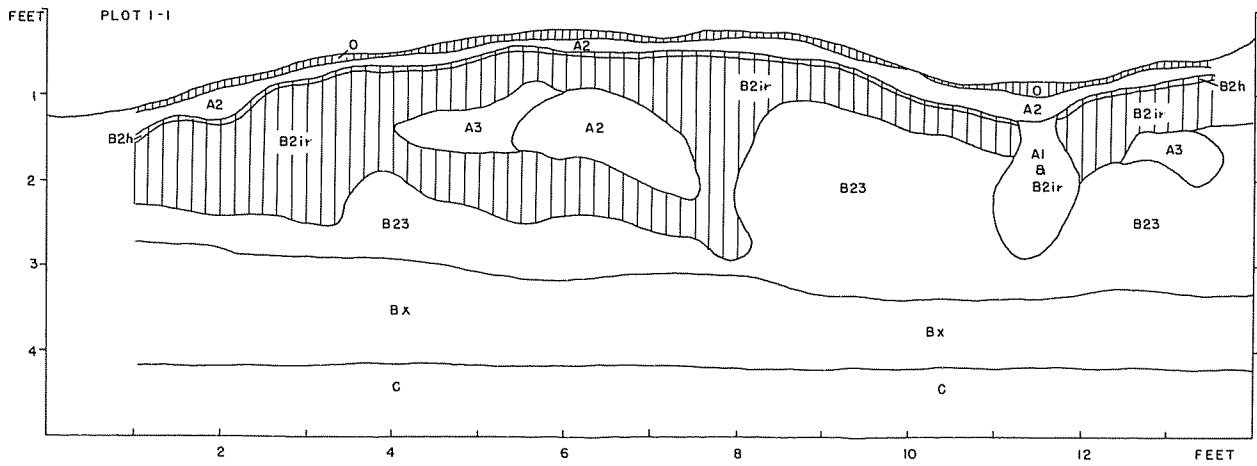


Figure 6 Soil horizons exposed in trenches across faint (top) distinct (middle) and prominent (bottom) mound-pit sequences on Plot 1. The soil is well drained and on sandy glacial till. The soil horizon symbols are those proposed in the May 1962 supplement to the Soil Survey Manual. U.S.D.A. Handbook No. 18. 1951.

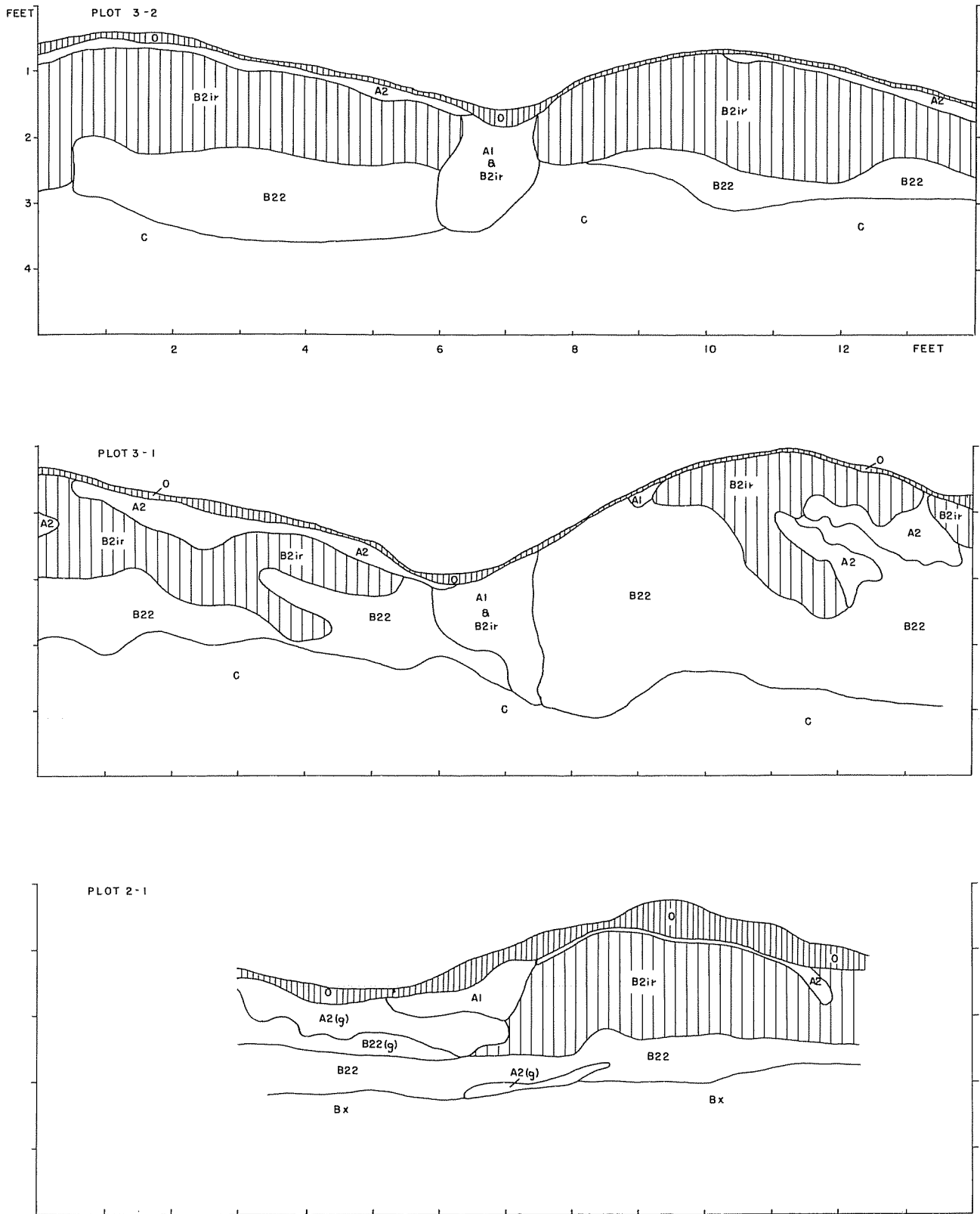


Figure 7 Soil horizons exposed in trenches across mound-pit sequences in Plots 2 and 3. The soil in Plot 2 is imperfectly drained and on sandy glacial till. The soil in Plot 3 is well drained on sandy glacial stream deposits. (The symbol (g) in the bottom diagram is used to indicate faint mottling).

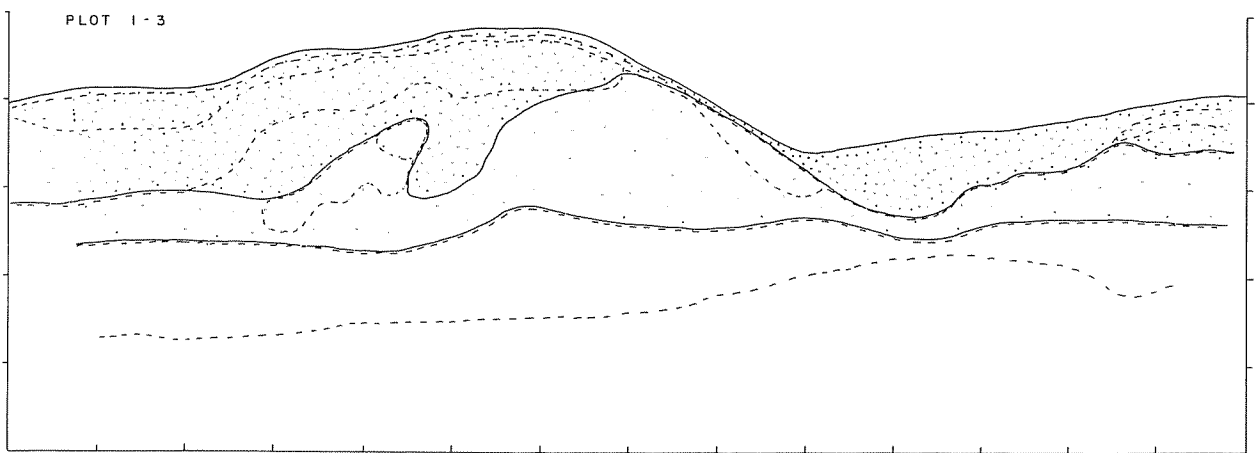
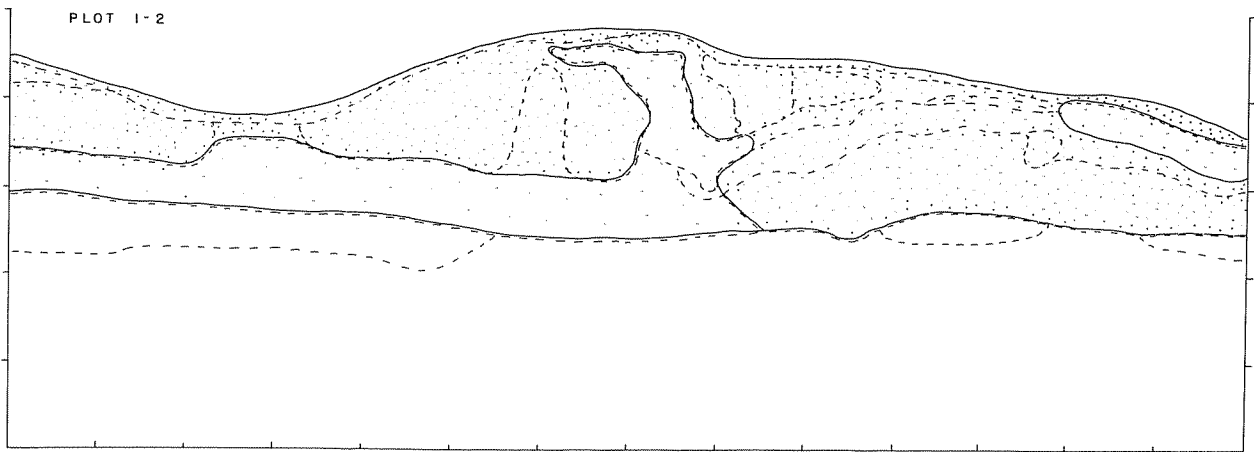
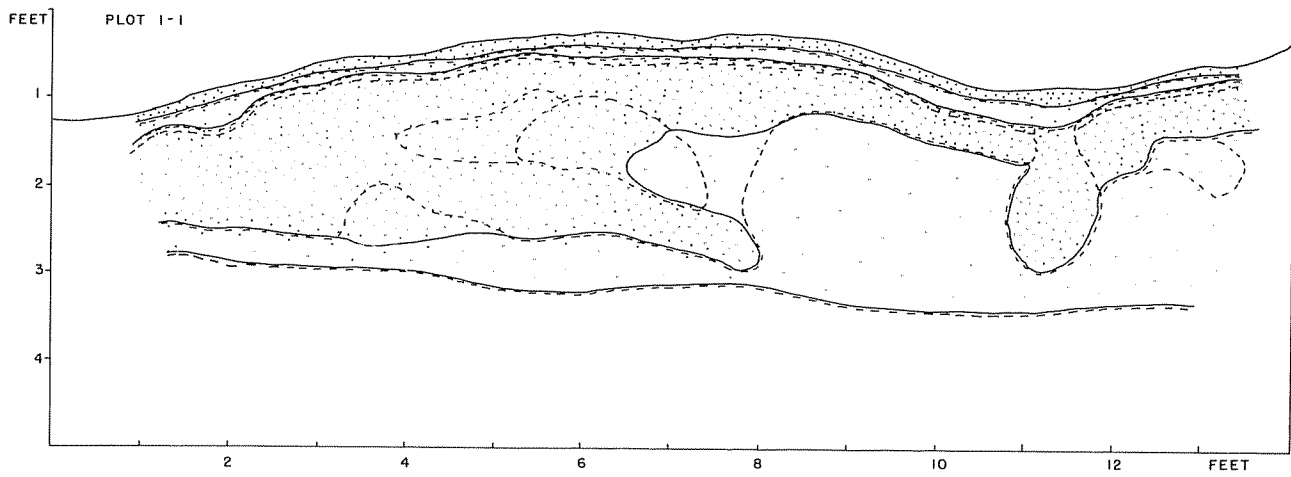


Figure 8 Root distribution in the three profiles shown in Fig. 6. Heavily stippled areas have many non-woody roots, lightly stippled areas have common, and non-stippled areas have few or no non-woody roots. Dashed lines show soil horizon boundaries.

## DISCUSSION

### Mode of formation and age of mounds and pits.

Many previous studies have indicated that the mounds and pits seen in the forest are without doubt the result of uprooting of live trees. In most instances uprooting is caused by wind. Both live and dead trees are uprooted but mounds produced by dead trees are much smaller than those produced by live trees of similar diameters. Certainly the process is now going on in the area studied, as is evident from many trees toppled by the hurricane of 1963. This windstorm blew down some 26,000 cords of wood in the 37 square miles of the Acadia Forest Experiment Station (Figure 9). Many of the fallen trees were isolated, averaging perhaps 5-10 per acre. In places, however, a half acre or so was flattened. If, say, an average of 10 trees per acre were blown down as a result of this one storm 50 such storms would be necessary to make the 500 mounds per acre mapped on the plots. If storms like the 1963 hurricane occur once every 50-100 years the 500 mounds per acre could be produced in a 2500-5000 years period.

It seems likely, however, that most of the mounds are produced more rapidly than this. Many storms are of much greater intensity than the 1963 hurricane, for example, the famous Saxby Gale in the mid-1800's in the vicinity of the Bay of Fundy and the well-known 1938 hurricane in New England. Then, too, there are many local windstorms such as the one of 1845 described by Gesner and one in the Gaspé region in 1945, mapped by one of us, that covered an area several miles long and 1 mile wide where most mature trees were blown down.

Some support for blowdown of a rather large number of trees at one time is given by the broad northwest-southeast directional pattern of many mounds and pits on our plots. Perhaps, then, the trees which made the mound and pits were uprooted by a single large southwesterly windstorm.

Observation of the mounds and pits from the spruce and fir trees blown down by the 1963 hurricane suggests that the plate-like root-soil mass, although head-high in many instances



Figure 9 Head-high masses of roots and soil (J.A. Flanagan provides scale) resulting from the uprooting of red spruce trees during the 1963 hurricane at the Acadia Forest Experiment Station.



(Figure 9) is not large enough to account for the size of many of the mounds and pits mapped on the seven plots. Rather it seems likely that some of the present mounds and pits were formed as a result of the uprooting of large hardwoods or white pine, or perhaps hemlock, such as are known to have been in the pre-settlement forest. These trees when uprooted tend to make bowl-shaped rather than plate-like masses of soil and there is apparently more soil in the bowl-shaped masses. This observation is based on few qualitative data, but it is support for the working hypothesis that some of the mounds date from prior to about 1800 when the large white pine were harvested.

The rate at which the mounds are leveled by natural processes, such as washing of soil particles from the bare surface of the mound, frost action, or by simple subsidence or collapse as the root system decays is not known. Decay of the rather large sized roots in the mounds is slow because of the resinous wood, and some fragments may persist for tens of years. At the Harvard Forest for example, the root systems in mounds from the 1938 hurricane still show very little decay even after 25 years. On the other hand root systems in areas where fires are common, as in New Brunswick, may be completely destroyed in a single conflagration. In none of the eight cross sections of mounds and pits at the Acadia Forest Experiment Station was any old wood of any kind found. If roots were not destroyed by fire (and there was no evidence of charcoal in the body of the mounds) their absence suggests the mounds were old enough to allow the decay of all roots that might have been within them.

Not enough is known about rate of soil development to use the study of horizonation in the soil trenches as a sure means of dating mounds. Such dating is of course complicated by the fact that the soil showed development before it was disturbed. Several of the mounds do have more or less continuous horizons parallel to and just under the surface and these particular mounds may have been formed a rather long time ago. Stephens' work suggests an interval of about 500 years for this to occur in central Massachusetts. On the other hand there have been reports that recognizable mineral soil development under black spruce can be rapid and possibly this is true for red spruce or balsam fir, or other trees, although no one has studied this in detail.

It seems probable that the mounds with nearly continuous A2 and B2ir horizons nearly parallel to the surface are older than the ones with disrupted irregular horizons. At any rate soils with well developed horizons essentially parallel to the surface are generally considered to have been undisturbed a long time. But so little is known about rate of soil development that not much can be said about age. On the basis of Stephens' hypothesis that mounds about 500 years old begin to show continuous horizons we can postulate that mounds with nearly continuous horizons are rather old -- say at least 500-1000 years as an estimate.

Interesting and intriguing in this respect is the thin continuous Bh horizon that exists below the A2 on one of the mounds. This may have developed as a result of age but in view of the fact that similar Bh horizons are not common in the plots studied it may be the result of the influence of a particular species of tree that grew on or near this mound (say black spruce). But just as likely is the possibility that it resulted from the effects of some shrub, herb, or even an overly thick or thin forest floor.

One bit of soil evidence pointing to a rather great age for several of the mounds is the gradual yellowing of former A2 horizons (the A3 horizons in Figure 6 and 7) disrupted and buried to a depth of a foot or so when the tree was uprooted. This A2 horizon material has remained in the zone of B horizon formation long enough to allow some color change. Here again no studies of the rate have been made but it seems likely that hundreds rather than tens of years are involved.

So in conclusion we are not able on the basis of the studies made, to date the mounds and pits that were mapped, and can only be certain that almost all predate the present forest which in turn dates from the last major fires of 1875 and 1900. Our observations do however lead us to a working hypothesis that most mounds date from at least as early as the late 1700's, before the lumbering era.

### Land management implications

Roughness of the surface and the prevalence of many pits that hold water indicate the importance of mound and pit microrelief in any water management of the land. Similarly the persistent roughness and prevalence of pits indicate that there is little or no erosion.

No doubt the first settlers found the microrelief a drawback in clearing land and, as Gesner indicates, probably it was necessary to learn how to cultivate advantageously. Repeated plowing and harrowing soon leveled the microrelief and caused a rather thorough mixing or homogenization of the horizons in the upper foot or so of soil. This mixing and leveling of the microrelief was overlooked by soil scientists for many years because most of the early soil studies were made in areas once cultivated and were primarily concerned with agricultural production.

Roughness of the surface may be of considerable benefit to the growth of trees in some instances. Loosening of the soil and piling in mounds allows a greater amount of rooting in some horizons as is evident in the root distribution diagrams. In the pits almost all roots are in the forest floor or the mixed A1-B21ir horizons, and here they thrive. In a well-drained soil, then, this microrelief may be more advantageous for some trees than the more uniform microrelief resulting from cultivation. Shallow rooted trees such as spruce and balsam fir which tend to have their roots in the forest floor may benefit, and also trees like red maple which tend to have their woody horizontal roots concentrated in the more highly organic pits. (Lyford and Wilson 1964).

This study shows that irrespective of the kind of soil (within the limits we studied) the largest and most rapidly growing trees tend to occur on mounds and there are few in pits. This is obvious for both plantations and natural stands as shown in Figures 3 and 5.

Considerations of the relation of trees to the microrelief lead to many implications in terms of forest management. For example, the common practice of establishing plantations is to plant trees at more or less regular intervals without much attention to microtopography. This study suggests that such a procedure can be wasteful. The study further suggests that for planting red pine, white spruce or Douglas fir on soils of the Harcourt catena, mounds are the most suitable locations, intermediate areas between mounds and pits are satisfactory, and pits are quite unsatisfactory. It is likely, however, that the most suitable microtopography for planting varies with tree species and kind of soil. This view is supported by observations of a very small plantation of hybrid larch at the Acadia Forest Experiment Station. Here the trees were presumably planted with little attention to microrelief but all living stems were in pits.

Regeneration of trees may be influenced by the microrelief. This has been pointed out by Dixon and Place (1952) as a result of another study at the Acadia Forest Experiment Station. In the course of our study standing water, ice and snow were observed in some pits so undoubtedly regeneration of most tree species is affected by the presence of long-continued standing water and perhaps to an even greater degree by ice.

Direction and shape of mounds, especially of the larger ones, may also play a role in regeneration. For example moisture relationships and shading in open areas may vary enough on different slopes and aspects of the larger mounds to have an influence on survival of seedlings or young trees.

Recent mounds such as those which resulted from the 1963 hurricane (Figure 9) have considerable exposed mineral soil and offer a choice seedbed for species like birch and spruce. Old mounds on the other hand have a continuous cover of forest floor (1 3/4 inches thick on the average for the mounds in our study area according to Youngberg's study). In old mounds therefore, regeneration and root growth probably are not much different than in intermediate areas.

Location of trees in respect to mounds and pits may have some importance in thinning, selective cutting, pruning or other management practices. Our studies indicate that on some soils at least the larger and more rapidly growing trees are on mounds. No doubt this response of trees is most marked where soils are intermediate between wet and dry so that a slight change in relief is enough to bring the water table within the rooting zone in the pits. But in any case, wherever the growth of trees is influenced by microtopography, it would seem that this should be used to advantage in silvicultural treatments.

Agricultural experience indicated that soil is not injured and made less productive by leveling mounds and pits. Certainly the leveling promotes ease of management with motorized equipment and in this day of huge bulldozers and other large equipment it may even be feasible in some instances to promote leveling in areas to be used intensively for forest production.

#### LITERATURE CITED

- DAWSON, J.W. (Sir). 1847. On the distribution and partial reproduction of forests in British North America. *Edinburgh New Philosophical Jour.* (April), XLII 250 2nd Series. Vol. IV. No. 11.
- DENNY, C.S. and J.C. GOODLETT. 1956. Microrelief resulting from fallen trees. In Denny, C.S., *Surficial Geology and Geomorphology of Potter County, Pennsylvania*. U.S. Geol. Surv. Prof. Paper 288.
- DIXON, A.C. and I.C.M. PLACE. 1952. Influence of microtopography on the survival of spruce and fir reproduction. *Silvicultural Leaflet: No. 68*, Forestry Branch, Canada Dept. of Resources and Development.
- GESNER, A. 1847. *New Brunswick with Notes for Emigrants: Landon, Simmonds and Ward*, 6 Barge Yard, Bucklersburg.
- GOODLETT, J.C. 1954. Vegetation adjacent to the border of the Wisconsin drift in Potter County, Pennsylvania. *Harvard Forest Bull.* 25.
- HART, G., R.E. LEONARD and R.S. PIERCE. 1962. Leaf fall, humus depth, and soil frost in a northern hardwood forest. U.S. Dept. Agri., Forest Service, Forest Res. Note No. 131.
- LOUCKS, O.L. 1962. A forest classification for the Maritime Provinces. *Proc. Nova Scotia Instit. of Sci.* 25: Part 2, 85-167. 1959-60. (Date of publication April, 1962.)

- LUTZ, H.J. 1940. Disturbance of forest soil resulting from the uprooting of trees. Yale School of Forestry, Bull. 45.
- LYFORD, W.H. and B.F. WILSON. 1964. Development of the root system of Acer rubrum L. Harvard Forest Paper: No 10.
- PINCHOT, G. 1901. Forest destruction. In Annual Report of the Smithsonian Institution for the year ending June 30, 1901. pp. 401-404.
- RODE, A.A. 1955. Soil Science (Pochvovedenie): Goslesbumizdat, Moskva 1955. Leningrad. English translation 1962. Published for the Nat. Sci. Found. Wash. D.C. and the Dept. of Agri. by the Israel Program for Sci. Translations.
- SCHUBERT, T.H. 1954. The effect of mound and pit microrelief on the growth of several plantations on the Harvard Forest: Manuscript report, in files of Harvard Forest.
- SHALER, N.S. 1891. The origin and nature of soils. Twelfth Annual Report, U.S. Geol. Survey, 1890-91: Part 1, Geology 213-345.
- STEPHENS, E.P. 1956. The uprooting of trees: a forest process. Soil Sci. Soc. Amer. Proc. 20: 113-116.