1962 No. 5

HARVARD FOREST PAPERS

A SURVEY OF THE INCIDENCE OF RING SHAKE IN EASTERN HEMLOCK

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A SURVEY OF THE INCIDENCE OF RING SHAKE IN EASTERN HEMLOCK

A shake in timber may be defined as a crack, or cracks, formed in the wood during the growth of a tree. The type of shake in which the cracks are confined to growth rings is called ring shake, a common defect of eastern hemlock, Tsuga canadensis (L.) Carr. However, the incidence of ring shake in eastern hemlock stands varies; some stands consist almost entirely of sound trees, while others consist mostly of "shaky" trees. In this survey, the incidence of shake within a stand was measured and correlated with the average age of the trees; their average diameter; and the site on which they were growing. Preliminary observations had suggested that relationships did exist, especially between the age of the trees and the incidence of shake, and that they might provide some insight into the actual cause of ring shake in hemlock.

It had been generally accepted that the stress which causes shakes to form was due to the external action of wind or subfreezing termperatures. Wind could cause shear stresses by bending the stem of the tree. Dimensional changes which occur in the wood during freezing and thawing could set up high stresses within the stem (Mayer-Weglin 1955; Mergen 1958).

The possibility that stresses of internal, rather than external, origin cause shake was first suggested by Koehler (1933). Jacobs (1945) was able to demonstrate that internal stresses (called growth stresses) were present in many tree species, including T. canadensis. Wardrop and Dadswell (1947) suggested that growth stresses caused the minute compression failures which are found in the wood of many trees. Jacobs (1945) and Boyd (1950), working with Eucalyptus, measured the magnitude and distribution of growth stresses, and showed that they could exceed the strength of the wood in the older parts of the stem. Although minute compression failures and ring shakes are not directly related, it is important to note that growth stresses may be of sufficient magnitude to cause defects in growing trees.

There have been several explanations of the cause of shake, but none of them account for variability in the incidence of shake. If the stress which causes shake was of external origin, then presumably the variation would be due to differences in site characteristics affecting either the magnitude of the stress, or the susceptibility of the trees to its action. If the stress was of internal origin, then the variation would be due to differences within the trees themselves. Internal differences could result from genetic or site factors, or they could be related to the age or size of the trees.

MATERIALS AND METHODS

Hemlock stands were studied in Franklin county, Hampshire county, and Worcester county in Massachusetts during the autumn of 1956. The location of the 60 stands (Fig. 1) was determined from information which the District Foresters of the three counties had gathered under the Massachusetts Cutting Practices Law. Only stands from which more than 5000 board feet had been cut within the last 5 years were selected. From each of these stands a sample was taken on an area with uniform slope, exposure, and relief features.

SITE CLASS	DESCRIPTION OF SITE	NUMBER OF SAMPLES	PERCENT OF SHAKY TREES
I	Poorly drained, 0-8% slope, no ledge.	17	38
II	Moderately well drained, 9-15% slope, no ledge.	14	29
III	Well drained, 15-20% slope, some ledge.	14	39
IV	Excessively drained, 20%+ slope, usually ledge.	15	46
	ALL SITES COMBINED	60	38

Table 1. The site classes used in this survey, and the percent of trees with shake on each site.

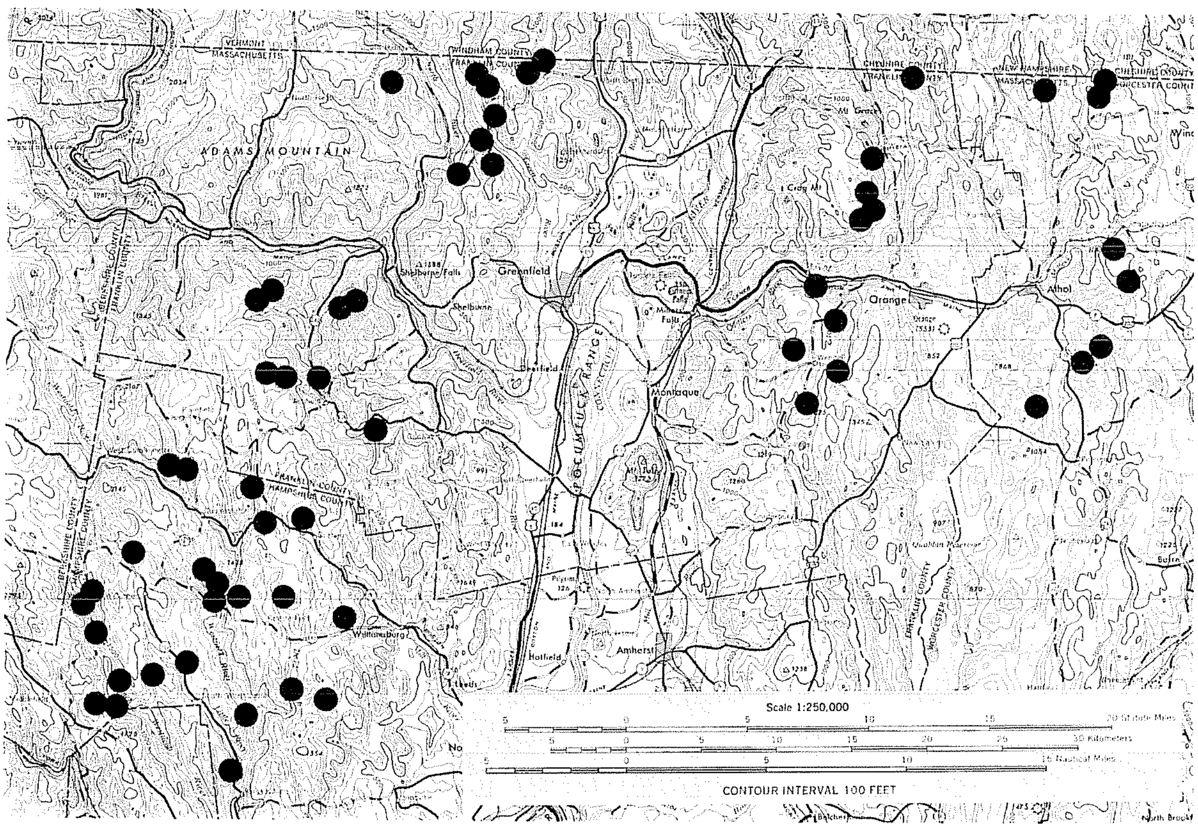

Figure 1. Map of north, central Massachusetts which shows the location of the 60 stands studied in this survey.

Observations were made on the cut surfaces of stumps left from logging operations. A tree was chosen from the center of the stand, and the nearest 20 stumps selected for measuring. The data taken from these stumps were: the presence or absence of shake; the number of shakes if present; age (from a ring count at stump height); and site characteristics. A stump was considered shaky if there was a circular crack in all four quadrants. If the quadrants could be so arranged that one had no circular crack, that stump was considered sound. The presence of old, ground up, cell walls in the larger circular cracks showed that they had been formed in the standing tree. In addition, sound stumps developed radial, not circular, cracks with age. The site data taken were on the presence or absence of ledge to indicate soil depth, and standing water if present. The location of each sample was marked on a U. S. G. S. topographic map (1:31680) for later determination of slope, exposure, and relief features.

The sites on which the trees were growing were divided into four classes (Table 1) on the basis of drainage characteristics. Previous studies at the Harvard Forest had shown the importance of soil drainage to the growth and distribution of trees (Goodlett 1960), therefore this characteristic was selected as the most important in the determination of patterns of tree growth. Although wind and temperature were not determined as site characteristics, presumably the trees on site I, which is almost flat, were exposed to relatively little wind and relatively low temperatures, while the trees on site IV, on steep slopes, would have been exposed to relatively more wind and higher temperatures during the winter.

RESULTS

Data were taken from 1284 stumps in samples from 60 sites. Of these trees 468, just over one third, had shake. As expected, the incidence of shake in a stand was not uniform, but varied from 0 to 90 percent (Fig. 2a). Stands composed of younger trees had less shake than those of older trees (Fig. 2b). Stands of smaller diameter had about the same amount and distribution of shake as those of larger diameter (Fig. 2c). Although site II had slightly less shake, and site IV slightly more, there were no obvious differences between stands growing on different sites (Figs. 2d, 2e, 2f, 2g).

The relationship of age to the incidence of shake

The relationship of age to the incidence of shake was most striking. All but two of the 150 trees less than 60 years old were sound, while the 50 trees older than 127 were all shaky (Fig. 3). During the 60 year period in which shakes were formed, the percentage of shaky trees increased linearly with age (Fig. 3).

The relationship of the average age of the trees in a stand to the incidence of shake within a stand was also linear (Fig. 4), however the fact that the stands were not even aged affected the relationship. The standard deviation from the average age of the trees in a sample ranged from 5.5 to 41.0 years with an average of 14.1 years. Therefore, a stand with an average age of less than 60 would have included some trees older than 60 and possibly shaky. The same reasoning applies to stands with an average age of more than 127, which would include sound trees.

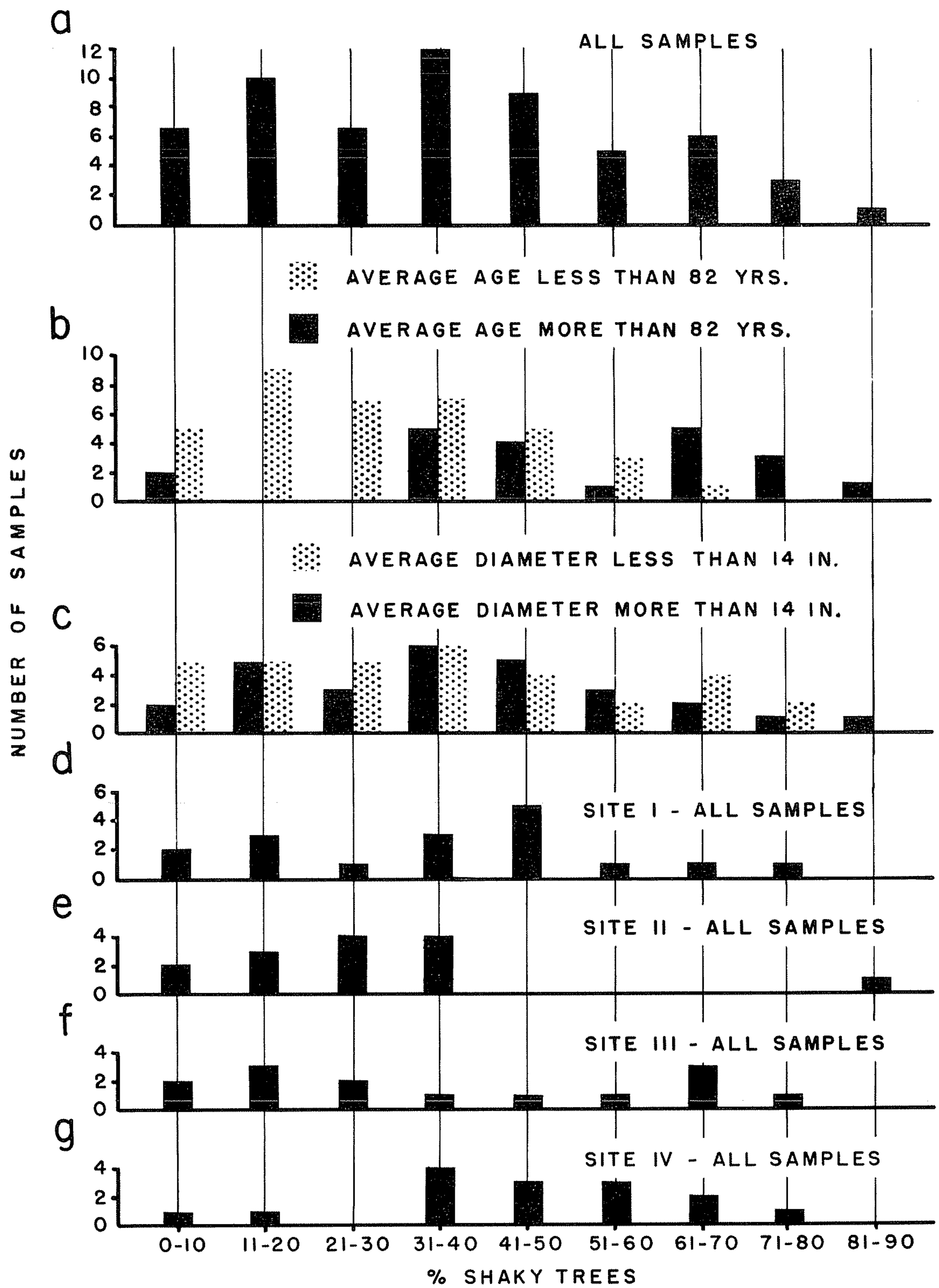

Figure 2. The incidence of shake in samples from: a) all 60 stands; b) all 60 stands classified as younger (under 82 years old) and older (over 82 years old); c) all 60 stands classified as smaller (under 14 inches in diameter) and larger (over 14 inches in diameter); d) the 17 stands on site I; e) the 14 stands from site II; f) the 14 stands on site III; g) the 15 stands on site IV.

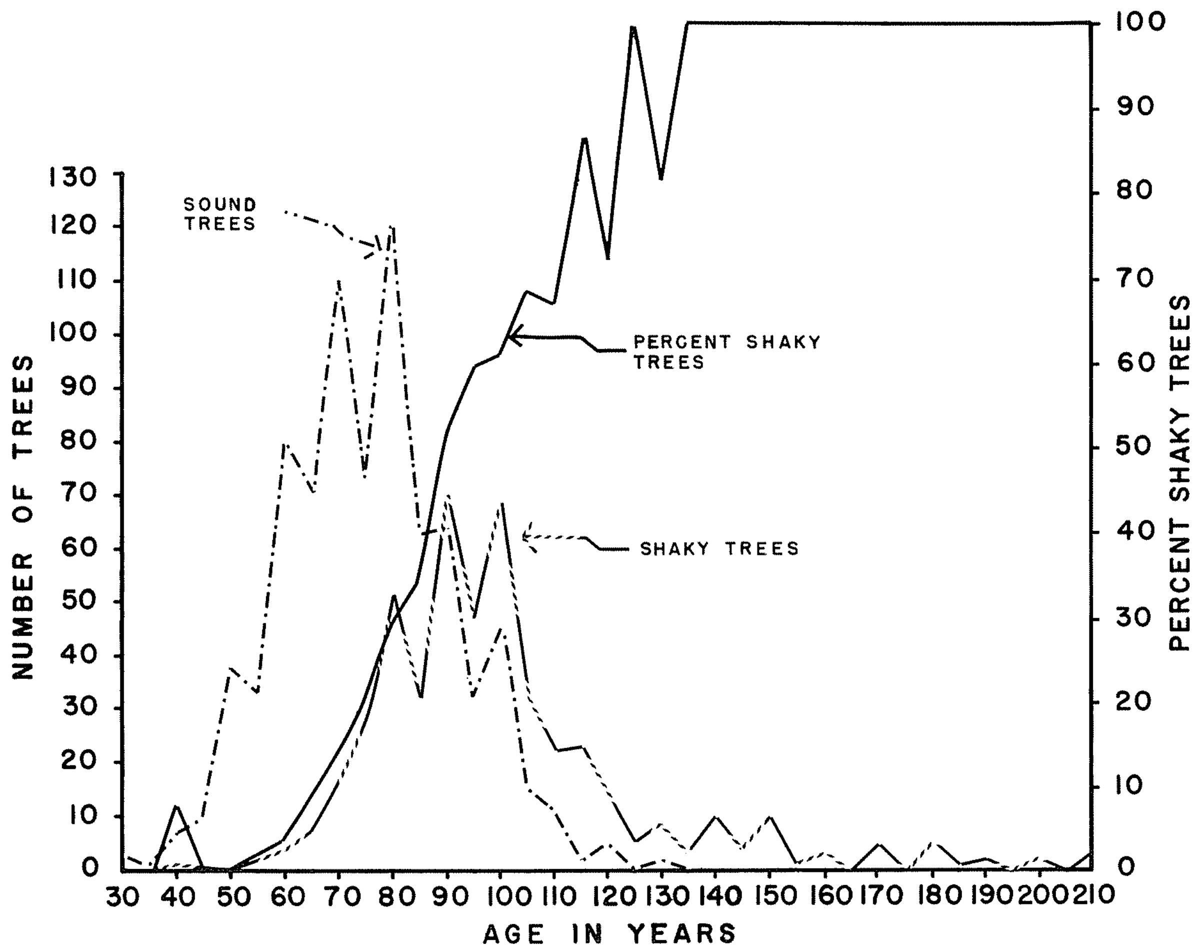

Figure 3. The incidence of shake in 1284 trees classified in 5 year age classes, and the percent of shaky trees in each age class.

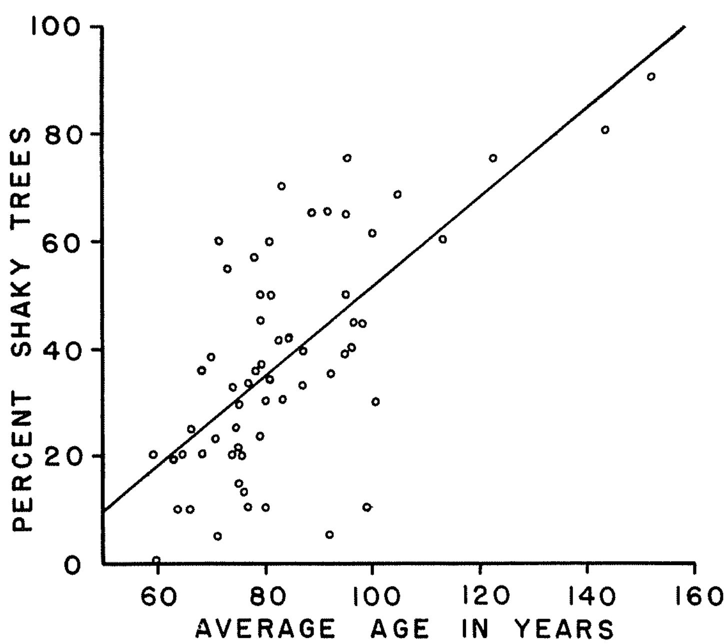

Figure 4. The percent of shaky trees in each of the 60 stands related to the average age of the trees in the sample from the stand.
The regression line is $Y = -32.2607 + 0.8392X_1$.

Not only the percent of shaky trees, but also the number of shakes per tree increased with age. The number of very shaky trees (more than 5 separate shakes per tree) showed a definite increase with age, e.g. eight percent of the shaky trees less than 100 years old were very shaky, 15 percent of those from 100 to 125 and 66 percent of those over 125.

The relationship of diameter to the incidence of shake

The relationship of diameter to the incidence of shake was much less strong than that of age, either within diameter classes (Fig. 5) or within stands (Fig. 6). If the diameter of the trees had been determined strictly by their age, it would have been impossible to tell whether the relationship of diameter to the incidence of shake was due to diameter itself, or only secondarily through the age-diameter relationship. However, the relationship of age to diameter was poorly defined both in the 60 stands (Fig. 7) and in the individual trees that composed them. It was possible, therefore, to separate the relationships of diameter from those of age.

The statistical treatment (appendix page 10) was designed to test the relative significance of diameter and age to the incidence of shake. The statistics supported the general observations in the field that small diameter trees were shaky if they were old enough, and large diameter trees were sound if they were young. When separated from age, the relationship of diameter to the incidence of shake was not significant. The relationship that did exist was merely due to the rough correspondence between age and diameter.

The relationship of site to the incidence of shake

From field measurements, it appeared that there was little relationship between the incidence of shake in a stand and the site on which the trees were growing. Even on extreme sites (I and IV), stands with a low average age had a low incidence of shake, and those with a high average age had a high incidence of shake. For example, the low incidence of shake on site II (Fig. 2d) was due to the fact that sample trees had a low average age, and vice versa for site IV (Fig. 2f).

The statistical treatment of the data (see Appendix page 10) again supported the observations in the field. The previously established relationship of age and diameter to the incidence of shake held, regardless of the site on which the trees were growing. When the incidence of shake in the samples was estimated using the average age and diameter of the samples as variables, the error in this estimate was greater within any one site than between sites.

DISCUSSION

The results of this survey show that the incidence of ring shake in hemlock: (1) was closely related to the age of the trees; (2) was poorly related to the diameter of the trees; (3) was not related to the site on which the trees were growing. These three points are of especial interest because they are rare among growth phenomena in trees. The absolute age of a tree is usually unimportant, although the "physiological" age of a tree is sometimes related to other phenomena (Morris 1948). Growth studies of trees are usually concerned with the increase in size of the tree because of the increased economic value.

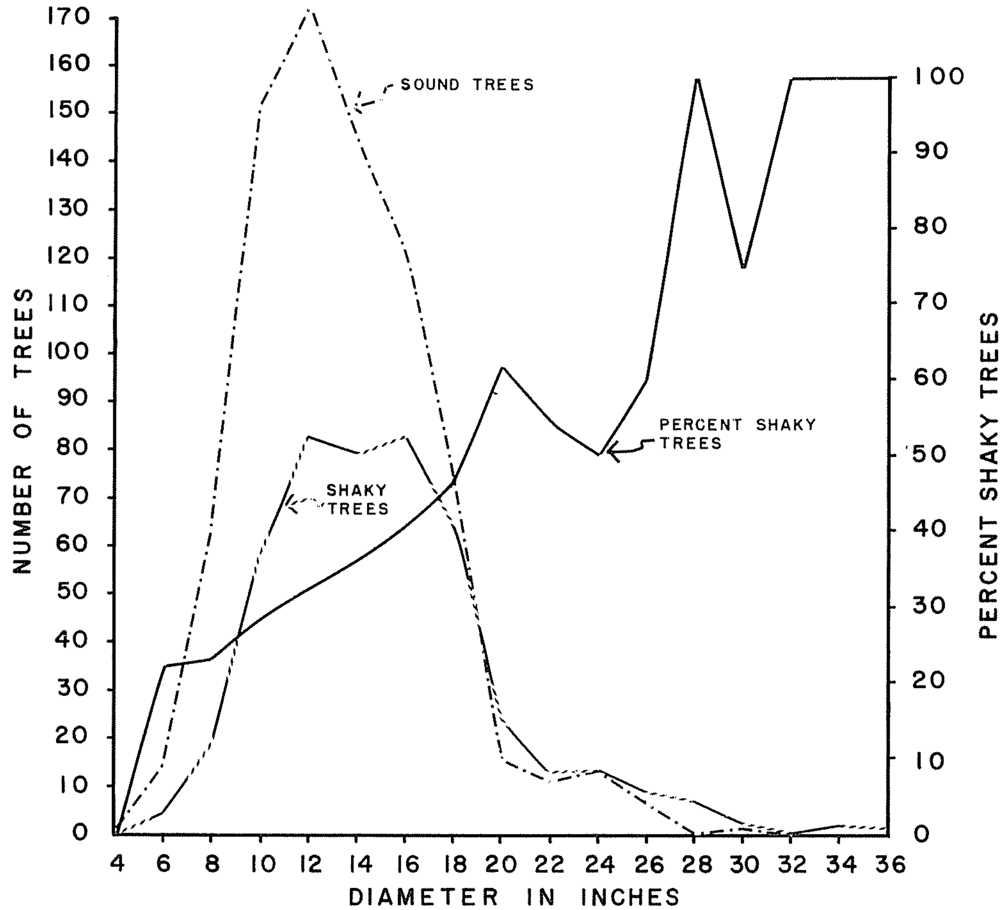

Figure 5. The incidence of shake in 1284 trees classified in 2 inch diameter classes, and the percent of shaky trees in each diameter class.

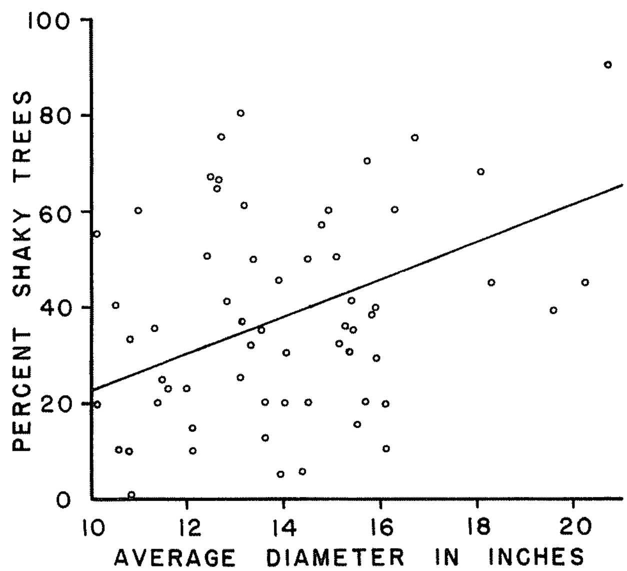

Figure 6. The percent of shaky trees in each of the 60 stands related to the average diameter of the trees in the sample from the stand. The regression line is $Y = -16.2098 + 3.8684X_2$.

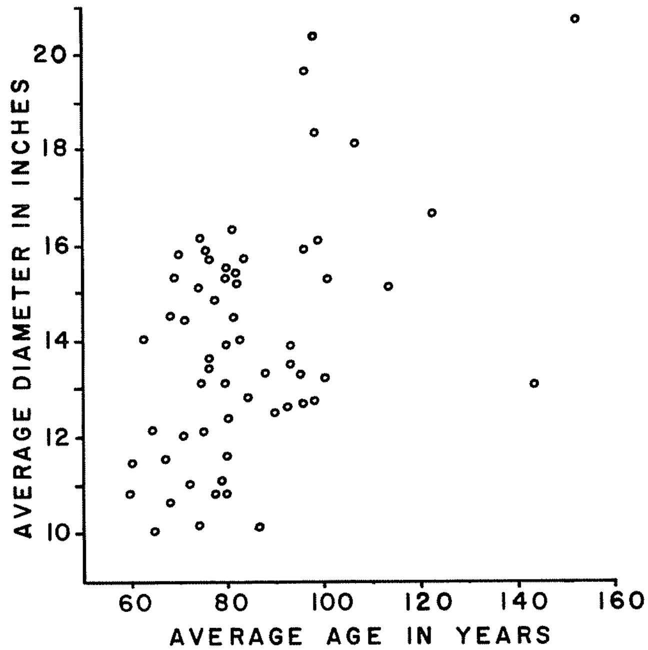

Figure 7. The relationship of average age to average diameter of the samples from the 60 stands.

The data show, however, that in those species where size is not closely related to age, there may be aspects of growth and "maturity" which are related to the absolute passage of time, rather than the growth rate or time since release from suppression. The unimportance of site in the determination of the incidence of shake is particularly striking because site characteristics strongly modify most growth phenomena in trees.

The data appear to rule out the external origin of the stress which causes shake, e.g. wind or cold temperature. There is no reason why the action of such external factors, which act presumably throughout the entire life of the tree, should be delayed in their effect for 60 years. In addition, external factors vary in magnitude and distribution between sites, and if they are causal factors the incidence of shake should be related to differences in sites.

The most likely explanation seems to be that the stress is of internal origin. Growth stresses can be used to explain both the lack of relationship to site factors and the delay in the formation of shakes. Growth stresses are a result of the normal development of the tree (Jacobs 1945), and they are subject primarily to genetic control rather than control by site factors. They are formed as each growth ring matures and the yearly increment of stress is additive (Jacobs 1945; Boyd 1950). Therefore, the 60 year delay can be explained if it is assumed that 60 to 125 years are required before the sum of yearly stress increments reaches a sufficiently high value to cause failure of the wood.

The results of this survey provide a basis for speculation about the cause of shake. The ultimate cause must be a stress, internal or external, which is large enough to cause mechanical failure of the wood. The real problem, however, concerns the origin of such stress. Any satisfactory explanation of stress origin should account for the 60 year delay in the formation of shakes, and the independence from control by site, both of which were characteristic of the incidence of ring shake in the hemlock studied.

SUMMARY

Data from 60 hemlock stands in Massachusetts showed that the incidence of ring shake was related to the age of the trees. Shakes were formed between the ages of 60 and 125 years. This relationship was not influenced by the diameter of the trees or the site on which the trees were growing. The results suggested that ring shake was caused by the internal action of cumulative growth stresses, rather than the external action of wind or cold temperature.

ACKNOWLEDGMENTS

This paper is part of a thesis submitted in partial fulfillment of the requirements for the degree of Master in Forestry at Harvard University. I am indebted to the staff of the Harvard Forest for their guidance; to Dr. M. N. Palley, University of California (Berkeley) for statistical advice; and to Mr. N. W. Lake for many practical suggestions.

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APPENDIX

The following regressions were set up to determine the relative value of age and diameter for estimating the percent of shake in a sample: (1) using only the average age of the samples as the independent variable (Fig. 4); (2) using only the average diameter of the samples (Fig. 6); (3) using both the average age and the average diameter of the samples.

$$(1)\quad Y = -32.2607 + 0.8329X_1$$

$$(2)\quad Y = -16.2098 + 3.8684X_2$$

$$(3)\quad Y = 23.2766 + 0.9171X_1 - 1.1496X_2$$

where: Y = the percentage of trees with shake in a sample.

X_1 = the average age of the trees in a sample.

X_2 = the average diameter of the trees in a sample.

The following hypothesis was then tested: that the error in estimating Y (in terms of the sum of squared residuals) using only one variable is not significantly reduced by the addition of a second variable. The hypothesis cannot be rejected when age is used as the single variable and diameter added as the second (Equation 4), but it must be rejected if diameter is used as the single variable and age added as the second (Equation 5).

(4)

$$F = \frac{SSR_{X_1+X_2} - SSR_{X_1}}{S^2} = \frac{97112.2164 - 96882.9295}{243.7764} = 0.9406 \text{ (ns)}$$

(5)

(5) $$F = \frac{SSR_{X_1+X_2} - SSR_{X_2}}{S^2} = \frac{97112.2164 - 87762.8994}{243.7764} = 38.35208^*$$

*highly significant

where: there are $F_{1,57}$ degrees of freedom

SSR = the reduction in sum of squares due to regression.

S^2 = sum of squared errors divided by the degrees of freedom (57).

A further hypothesis was tested: that site did not affect the accuracy of the prediction of the percent shake in a sample based on the age and diameter and that therefore the error in prediction using age and diameter as variables was larger within sites than between sites. The statistics in Table 2 show that the hypothesis cannot be rejected. The error within sites was larger than the error between sites. Therefore there was no effect of site on the relationship of age to the incidence of shake.

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES
Between sites	117.584	3	38.8613
Within sites	11,112.3725	56	198.4325
Total	11,230.2565	59	

Table 2. Analysis of variance showing that the error in predicting the percent of shake within samples using diameter and age as independent variables was greater within sites than between sites.