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CONTENTS

INTRODUCTION

Trembling aspen, *Populus tremuloides* Michx., is frequently called quaking aspen, aspen, aspen poplar, or poplar. Throughout this publication the name aspen is used for this species. Aspen is one of Canada's most widely distributed hardwood species. It extends from the Atlantic Provinces to British Columbia, and to the Yukon in the northwest. In northern Ontario it accounts for between 15 and 30 per cent of the primary growing stock on productive forest lands. Since World War II, new techniques for handling and processing aspen have been developed by the pulp and paper industry. The number of cords of poplar, mostly aspen, cut from Crown lands in Ontario for pulping purposes increased from 19,000 cords in 1944-45 to 189,000 cords in 1951-52; at present the cut averages 150,000 cords a year.[1]

The increase in the amount of aspen utilized by the pulp and paper industry is encouraging, for there are innumerable accessible, mature and overmature stands of this species in Ontario. The heavy decay losses frequently encountered in aspen stands at relatively young ages have hindered the utilization of this species. Marginal stands in which the recovery of sound wood would have proved profitable have been rejected, whereas in other stands operations have been undertaken which, because of excessive heart rot, have been highly unprofitable. Enlightened management and a knowledge of the relationships between decay and age, site, and diameter would help foresters avoid these mistakes.

In 1950 the Forest Pathology Laboratory in Ontario received requests from the pulp and paper industry for information concerning the decay relationships of aspen. An investigation, supervised by the late Mr. R. L. Black, was begun immediately in the Upper Pic River region. Upon Mr. Black's transfer to another province in 1952 the investigation was halted until the author was able to complete the field work in 1955. A paper stressing the mycological and pathological aspects of this study was published in 1958 (2).

LOCATION AND DESCRIPTION OF STUDY REGION

This study was carried out in northern Ontario in what is referred to as the Upper Pic Region, approximately 150 miles east of Lake Nipigon (Figure 1). The growing season in this region is quite short. The annual precipitation is only about 24 in., but because of the relatively short warm season conducive to evaporation the region has adequate moisture to support forest growth.

The geology and topography of the Upper Pic region have been profoundly affected by glaciation. The characteristic low, rolling hills are covered by a thin mantle of glacial till. The soils derived from these tills are predominantly loamy, and because of good drainage on the slopes the soil horizons are poorly developed. The resulting intrazonal podzolic soil type constitutes about 50 per cent of the study area. Outwash sand plains 3 to 15 ft. deep make up about 10 per cent of

[1]Figures from the Minister's Annual Report, Ontario Department of Lands and Forests, Toronto. 1946–58.

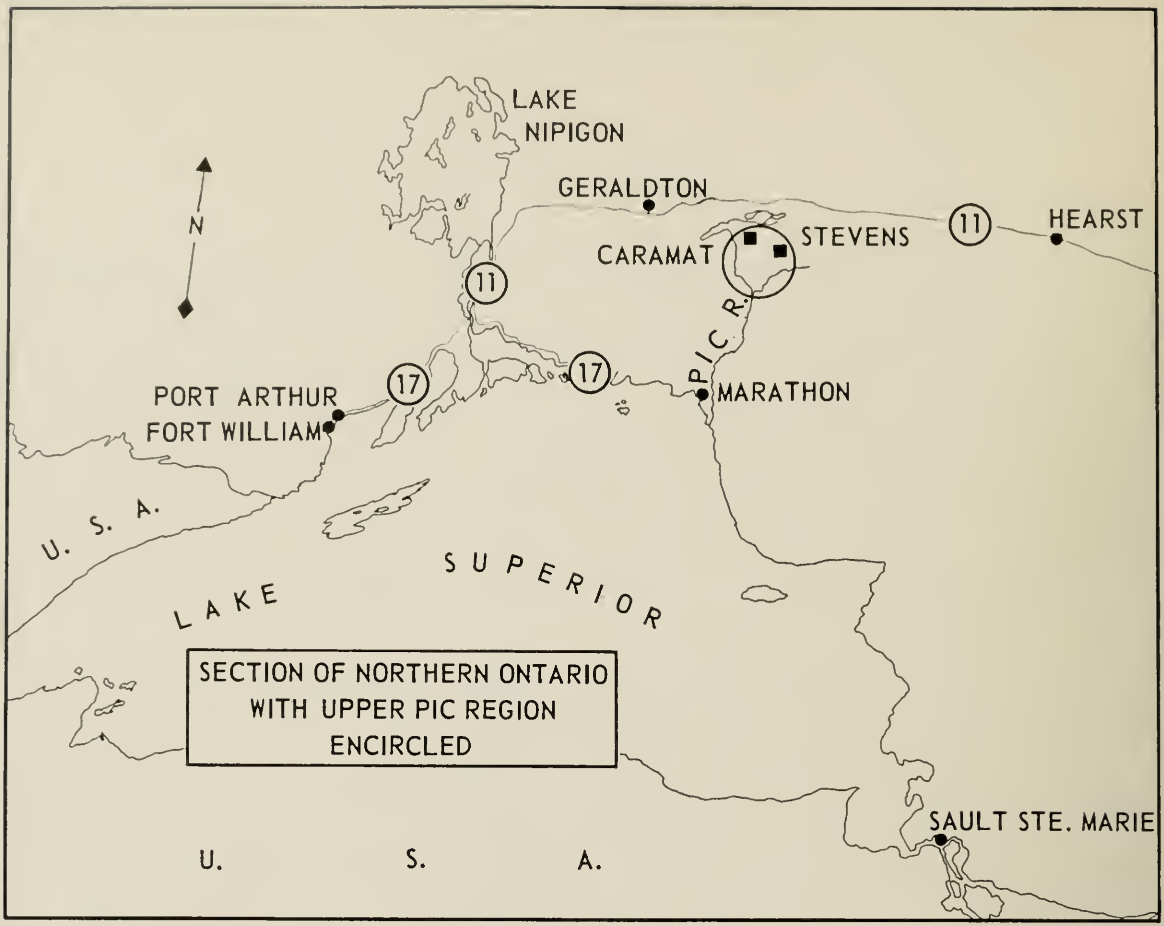

FIGURE 1 Map showing location of the region investigated.

the land area. These plains have fair drainage and the soil horizons are better developed than are those of the drift-covered slopes. Eskers and kames account for about 15 per cent of the study area. The soils of these ridges are pebbly and are excessively drained. The remaining 25 per cent of the land area is composed of lacustrine flats associated with river valleys. The soils in these areas are composed of silts and fine sands several feet deep which usually rest on varved clay deposits. Drainage is impeded because of the silts and clays, and where the slopes are less than 1 per cent is probably inadequate.

The slopes and hilltops of the Upper Pic region generally support stands of aspen with some white birch (*Betula papyrifera* Marsh.). Spruce and balsam fir (*Abies balsamea* (L.) Mill.) are usually scattered throughout these stands; the latter is particularly noticeable where the broad-leaved species are overmature. Black spruce (*Picea mariana* (Mill.) B.S.P.), white spruce (*Picea glauca* (Moench) Voss), and balsam fir are found on the lower slopes and in the valleys, while stands of jack pine (*Pinus banksiana* Lamb.) occur on many of the sandy outwash plains.

Forty-five plots, ranging in size from 1/10 to 1/2 ac. and totalling 10 ac., were established in pure or nearly pure aspen stands of different ages and on different sites. These stands were considered representative of optimum stocking for aspen in the Upper Pic region. The stand composition by species on these plots is presented in Table I. Aspen accounted for over 60 per cent of the trees of merchantable pulpwood size, and considerably more of the merchantable

Table I

A COMPOSITE TALLY OF THE TEN ACRES IN THE SAMPLE PLOTS ESTABLISHED IN ASPEN STANDS IN THE UPPER PIC REGION OF ONTARIO

Species	Number of trees: 3.4 in. D.B.H.* and less	3.5 in. D.B.H.* and over (merchantable pulpwood size)	Merchantable trees per acre
Aspen poplar	40	1,843	184
Balsam poplar	—	14	1
White birch	53	189	19
Balsam fir	788	489	49
Black spruce	132	232	23
White spruce	113	177	18
Jack pine	—	26	3
Total	1,126	2,970	297

*Diameter at breast height ($4\frac{1}{2}$ ft.), outside bark.

pulpwood volume, on these plots. Balsam fir accounted for 70 per cent of the trees that were below merchantable pulpwood size. The underbrush of these stands consisted mainly of mountain maple, witch hazel, mountain ash, and alder.

METHODS OF STUDY

Field Procedure

On each plot all living aspen trees measuring over 5 in. D.B.H.[2] were felled and bucked into 4- or 8-ft. bolts up to a $3\frac{1}{2}$-in. top diameter. The transverse face of each bolt was carefully examined for the presence of stain and decay, and, when necessary, bolts were sectioned again to determine the extent of disappearing decays. Each tree was plotted and described in detail on a tree-measurement form, Form SFB 239, a modification of the United States Department of Agriculture Form 558A.

Wood that was noticeably softer than normal healthy aspen wood was classified as decay. In many instances, particularly in younger trees, the reduction in strength of decayed wood was very slight; this wood was referred to as incipient decay. Discolored wood which seemed as hard as healthy wood when tested with the point of a sharp knife, was recorded as stain. It was sometimes difficult to distinguish between stain and incipient decay, particularly in younger trees.

Past experience has shown that decay in aspen associated with *Fomes igniarius* var. *populinus* (Neu.) Campb. is quite distinctive and easily recognized; it can be identified in the field by visual inspection. For this reason, only a few samples of this decay were collected. Samples were collected of all other decays and of about one half of the stains encountered; these were shipped to the Laboratory at Maple where the fungi associated with these defects were isolated. Those organisms that could not be identified at Maple were sent to the Botany and Plant Pathology Division at Ottawa, where they were identified by Dr. M. K. Nobles and her staff.

[2]Outside bark diameter at a height of $4\frac{1}{2}$ ft.

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Stand ages were determined by counting the annual rings of aspen trees at stump height. The total height of each tree was also measured. Each sample plot was assigned to one of four site types, based mainly on an estimate of the availability of soil moisture, arrived at by examining soil pits, topography, and other related features. All visible wounds and fungus sporophores on each tree were recorded.

Office Tabulations

The total volume in cubic feet of each tree was calculated from the area representing this volume on each tree-measurement form. The volumes of the different types of stain and heart rot within the merchantable portions[3] of the trees were determined in the same manner.

The total merchantable volume in cubic feet of each tree was also computed according to the Ontario scaling regulations (1). Deductions for heart rot were made according to these regulations. For these computations, one half of the trees were scaled from the bases of the 8-ft. logs, the remainder from the tops.

In addition to the site classification based on soil moisture, the site of each plot was classified on the stand-height development basis as outlined by Plonski (4). The average stand height for each plot was determined by calculating the mean height of dominant and codominant aspen trees of approximately average diameter at breast height.

STAIN AND DECAY IN LIVING ASPEN

A total of 1754 aspen were felled and examined during the course of this investigation. Decay was detected within the merchantable portion of the boles of 1212, or 69.3 per cent, of these trees. Butt rot was encountered in 530, or 30.2 per cent, of the trees, and 1108, or 63.2 per cent, were infected with trunk rot. Practically all of the 542 trees with no detectable decay occurred in stands younger than 100 years old. All trees with the exception of a few in the younger stands had some stained heartwood.

Two distinctly different stains were frequently encountered in aspen heartwood. One was light brown to dark grayish brown (Figures 2 and 3); the other was predominantly red, although usually mottled with yellow, brown, and green hues (Figures 4 and 5). Both stains occurred extensively in the central heartwood of aspen in young stands prior to or concurrently with the development of heart rot.

In maturing aspen, portions of the heartwood almost always became decayed. In the aspen sampled, these heart rots were invariably surrounded by stained wood. This stain was generally light brown and quite extensive when associated with small or incipient decays, and dark brown to grayish brown in the form of a fairly narrow collar when it surrounded extensive, advanced decays. Red mottled stain occasionally replaced the brown stain in this association, and was frequently observed mixed with the extensive brown stain which was nearly always present at stump height in aspen of all ages. In many mature and overmature defective trees, this mottled stain was the only interior defect in the top logs cut in the vicinity of the crowns. Red mottled stain was also frequently associated with knots and branch stubs in trees of all ages.

[3]Between stump height (1 ft.) and a 3½-in. top diameter.

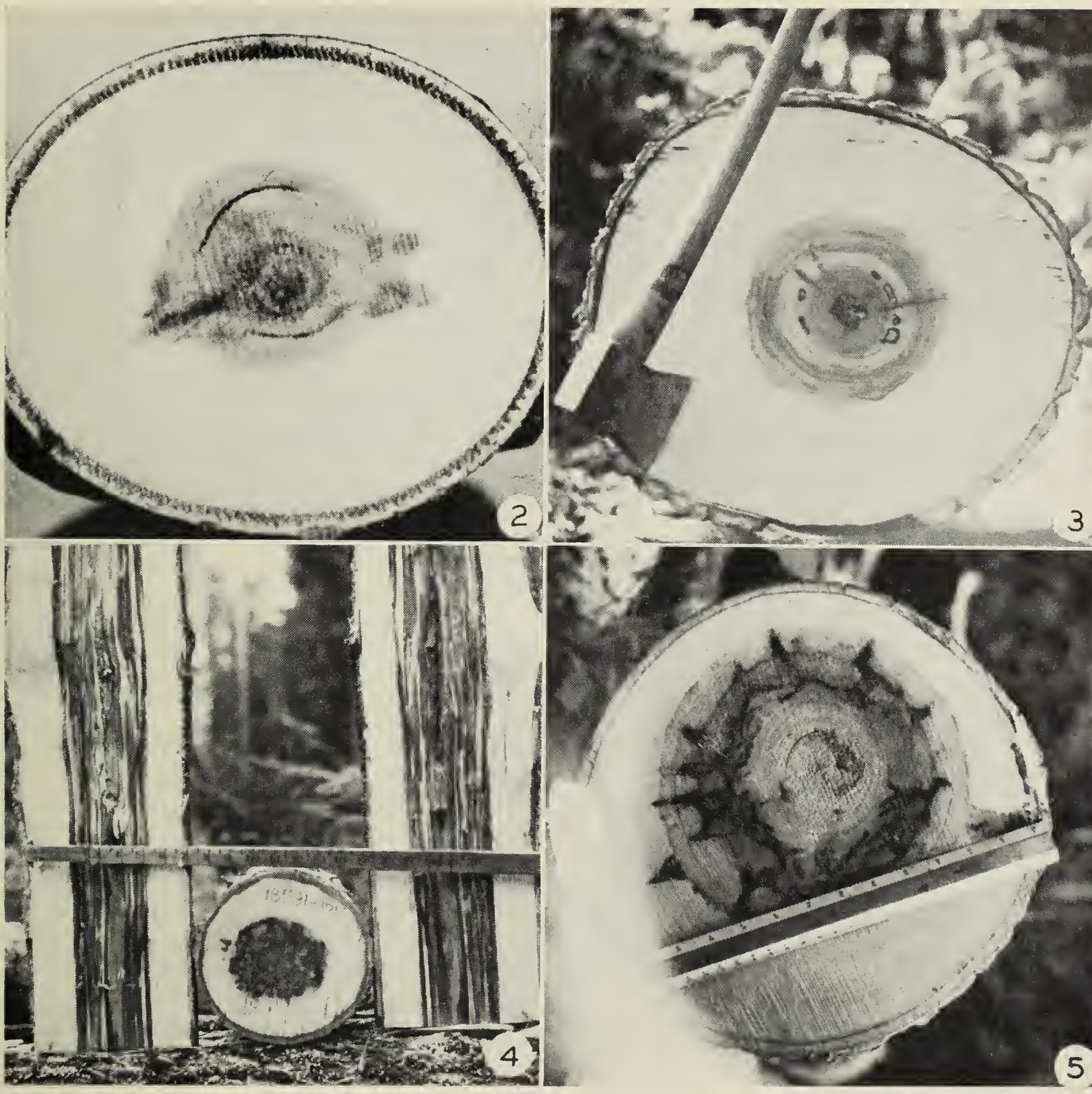

PLATE I

FIGURE 2 Transverse section of aspen with light brown stain surrounding incipient decay.

FIGURE 3 Transverse section of aspen with grayish brown stain surrounding small pockets of spongy trunk rot.

FIGURE 4 Transverse and longitudinal sections of the trunk of an aspen estimated to be 76 years old. The sections include the portion of the trunk from 16 to 20 ft. above ground level, and show extensive red mottled stain in the heartwood.

FIGURE 5 Transverse section of aspen with red mottled stain surrounding incipient decay.

The percentages of the total tree volume affected by the two types of stain in stands of different ages are shown in part 1 of Table II. It is evident that red mottled stain occupied approximately 2 per cent of the total tree volume at all ages, whereas the percentage of the volume affected by brown stain increased from about 10 per cent in stands 41 to 60 years old to over 20 per cent in stands over 120 years old.

The decays encountered in living aspen may be divided into three broad types. The first and most prevalent of these is that associated with *Fomes igniarius*. This is a yellowish white trunk rot[4] or butt rot[5] with characteristic

[4]Occurring in the stem but seldom extending down to ground level.

[5]Confined to the roots and base of the stem.

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Table II

THE OCCURRENCE OF STAIN AND HEART ROT AT DIFFERENT AGES IN ASPEN IN THE UPPER PIC REGION OF ONTARIO

Age class	Percentage of the total volume of trees stained within the merchantable portions of those trees			Percentage of the total volume of trees decayed within the merchantable portions of those trees.			
	Red mottled stain	Brown stain	Total stain	White spongy rot (*Fomes igniarius*)	Stringy trunk rot	Stringy butt rot	Total rot
41–60	3.2	9.4	12.6	0.7	0.2	0.1	1.0
61–80	1.5	13.2	14.7	1.4	1.3	0.0	2.7
81–100	1.4	16.7	18.1	3.6	1.0	0.4	5.0
101–120	1.2	17.6	18.8	4.7	3.2	0.3	8.2
121–140	1.9	21.7	23.6	6.1	1.5	0.4	8.0
141–160	2.2	20.4	22.6	12.3	1.2	1.1	14.6
161–180	2.1	22.3	24.4	10.9	1.3	4.6	16.8
Average........	1.7	18.2	19.9	6.4	1.5	0.7	8.7
Total volume of defect (cu. ft.)	679.2	7,173.3	7,852.5	2,532.6	605.3	273.5	3,411.4
Percentage of total rot or stain.........	8.6	91.4		74.3	17.7	8.0	

black zone lines; the wood texture varies from fairly firm to punky or spongy, depending upon the stage of decay (Figures 8 to 11). The fruiting bodies of *F. igniarius* are fairly large and woody, with black, wrinkled upper surfaces and brown lower pore surfaces (Figures 6, 7, and 11). The second type is a yellow or yellow-brown stringy trunk rot. All stages of this decay were encountered, ranging from incipient to advanced (Figures 13 to 15). A basidiomycete, *Radulum casearium* (Morgan) Lloyd, accounted for over 80 per cent of the identified isolates obtained from samples of yellow stringy trunk rot. The fruiting bodies of this fungus are yellow-brown, resupinate, with coarse teeth (Figure 12). The third type is a yellow or yellow-brown stringy butt rot (Figures 18 to 21). This decay usually occurs as cones of advanced rot 1 to 3 in. in diameter at stump height, tapering out usually 2 or 3 ft. above ground level, although in a few instances extending to 9 ft. Two fungi, *Pholiota spectabilis* Fr. and *Armillaria mellea* (Vahl ex Fr.) Quél., accounted for approximately two thirds of the identified isolations obtained from samples of this type of decay. The fruiting bodies of both fungi are mushroomlike, and often develop in clusters on dead stumps or at the base of dying or dead trees (Figures 16 and 17).

The two types of trunk rot were frequently mingled in a single tree, and frequently the stage of decay and diameter of rot varied considerably at the different saw cuts. In overmature trees they generally occurred as extensive columns throughout most of the merchantable bole, occupying all or most of the heartwood. As mentioned previously, all three types of decay were always surrounded by firm, stained wood. The average volume of decay in the merchantable portion of each infected tree was 3.4 cu. ft. for *Fomes igniarius* decay, 1.1 cu. ft. for yellow stringy trunk rot, and 0.6 cu. ft. for stringy butt rot. Although there were nearly as many trees with yellow stringy trunk rot as there were with *Fomes igniarius* decay, the latter type of rot accounted for roughly four times as much decay, on a volume basis, as the former (Table II).

PLATE II

FIGURES 6 AND 7 *Fomes igniarius* fruiting bodies on living aspen trees.

FIGURE 8 Transverse and longitudinal sections of aspen decayed by *F. igniarius*. The characteristic black zone line can be seen at the border between this decay and the encompassing collar of grayish brown stain.

FIGURE 9 Transverse sections of aspen decayed by *F. igniarius*, showing radial extensions of the decay associated with dead branch stubs.

FIGURE 10 Transverse and longitudinal sections of aspen showing the association of *F. igniarius* decay with a dead branch stub.

FIGURE 11 Transverse section of aspen with extensive *F. igniarius* decay, showing lower pore surface of a fruiting body.

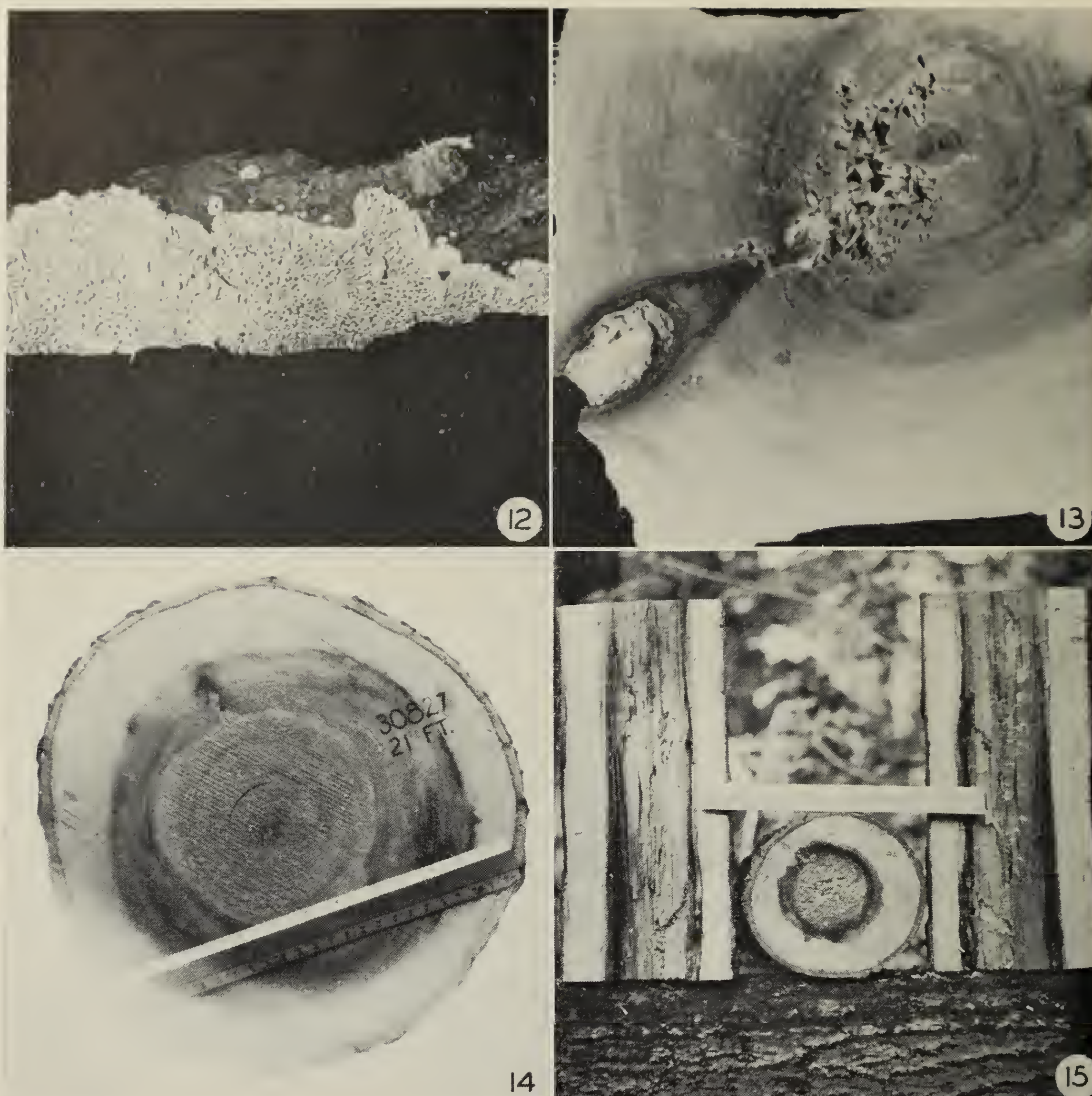

PLATE III

FIGURE 12 *Radulum casearium* fructification growing on the underside of an old aspen log.

FIGURE 13 Transverse section of aspen with a small central core of yellow stringy trunk rot, and red mottled stain associated with a knot.

FIGURE 14 Transverse section of yellow stringy trunk rot in aspen.

FIGURE 15 Transverse and longitudinal sections of aspen with advanced yellow stringy decay.

The percentages of the total volume of aspen affected by the three types of decay at different stand ages are presented in Table II. In stands more than 60 years old, age apparently had very little effect upon the percentage of the total volume affected by yellow stringy trunk rot, whereas there was a marked relationship between age and the percentage of the total volume affected by *Fomes igniarius* decay. Almost three fourths of the total volume of rot encountered in this study was attributed to *Fomes igniarius*. It is evident that in stands younger than 140 years, stringy butt rots accounted for a negligible volume of decay in the merchantable portions of the sampled trees. Although butt rots accounted for only 7.5 per cent of the total rot volume, their importance is not fully indicated by this figure. If losses from wind breakage indirectly due to butt rot could have been tabulated, it is possible that total volume losses caused by butt rot would have equalled or perhaps even surpassed those caused by trunk rot.

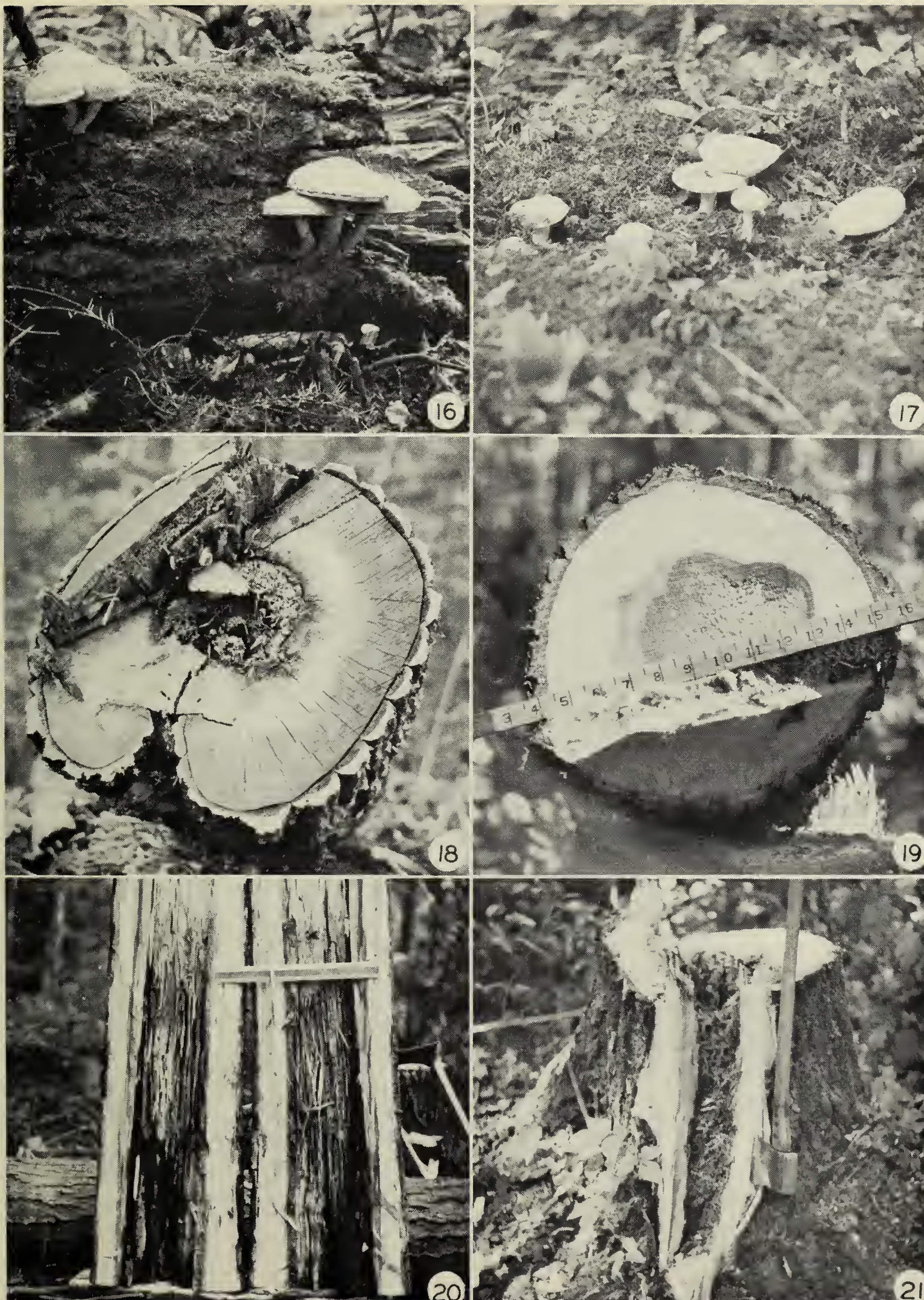

PLATE IV

FIGURE 16 *Pholiota spectabilis* fruiting bodies.

FIGURE 17 *Armillaria mellea* fruiting bodies.

FIGURE 18 Transverse section of aspen with yellow stringy butt rot from which *P. spectabilis* was isolated.

FIGURE 19 Transverse section of aspen with yellow stringy butt rot from which *A. mellea* was isolated.

FIGURE 20 Longitudinal section of aspen with yellow stringy butt rot from which *P. spectabilis* was isolated.

FIGURE 21 Longitudinal section of aspen with yellow stringy butt rot from which *A. mellea* was isolated.

ENTRANCE OF FUNGI AND EXTERNAL INDICATIONS OF DECAY

It is sometimes difficult to ascertain the exact mode of entrance of a fungus suspected of having caused heart rot in a living tree. For this reason definite figures for the frequency with which different avenues of entrance associated with decay were used cannot be given. The conclusions are based upon general observations, and upon the majority of decays which fortunately permitted the determination of the point of entrance of the associated fungus or fungi with reasonable accuracy.

Most of the fungi responsible for butt rot in aspen probably entered through roots. Aspen occurs in relatively pure, dense stands with intermingling root systems and the breakage of small rootlets, because of frost heaving and wind bending, may provide good infection courts. It seems likely that those fungi associated with most butt decays in aspen can and do exist throughout much of the root system. There is little doubt that many of the 1224 trees recorded as sound at stump height actually were infected by butt-rot fungi in the roots and in the stem below stump height. Stringy butt rots were associated with each of the 56 basal scars encountered in the first 24 sample plots, indicating that a minority of butt rot infections probably originated from basal wounds such as fire scars, frost cracks, and basal branch stubs.

The fungi connected with trunk rots of aspen appear to be limited to one main avenue of entrance. Approximately 90 per cent of these rots could be traced to dead, broken branch stubs (Figures 22, 23, and 26). As an aspen tree ages, the lower branches continually die and break off, providing direct passages for the entry of decay-causing fungi through the resistant sapwood into the heartwood. A few trunk rot infections originated in forked crowns, frost seams, and at mechanical injuries (Figures 24, 25, and 27). Seventy-five aspen with pronounced trunk wounds were encountered on the first 24 sample plots; of these, 63, or 85 per cent, had extensive heart rot. Thus, visible trunk wounds in aspen are fairly reliable indicators of heart rot.

The most reliable external indication of decay in aspen is unquestionably the appearance of *Fomes igniarius* fruiting bodies. These often project from branch stubs scattered throughout the length of the bole (Figure 7). The occurrence of a series of conks on a single tree, or of conks exceeding 4 in. in width, invariably was associated with extensive *F. igniarius* heart rot. The close relationship between the occurrence of *F. igniarius* fruiting bodies and the presence of *F. igniarius* decay in aspen stands older than 60 years is shown in Table III.

TABLE III

THE RELATION BETWEEN THE NUMBER OF VISIBLE *FOMES IGNIARIUS* FRUITING BODIES AND THE OCCURRENCE OF *F. IGNIARIUS* DECAY IN ASPEN

Age class	Number of trees sampled	Number of trees with *F. igniarius* decay	Number of trees with one or more visible *F. igniarius* fruiting bodies	Percentage of trees with *F. igniarius* decay with fruiting bodies
41– 60	131	18	11	61.1
61– 80	271	52	41	78.8
81–100	553	183	150	82.0
101–120	357	179	151	84.4
121–140	165	100	86	86.0
141–160	238	170	166	97.6
161–180	39	29	25	86.2

PLATE V

FIGURE 22 Branch stub on the trunk of a living aspen.

FIGURE 23 Longitudinal section through the branch stub illustrated in Figure 22, showing the development of stain and incipient decay from this locus.

FIGURE 24 Large wounds on the trunks of aspen in a stand estimated to be 92 years old.

FIGURE 25 Transverse section of wounded aspen trunk illustrated in Figure 24, showing extensive heart rot associated with this wound.

FIGURE 26 Aspen trunk with wounds caused by the breakage of dead branches.

FIGURE 27 Transverse section of aspen showing rot and stain associated with a frost seam.

DECAY RELATIONSHIPS

Decay in Relation to Stand Age

From Table IV it is evident that the percentage of aspen trees with heart rot in the merchantable portion of the bole increased steadily from 26.7 per cent in stands at age class 41-60 to 100 per cent in stands at age class 161-180. This is not surprising since the number of infection courts and the time they have been effective increase with increasing age of the trees. Many decayed trees in young stands had only traces of heart rot, whereas the majority of infected trees in older stands had extensive decay. For example, the average volume of heart rot encountered in a decayed aspen tree in stands within the 41-60 age class was only 0.3 cu. ft., compared with approximately 7 cu. ft. per infected tree in stands older than 140 years. For this reason, not only the occurrence of infected trees but also the volume of heart rot must be considered if a reasonable assessment of the relationship between age and decay is to be made. The percentage of the merchantable volume of the sample trees deducted because of heart rot was calculated according to the Ontario scaling regulations (1). The pronounced increase in the magnitude of these deductions with increasing stand age is evident from Figure 28 and the last two columns of Table IV.

Table IV

THE RELATION BETWEEN AGE, INCIDENCE OF, AND DEDUCTIONS BECAUSE OF HEART ROT IN ASPEN IN THE UPPER PIC REGION OF ONTARIO

Age class	Average tree age	Number of trees sampled	Trees with heart rot		Total merchantable volume of sample trees, Ontario scaling regulations, cu. ft.	Total volume deducted because of heart rot, Ontario scaling regulations, cu. ft.	Percentage of merchantable volume deducted because of heart rot	
			Number	Percentage			Actual	Curved*
41- 60....	48	131	35	26.7	833.3	12.5	1.5	2.0
61- 80....	71	271	130	47.8	3,571.4	167.9	4.7	4.2
81-100....	92	553	321	58.0	9,009.0	657.7	7.3	7.2
101-120....	111	357	313	88.9	6,909.1	863.6	12.5	10.7
121-140....	128	165	149	90.3	5,092.6	509.3	10.0	14.6
141-160....	150	238	225	94.5	9,761.9	2,176.6	22.4	20.1
161-180....	166	39	39	100.0	1,571.4	422.7	26.9	27.8
Total......		1,754	1,212		36,748.7	4,810.3		
Average....				69.3			13.1	

*Percentages read from curve shown in Figure 28.

The site class of each plot was classified on the basis of stand-height development as outlined by Plonski (4). The age–height curves for aspen, Figure 11 of Plonski's report, indicate that 27 of the 45 sample plots in this study were in the "middle or average" site class, Site-class 2. All but four of the remaining 18 plots were outside but close to the limits of Site-class 2. It is assumed, therefore, that in the Upper Pic region most aspen stands fall in the Site-class 2 classification.

The sample plots which form the basis for this study were established in stands 40 to 170 years old which were considered representative of optimum stocking for aspen in the Upper Pic region. A normal yield table for aspen stands 20 to 100 years old in Site-class 2, based on stands of optimum stocking in northern

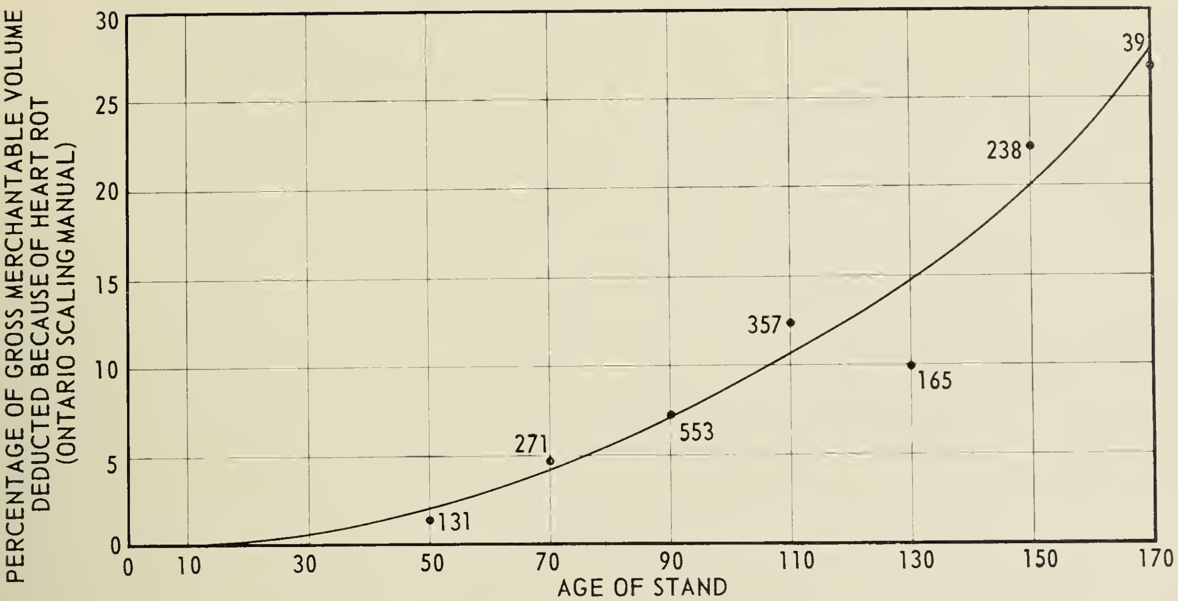

FIGURE 28. Relationship between age of stand and percentage of gross merchantable volume deducted because of heart rot in aspen in the Upper Pic region of Ontario.

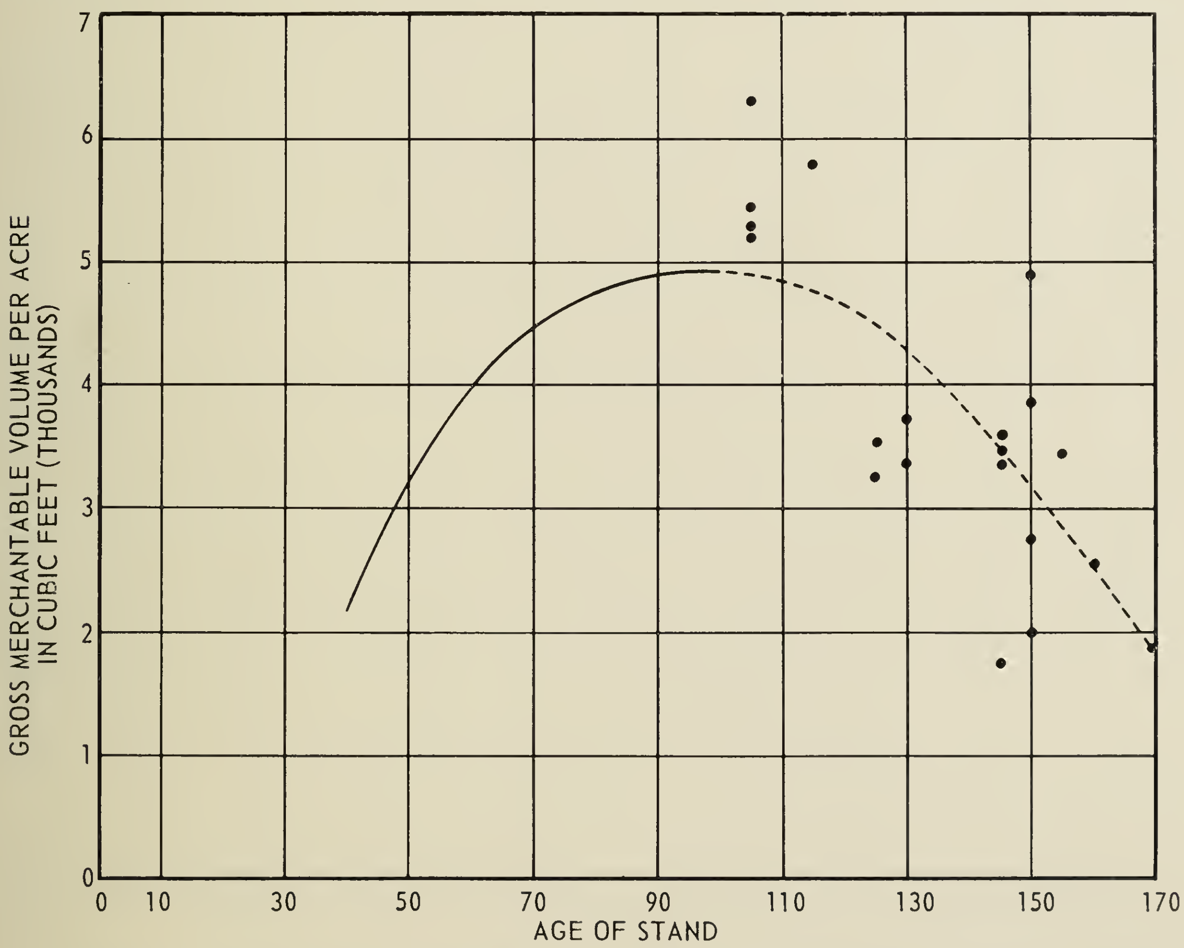

FIGURE 29. Relationship between age of stand and gross merchantable volume per acre in aspen in the Upper Pic region of Ontario. Dots represent values for the sample plots located in stands older than 100 years. The solid-line portion of the curve is based on Table 10 of Plonski's report (4), the broken-line portion is an extrapolation of that curve.

Ontario, is presented in Table 10 of Plonski's report. The average gross merchantable volume per acre of stands sampled from 40 to 100 years old was, as would be expected, quite comparable in both studies. Figure 29 shows how the average gross merchantable volume per acre of aspen stands from 100 to 170 years old in the Upper Pic region was determined. The dots in this figure represent the gross merchantable volumes per acre of the sample plots located in stands over 100 years old. The solid-line curve is based on Table 10 of Plonski's report; the broken-line portion is an extrapolation of this curve, based on the 100- to 170-year-old sample plot values.

The relation between age and gross and net increment in aspen stands in the Upper Pic region of Ontario is presented in Table V. A comparison between gross and net merchantable volumes per acre is also presented in this table. It is evident that whereas the gross merchantable volume per acre is greatest at 100 years, the net merchantable volume per acre is at a maximum at 90 years. The mean annual increment reaches a peak value at 60 years for both gross and net volumes.

Table V

THE RELATION BETWEEN AGE AND GROSS AND NET INCREMENT IN ASPEN STANDS IN THE UPPER PIC REGION OF ONTARIO

Age of stand	Gross merchantable volume, cu. ft. per acre*	Gross increment		Percentage of merchantable volume deducted because of heart rot**	Volume deducted because of heart rot, cu. ft. per acre	Net merchantable volume, cu. ft. per acre	Net increment	
		Current annual	Mean annual				Current annual	Mean annual
40	2150		53.8	1.3	28	2122		53.1
		105.3					101.7	
50	3203		64.1	2.0	64	3139		62.8
		75.9					70.4	
60	3962		66.0	3.0	119	3843		64.1
		50.2					43.4	
70	4464		63.8	4.2	187	4277		61.1
		29.7					21.7	
80	4761		59.5	5.6	267	4494		56.2
		13.5					4.9	
90	4896		54.4	7.2	353	4543		50.5
		1.9					− 6.5	
100	4915		49.2	8.9	437	4478		44.8
		− 6.5					−14.7	
110	4850		44.1	10.7	519	4331		39.4
		−20.0					−26.7	
120	4650		38.8	12.6	586	4064		33.9
		−37.5					−42.2	
130	4275		32.9	14.8	633	3642		28.0
		−49.0					−51.2	
140	3785		27.0	17.3	655	3130		22.4
		−60.0					−58.5	
150	3185		21.2	20.1	640	2545		17.0
		−67.5					−63.0	
160	2510		15.7	23.7	595	1915		12.0
		−67.0					−59.0	
170	1840		10.8	28.0	515	1325		7.8

*Values for 40 to 100 years taken from Table 10 of Plonski, W.L., Normal yield tables for black spruce, jack pine, aspen and white birch in northern Ontario, 1956. Remaining values read from broken-line portion of curve shown in Figure 29.

**Values read from curve shown in Figure 28.

The relationships between gross and net merchantable volumes and volumes deducted because of heart rot in aspen stands in the Upper Pic region is illustrated in Figure 30. The volume per acre deducted because of heart rot begins to decrease as stands pass the 140 year mark. The reason for this is that the greater average volume deducted per tree in these older stands is more than compensated

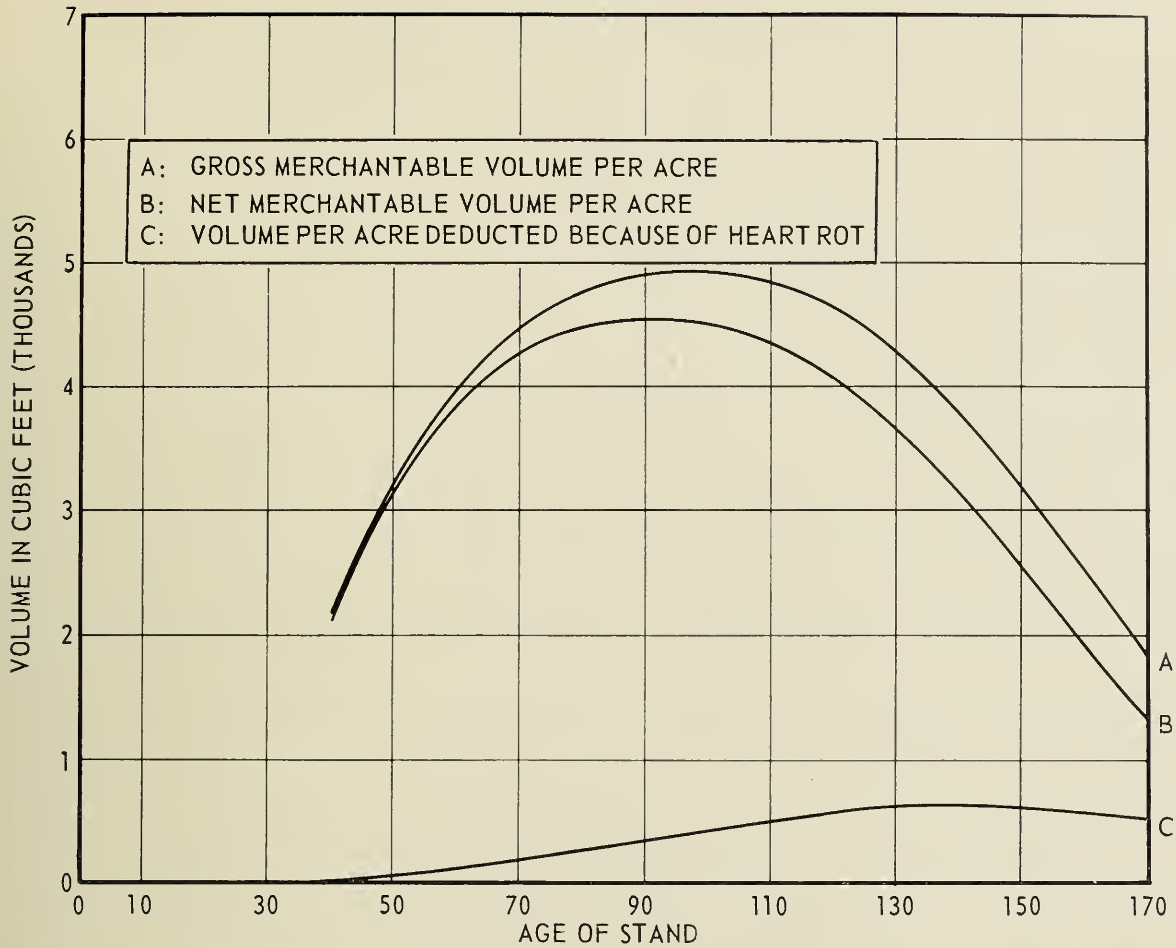

Figure 30. Relationship between age and gross volume per acre, net volume per acre, and volume per acre deducted because of heart rot in aspen in the Upper Pic region of Ontario.

for by the decrease in the gross merchantable volume per acre because of natural mortality.

In calculating the portion of the gross merchantable volume of aspen deducted because of heart rot, no deductions were made for stained heartwood, in accordance with the Ontario scaling regulations (1). It was shown in Table II that an increase in the percentage of the tree volume affected by heartwood stain occurred with increasing stand age. Hence, the net merchantable volume per acre shown in Table V and in Figure 30 would, as a rule, include a higher proportion of stained wood in older stands than it would in younger stands.

Decay in Relation to Tree Diameter

All the sample plots were established in even-aged aspen stands, nevertheless there was a wide distribution of diameter classes in practically every plot. To determine whether or not there was any noticeable difference in the extent of heart rot deductions between aspen of different diameters irrespective of age, the trees in each sample plot were classified into two groups. Trees 9.5 in. D.B.H. and over were assigned to one group, and the smaller trees were placed in the other.

The increase with age in the percentage of the gross merchantable volume of aspen trees deducted because of heart rot, for the two groups of trees, is illustrated graphically in Figure 31. The values derived from these curves at 10-year intervals are presented in Table VI. It is evident that, in general, a greater

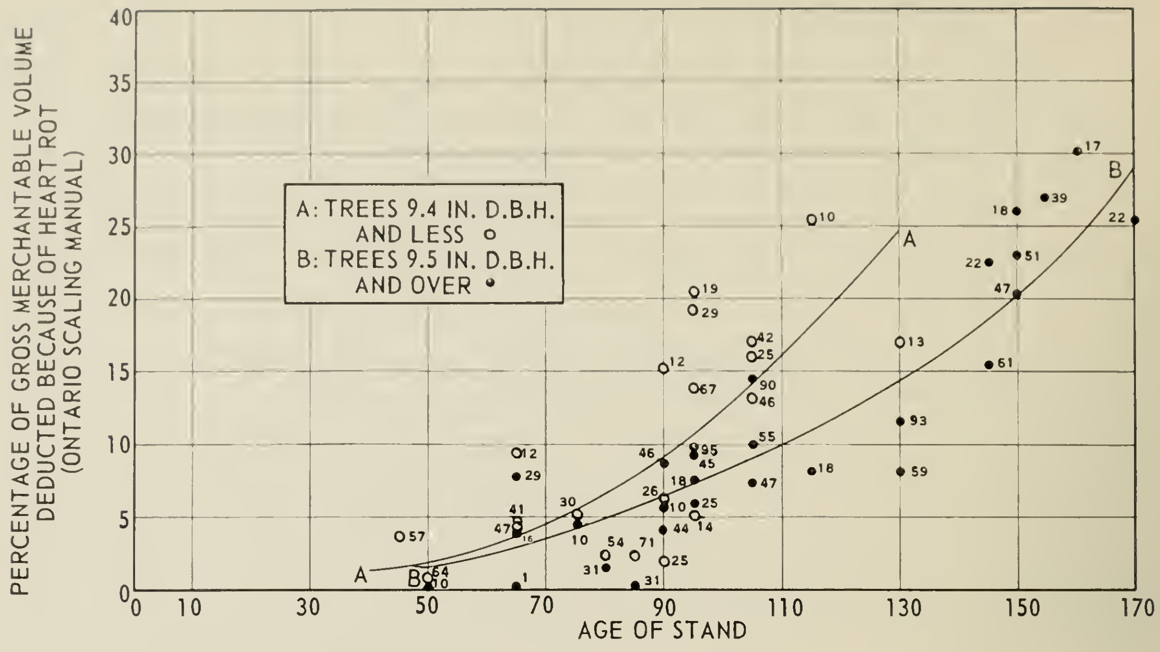

FIGURE 31. Relationship between age of stand and percentage of gross merchantable volume deducted because of heart rot in two diameter class groups of aspen in the Upper Pic region of Ontario.

TABLE VI

A COMPARISON OF HEART ROT DEDUCTIONS IN SMALL AND LARGE TREES IN ASPEN STANDS IN THE UPPER PIC REGION OF ONTARIO

Age of stand	Percentage of merchantable volume deducted because of heart rot, Ontario scaling regulations*	
	Trees 9.4 in. D.B.H.** and less	Trees 9.5 in. D.B.H.** and over
40	1.3	—
50	1.8	1.5
60	2.9	2.4
70	4.5	3.5
80	6.6	4.8
90	9.2	6.4
100	12.4	8.1
110	16.1	10.0
120	20.2	12.0
130	24.7	14.3
140	—	17.0
150	—	20.2
160	—	24.0
170	—	29.0

*Values read from curves shown in Fig. 31.

**Diameter at breast height ($4\frac{1}{2}$ ft.), outside bark.

percentage of the merchantable volume of trees under 9.5 in. D.B.H. was deducted because of heart rot than of the larger trees in even-aged aspen stands in the Upper Pic region. This difference increases with increasing stand age, and is particularly pronounced in stands older than 90 years. It is perhaps significant that of the 36 sample plots with at least three aspen trees in each diameter group, this relationship was encountered in all but four plots.

Decay in Relation to Site

The growth and yield of a forest stand is undoubtedly related to the nature of the soil. However, there is much conflicting evidence concerning the effect of soil conditions upon the extent of heart rot in trees (5). This is not surprising when one considers that trunk rots, which generally account for a far greater proportion of the decay volume than butt rots, originate mainly at branch stubs or trunk wounds and hence are less likely to be directly influenced by soil characteristics. Nevertheless, indirect influences of the nature of the soil on the progress of trunk rots through changes in the growth rate, vigor, and moisture content of the tree, and in stand density should not be overlooked.

In forestry, the capacity of an area to support forest growth is referred to as site. Although all environmental factors should be considered in determining the site of an area, it is generally agreed that the availability of soil moisture is of prime importance. In assessing the influence of this factor upon the extent of heart rot in aspen in the study region, detailed examinations of the soil conditions were made in soil pits dug to a depth of about 4 ft., or to bedrock, on each of the sample plots.

Aspen stands occur as a rule within a fairly definite range of soil conditions throughout northern Ontario. The soil types, or sites, on which aspen stands occurred in the study region were arbitrarily divided, with the assistance of foresters of the Marathon Paper Mills of Canada, Limited, into four categories, based on the site classification system designed by Hills for the forests of Ontario (3). Brief descriptions of the soils of each of these four sites follow:

Site 1: Moisture regime 1 (dry). Slightly silty or fine pervious sands, or coarse mixtures of sand and pebbles. Fast drainage.

Site 2: Moisture regime 2 (adequate). Permeability 1 or 2 (good). Medium silty or loamy sands over pervious sands or coarse material.

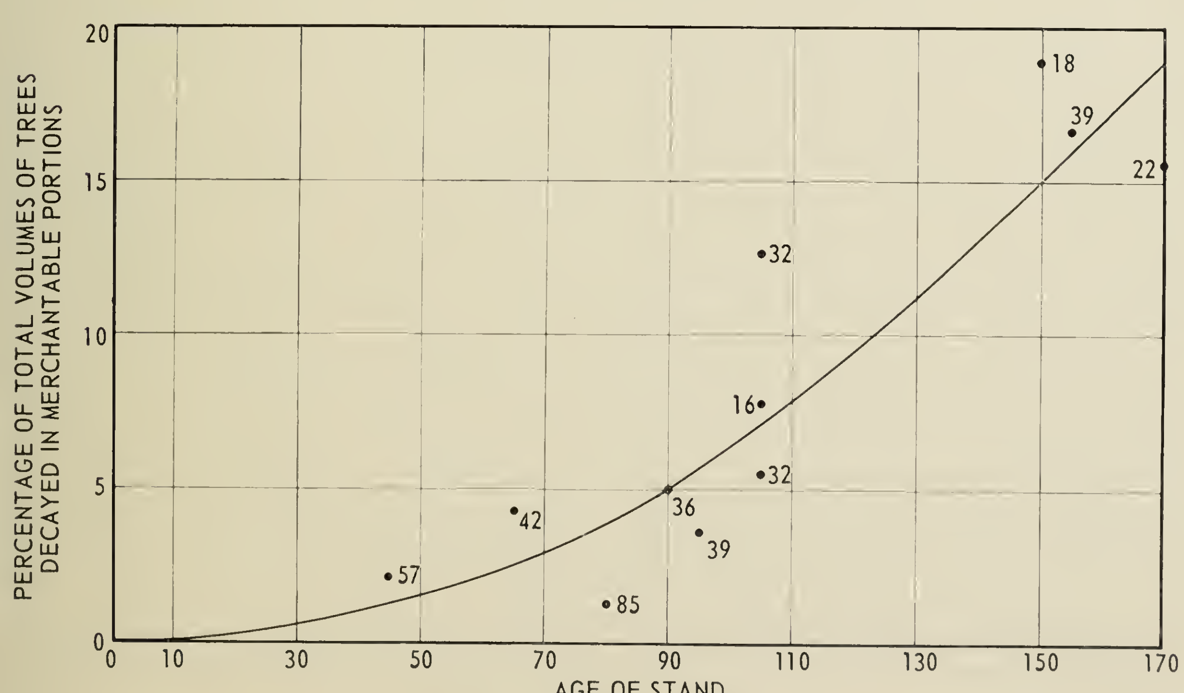

Figure 32. Relationship between age of stand and percentage of total tree volumes decayed in aspen growing on Site 1 in the Upper Pic region of Ontario.

Site 3: Moisture regime 2 (adequate). Permeability 3 to 5 over 9 (fair to poor). Deep sandy silts and loams, or shallow loams over clay or bedrock.

Site 4: Moisture regime 4 (moist). Deep silty loams and clays, or sandy loams over somewhat impervious clay.

In assessing the effects of site on the incidence of heart rot in aspen, the actual volumes of decay per tree were used, rather than those derived from the

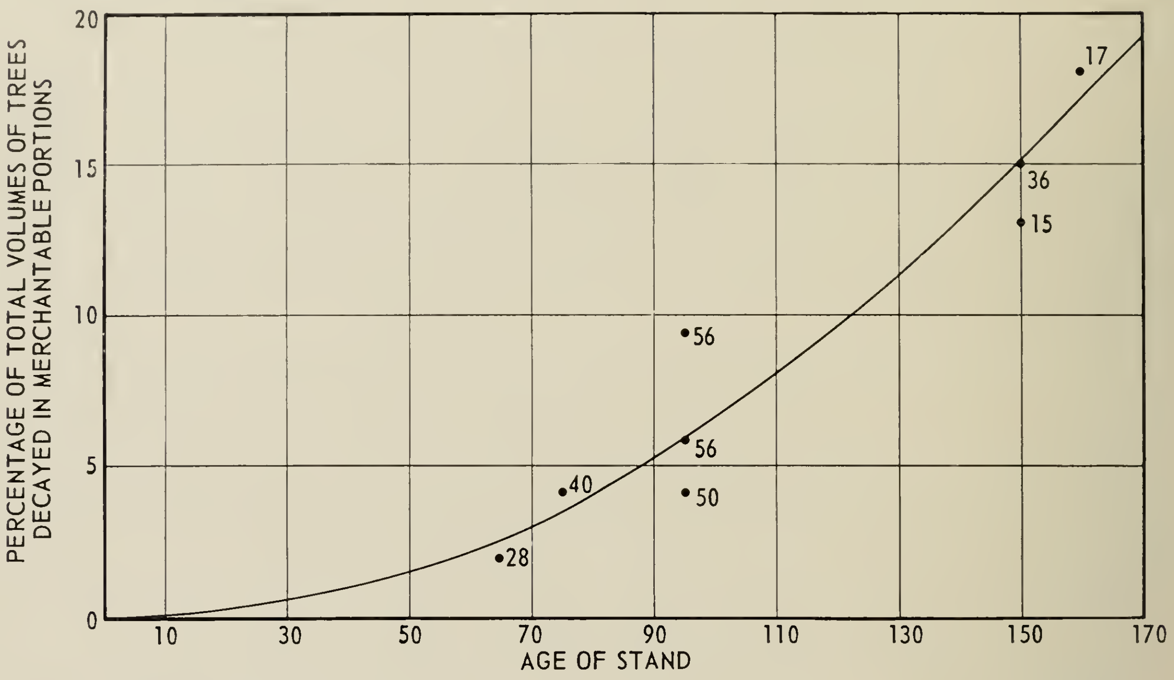

FIGURE 33. Relationship between age of stand and percentage of total tree volumes decayed in aspen growing on Site 2 in the Upper Pic region of Ontario.

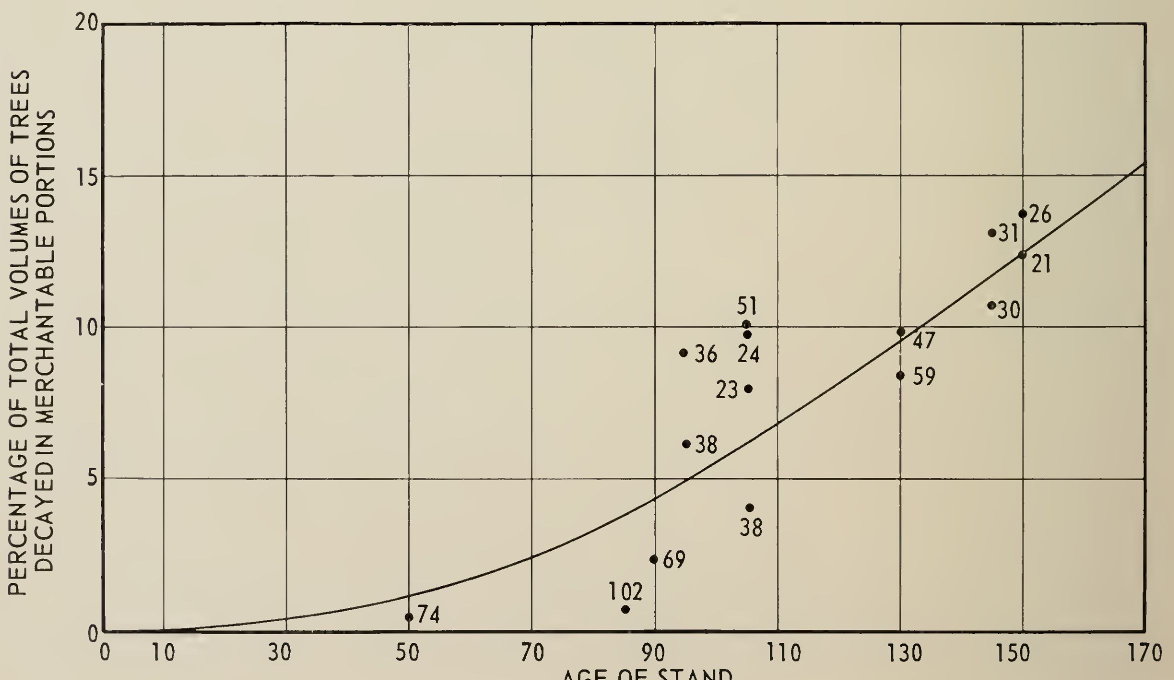

FIGURE 34. Relationship between age of stand and percentage of total tree volumes decayed in aspen growing on Site 3 in the Upper Pic region of Ontario.

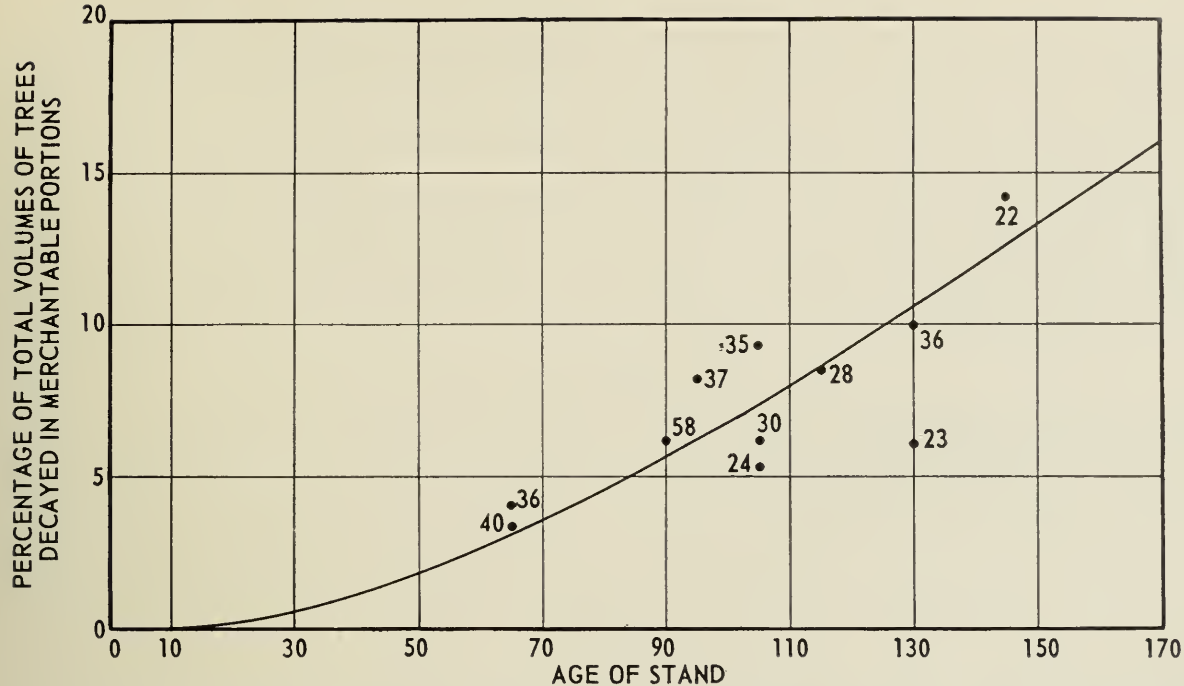

Figure 35. Relationship between age of stand and percentage of total tree volumes decayed in aspen growing on Site 4 in the Upper Pic region of Ontario.

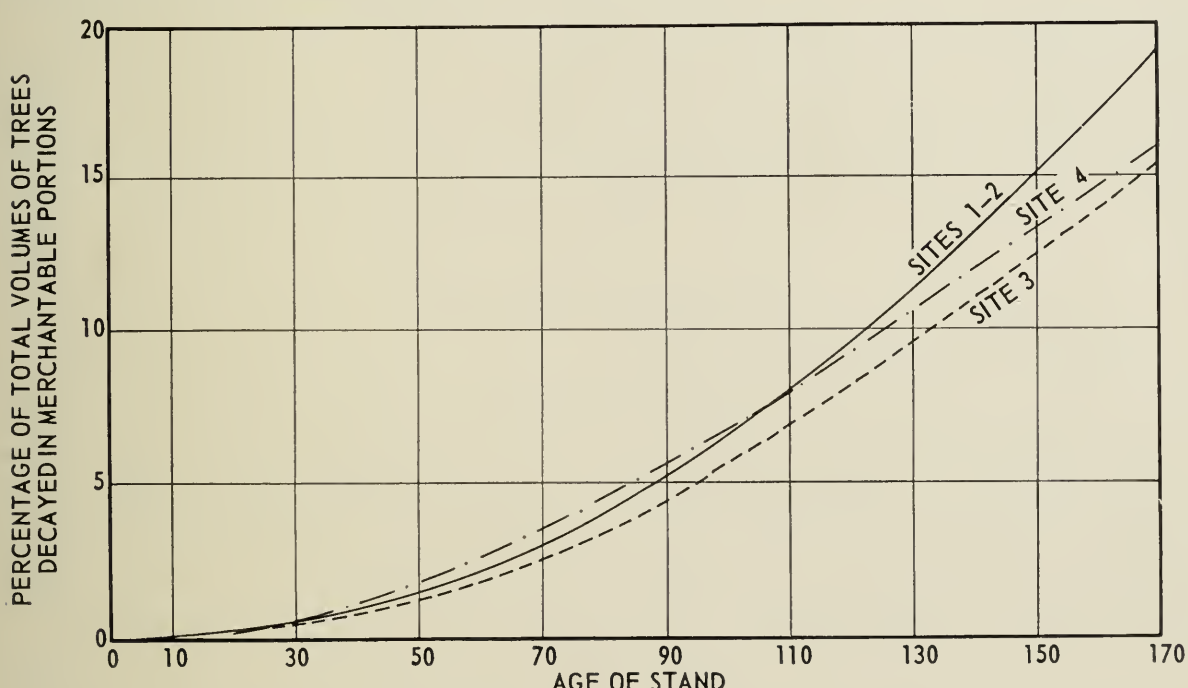

Figure 36. Relationship between age of stand and percentage of total tree volumes decayed in aspen growing on Sites 1, 2, 3, and 4 in the Upper Pic region of Ontario.

Ontario scaling regulations. This was done when it became apparent that any differences in the amount of heart rot on different sites were relatively slight. Hence, accuracy in calculating decay volumes was considered to be more important than the use of a method more suitable for practical application.

The percentages of the total volumes of trees decayed within their merchantable length at different stand ages for trees in Sites 1, 2, 3, and 4 are shown graphically in Figures 32, 33, 34, and 35, respectively. The curves in Figures 32 and 33, representing Sites 1 and 2, are almost identical and have been combined in one curve in Figure 36. The curves for Sites 3 and 4 are also presented in Figure 36 so that a direct comparison may be made of the incidence of decay at different stand ages for all four sites. This information is also summarized in Table VII. It is evident that variations in the extent of decay on the four sites were not great. Aspen stands located on deep, sandy silts or loams, or on shallow, sandy loams over impervious material (Site 3), were generally less defective than stands located on drier sites (Sites 1 and 2), or on wetter sites (Site 4). Stands on the wetter sites were somewhat more defective than those on the dry sites at ages lower than 100 years, but in stands more than 100 years old this situation was reversed.

TABLE VII

THE RELATION BETWEEN AGE, SITE, AND PERCENTAGE OF VOLUME DECAYED IN ASPEN STANDS IN THE UPPER PIC REGION OF ONTARIO

Age of stand	Curved percentage of total volume of trees decayed in the merchantable portions of those trees*			
	Site 1	Site 2	Site 3	Site 4
40	0.9	0.9	0.7	1.1
50	1.4	1.4	1.1	1.8
60	2.1	2.1	1.7	2.8
70	2.9	2.9	2.4	3.6
80	3.9	3.9	3.3	4.5
90	5.1	5.1	4.4	5.6
100	6.5	6.5	5.6	6.7
110	7.9	7.9	6.8	8.0
120	9.6	9.6	8.2	9.3
130	11.3	11.3	9.6	10.6
140	13.1	13.1	11.0	11.9
150	15.1	15.1	12.4	13.2
160	17.1	17.1	13.9	14.6
170	19.1	19.1	15.4	16.0

*Percentages read from curves shown in Figure 36.

SUMMARY

An increasing amount of aspen has been utilized by the pulp and paper industry in Ontario since World War II. Heavy decay losses are frequently encountered in aspen stands at relatively young ages. This difficulty may be minimized through enlightened management and a knowledge of the relationships between decay and age, diameter, and site.

A total of 1754 aspen trees, located in even-aged stands considered representative of the Upper Pic region of Ontario, were examined. All trees except for a few in the younger age classes had some stained heartwood. Decay was present in the merchantable portions of the trunks of 1212, or 69 per cent, of these trees. Butt rot was found in 530, or 30 per cent, of the trees, and 1108, or 63 per cent, were infected with trunk rot.

Two distinctly different types of stained heartwood were encountered. A grayish brown stain predominated, and occupied about 18 per cent of the merchantable volume of the sample trees, compared with approximately 2 per cent of the merchantable volume affected by a red mottled stain. Three types of heart rot were encountered, a white spongy trunk or butt rot, a yellow stringy trunk rot, and a brown or yellow stringy butt rot. These rots occupied 6.4, 1.5, and 0.7 per cent, respectively, of the merchantable volume of the 1754 trees sampled.

The fungi associated with butt rot in aspen probably entered mainly through the root systems, and to a less extent via basal wounds in the trunk. Most trunk rot infections could be traced to branch stubs. Fructifications of *Fomes igniarius* were the most reliable external indication of heart rot in aspen.

A pronounced relationship was found between age and decay; old stands generally contained much higher proportions of decayed heartwood than young stands. In most stands younger than 80 years, less than 5 per cent of the total merchantable volume, using the Ontario scaling regulations, was deducted because of heart rot, whereas in nearly every stand older than 140 years over 20 per cent of the merchantable volume was deducted.

The average gross merchantable volumes per acre of aspen stands in the Upper Pic region were estimated using Plonski's normal yield table for Site-class 2 (4), and an extrapolation of this table. Whereas the gross merchantable volume per acre was greatest at age 100, the net merchantable volume per acre was at a maximum at age 90. The mean annual increment was greatest at 60 years for both gross and net volumes.

A greater percentage of the merchantable volume was deducted because of heart rot for trees under 9.5 in. D.B.H. than for the larger trees. This difference was particularly pronounced in older stands.

The soil types or sites on which aspen stands occurred in the study region were arbitrarily divided into four categories, based mainly on the availability of soil moisture. Variations in the extent of decay on the four sites were not pronounced, although aspen stands located on deep, sandy silts or loams, or on shallow, sandy loams over impervious material, were generally less defective than stands located on drier or wetter sites.

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