

AN ABSTRACT OF THE THESIS OF

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Extent of Actual Incipient Decay Beyond Apparent Incipient
Decay

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Abstract Approved. -----
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High grade Sitka spruce lumber is in demand for airplane construction (training planes), and as stained material is being discarded because it is believed to be of inferior quality, a study was undertaken to determine the cause of stains and their effect on the wood.

Sitka spruce lumber with stained areas was collected at 3 mills in Oregon and Washington. Cultures were made and the following fungi were obtained: Fomes Pini, Fomes Pinicola, Polyporus sulphureus, and 3 others as yet undetermined. The first two listed were found the greatest number of times. Ten of the boards with stained areas gave negative results when cultured. As many of these boards were fresh from the mill saw, the mycelium should have grown, had any been present. As it did not, it is assumed that the stain was caused by some other agent than a fungus. ?

Examination of 5 boards, each of which was stained with a different fungus (Fomes Pini, Fomes Pinicola, Polyporus sulphureus, Unknown "A", and Unknown "B") were made by various methods to determine the extent of actual incipient decay beyond apparent incipient decay. Apparent incipient decay means incipient decay which may be distinguished by microscopic examination; that is, the area of discoloration. Actual incipient decay is determined by the presence of mycelium in the wood and may extend beyond the apparent incipient decay.

Determinations of extent of actual incipient decay were made by tests by microscopic examination, ultra-violet light, acidity indicators, a combination of ultra-violet light and acidity indicators, and a combination of ultra-violet light and hydrogen peroxide. The first method listed, microscopic examination, was the only one which gave satisfactory results.

The actual and apparent incipient decay of Fomes Pini and Unknown "B", both of which are white rots, were the same. That is, the mycelium did not extend beyond the limits of discoloration. The actual incipient decay of Fomes Pinicola extended 3 inches longitudinally and 2.3 inches transversely beyond the apparent incipient decay. The actual incipient decay of Polyporus sulphureus extended 9 inches longitudinally and 2.5 inches transversely beyond the apparent incipient decay.

From this data it may be concluded that for the samples tested, the hyphae does not extend beyond the limits of discoloration in the white rots, but does in the brown rots. In sawing logs infected with these rots, it will be necessary to cull those with white rots to the limit of discoloration, and those with brown rot 9 inches longitudinally and 2.5 inches radially beyond the discoloration.

An examination of the Morrow Brothers (Cook Creek) timber sale at Quinalt, Washington showed Polyporus Schweinitzii to be the most important rot in Sitka spruce. Conks and decay of Fomes Pini and F. Pinicola were also found.

Recession of discoloration both longitudinally and transversely was tested. None was noted transversely, but 2 of the 4 samples tested longitudinally showed a recession as the boards became dry.

The boards which had been stained by some other agent than a fungus could not be separated microscopically from those having stain caused by fungi.

DECAY OF SITKA SPRUCE
WITH REFERENCE TO DETECTION OF EXTENT OF
ACTUAL INCIPIENT DECAY BEYOND APPARENT
INCIPIENT DECAY

by

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DECAY OF SITKA SPRUCE
WITH REFERENCE TO DETECTION OF EXTENT OF
ACTUAL INCIPIENT DECAY BEYOND APPARENT INCIPIENT DECAY

INTRODUCTION

Sitka spruce, Picea sitchensis (Bongard) Carriere, is one of the important forest trees of North America. It extends in a narrow strip down the Pacific coast from southern Alaska to about 300 miles south of the Oregon-California line. It usually extends less than 100 miles inland from the ocean. Its range is shown in Plate I. This tree is the largest of its genus, and the mature trees sometimes attain a diameter as large as 12 feet at the stump (8). The bark is thin and scaly. The tree is fast growing and because of its size produces much clear lumber. As the wood is light in weight and strong, it is excellent for use in airplane construction (2). Although the percentage of spruce used in airplane construction is not so high as a few years ago, because of the new metal planes, there is still a heavy demand in the world markets for airplane spruce to be used in the construction of training planes. However, only a small percentage of the highest quality material conforms to the very exacting specifications for airplane stock.

Wood which is to be used for airplane construction must be straight-grained, and its specific gravity and number of rings per inch must fall within certain limits. It must be free from shakes, pitch pockets, worm holes, and decay. It must also be free from any discoloration which might indicate the presence of an early stage of decay. If it can be shown that certain discolorations are not at all indicative of the presence of decay, or that material taken from apparently sound portions of partly decayed logs is entirely satisfactory for use in airplanes, then a much larger percentage of the lumber manufactured from this species can be placed in the higher grades. This will result not only in increased profits to the lumberman, but also in an urgently needed increase in the supply of high-quality stock.

No extensive study has been carried on to determine the relative importance of fungi attacking Sitka spruce, such as has been made for Douglas fir by Boyce (1) and for western hemlock by Englerth (9).

During the World War, when Sitka spruce was in great demand for airplane construction, a study was carried on to determine the effect of various decays on the strength of the wood, the extent of decay beyond the

furthest conspicuous signs of its presence, and the important associated fungi, but the results have not been published. However, Polyporus Schweinitzii Fr. and Fomes Pini (Brot. ex. Fr.) Lloyd were listed as 2 of the important fungi present.

Hubert (13) and Boyce (2) describe the appearance of Polyporus Schweinitzii in Sitka spruce. Eades (8) mentions several fungi that occur in Sitka spruce, and lists P. Schweinitzii and Fomes Pini as important.

Hubert (14) summarizes the information available in 1924 on the extent of mycelium in the wood beyond the last visible signs of incipient decay, and in Table II of that publication shows the extent of actual incipient decay beyond the apparent incipient decay^{1/}

^{1/} In this paper "apparent incipient decay" means incipient decay which may be distinguished by microscopic examination; that is, the area of discoloration. "Actual incipient decay" is determined by the extent of the mycelium in the wood, and may extend beyond the apparent incipient decay.

"Actual incipient decay" although determined in this paper by extent of mycelium in the wood, may extend beyond the mycelium because of enzyme action in advance of the hyphae. Possibly no such action occurs beyond the furthest mycelium, but tests of the breaking strength of the wood might give an indication of this. It should be looked for especially in the brown cubical rots, such as that caused by Polyporus Schweinitzii, as tests have shown that these brown cubical rots affect the strength of the wood a great deal, even in the early stages of decay.

for 8 of the 19 different fungi discussed. The results were based on microscopic examinations. In Table III of the same publication he shows quite similar results obtained by cultural methods.

Other workers who have studied wood-destroying fungi by cultural methods are Cartwright (5), Fritz (10), Mounce (17), Campbell (4) and Davidson (7).

No material could be found on detection of decay in wood by means of chemical indicators or ultra-violet light, but the heartwood and sapwood of pine have been differentiated by chemical indicators (15). Another method of differentiation of heartwood and sapwood is by the use of ultra-violet light. Such work is now being done by Dr. C. A. Richards of the Division of Forest Pathology at the Forest Products Laboratory at Wisconsin. In view of these findings it is believed that there may be a difference in color reaction of decayed and normal wood when tested with indicators or with ultra-violet light. This difference is due to the change in the wood structure brought about by the presence of the fungus. If this proves to be true, it may be possible to determine the extent of the actual incipient decay by either or both of these methods or by a combination of the two.

PROCEDURECOLLECTION OF MATERIAL

Sitka spruce lumber showing discolorations apparently associated with incipient decay was collected from the Multnomah Box and Lumber Company in Portland, Oregon; the Johnson Lumber Company at Toledo, Oregon; and the Crown-Willamette Mill at Cathlamet, Washington. The collections at the first mill named were from stacks of freshly sawed lumber in the yard, and from the chain which carried rejected boards and sawdust to the hog. At the time the second mill listed above was visited, Douglas fir was being sawed, but spruce had been going through the mill a few weeks before. Permission was given by the mill superintendent to take any desired lumber from the stacks of spruce in the yard. The Crown-Willamette mill at Cathlamet, Washington offered the best opportunity for a mill study of the decay in Sitka spruce. Permission from Mr. Shull of the Crown-Willamette office in Portland, Oregon, enabled the writer to follow logs from the pond through the mill to the final production of lumber and box shooks. By this method, a log showing decay could be spotted as it came up to the head-rig, and the decayed boards could be followed from the head-saw through the gang-saw to the cut off saws. Here

the decayed boards were cut into short lengths and sent on belts to the hog. Some of the larger sizes that got by the cut off saws but still had decay went to the chipper, while other material showing some stain went on to the final operation of the mill, in which circular saws cut out defects including stains suspected of being caused by fungi. As the desired boards could be taken at any place beyond the cut off saws, there was no difficulty in obtaining material showing stain, although it was difficult for one person to follow a desired piece of decayed wood after it had gone through the cut off saws. In selecting decayed lumber, preference was given to boards showing the termination of longitudinal spires thought to indicate decay. It was, however, very difficult to get such material.

The size of the boards varied a great deal. The lengths varied from 2 to 12 feet, the widths from 4 to 16 inches, and the thickness from 1 to 6 inches. The smallest piece of lumber (by volume) measured 4 feet by 16 inches by 6 inches.

The collected material was taken to the laboratory and the spires which terminated in the boards were marked with pencil at the outer limits of discoloration. Such marking is shown in Plate IV. The reason for marking the limits of decay (if a fungus is respons-

ible for the discoloration) is to discover whether a recession of the discoloration becomes evident as the wood dries.

All the lumber collected and worked with was from the heartwood of the tree.

CULTURING.

After the wood had been collected and marked, cultures were made to determine whether a fungus was responsible for the stain, and if so, to discover the identity of the fungus. Malt agar was the growth medium most commonly used, but a more acid medium, prune agar, was used occasionally when working with specimens which showed bacterial growth on malt agar. An acid medium cuts down the amount of bacterial growth. Chisel forceps as developed by Hubert (11) were used in making cultures. Both petri dishes and test tubes were used for culturing.

MICROSCOPIC EXAMINATION.

Squares from a board in which the spires of incipient decay terminated were cut at half-inch intervals in longitudinal and transverse directions away from the outer edge of the apparent incipient decay. This is

shown in Plate II. Similar examinations were carried on in only transverse directions for boards having stain running the entire length of one side, and appearing normal on the other.

Each half-inch square was sectioned on a sliding microtome and then examined under the microscope for the presence of mycelium. Where the mycelium was scanty, several sections of the same block were often examined before any hyphae were found. In sections where mycelium was plentiful, a single stain of safranin would show up the mycelium satisfactorily, but where hyphae were rare a double stain was needed. The most satisfactory method of staining was with Bismark brown and methyl violet. Hyphae, contents of rays, and bordered pits stain violet by this method, and the rest of the wood stains brown or brown-violet. This technique was worked out by Hubert (14). Squares of wood were examined from the edge of the stain into the normal-appearing wood until several successive negative results were obtained.

TESTS WITH ULTRA-VIOLET LIGHT AND CHEMICAL INDICATORS.

These tests include application to the wood of ultra-violet light, acidity indicators, ultra-violet

light and acidity indicators together, and ultra-violet light and hydrogen peroxide together.

Five pieces of lumber, each having a stained area caused by a different fungus (Fomes Pini, Fomes Pinicola, Polyporus sulphureus, Unknown "A", and Unknown "B") were used for the tests. These boards had been in the laboratory several days before the tests were made and were consequently well dried out. With one exception, each board had both incipient decay and normal wood present. The single exception consisted of the board which was infected with the fungus determined as Unknown "A", and which had no normal wood. The boards with the rot caused by Fomes Pini and Unknown "A" showed the advanced stage of their respective decays.

Ultra-violet Light

To test the boards for extent of decay by ultra-violet light it was necessary to apply the lamp to the surface of the stained and normal appearing areas of each piece and observe the color reaction.

Acidity Indicators

Five acidity indicators (Meta Nitro Phenol, Neutral Red, Benzo-purpurin 4 B, Chrysoidin Y,

and Chrysoidin R) were used to test differences between decayed and normal wood. These were selected at random, as the writer was unable to obtain any information about such tests. Some work has been done on this subject by Dr. York of the University of Pennsylvania, but his work has never been published.

With what little information could be gathered from work with indicators by Kolthoff and Furman (16), Clark (6), and literature from the Hartman-Leddon Company of Philadelphia, Table I was constructed. As the data in the table are used for determinations of the pH of solutions, this may not be the best means of approaching the problem, but no other information was available.

The 5 indicators were in the dry form (powder or crystal) and had to be mixed in either water or alcohol to the desired concentration as shown in Table I. Wherever alcohol was the solvent, a 70 percent solution was used. The indicators were applied with a glass rod; a band of each of the 5 solutions being painted across a planed surface of the board. The bands extended from well within the region of apparent incipient decay, through the

TABLE I.
INDICATORS USED AND
THEIR ACIDITY REACTIONS

Name	: Approximate : pH Range	: Acid : Color	: Alkaline : Color	: Solvent	: Concen- : tration %
Meta Nitro Phenol	: 6.6 - 8.6	: Colorless	: Yellow	: Water	: 2.0
Neutral Red	: 6.8 - 8.0	: Red	: Yellow	: Alcohol	: 1.0
Benzopurpurin 4B	: 1.3 - 4.0	: Violet	: Red	: Alcohol	: 0.5
Chrysoidin Y	: 4.0 - 7.0	: Orange	: Yellow	: Water	: 1.0
Chrysoidin R	: 4.0 - 7.0	: Orange	: Yellow	: Water	: 1.0

actual incipient decay (if this region extended beyond the apparent incipient decay), and into the normal wood.

It was hoped that there would be a difference in the color reaction of the indicators according to the amount of decay in the lumber. It was thought best to use normal wood of each partly decayed board to compare with the different decays, as the color of normal wood varies in different pieces of lumber and this might affect the reaction of the indicator.

Ultra-violet Light and Acidity Indicators.

In order to test the extent of decay by means of ultra-violet light and acidity indicators it was necessary to apply the lamp to the acidity indicators on the 5 different boards and observe the color reaction of each band.

Ultra-violet Light and Hydrogen Peroxide

Tests for determining the extent of decay by ultra-violet light and hydrogen peroxide were carried out on the 5 boards. Bands of the chemical

were streaked on each board, extending from the zone of visible incipient decay to the normal wood, and then the ultra-violet lamp was turned on them at intervals of 30 seconds, 1 minute, 5 minutes, and 10 minutes following the application of the hydrogen peroxide. The reason for making the examinations at the above listed intervals of time was to give the chemical time to react with the wood.

This test was suggested by Dr. C. A. Richards of the Madison branch of the Division of Forest Pathology. It was believed that the hydrogen peroxide might act more rapidly on the wood which was partly hydrolyzed by the fungi than on the normal wood, and when observed under the light the normal and decayed areas might reflect different colors. This idea was based on work with insulating pins, in which Dr. Richards found that a leakage of electricity around wet insulating pins caused a disintegration of the wood. This disintegrated area showed a different color under the ultra-violet lamp than did the normal pins. 2/

2/ Letter from Dr. Richards to the writer.

It is hoped that one or more of these 4 methods (ultra-violet light, indicators, ultra-violet light and indicators, and ultra-violet light and hydrogen peroxide) may eventually be developed into a satisfactory method for detecting the earliest stages of decay in wood. These methods are rapid and fairly simple, and might be put to a practical use at mills where high grade material is involved. For experimental work in determining the extent of actual incipient decay beyond apparent incipient decay, the above methods would be several times faster than the use of cultural and microscopic examinations, which are not highly accurate at best.

FIELD STUDY.

An examination was made of the Morrow Brothers (Cook Creek) timber sale at Quinault, Washington, on the Olympic National Forest. This area was of Sitka spruce - western hemlock type and had been logged the preceding year (1939). It proved to be an excellent place for observations of fungi causing decay in Sitka spruce, as the selective logging system employed took out many of the overmature trees which had been infected with butt-rot. No data were taken on relative amounts and extent

of decay in logs, but general notes were taken on species of fungi observed in Sitka spruce.

RESULTS AND CONCLUSIONS

FUNGI ISOLATED FROM SITKA SPRUCE LUMBER

The various fungi isolated from the Sitka spruce lumber collected at mills in Oregon and Washington are shown in Table II. The only fungi identified were Fomes Pini, F. Pinicola, and Polyporus sulphureus. Three other fungi, which have not been identified as yet, are designated as Unknown "A", Unknown "B", and Unknown "C". These unknowns are included in the table because they were used in tests to determine the extent of actual incipient decay beyond apparent incipient decay.

Ten of the stained boards, from which cultures were made, gave negative results. This seems to indicate that those stains were not caused by fungi as most of the samples were cultured within a day of being sawed. The few cultures listed in the table do not give a complete indication of the amount of culturing done during the study, as between 200 and 300 cultures were made, often 3 to 5 cultures were made from the area of stain in a single board. Much of the stained lumber had bacteria present along with the causal fungus. This

TABLE II
FUNGI CULTURED FROM SITKA
SPRUCE LUMBER

Name of Fungus	Mill from which Lumber Obtained	Area from which Logged
<u>Fomes Pini</u>	Crown-Willamette Mill	Bear Creek, Wn.
" "	" "	" " "
" "	" "	Necanicum River, Oregon
" "	" "	" "
" "	Johnson Lumber Company	Oregon Coast Near Depoe Bay
<u>Fomes Pinicola</u>	Multnomah Box & Lumber Company	Oregon Coast
" "	" "	" "
" "	" "	" "
<u>Polyporus sulphureus</u>	" "	" "
Unknown "A"	Crown-Willamette Mill	Bear Creek, Wn.
" "	" "	Necanicum River, Oregon
Unknown "B"	Multnomah Box & Lumber Co.	Oregon Coast
Unknown "C"	" "	" "

was especially true of the lumber collected at the Johnson Lumber Company at Toledo, Oregon. The boards had been standing in piles in the rain for several weeks before being collected, and as none were over an inch thick the bacteria were apparently able to penetrate in to the center. Even cultures in which the sliver of wood was taken from the center of the board usually produced bacterial growth which outgrew the causal fungus. Another contaminant which was frequently present in cultures from much of the lumber was an unidentified imperfect which grew rapidly and formed a thin smooth mat with an irregular margin.

The cultures were identified by comparison with other cultures maintained at the Portland branch of the Division of Forest Pathology, and with the help of G. H. Englerth of the same office. One culture, designated as Unknown "B", was obtained from wood in which only the incipient stage of decay was present, and was thought to be Fomes Pinicola, but was sent to R. W. Davidson, Associate Mycologist, of the Division of Forest Pathology at Washington, D. C., for verification. His reply stated that this fungus resembles F. Pinicola microscopically, but that it gives a strong oxidase reaction on media containing tannic or gallic acid and therefore must be a white-rot organism. F. Pinicola

causes a brown rot and gives no oxidase reaction on tannic or gallic acid media (7).

The rot caused by the fungus designated as Unknown "A" has white pockets in the advanced stage, much the same as those of Fomes Pini, but it does not resemble F. Pini in culture.

No uncontaminated culture could be obtained from the wood stained by the fungus designated as Unknown "C". However, microscopic examination of the wood clearly showed the presence of hyphae which had clamp connections.

Table III shows the relative importance of the different fungi obtained in culture from decayed Sitka spruce lumber. The fungus isolated most frequently was Fomes Pini, with F. Pinicola next. Of course such a small sample could not be expected to be representative. It should be noted here that not once was Polyporus Schweinitzii Fr. isolated from the boards. This is undoubtedly also due to the smallness of the sample. Of course, one or more of the boards from which pure cultures could not be obtained might have shown P. Schweinitzii if the contaminants could have been eliminated.

TABLE III

RELATIVE IMPORTANCE OF DIFFERENT FUNGI OBTAINED
IN CULTURES FROM DECAYED SITKA SPRUCE
LUMBER

Name of Fungus	Number of Cultures	Percentage of Total Success- ful Cultures
<u>Fomes Pini</u>	5	38
<u>Fomes Pinicola</u>	3	23
Unknown "A"	2	15
<u>Polyporus Schweinitzii</u>	1	8
Unknown "B"	1	8
Unknown "C"	1	8
Totals	13	100

Until recently, Fomes Pinicola has been considered of importance principally as a scavenger fungus attacking dead trees, Englerth (9) has shown, however, that it is a common cause of heartrot in living western hemlock, and the data in table III suggests that it may also be of considerable importance as a cause of heartrot in living Sitka spruce.

Stains caused by fungi could not be distinguished microscopically from those with which no fungi could be found associated.

FUNGI OBSERVED IN THE FIELD

The fungus fruiting most commonly on Sitka spruce on the Cook Creek timber sale at Quinault, Washington, was Polyporus Schweinitzii. The rot most prevalent in the stumps and butt logs was caused by the same fungus (Plate XIII), with a white pocket rot(perhaps caused by Fomes Pini or Polyporus Cirinatus Fr.) next. Three Sitka spruces which had been felled on this area were of special interest because of combination of fungi attacking them. The first tree had a d.b.h. (diameter at breast height) of 8 feet. The butt cut was about 4 feet from the ground, and the first log had been long-butted 8 feet further up. Throughout this long-butted

section was a brown cubical rot which had destroyed 50 per cent of the cubic-foot volume. At the butt end were three large P. Schweinitzii sporophores and at the upper end of the long-butt were 2 immature sporophores which seemed to be F. Pinicola. Although it was impossible to distinguish the two rots with certainty, the F. Pinicola seemed to be working around the periphery of the region attacked by P. Schweinitzii. The second tree had a d.b.h. of 10 feet. The stump showed a brown cubical rot in the center and bordering this was a white pocket rot probably caused by F. Pini. The third tree had a d.b.h. of 6 feet. The center of the stump and butt log had been rotted away, but between the hollow and the sound wood at the periphery was an area decayed by a white pocket rot. All 3 of these trees had old scars at the butt through which infection had probably occurred.

On a nearby area Dr. T. W. Childs of the Portland office of Forest Pathology discovered Fomes Pinicola sporophores at the base of 2 overmature Sitka spruce. In one instance, infection had occurred through a mechanical injury. In the other instance the infection court could not be determined.

DESCRIPTION OF PRINCIPAL FUNGI OCCURRING IN SITKA SPRUCE

Polyporus SchweinitziiStages of Decay

Incipient Stage

Yellow spires extend from the advanced decay several feet into the normal wood. This wood is soft and loses much of its strength after being attacked by the fungus.

Advanced Stage

In this stage the wood is reddish-brown and broken up into cubes (Plate XIII) which later become crumbly and brittle (13). Thin mycelial mats may occasionally be formed in the shrinkage cracks between the cubes.

Sporophores

The sporophores are annual and may be found on the base of the tree or on the ground nearby. They are bracket-shaped or circular (Plate VI, A). The upper surface is reddish-brown and plush-like. The under surface is green or brown and contains irregularly shaped pores, most of which are large.

Hyphae

No data are available for this fungus, as it was observed only in the field.

Fomes PiniStages of Decay

Incipient Stage

This stage is evident in lumber as reddish or reddish-brown streaks extending in a longitudinal direction. The streaks in the lumber observed did not extend a great distance beyond the advanced stage. When the advanced stage is present, the reddish discoloration characteristic of the incipient stage characterizes it. The discolored wood is hard; this indicates that this fungus does not act rapidly in reducing the strength of infected wood. In this stage resin may infiltrate the wood (Boyce, 1938).

Advanced Stage

In the advanced stage (Plate XII) the wood is about the same color as during the early incipient stage. The characteristic feature of the decay caused by this fungus is the small

pockets (Plate V, A) which run parallel to the grain and are separated by normal-appearing strips of wood. These pockets are usually pointed at both ends and white in color, being partially filled with cellulose, and they vary in number from few where the incipient and late stages of decay meet to numerous in the typical advanced stage.

Sporophores

The conks (Plate XI, A) may be bracket- or hoof-shaped. The upper surface is rough and dark brown to black; however, the margin where the new pore-layer is being added is not so dark. Concentric rings are prominent, showing the annual growth of the conk. The under surface is light brown in color and has rather large, irregularly shaped pores. A sporophore is shown in Plate V, A.

Hyphae

In Culture 3/

3/ The descriptions of the cultures in this paper are not necessarily typical for the species. They are based entirely on the cultures listed in table II.

Malt agar was used as the growth medium and all cultures were kept at room temperature. The mycelium grew 0.6 cm. in 5 days, and 3.2 cm. in 21 days. The mycelial mat was thick and slightly zoned, being yellow and yellow-brown. The margin was colorless. Few clamp connections were noted (Plate X, B).

In Wood

The hyphae in the infected wood may be small or large (Plate III, A). The hyphae branch frequently and readily penetrate the bordered pits and other portions of the cell walls (Plate III, A). Clamp connections are shown in this same plate. In penetrating the tracheid walls the hyphae may be constricted (Plate III, A).

Fomes Pinicola

Stages of Decay

Incipient Stage

Narrow yellow or yellow-brown streaks extending longitudinally ahead of the advanced stage are typical of the early or incipient

stage. There may be only a single streak or spire, or there may be 2 or 3 tips at the termination of the stain. During this early stage of decay the wood is weaker than during the corresponding stage of the white rots.

Advanced Stage

The advanced stage of decay is brown and cubical, becoming very dry and crumbly. Mycelial felts are often present.

Sporophores

A typical Fomes Pinicola sporophore is shown in Plate V, B. The upper surface is zoned, smooth, and usually black or nearly black in color, except at the margin, which is frequently red or yellow-red. The under surface (Plate XI, B) is pale yellow to nearly white, and has many small circular pores.

Hyphae

In Culture

Malt agar, kept at room temperature, was used as the growth medium of all cultures. The

mycelial mat grew 3.4 cm. in 10 days and in 14 days had reached the edge of the petri dish (4.0 cm.). The texture of the mat was at first thin and cottony, later becoming fluffy. The color of the mat was white (Plate VII, A and B). Clamp connections were numerous.

In Wood

The infected wood (Plate III, B) showed penetration of the tracheid walls by constricted hypha. This does not agree with Hubert (13, p. 383), who found the boreholes larger than the mycelium in many cases. Clamp connections may be noted in Plate III, B.

Polyporus sulphureus

Stages of Decay

Incipient Stage

A narrow yellow-brown streak representing the early stage of decay runs ahead of the advanced stage. This is shown in Plate VI. The wood loses its strength properties quite rapidly after the mycelium first attacks the cell walls.

Advanced Stage

In the late stage of the decay the wood takes on a dark brown or reddish-brown color and breaks up into cubes which later become crumbly. The cracks between the cubes are filled with white mycelial mats.

Sporophores

These are annual, thin, and shelf-like (Plate V, B); soft when fresh, and dry and crumbly when old. The upper surface of the young sporophore is orange-yellow and the under surface bright yellow with many small pores; as the sporophores age they become dirty grey in color.

Hyphae

In Culture

Malt agar was used for the culture medium and all the cultures were kept at room temperature. The mat extended 1.8 cm. from the point of inoculation at the end of 14 days. It was soft, fine, fluffy, and yellow-brown to orange-brown (Plate VIII). Clamp connections were noted.

In Wood

Hyphae growing in the tracheids are shown in Plate III, C, where branching and presence of clamp connections may be noted. Constriction of the hyphae in penetrating the cell walls is shown in Plate III, C.

The 3 unknown fungi "A", "B", and "C" cannot be completely described as only scattered information about them is now available.

EXTENT OF ACTUAL INCIPIENT DECAY BEYOND APPARENT INCIPIENT DECAY

Microscopic Examination

Six Sitka spruce boards having different species of fungi (Fomes Pini, F. Pinicola, Polyporus sulphureus, Unknown "A", Unknown "B", and Unknown "C") causing decay were examined for the transverse extent of actual incipient decay beyond apparent incipient decay. The results of these tests are listed in table IV.

Fomes Pini and Unknown "B" showed the actual and apparent incipient decay to be the same transversely; that is, no hyphae were observed in any transverse direction beyond the discoloration caused by either of

TABLE IV

EXTENT OF ACTUAL INCIPIENT DECAY BEYOND
APPARENT INCIPIENT DECAY AS DETERMINED BY MICROSCOPIC
EXAMINATION

Fungus	Longitudinal Distance (inches)	Transverse Distance (inches)	Number of Specimens Tested
<u>Fomes Pini</u>	<u>1/</u>	0	2
<u>Fomes Pinicola</u>	3.0	2.3	2
<u>Polyporus sulphureus</u>	9.0	2.5	1
Unknown "A"	<u>2/</u>	<u>2/</u>	0
Unknown "B"	<u>1/</u>	0	1
Unknown "C"	5.5	1.5	1

1/ Data not available, since decay extended full length of board.

2/ Boards were too badly decayed to permit accurate tests.

these fungi. Material was not available for study of longitudinal extent.

Actual incipient decay caused by Fomes Pinicola, Polyporus sulphureus, and Unknown "C" extended beyond the apparent incipient decay in both transverse and longitudinal directions. These findings agree closely with similar findings by Hubert (Diagnosis Table II), except for the fungus P. sulphureus. He found that no hyphae of this fungus extended beyond the discoloration radially, but shows no results for the extent of the hyphae longitudinally. The results obtained for that same fungus in the present study show the actual incipient decay to extend 9.0 inches longitudinally and 2.3 inches transversely beyond the apparent incipient decay.

Only one of the tests shown in Table IV was checked by culture, and that was for the fungus Fomes Pini. All the cultures outside of the zone of discoloration were negative, verifying the results of the microscopic examination which also showed no hyphae outside the discolored area.

The white rots, Fomes Pini and Unknown "B", showed no hyphae beyond the limits of discoloration, whereas the brown rots, F. Pinicola and Polyporus sulphureus, showed mycelium beyond the discoloration in both transverse and

longitudinal directions. Hubert (14, table II) finds that P. Schweinitzii, which causes a brown rot, also produces hyphae beyond the limits of discoloration. It is not known whether Unknown "C" is a white or brown rot, as only the incipient stage of decay was present in the board and no pure culture could be obtained.

From these data, although they are limited in total number, in trials for each fungus, and in number of different fungi tested, it appears that mycelium does not extend beyond the limits of discoloration in the white rots but does extend beyond the limits of discoloration in the brown rots.

In sawing Sitka spruce logs with these rots present it will be necessary to cull to the maximum extent of the hyphae in both transverse and longitudinal directions in order to cut out all infected wood. For the white rots culling need extend only to the edge of the discoloration; but for the brown rots culling must extend at least 3 inches transversely and 9 inches longitudinally beyond the limits of discoloration.

Tests with Ultra-violet Light and Chemical Indicators

The results of the tests made with ultra-violet light, acidity indicators, ultra-violet light and acidity indicators, and ultra-violet light and hydrogen

peroxide were unsatisfactory for determining the extent of actual incipient decay beyond apparent incipient decay.

Ultra-violet Light

The results from the application of the ultra-violet light tests to the 5 pieces of lumber infected with 5 different fungi are given in table V. This table shows that the normal wood and the regions of apparent incipient decay appeared red or reddish-purple under the lamp, the only difference being that the region of apparent incipient decay showed a darker color than did the normal wood adjacent. This may be due to the naturally darker color of the area of apparent incipient decay. An interesting observation made in connection with this work is that the white cellulose-filled pockets of Fomes Pini showed a light blue fluorescence under the ultra-violet lamp, while a zone line around the outer edge of the incipient decay was black with a quarter-inch zone of bright green fluorescence on each side.

Acidity Indicators

The 5 indicators (Meta Nitro Phenol, Neutral

TABLE V

COLOR OF SITKA SPRUCE WOOD EXAMINED
BY ULTRA-VIOLET LIGHT

Name of Infect- ing Fungus	:Apparent Incip- :ient Decay	:Actual Incip- :ient Decay	:Normal : Wood
<u>Fomes Pini</u>	:Dark reddish- : purple :Zone lime around: :edge of decay :black with $\frac{1}{4}$ - :inch zone of :green fluores- :cence on both :sides. :	: : : <u>1/</u> : : : : : : : :	: : : : : : : : : :
<u>Fomes Pinicola</u>	: Dark reddish- : purple :	: Reddish- : purple :	:Reddish- : purple :
<u>Polyporus sulphureus</u>	: Dark red :Natural dark :line (not zone :line) around :edge of decay :appears deep :red. :	: : Red : : : : : : :	: : Red : : : : : : :
Unknown "A"	:Dark reddish- : purple :	: : None :	: : None :
Unknown "B"	:Reddish-purple : :	:Light red- :dish-purple : :	:Light :reddish- :purple :

1/ Regions of actual incipient decay and apparent incipient decay identical.

Red, Benzopurpurin 4B, Chrysoidin Y, and Chrysoidin R) were applied to the 5 pieces of lumber infected by different fungi as described under "Procedure, Tests with Ultra-violet Light and Chemical Indicators". The Meta Nitro Phenol gave no color whatsoever. Neutral Red gave a deep violet color. Benzopurpurin 4B gave a rose color. Chrysoidin Y and Chrysoidin R both gave an orange color. Comparisons were made between the apparent incipient decay; actual incipient decay, where this varied from the apparent; and the normal wood. The results were identical for each region and for each of the 5 pieces of lumber. All shades of the painted band of each of the indicators on each of the samples of wood were the same except for a slightly darker shade in the region of apparent incipient decay. This was probably due to the color of the wood being darker in that area than in the others.

Ultra-violet Light and Acidity Indicators

No results were secured from ultra-violet light irradiation of the wood treated with acidity indicators - that is, within the area treated with each indicator there was no difference in color

between the normal wood and any of the decayed wood. On all 5 pieces, the Meta Nitro Phenol treatment was a light rose color under the ultra-violet light, Neutral Red was a deeper rose, Benzopurpurin 4B was red, and both Chrysoidin Y and Chrysoidin R were reddish-orange.

Ultra-violet Light and Hydrogen Peroxide

Wood treated with hydrogen peroxide did not differ in color from untreated wood when inspected with ultra-violet light.

RECESSION OF APPARENT INCIPIENT DECAY

The boards in which the boundaries of the discolored areas had been marked immediately after collection were tested about 3 weeks later for recession of the discoloration in both transverse and longitudinal directions. No determinations of moisture content were taken, but the 3-week period during which the boards were left in the laboratory at room temperature had given them time to dry out considerably.

No transverse recession was observed in any of the samples.

Recession of discoloration in a longitudinal direction was definitely observed in 2 samples out of the 4 which were tested in this way. The discoloration in one was caused by Fomes Pinicola, and terminated in 3 short spires. The recession of apparent decay in these 3 spires varied from 1 to $2\frac{1}{2}$ inches. The discoloration in the other specimen was caused by Polyporus sulphureus. This specimen is shown in Plate IV. The recession of discoloration in this single spire was between 3 and 5 inches.

In an attempt to detect whatever relationship might exist between the recession of the discoloration and the moisture content of the board, the first specimen discussed, which was infected by Fomes pinicola, was submerged in a tank of water for 12 hours and then taken out to dry. At this time some of the color seemed to have returned to the area from which it receded prior to the submersal. A few hours later the discoloration in this board had again receded to the point at which it was before the board was soaked in water.

In this paper, all conclusions concerning extent of actual incipient decay beyond apparent incipient decay are based on material in which the limits of the discoloration were marked within a day or so after the

lumber had been sawed. In all cases, the limit of apparent incipient decay was considered to be the pencilled outline, and not the edge of the discoloration if recession had taken place.

SUMMARY

High grade Sitka spruce lumber is now in demand for airplane construction, and with this in mind a study was undertaken to determine the important fungi attacking this tree and the extent of hyphal penetration beyond the limits of discolorations caused by incipient decay. Lumber showing discolorations in the heartwood was collected at 3 mills in Oregon and Washington, taken to the laboratory, and cultured in order to determine what fungi, if any, were present. The most important fungi seemed to be Fomes Pini, and F. Pinicola. Four other fungi were isolated: Polyporus sulphureus and 3 unidentified species. P. Schweinitzii as well as F. Pini and F. Pinicola were observed in the field.

Microscopic examination, ultra-violet light, acidity indicators, a combination of ultra-violet light and acidity indicators, and a combination of ultra-

violet light and hydrogen peroxide were used in attempts to determine the extent of actual incipient decay beyond apparent incipient decay. The first method mentioned, microscopic examination, proved to be the only successful method employed. Other workers have found cultural methods to give good results. The results of this examination indicated that the 2 white rots, Fomes Pini and Unknown "B", produce no mycelium beyond the limits of discoloration, while the hyphae of the 2 brown rots, F. Pinicola, and Polyporus sulphureus, were found to extend beyond the limits of discoloration both transversely and longitudinally.

Plate I. Map showing distribution of Sitka spruce.

Taken from Munns (18) Map 34, page 38.

Plate I

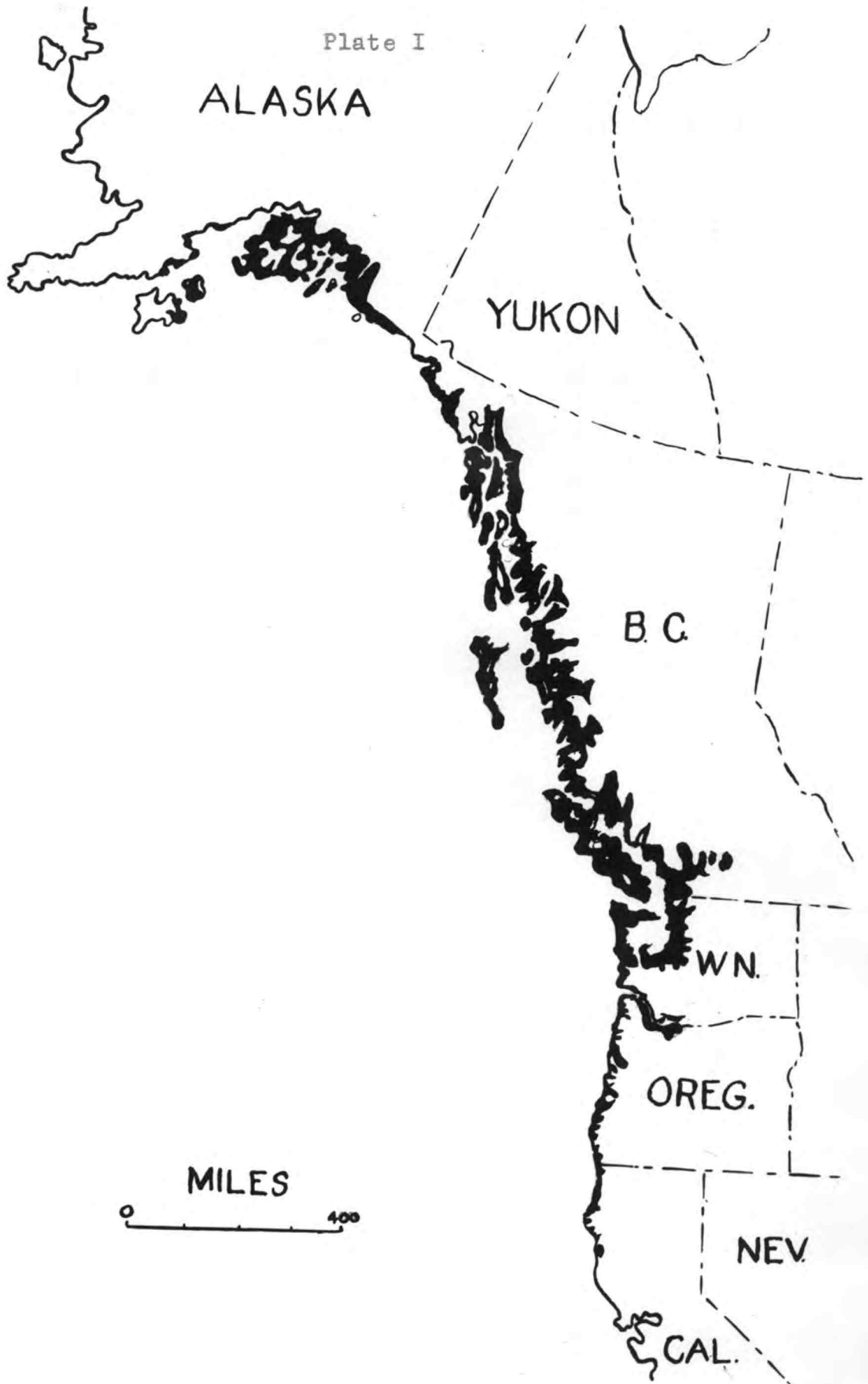


Plate II. Section of Sitka spruce board infected with Fomes Pinicola. Heavy stippled area represents apparent incipient decay. Less heavily stippled area represents actual incipient decay.

Squares extending longitudinally and transversely from area of apparent incipient decay represents sections examined microscopically for hyphae.

Plate II

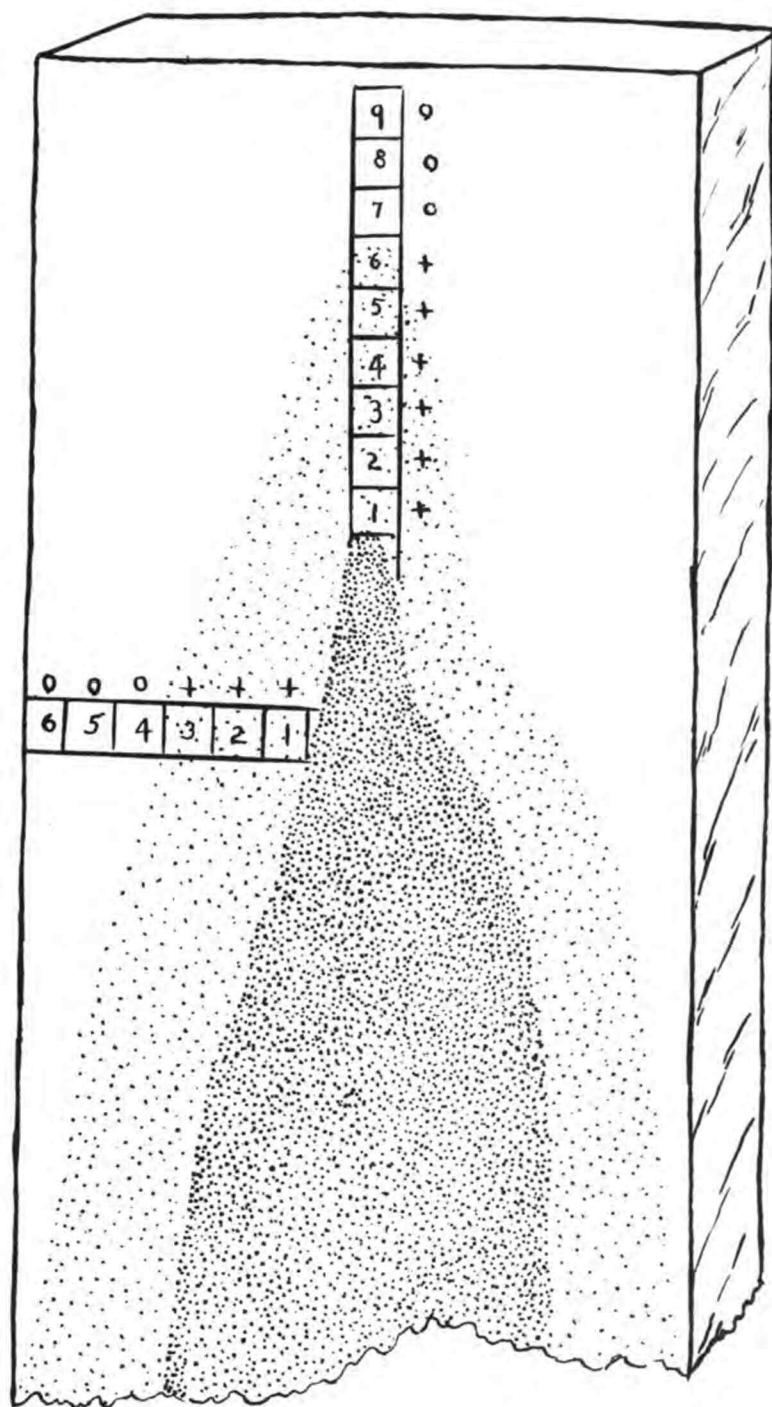
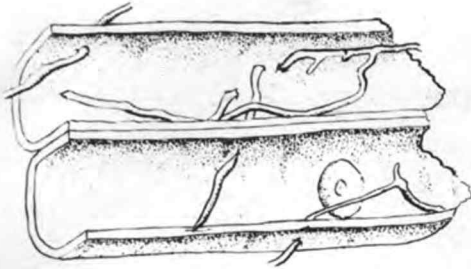


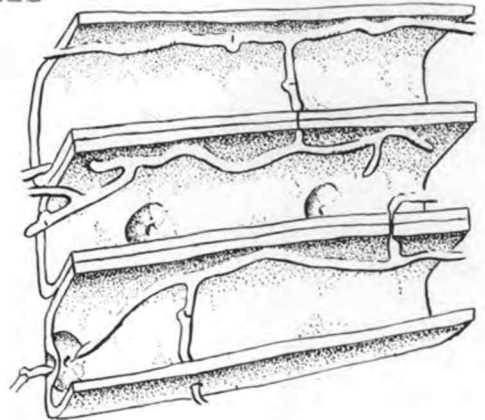
Plate III.

- A. Mycelium of Fomes Pini in radial section of heartwood. Cut from area where the advanced stage of decay ends and the incipient stage begins. Shows penetration of tracheid wall by hypha, large and small mycelial strands, and clamp connections.
- B. Mycelium of Fomes Pinicola in radial section of heartwood. Cut from area of apparent incipient decay. Shows clamp connections and penetration of tracheid by hyphae. Note penetration of walls by branched mycelia in lower left.
- C. Mycelium of Polyporus sulphureus in tangential section of heartwood, cut from area of the incipient stage of decay. Shows branching mycelium and clamp connections.

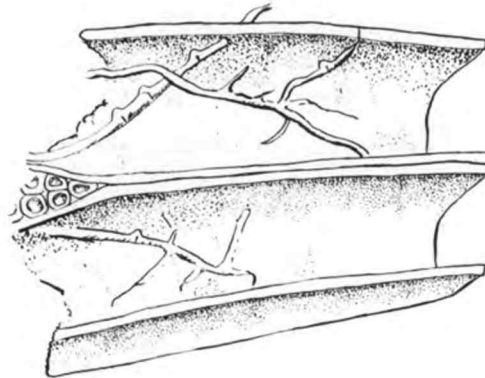
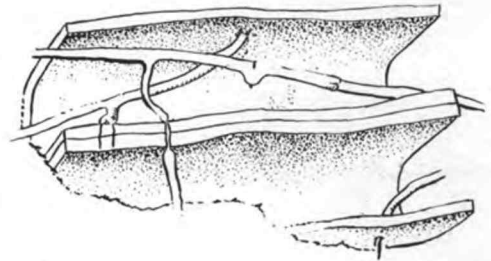
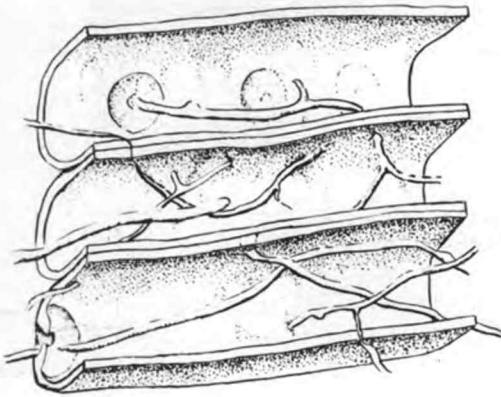
Plate III



A



B



C

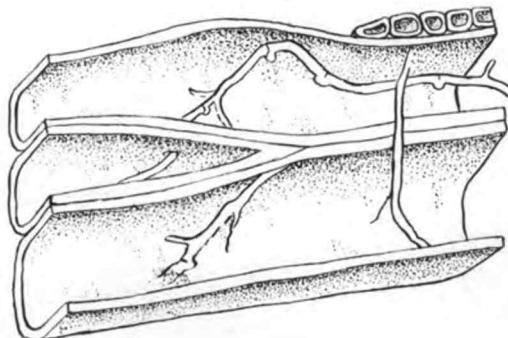


Plate IV. Spruce lumber infected with Polyporus
sulphureus. Advanced stage at bottom and
apparent incipient stage (outlined in
pencil) at top.

Plate IV

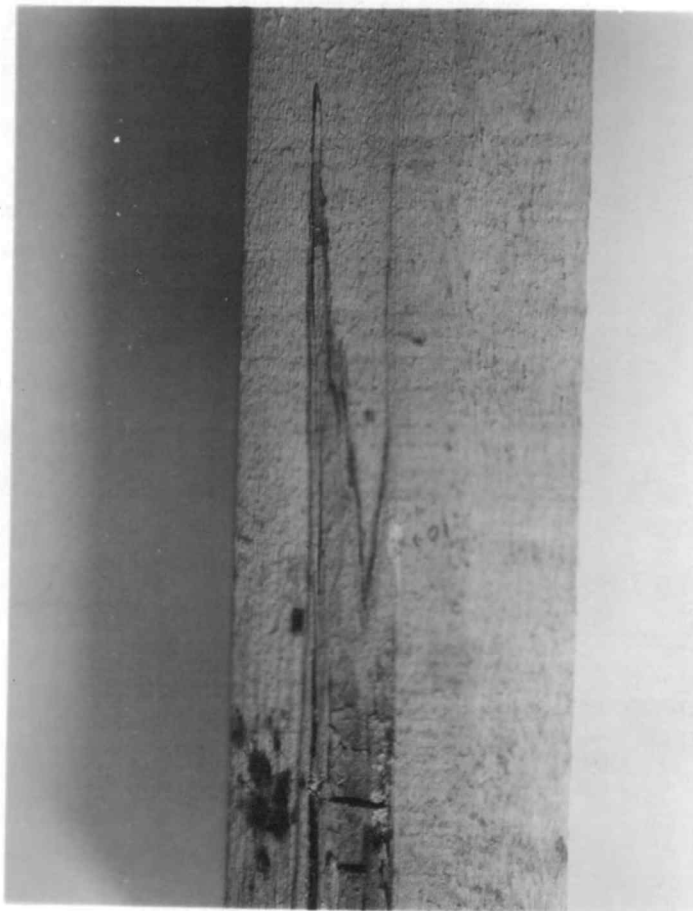
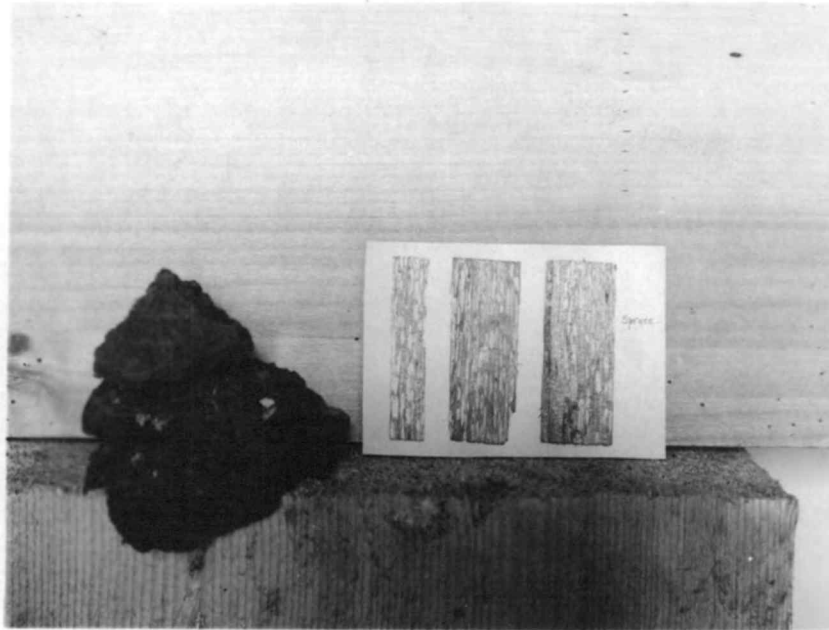


Plate V. A. Fomes Pini sporophore and advanced stage
of decay in Sitka spruce.
B. Fomes Pinicola sporophore.

Plate V



A



B

- Plate VI. A. Polyporus Schweinitzii sporophore on
Sitka spruce.
- B. Polyporus sulphureus sporophore on
Sitka spruce.

Plate IV



A

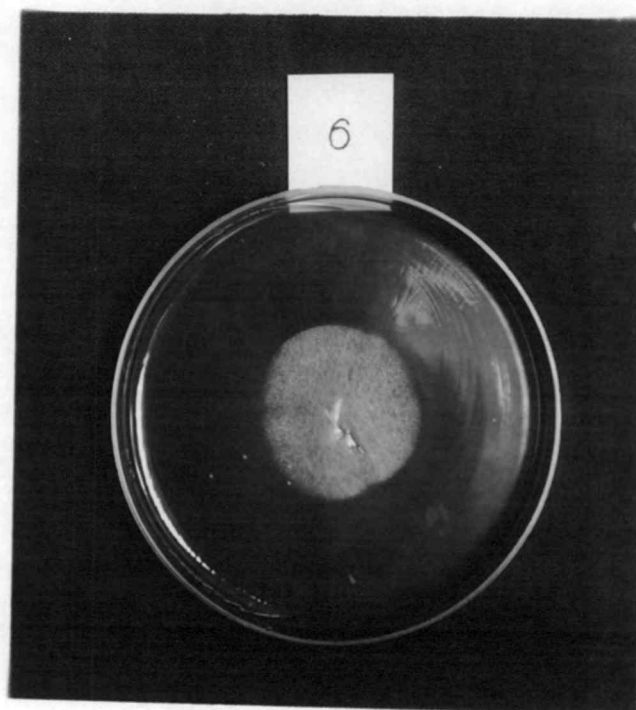


B

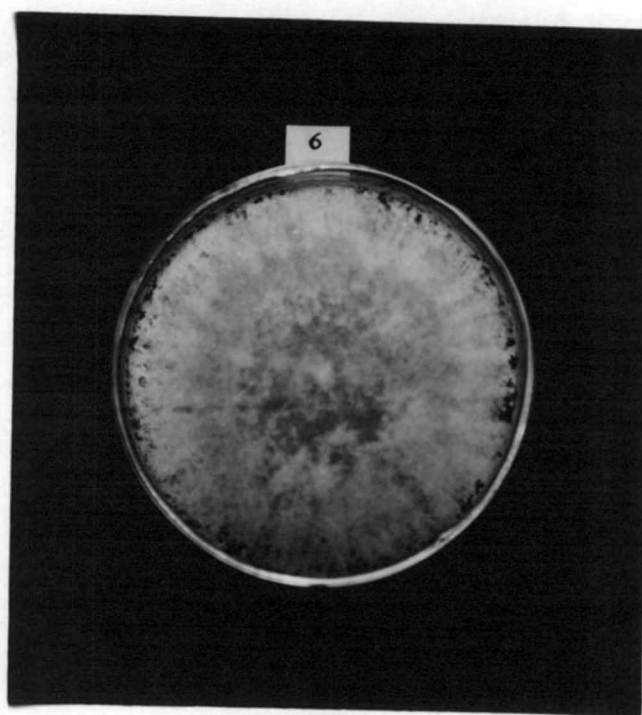
Plate VII. A. 7 day old culture of Fomes Pinicola.

B. 52 day old culture of Fomes Pinicola.

Plate VII



A



B

Plate VIII. 14 day old culture of Polyporus sulphureus.

Plate VIII

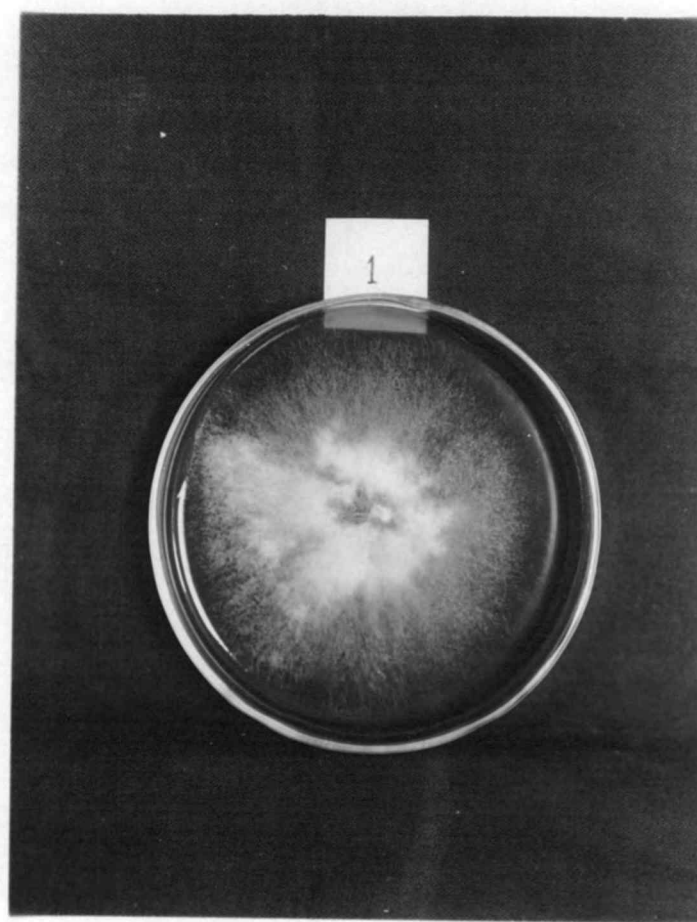


Plate IX. 16 day old culture of fungus designated as
Unknown "B".

Plate IX

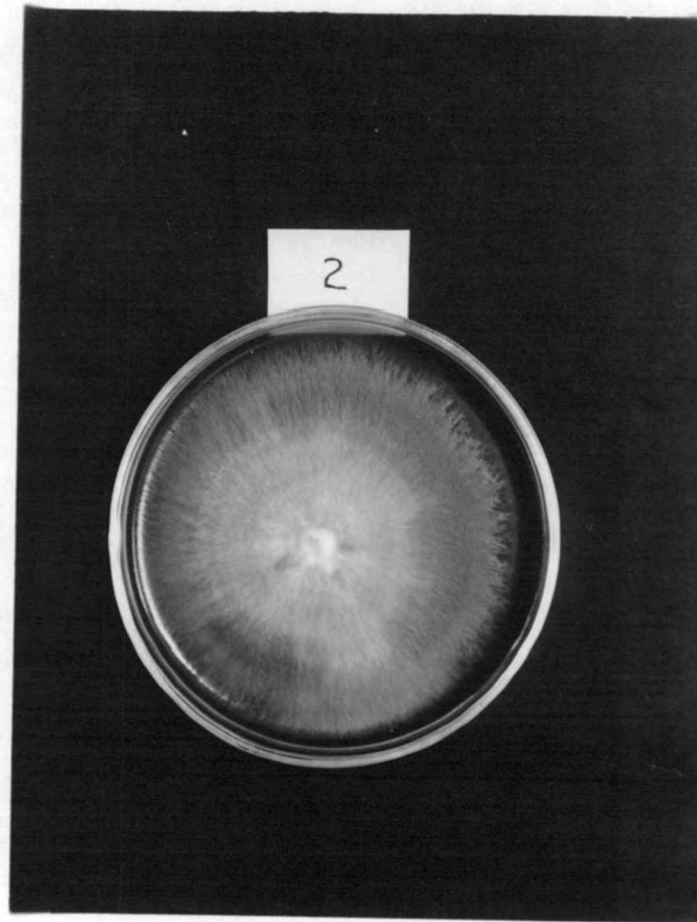
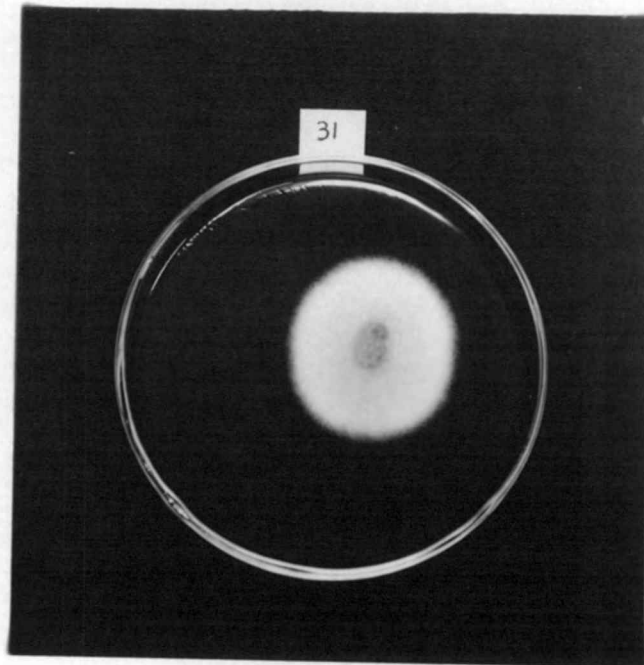


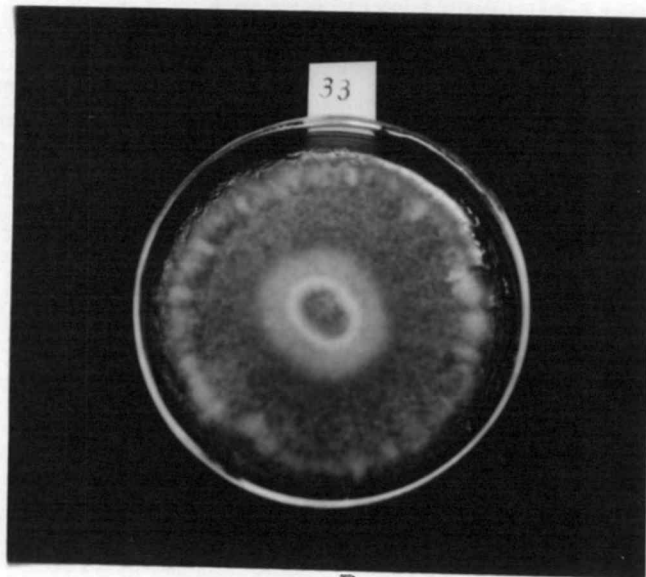
Plate X. A. 21 day old culture of fungus designated
as Unknown "A".

B. 30 day old culture of Fomes Pini.

Plate X



A



B

Plate XI. A. Fomes Pini conks on living Sitka
spruce tree. Photo by Englerth.

B. Fomes Pinicola sporophore and advanced
stage of decay on dead Sitka spruce.
Photo by Englerth

Plate XI



A



B

Plate XII. A. Cross section of Sitka spruce log showing advanced stage of decay by Fomes Pini.

Photo by Englerth

B. Longitudinal section of Sitka spruce log showing advanced stage of decay by Fomes Pini. Conks are present on log. Photo by Englerth.

Plate XII



A



B

Plate XIII. Cross section of Sitka spruce butt log showing advanced and early stages of decay by Polyporus Schweinitzii. Photo by Englerth.

Plate XIII



LITERATURE CITED

1. Boyce, J. S. Decay and other losses in Douglas in western Oregon and Washington. U.S.D.A. Tech. Bull. 286, 1923.
2. _____. Decays and discolorations in airplane woods. U.S.D.A. Bull. 1128, 1923.
3. _____. Forest pathology. New York, McGraw-Hill Book Company, Inc. 1938.
4. Campbell, W. A. The cultural species of Fomes. Bulletin of the Torrey Botanical Club, 65:31-69, 1938.
5. Cartwright, K. St. G. A decay of Sitka spruce timber caused by Trametes serialis, Fr. Forest Products Research, Bull. No. 4, London, 1930.
6. Clark, W. M. The determination of hydrogen-ions. Williams and Wilkins Company, 1928.
7. Davidson, R. W., Campbell, W. A., and Blaisdell, B. J. Differentiation of wood-decaying fungi by their reactions on gallic or tannic acid medium. Jour. of Agr. Research 57:683-695, 1938.
8. Eades, H. W. British Columbia softwoods, their decays and natural defects. Ottawa, F. A. Acland, 1932.
9. Englerth, G. H. Decay of Western Hemlock in western Oregon and Washington. Yale University Thesis, 1940.
10. Fritz, Clara W. Cultural criteria for the distinction of wood-destroying fungi. Transactions of the Royal Society of Canada, III 17 (Sect. V): 191-288, 1923.
11. Hubert, E. E. A chisel forceps. Phytopath. 11:1921.
12. _____. A staining method for hyphae of wood inhabiting fungi. Phytopath. 12:440-441, 1922.

13. _____. An outline of forest pathology.
New York, John Wiley and Sons, 1931.
14. _____. The diagnosis of decay in wood.
Jour. Agr. Research, 29:523-567, 1924.
15. Koch, J. E., and Kreig, W. New method for the
differentiation of heart and sap in pine wood.
Chemiker Zeitung, 140-141, Feb. 19, 1938. (Trans-
lation by Dr. Eloise Gerry)
16. Kolthoff, I. M., and Furman, N. H. Indicators;
their use in qualitative analysis and in color-
imetric determination of hydrogen-ion concentra-
tion. New York, John Wiley and Sons, 1926.
17. Mounce, Irene. Studies in forest pathology, II.
The biology of Fomes Pinicola (Sw.) Cooke.
Dominion of Canada Dept. of Agr. Bull. No. 111,
New Series, 1929.
18. Munns, E. N. The distribution of important forest
trees of the United States. U.S.D.A. Misc.
Publication 287, 1938.