RESISTANT VITALITY OF THE SEQUOIAS

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A Thesis

Presented to the Faculty

of the

School of Forestry

Oregon State College

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Science

June 1948

Approved:

[redacted]

Professor of Forestry

TABLE OF CONTENTS

PURPOSE OF THE STUDY

Anyone traveling along the Redwood Highway in California, or visiting one of the few Big Tree groves of the Sierras, marvels at the size of these gigantic trees. For some strange reason these trees have been able to survive the agents of destruction which other trees of the forests are not able to live through. I believe that one of the first questions asked by admirers of these great trees is: What is there about these trees that enables them to live so long? I asked that question; now I will attempt to answer it by showing in this paper the remarkable manner by which these ancient trees of the genus Sequoia have triumphed over the destroyers of the forests.

SOURCE OF DATA

The data used in this paper were collected from reports and records of observations of men who spent their lives studying the characteristics and habits of the magnificent trees of the Sequoia genus. A good share of these reports were very old and duplicated material from other sources. The subject as a whole was not elaborated upon in any one reference, for each author simply touched on one or two points which came to his attention. I have also used the results of tests that were made on the wood and bark of these trees, to explain more fully the relation of certain properties to the remarkable resistance enjoyed by the genus. Correlated with these facts and studies are observations of three summers in the Big Tree groves of Sequoia National Park, and it is hoped that this correlation will show the characteristics and properties to which the surviving species of this age old genus can attribute their remarkable resistance to the agents of destruction.

SURVIVAL OF THE GENUS

The pick of the fossil hunter has unearthed fossil remains disclosing the fact that the genus Sequoia flourished on the earth as early as the Mesozoic Age. Before the glacial period trees of the genus were distributed widely in the temperate zones of three continents. There were many species, and Europe, Asia and America each had their share. With the downward movement of the ice fields, out of the north, the luxuriant forest growth, with its strange inhabitants, declined. One after another the different species gave way, their relics became buried, and when the ice receded there were left in all the world only two species of the genus to carry on the noble line in these feeble times. Scions of a race whose ancestors extended into the depths of ages, they seem to be not a part of this puny world. Gigantic in proportion, numbering their years by the thousands, they are "an unaccountable oversight in a world where the lives of their neighbors are limited to a few hundred years."(2)

The Surviving Species

The two species of the genus Sequoia that have survived through the ages are Sequoia sempervirens, Redwood, and Sequoia gigantea, Big Tree. Both of these great trees are found only in the United States and the range of each is very limited.

Sequoia sempervirens

The Redwood is found in a narrow strip from 15 to 25 miles wide, extending from the southwestern corner of Oregon southward through the California coast region to a point somewhat south of San Francisco Bay.[10] It occurs on protected flats and benches along larger streams, sheltered, moist coastal plains, river deltas, moderate west slopes and valleys opening toward the sea; at elevations from sea level to 3,000 feet. A relatively small part of the Redwood forest is pure growth, the greater part is a mixture of Douglas-fir, tan oak, grand fir, western red cedar, and western hemlock.[8]

Sequoia gigantea

The Big Tree is found in scattered groves on the west side of the Sierra Nevada Mountains of California, extending from southern Placer County to Tulare County. It generally occurs at elevations from 5,000 feet to 8,500 feet, preferring slopes, low ridges, depressions and draws near or on headwaters of streams.

It is occasionally found in pure stands but generally in a mixture of sugar pine and white fir.[8]

Longevity of the Species

Trees never die of old age, but only from injury and disease. There is no absolute limit to the life span of any tree. Some trees are longer lived than others; true, but this is due to the fact that they become mature at a later part of their life, or are more resistant to the agents that cause death of the forest trees. The death of trees is due to accidents, not, as of animals, to the wearing out of organs. Only the leaves die of old age, their fall is foretold in their structure; but the leaves are renewed every year and so also are the essential organs, wood, roots, bark and buds.[6]

The remaining species of the Sequoias are the Methusalas of the forests, or of the world today, for there is no living thing known that is as old as either of these great trees. The age of the Redwood is from 1,000 to 2,500 years and the Big Tree keeps its youth longer than any known tree, attaining an age of 2,500 to 4,000 years.[5]

The death of large old Sequoias usually results from some catastrophic occurrence, mainly fire, and perhaps never from insects attacks or disease. The trees do disappear from the forest in time, but their death comes after a fall rather than while standing. It is a direct result of becoming top-heavy after the ultimate height growth has been reached, and the crown has attained an unwieldy bulk and weight.[22] Once the massive trunk is overbalanced the tree is doomed to fall for its great weight will gradually overpower the anchoring roots.

The enemies of the Redwood are few and it suffers from them less than other trees. The wind can scarcely uproot it, insects seem to do it little harm, and fungi seldom affects its life. Even fire, the greatest enemy of all trees, though it may occasionally kill whole stands of young growth, is unable to penetrate the fireproof sheathing beneath the shaggy bark with which the old trees protect themselves.[20]

Since no tree apparently surpasses the Sequoias in longevity, they must enjoy immunity from the causes that take other trees. In the Big Tree the principal reason for this is believed to be found in the protective qualities of the heavy non-resinous sap. This sap resists almost completely the attacks of both insects and fungi from the outside of the tree. When the tree is wounded this sap oozes out and forms a glossy covering which looks as though a tree surgeon had painted the scar with creosote.(3) These protective qualities and their affect on the resistance of the trees will be discussed further in other parts of this paper. The fact remains that the Sequoias, whether dead or alive, are remarkably resistant to the natural enemies of the forest; namely, insects, fungi and fire.

RESISTANCE TO FIRE

Fire is the quick destroyer of the forests and the greatest enemy of trees. It is needless to say that a forest which has been growing for hundreds of years, can be wiped out in a few hours by a fire. All the Sequoia forests have been more or less injured by this enemy, sometimes of ancient origin, but since the coming of man and his great saws and axes the fires have been deliberately started while clearing land and burning slash. Though these fires have injured most of the relatively small stands of Sequoias, the great trees have been able to live through them.

Sequoias contain neither pitch nor resin, furthermore their asbestos-like bark grows at least one foot thick on the Redwood and from eighteen inches to three feet thick on the Big Trees. Two principal factors, the fireproof quality of the bark, and the fire-resistant properties of the wood of these trees are the main reasons why fires are seldom able to kill them.(7) Of course, hot fires will kill young trees and crown fires will kill mature ones by killing the foliage, but once the trees have reached maturity they are not easily killed by fire, as shown by the great fire scars found on many of the Sequoias. Old trees are very fire-resistant, but even then recurrent fires leave large fire scars, hollow trunks and otherwise damage the trees, causing considerable loss in the average mature forests.(4)

The defoliation of Redwood by a hot fire causes the tree to sprout along its trunk. To the immature trees this sprouting is serious because it prevents growth of good lumber. Fire also increases the size of old fire scars and hollows already present in some of the trees and gives entrance to decay. Most of the present decay in old Redwood gained its start through old wounds caused by fire.(24)

Fire-Resistant Properties of the Bark

One might believe that a tree so resistant to fire would have a thick, very hard bark. True, the bark is very thick, but instead of being hard it is quite soft, spongy on the Big Tree, and stringy on the Redwood. The bark of the Big Tree is so soft that a bear will not attempt to climb the tree, for if he does the bark will give with his weight and he will sit on the ground with a thump. That the bark of the Big Tree is fireproof is obvious to the observant visitor of the Big Tree groves, but I have observed its fireproof qualities in another way. A cubic foot of bark was placed with pine and fir logs and splashed with oil and ignited. After the pine and fir logs had burned completely and the ashes were cool the Big Tree bark was removed and cut open. The bark was charred to a depth of about a half inch, the remainder showed no sign of being in the fire.

A test similar to this was run at the Atwell Sawmill on the Mineral King Road in the Sierras, on August 25, 1899.

> "A slab of bark 18 inches in diameter, 2 feet broad and 6 feet long was placed in the furnace of the Atwell Sawmill, surrounded by dry pine, and the whole set on fire. When the fire had died down it was found that, although all of the pine had burned to ashes, the Big Tree

bark remained practically unharmed, except that it was, of course, charred on the surface."(3)

Not only is the thick bark of the Big Tree fire-resistant but it insulates against heat and cold, and in a marked degree it is a non-conductor of electricity. An interesting experiment was made by Mr. A. J. Robertson, Superintendent of the Mount Whitney Power Company, on September 6, 1907. He tried to force 5,000 volts of electricity through a piece of bark one inch square and five inches long, but without success.(3)

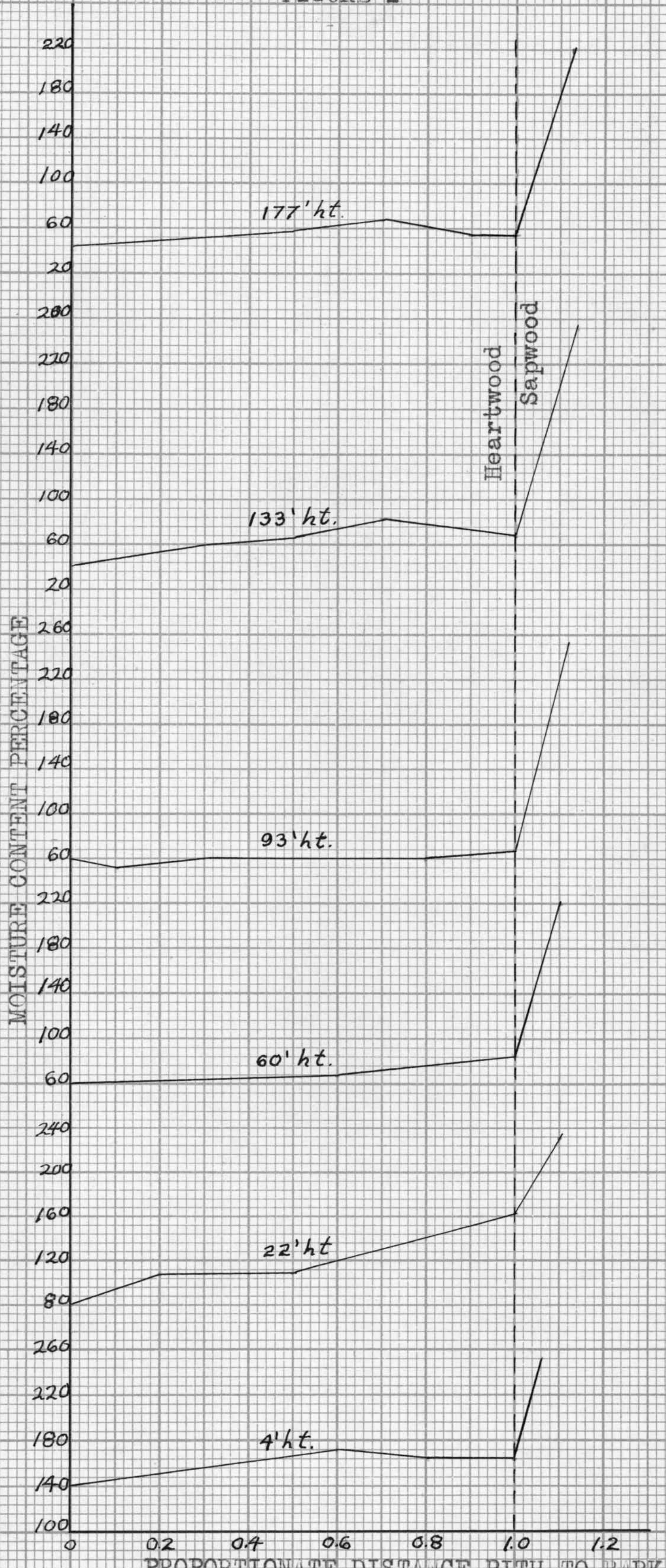
The bark of the Redwood is different from that of the Big Tree in the respect that it is fiberous and stringy. It is not quite as highly resistant to fire as that of the other species of Sequoia, but still it takes more than one fire to penetrate it and do damage to the tree.

Fire-Resistant Properties of the Wood

The other factor of fire-resistance in these great trees is the resistant properties of the wood. When repeated fires burn through the thick protective bark they come in contact with sapwood which contains no pitch or resin , will not ignite easily, and burns very slowly. The absence of pitch, resins, or gums alone make Redwood a naturally fire-resistant wood.(9) This is not the only reason however, for a Redwood tree of ordinary size contains tons of water. To understand the effects of water on burning we must look into the theory of the fuel value of wood.

In theory, equal weights of various woods, upon burning, will produce the same amount of heat. Actually there are some variations in the heat value of different woods, due to the presence of oils,

FIGURE 1



Average distribution of moisture in virgin redwood trees throughout cross section taken at various heights. (27)

gums, tannins, pigments, resins and water. The presence of water raises the amount of heat necessary for ignition and reduces the heat produced. Before combustion can take place, sufficient heat is required to raise the temperature of the water in the wood to the boiling point, evaporate it, then raise the temperature of the wood and air contained in it to the ignition point of the wood.[16] The greater the amount of water present the more heat that is lost and the less the amount of heat available for further combustion.[12]

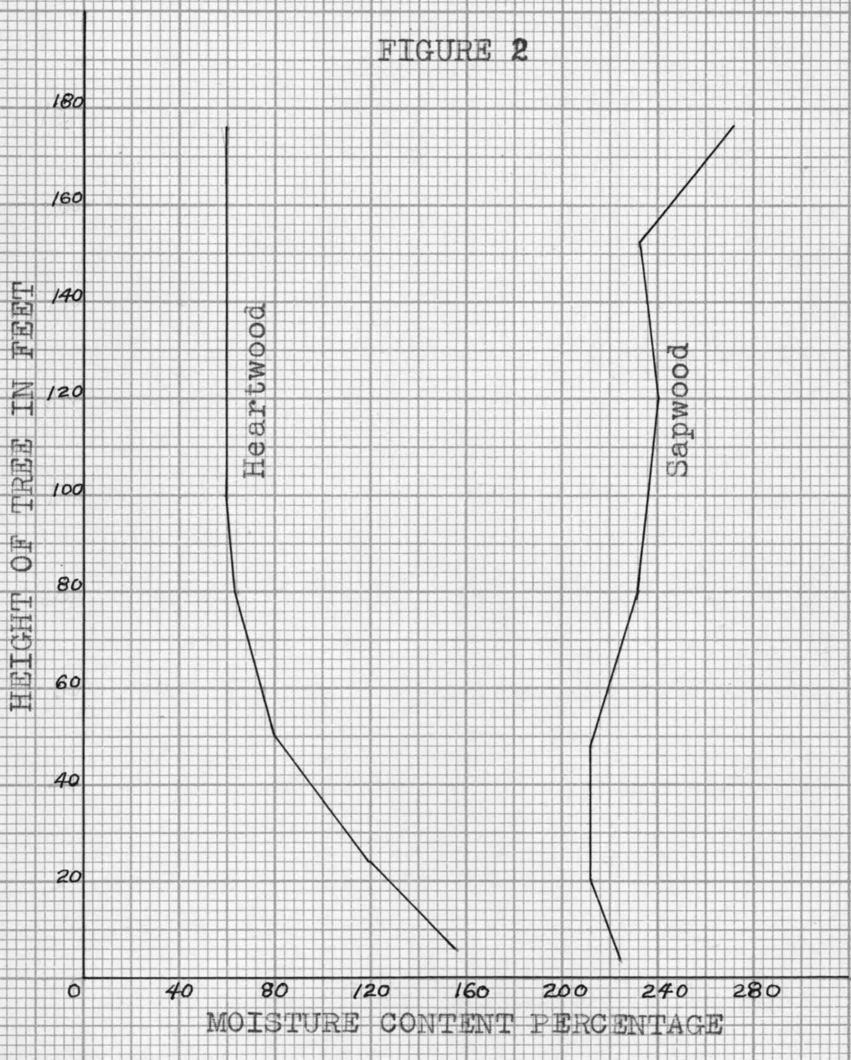
It is calculated that the trunk of a Redwood tree five feet in diameter and 200 feet high will contain about 34,000 pounds or 17 tons of water. The moisture in the sapwood averages over 200 per cent (see Figure 1). This means that the sapwood contains twice as much water by weight as the kiln dry weight of the wood.[27]

The moisture content of the heartwood is highest at the base of the tree. It is considerably lower than that of the sapwood. From the base upward to a height of 80 feet, the moisture in the heartwood gradually decreases to about 60 per cent. From this point it remains practically constant throughout the remaining height of the tree. (see Figure 2). The moisture content of the sapwood gradually increases with the height of the tree.

The high moisture content of green or standing Redwood explains why the trees are so able to resist fire. There is so much water present that the fire, in attempting to drive off the moisture, loses heat until there is not enough available for further or complete combustion of the tree.

It is not only the standing Redwood that is fire-resistant for the lumber is also resistant to a certain degree. Unless kiln dried, wood never becomes bone dry and air seasoned wood, even in a shed,

FIGURE 2



Avarage distribution of moisture content of heartwood and sapwood in redwood trees relative to height. Based on 43 trees (27)

Moisture content should have been plotted over tree height!

normally retains about 25 per cent of its original moisture.[23] This fact combined with the fact that redwood absorbs moisture readily makes the wood fairly resistant to fire. When a fire does start in it, the ability to absorb moisture is a great aid in extinguishing the fire. In the great San Francisco earthquake and fire of 1906, this characteristic was put to a severe test, as houses enclosed with redwood siding and covered with redwood shingles were saved.[21] This characteristic was so apparent that the building committee of the city at that time adopted the following resolution:

> "Resolved that no permits will be given at the present time for the construction of any buildings in San Francisco, but property owners will be allowed to proceed to erect upon their premises, temporary one-story buildings, constructed of galvanized iron or redwood without a permit."[20]

VITALITY AFTER INJURY

Perhaps even greater and more remarkable than the resistance of the Sequoias to fire is their amazing vitality after an injury. Both species have a wonderful ability to heal their wounds and a growth persistance unequaled by any other tree.

Growth Persistance

This unique vitality is probably more obvious in the Redwood. A person visiting the Redwood forest of Humbolt County, California, might notice that a group of Redwoods is growing in a circle about an old stump. They are trees which have actually sprouted from that stump. It isn't only from stumps that the Redwood sprouts however; for old spar trees and snags frequently have long sprouts, reaching skyward, along the side of their trunks. Even logs lying on the ground for a year or more develop sprouts like whiskers from end to end. On one occasion some Redwood logs were used as columns for the front of a new bank building. Shortly after they were set in place they sprouted at many points, giving the building a most grotesque appearance.(22)

One of the most striking examples of growth persistance I have ever seen is that of the Black Chamber, on Crescent Meadow Road, Sequoia National Park. This Big Tree appears, at first glance, to be a burned-out coffin, a shell of crumbling charcoal and weathered wood. There appears to be no cambium left to support the crown which is still living. A closer examination will reveal a narrow strip of thick bark, only a few inches wide, which hides the life line of cambium that supplies sap and new life to a heaven reaching branch of foliage. There are many other trees in the park that show this same persistance, one of which is the Keyhole Tree (See Figure 3).

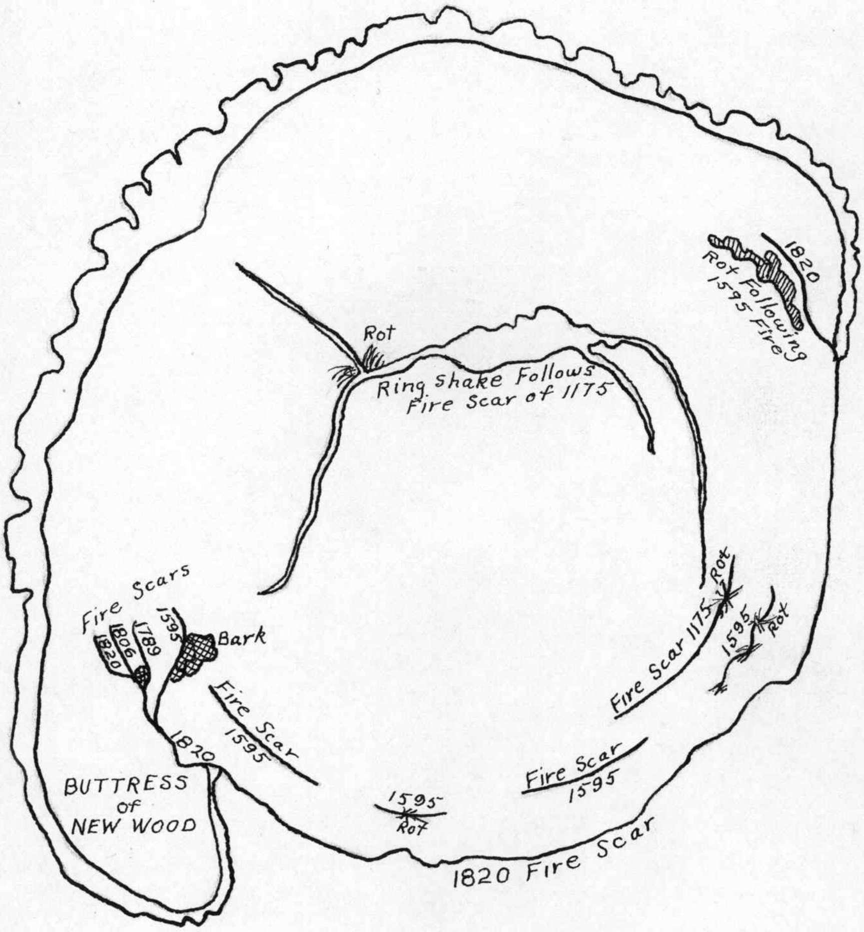
Healing Power

The spring following a wound, in either a Big Tree or a Redwood, will be the start of a long period of healing. In the case of the Big Tree, the first thing will be the application of an antiseptic, a heavy coating of black tar-like substance covering the wound. In this first spring the injured trees start the formation of a layer of wood and bark all along the margins of the wound. This process is repeated each year, with the new tissue taking on the form of solid folds of wood growing uniformly broader on each side of the wound, until the folds meet, thus closing the wound, and the annual rings once again become continuous around the circumference of the tree. Once the wound becomes healed over completely the annual growth is normal and in time no sign of the scar can be noticed unless the tree is felled. When a Sequoia is fallen, records of these fire scars can be seen back through the ages (see figure 4). When a Big Tree 2,171 years of age was cut, in addition to a great fire scar on its trunk, eighteen feet in width, the record of three other fires was revealed. The history of the tree is as follows:

> It began its existence in 271 B.C. At the beginning of the Christian era it was estimated to be 12 feet in circumference just above its base.
>
> At 516 years of age (A.D.245) a burning three feet in width occurred on the trunk. It took 105 years to heal this wound.
>
> At 1,712 years (A.D.1441) a second burning made two wounds one foot and two feet wide, respectively. The tree took 139 years to heal these wounds.
>
> At 1,851 years (A.D.1580) another burn, caused a wound two feet wide, taking fifty-six years to heal.
>
> In 1797, at the age of 2,068 a tremendous fire occurred, leaving a scar eighteen feet wide and estimated at thirty feet high. In 103 years this scar had been reduced to fourteen feet in width.[1]

As can be seen from records on fallen trees, the healing of fire scars and wounds takes many years, perhaps even hundreds, still this great healing power shows the vitality of the Sequoias in their persistance to live. In order to realize how great this power is one must look into the fire scars on the Big Trees in Sequoia National Park. He must observe the size of the openings as they are today and look into them and see the size they originally were. He will then marvel at his discovery.

FIGURE 4



Cross section of a fallen Redwood showing history of fires and the healing buttress of new wood and bark growing over the scar of 1820. (Diameter of the section inside bark--12.1 feet; Fire scar of 1820 was originally 18 feet wide, in 1933 the scar was 13 feet wide.) (18)

RESISTANCE TO FUNGI AND DECAY

Most trees, if injured by fire or by breakage of limbs, soon become infected with fungi, and are likely to die as a result. This is not true of the Sequoias, for neither of the two species have been known to die from fungi attacks. Redwoods are often found with a small amount of heartrot but the life of the tree is not imperiled for the heartwood is non-living tissue.

Diseases of Sequoias

Very little is known about the diseases of the Sequoias. The Big Tree is practically immune from them, being affected only by leaf spot, Cercospora sequoiae.[(14)] The Redwood is affected by about five different diseases but the only one that is of any significance is Poria sequoiae; of the others very little is known.[(24)]

The association of rot with fire scars is so perfect that one can safely say a fire scar is practically always the precursor of the brown heartrot, Poria sequoiae. The decay enters old fire scars and extends upward through the heartwood, often reducing it to a punky mass which, if ignited by a recurring fire, will burn like charcoal and cause the old fire scar to extend farther upward. Repeated fires and heartwood decay often burn the heart out of the trees and soon the trees lose their tops, literally burned off, and the trunk becomes a living, hollow chimney. Many of the trees without tops or with snag tops have had their tops blasted out by lightning but in all probability many of these have lost their tops by decay and fires instead of by lightning.[(22)]

Further evidence that fire scars are the cause of decay is shown by the fact that young growth and sprouts, even though they are from decayed parents, do not suffer from attacks unless by entry through fire scars. Other trees of sprout origin, such as the hardwoods of the east, are more susceptable to decay and if they are from infected parents, they too are often infected.

The Toxic Principle

It has been shown that the wood of the Sequoias is extremely resistant to the attacks of wood destroying fungi. This is true only of the heartwood, for the sapwood is no more resistant than any other softwood. The difference between the heartwood and sapwood is mainly in the extractive content of the former, (11) hence a study of the toxic principle is chiefly a study of the extractives of the heartwood.

In May 1937 experiments were conducted by the Institute of Paper Chemistry to separate the extractives of Redwood. The purpose of the experiments was to isolate the active principle and to determine the activity of that substance in preventing the growth of wood-destroying fungi. It was found that the extractives contained the following materials:

a. Coloring matters
    1. phlobaphene
    2. oxidized phlobaphenes
    3. tannin
    4. sequoyin
    5. humic acid material
    6. a material resembling tannin but insoluble in ethyl acetate

b. sugars and polysaccharides

c. cycloses

d. mineral salts

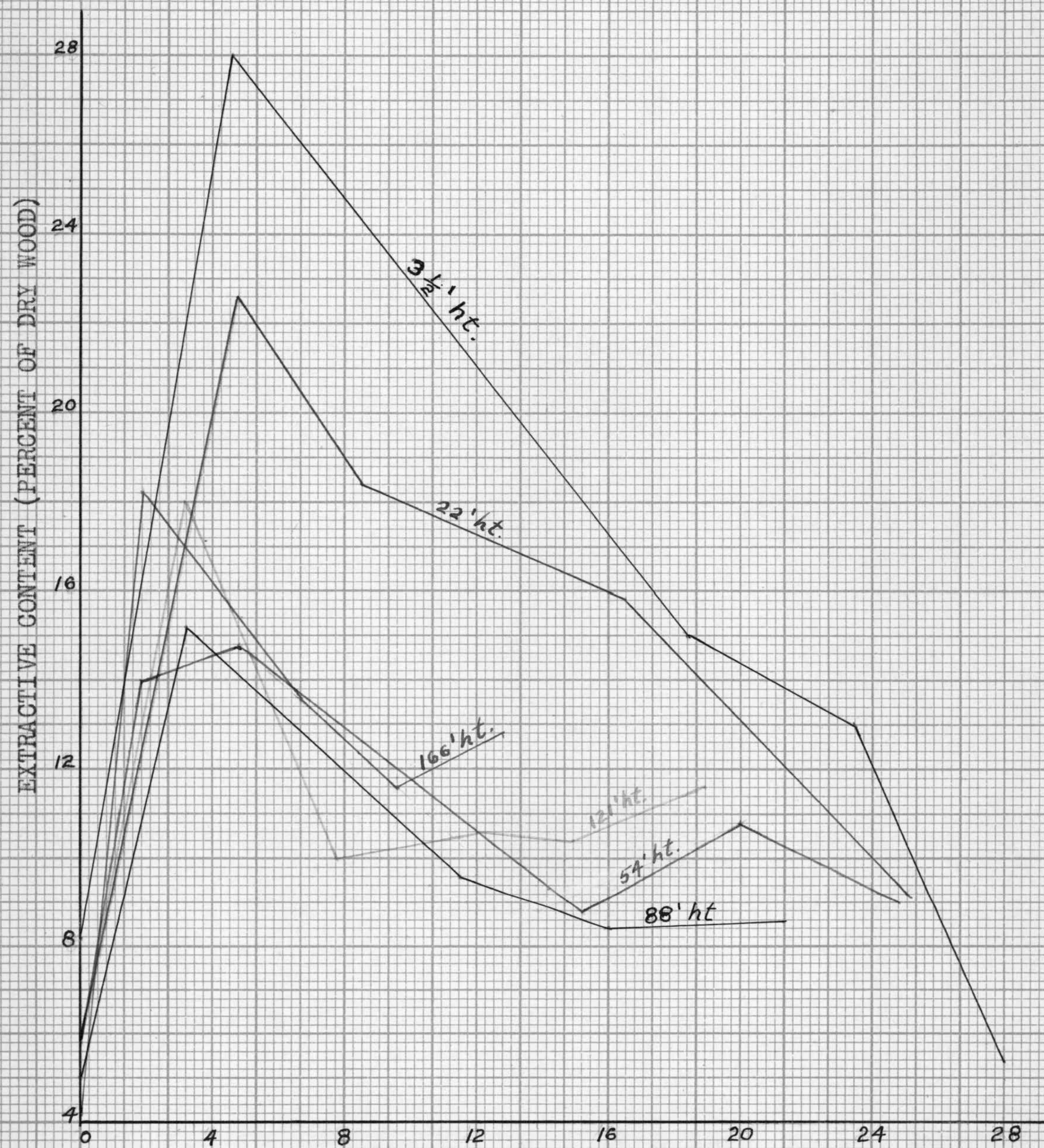
To determine the active substance and its activity in preventing fungus growth, mediums of Fomes annosus were innoculated with each substance. It was found that the sugars, cycloses, and mineral salts were non-toxic. The phlobaphene was practically non-toxic, probably due to its insolubility, but it still may be a factor in the resistance to insect attacks. The ethyl acetate insoluable material possesses some toxicity but not to any extent.

The main toxic principle is found in the tannin fraction of the extractives. In the concentrations used, complete inhibition of Fomes annosus was observed for heartwood and stumpage tannin, and an 80% retardation for the root tannin.(11) The amount of tannin present in the wood varies with the extractive content.

Studies at the Forest Products Laboratory in Madison, Wisconsin, 1933, demonstrated a clearly defined variation in extractive content of the heartwood of virgin Redwood. The extractive content varies with the height of the heartwood in the tree and the position in the cross section of the trunk. (see Figure 5) In virgin-growth trees the extractive content is highest in heartwood adjoining the sapwood of the butt and decreases toward the center of the cross section. In the outside heartwood there is a gradual decrease of extractives with an increase in tree height.

The extracts from the heartwood of different parts of the Redwood tree were concentrated to the point where 3 cubic centimeters represented the extract from one gram of wood. Three different dilutions of these extracts were made with malt agar and inoculated with a wood-destroying fungus, Fomes annosus. The value of toxicity was obtained by measuring at definite intervals, the radial growth of the fungus. This growth subtracted from the normal gave the retardation. The retardation percentage was determined by dividing the retardation by the normal growth and multiplying by 100. The

FIGURE 5



Distribution of extractives in virgin-growth redwood throughout cross section at various heights. (25)

results of the tests are tabulated in Table I.[25] The extractives obtained from the outside sections of heartwood, which have a high extractive content, practically inhibited the Fomes annosus in the concentratives used.

It appears therefore that the resistance to fungi and decay in redwood varies with the distribution of the extractives. The most resistant and most durable wood should be the heartwood of the butt log nearest the sapwood, and the resistance decreases toward the pith and toward the top.

Little is known of the distribution of extractives in the Big Tree. This tree does contain a larger proportion of tannin than the Redwood.[4] We can therefore assume from experiments conducted on the Redwood, that the toxic principle of the Big Tree is tannin and its presence is responsible for the resistance of the wood to fungi and disease attacks.

Durability of the Wood

The wood of the Sequoias is extremely durable. Relatively few woods produced throughout the world possess as high a degree of durability as the Redwood, and the Big Tree is just as durable if not more so. As already shown, the durability of the wood will vary with the distribution of extractives and the position of the wood in the tree. Therefore some lumber is more durable than other pieces from the same tree.

Perhaps the best way to observe the durability of Sequoias is through a study of fallen trees which have lain on the forest floor for years. When a Big Tree falls across a stream it forms a dam about two hundred feet long and from ten to thirty feet high. Soon the stream builds up into a pond or a lake behind this natural dam and gradually

TABLE I

Tree Height (Feet)	Distance from Pith (Inches)	Extract Content (Percent)	Retardation Percentage 50 cubic centimeters of Extractive		
			45cc agar	35cc agar	16cc agar
166	12.5	13.97	99	100	100
121	17.5	18.15	99	100	100
88	22.0	15.5	99	100	100
54	24.5	18.29	100	100	100
22	23	22.92	100	100	100
3.5	27	28.23	99	100	100
166	1.5	12.75	100	100	100
121	2.0	11.48	94	99	100
88	4.0	8.83	84	90	96
54	1.5	9.15	87	92	96
22	1.5	9.40	87	95	98
3.5	3.5	5.45	51	92	95

Relation of toxicity to heartwood extractives of virgin redwood at various heights and distances from the pith. (25)

sediments and silt accumulate on the bottom of the pond until in time it is changed into a bog or meadow.[5] Even after these meadows have been formed the wood of the log dam is sound. Meadows formed in this way have been observed by many in the Big Tree groves of the Sierras. While walking toward the head of a small meadow in Sequoia National Park I came upon a log dam such as this and when I got around it I found that the natural dam had completely silted in and the meadow was flush with the top of the log. Just how many meadows are actually formed in this way is not known, but the fact remains that these huge log dams remain sound even on the wet floor of the meadows, while the small streams form bogs behind them.

Another startling example of durability is that of 3 hemlocks 235,250 and 340 years old, respectively, which were found growing directly over a fallen Redwood 78 inches in diameter. The hemlocks had evidently started from seed that had lodged in the bark of the fallen tree, germinated and continued growing on and around the log until their roots gained a strong foothold in the soil. The trees had grown on this Redwood for two or three centuries yet the wood of the log they were growing on was still sound.[7]

The remarkable durability of the wood of the two Sequoias shows only too well the resistance to fungi and decay that these great trees enjoy. So resistant are they to the vigorous and incessant forces of obliteration that it is hardly an exaggeration to say that "a log cabin built of Big Tree logs on granite will last as long as its foundation."[2]

RESISTANCE TO INSECTS

Many trees are killed by insects, or are so damaged by them that they are an easy prey for decay and fire. Great numbers of sugar pine and ponderosa pine have been killed by beetles, but the Big Tree (Sequoia gigantea), though it is found in the same forest and same locality, seems to be quite free from any serious infection by insects. Its coastal cousin, Redwood, (Sequoia sempervirens), however is often attacked by a larva which reduces the bark just under the surface to a very fine powder. The work of this larva does not imperil the life of the tree.[7]

Not only are the living trees very resistant to insect attacks but also their lumber. Redwood heartwood used for lumber in the Philippines, Mexico and the United States has successfully resisted termite attacks for 40 to 55 years.[7] This is not true of the sapwood for it is not as resistant to attacks as the heartwood.

Termites, commonly called white ants, are the most destructive insect enemies of wood. Tests were made from 1913 to 1922 in Falls Church, Virginia, to determine which woods were most resistant to termite attacks. The results of these tests appear to warrant the statement that there is no species of tree, the wood of which is absolutely immune to their attack. The fact remains however, that the heartwood of certain trees is very resistant to termite attacks. Among the most resistant woods which were tested are teak, and sal of India; cypress-pine and camphor wood of the orient; green-heart of South America; redwood, western red cedar, incense cedar, Port Orford cedar, Alaska yellow cedar, and species of juniper of United States.[13]

What makes the Sequoias so resistant to termites and attacks of other insects has not definitely been determined. There are two different theories which deal with this property of these ancient trees.

Bark Dust as Insecticide

The bark of the Big Tree is so soft that you can almost stick your finger into it. Its very character makes the bark very dusty and this dust impregnated with the tannin in it acts very much like insect powder.(3) This theory may be true providing that insects cannot enter through fire scars and other wounds. This may prohibit the entry of insects through the bark but if they do enter through wounds there must be some property of the wood which also repels their attacks.

Extractives as Insecticides

Little has been done, as yet, to determine the effect of the extractives found in the wood of Sequoias, upon insects. It is believed that the heartwood of Redwood contains certain substances which impart to the wood the characteristics of a natural preservative, making it one of the most termite resistant woods produced in the United States.(9) The extractive which gives the wood this property has not been tested but it is probably the tannin fraction, which most authorities agree upon. There is also a possibility, as previously stated, that the phlobaphene and ethyl acetate insoluble fraction of the extractives may be factors in the resistance to the attacks of insects.

SUMMARY OF CONCLUSIONS

The only surviving species of the ancient genus Sequoia are the Redwood, S. sempervirens, and Big Tree, S. gigantea. They are the oldest living things on the earth today and their range is very limited. Other species have existed but are now buried deep in rock formations, to be found only by fossil hunters.

The thick bark of the Sequoias acts as a fire-resistant sheathing for the vital cambium and sapwood. The wood is also highly fire-resistant due to its high moisture content, which makes it hard to ignite and difficult to burn once ignited.

The amazing vitality of the Sequoias after injury is another factor contributing to their long life. Their ability to heal wounds makes them less susceptible to damage by fire and covers openings which might be used for entrances by fungi. Their persistance in growth is demonstrated by the sprouting ability of the Redwood and the ability of Big Tree to live on when only a narrow strip of cambium supplies the nutrient to the foliage.

Very few fungus are known to attack either of the two species. The Big Tree is free from any attack and the Redwood is attacked mainly by Poria sequoiae, brown heartrot, which enters through fire scars. The principal factor in this resistance to fungi attacks is due to the toxicity of the tannin factor of the extractives of the heartwood. This factor also contributes to the high durability of the lumber from these trees.

The Sequoias are able to resist attacks by insects. The Redwood is attacked by a larva which reduces the bark just under the surface to a fine powder. This resistance is due to the high tannin content of the bark and wood.

The enemies of these magnificent trees are few and it is their remarkable resistance to the enemies of the forest that have enabled them to survive through the ages. Insects seem to do them little harm, and fungi seldom affect them. Even fire, the greatest of all forest enemies, though it may occasionally kill whole stands of young trees, is not able to destroy the mature Sequoia.

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