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Samuel J. Record

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YALE UNIVERSITY · SCHOOL OF FORESTRY

BULLETIN No. 6

LIGNUM-VITAE

A STUDY OF THE WOODS OF THE ZYGOPHYLLACEAE
WITH REFERENCE TO THE TRUE LIGNUM-
VITAE OF COMMERCE—ITS SOURCES,
PROPERTIES, USES, AND
SUBSTITUTES

BY

SAMUEL J. RECORD

Professor of Forest Products



NEW HAVEN

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1921

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2012

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LIGNUM-VITAE

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OF COMMERCE—ITS SOURCES, PROPERTIES,
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Professor of Forest Products, Yale University

PART I: FROM THE BOTANICAL STANDPOINT

TREES AND WOODS OF THE LIGNUM-VITAE FAMILY

THE true lignum-vitae belongs to the family Zygophyllaceae. The plants included in this family are mostly herbs, undershrubs, and shrubs; many of them are xerophytic. The only trees of the family belong to three¹ closely related genera, namely *Guaiacum*, *Porlieria*,² and *Bulnesia*. These are confined to tropical and sub-tropical regions of the Western Hemisphere.

These three genera are composed of mostly evergreen trees and shrubs with opposite, compound, abruptly pinnate leaves, and with showy flowers solitary or in umbel-like clusters. The fruits are 2-5 lobed or parted, and each portion contains usually a single seed.

Guaiacum and *Porlieria* are alike in having blue or purple flowers, and leathery fruits containing seeds covered with a thin fleshy and often highly colored exocarp. *Bulnesia*, on the other hand, has yellow flowers, and the fruit, instead of being fleshy, is a 5-parted dry capsule with each part flattened into a conspicuous wing. The seeds are not provided with a fleshy covering.

In *Guaiacum* the stipules are deciduous, and the stamens are almost invariably without appendages. In the other two genera the stamens have prominent appendages and the stipules of the leaves are persistent, being thorny in *Porlieria*. The latter genus is further characterized by having small linear leaflets which exhibit nyctitrophic or "sleep" movements, and

¹ The genus *Balanites* is included in the Zygophyllaceae by some botanists, but the structure of the wood has no resemblance to that of the three genera herein described.

² Some botanists do not accord generic rank to *Porlieria*, but include it as a section of the extended genus *Guaiacum* (see 40, p. 59).

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flowers that are tetramerous instead of pentamerous as they are in the other two.

These trees are found commonly in very dry regions and are accordingly of very slow growth, short-baled and bushy. The trunks, however, are often very stout with little taper. Some of the species of each genus are typically shrubs and others tend to become so in the most unfavorable sites. In the better situations, however, the trees grow more rapidly and are taller, straighter, and smoother, though such timber is not necessarily better and may, indeed, be of poorer quality on that account.

The woods of *Guaiacum*, *Porlieria*, and *Bulnesia* have many properties in common. They are cross-grained, extremely hard and horn-like, and are considerably heavier than water even when thoroughly dry;³ the heart portion is infiltrated with a fragrantly scented gum-resin which gives the wood an oily appearance and feel.

Growth rings are often distinct, largely on account of color variations, though affected more or less by the relative abundance of pores and by the distribution of wood parenchyma. The woods are diffuse-porous and the pores, which vary in size from minute and indistinct to readily visible in some cases, are open in the sapwood but commonly filled with resin in the heart. They are often associated with or surrounded by parenchyma which may extend into fine tangential or irregularly spaced concentric lines. The rays are uniform and numerous but are too fine to be seen without a lens.

On the longitudinal surface, typically the tangential, very fine and regularly-disposed cross-lines or "Tipple marks" are visible with the lens but not without it. These lines are at right angles to the axis of the tree and are not affected in direction or regularity by the criss-crossing of the fiber-layers. The number of these markings per inch of length averages about 250, which is so much greater than in any other wood that this feature alone is sufficient to establish the identity of the group (36, p. 259).⁴ These ripple marks are also characteristic of the inner bark (sec-

³ The maximum density determined by the writer was 1.32 (about $82\frac{1}{2}$ lbs. per cubic foot) for Nicaraguan lignum-vitae. Kraus ('Die Hölzer') gives the range for dry wood of *Guaiacum* as 1.17 to 1.39, or from 73 to nearly 87 pounds per cubic foot. Other reliable figures of density are 1.248 (Laslett) and 1.33 (Beauverie). Stone (46) gives 89 pounds per cubic foot for *Guaiacum sanctum* and cites Sargent (40) as authority. This is an error, as the values given by Sargent are 0.9563 to 1.2736, average 1.1432. Boulger (5) uses the same figure as Stone.

⁴ In a specimen (Yale No. 974) of the shrub *Larrea divaricata* Cav. (Zygophyllaceae) from Argentina the number of ripple marks is about 270 per inch. In this wood

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ondary phloem). (For structure of the bark of *Guaiacum officinale* see Joseph Moeller's "Anatomie der Baumrinden," Berlin, 1882, pp. 332-3.)

Porlieria

The representatives of this genus are shrubs or small trees growing in dry sub-tropical regions, and are not of commercial importance. Four species have been described, one belonging to a group of plants connecting the Mexican and Texas flora, two inhabiting the corresponding zone in Argentina and Chile, and a fourth,⁵ little known, in Bolivia.

Porlieria angustifolia Gray (= *Guaiacum angustifolium* Engl.) is found in western Texas and adjacent regions of Mexico where it is common on the dry gravelly mesas of the valley of the lower Rio Grande. It is a small tree with very knotty branches, attains a height of 25 to 30 feet and a diameter of 6 to 8 inches, becoming reduced to a low shrub toward its eastern, northern, and western limits. "The hard and heavy yellowish-brown wood is called 'guayacan' about Saltillo, and used as a sudorific and in venereal diseases." (12, p. 113.)

"The wood is exceedingly heavy, very hard, close-grained, compact, the open ducts smaller and less regularly distributed than in *Guaiacum*; medullary rays very thin, numerous; color, rich dark brown turning green with exposure, the sapwood bright yellow; sp. gr. 1.1101; ash 0.51; probably possessing medicinal properties similar to those of lignum-vitae." (39, p. 29.)

Porlieria Lorentzii Engl. is a shrub or small tree on the Argentine steppes where it occasionally reaches a height of 25 feet and a diameter of 10 inches. It is covered with a thin dark-gray scaly bark. The yellowish wood is very compact and fine-textured and makes a fairly satisfactory substitute for boxwood in turnery and carving. Its most common use is in the manufacture of domestic utensils, particularly spoons, and to the latter owes its vernacular name of "cucharero" (maker of spoons). The Indians use the wood, called by them "chukupi," for making smoking-pipes (44, p. 378; 49, p. 105.)

the ground mass is composed of small thick-walled fiber-tracheids with very abundant and prominent bordered pits. The rays are 1 to 12, mostly 6, cells high, uni-seriate or more commonly bi-seriate in the median portion; rather indistinctly storied. The wood parenchyma contains crystals some of which are large and conspicuous.

⁵ This fourth species is described by Baillon (*Adansonia*, 10:315-16, 1872) under the name of "*Guaiacum (Porlieria) microphyllum*." It was found in Bolivia. The leaves are only 1/5 inch long and 1/6 inch broad.

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The above is probably the species referred to by Castro (8, p. 77) as "guayacan blanco," "chuchupi," "chucupi," or "chucarea," though he gives the scientific name as *P. hygrometrica*. The following information is on his authority: The tree is found in Córdoba, Salta, Jujuy, Tucuman, Mendoza, San Luis, San Juan, and La Rioja, and is very abundant in the Andean provinces. In its better development it reaches a height of 13 to 20 feet and a diameter of 4 to 6 inches. The wood is hard and very strong and resilient. Specific gravity 1.11. It is susceptible of a high polish, has a high luster, and on account of its flexibility is in demand for canes and whipstocks. It is also used for turnery and carves with ease. In general carpentry it finds a place in the making of sash, doors, and blinds.

Porlieria hygrometrica R. & P. (= *Guaiaecum hygrometricum* Bail.), is an ungainly shrub with sprawling branches and dropping leaves. When it "sleeps" it gives the appearance of being diseased or even in a dying condition. It was discovered by Ruiz and Pavon, first in Peru near Huanuco, where it was called "turucasa," meaning "thorns fragile and not sharp" (referring to the stipular spines); afterwards in Chile where the Spaniards, who have imputed to it the sudorific property of guaiac, call it "guayaco," also "palo santo." Misled, no doubt, by the common name, Molina, who did not see the plant, has erroneously referred to it as *Guaiaecum officinale* L. (13, pp. 465-6.)

Bulnesia

This genus, so far as known, is confined to South America. There are eight species, but only two, the "palo santo" of Argentina and the "vera" of Colombia and Venezuela, supply timber of commercial value. The others are low-branching shrubs on the dry foothills of the Andes Mountains in Argentina.

"*Retama*" or "*Retamo*"⁶

Bulnesia Retamo Gris. is one of the latter group which sometimes develops into a short stout broom-like tree with a height up to 25 feet and a diameter of from 10 to 20 inches. According to Castro (8, pp. 131-2) the tree occurs in Misiones, San Luis, La Rioja, San Juan, Córdoba, and Catamarca. The tree is said to be of fine appearance and the branches, which are without leaves during the greater part of the year, are slender and pendulous. The gray-yellowish-green bark is from 7 to 8 mm. thick and has prominent corky lenticels and shallow furrows.

⁶ In Patagonia the name "retamo" is given to *Lippia juncea* Sch. (38, p.194).

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According to the same authority, the sapwood is yellowish-white, the heartwood dark-yellowish with veins of deeper color. The specific gravity is given as 0.917. The moduli of elasticity in bending, in kilograms per square millimeter, are: maximum 1,053; mean, 897; minimum, 780. The coefficients of resistance to rupture in bending, in kilograms per square millimeter, are: maximum, 12.25; mean, 7.50; minimum, 4.50.

The wood is "hard as iron" and is used to a limited extent for cross-ties, carpentry, posts, canes, tool handles, and also in the construction of furniture of "great durability and beautiful appearance." The twigs and leaves have a place in medicine and the boughs are used by the mountaineers for thatching their huts. The charcoal from retamo wood is of a very high quality. Spegazzini (44, p. 397) states that the wood makes excellent fuel and occasionally supplies material for turnery.

"Palo Santo" or "Palo Balsamo"

This wood is supplied by *Bulnesia Sarmienti* Lorentz which is "indigenous to the Argentine province of Gran Chaco about halfway up the Rio Berjemo" (17, p. 453); Castro (8, p. 56) says it grows in Chaco, Salta, **Tucumán**, Jujuy, and Corrientes; it also occurs in Paraguay. It attains a height of 50 or 60 feet and a **diameter** of 40 inches (44, p. 376), has a straight bole with a very thin smooth gray bark, and in the interior of the Chaco generally rises above all of the other trees in the forest (49, p. 105). It is a tree of the dry regions and is for the most part in groups or patches yielding at most only a few hundred board feet per acre. Although the wood is well known to certain **local** minor industries making small cabinets and turnery, it is not obtainable in any considerable amount.

The sapwood is narrow and light-colored; the heartwood is usually deep-brown, often more or less greenish, and sometimes with alternate lighter and darker bands. The **pores** are small, thick-walled, numerous, and arranged in radial lines or **groups**, sometimes spreading or branching outward as in the late wood of white oak.

The specific gravity, as determined by the writer on two specimens, oven-dry, is as follows: All-heart specimen, 1.21; specimen with one-fifth sapwood, 1.18. According to Castro (8, p. 56) the sp. gr. is from 1.216 to 1.303. The moduli of elasticity in bending, in kilograms per square millimeter, are: maximum, 988; mean, 872; **minimum**, 827. The coefficient of resistance to rupture in bending, in kilograms per square millimeter, are: maximum, 14.07; mean, 10.81; minimum, 8.91.

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The heartwood is thoroughly impregnated with resin of the nature of guaiac and contains in addition a small amount of essential oil which is fragrantly scented, somewhat suggesting sandalwood. This odor is quite pronounced upon heating and the wood is in local demand for incense in churches; hence the name "palo santo"⁷ (holy wood). It is used by the Indians in northern Argentina for firewood, torches, and the making of utensils for various purposes.

The name "palo balsamo" is a commercial term which has been in use since 1892, and refers to the oil content of the wood. By distillation the heartwood yields 5 or 6 per cent of this oil which is known to the trade as "oil of guaiac wood," "oleum ligni guaiaci," "Guajakholzöl," or "essence de bois gaiac."⁸

For many years the manufacture of this oil was confined to Germany and France, but during the war 2,000 pounds were distilled in New York. Since the sale is limited, this represents at least a five years' supply. The wood is obtained in the form of logs, reduced to sawdust and fine chips, and distilled. Efforts to obtain the oil from the wood of *Guaiacum* were without success. Apparently no effort has been made to distill it from *Bulnesia arborea*.

Oil of guaiac wood is a viscous, heavy oil, yellowish in color, which at ordinary temperature gradually solidifies to a crystalline mass. The crystals are needle-shaped, sharply outlined, and characterized by a channel-like middle line. The solidified oil is white and of about the consistency of cold lard. The melting point is between 40° and 50°C. The odor of the specimens examined by the writer is mild, slightly pungent, and vaguely suggesting rose.

The following description of the properties and composition of the oil of guaiac wood is from Gildemeister and Hoffman (17, pp. 453-4). "The odor of the oil is very pleasant, being violet- and tea-like. The specific gravity lies between 0.965 and 0.975 at 30°; the angle of rotation is -6° to -7° at 30°. The oil is soluble in 70 per cent alcohol. The saponification number found of an oil was 3.9, the ester number 2.4, and the acid number 1.4.

⁷In Patagonia the name "palo santo" is given to *Flotowiacanthoides* Less. (38, p. 192).

⁸The name "champaca oil" was later given to this same oil although it has not the slightest resemblance to the genuine champaca oil from *Michelia champaca* L. (Bericht von Schimmel & Co., Apr. 1893, p. 33) (17, p. 453).

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"The crystalline constituent of the oil is guaiac alcohol or guaiol (Wallach), a sesquiterpene hydrate $C_{15}H_{26}O$. Guaiol is an odorless body, crystallizing in large transparent prisms, and melting at 91° . It boils under ordinary pressure at 288° , at 10 mm. pressure at 148° . Its solution in chloroform is laevogyrate. With dehydrating agents a hydrocarbon $C_{15}H_{24}$ is formed, accompanied by an intensely blue substance. On boiling guaiol with acetic acid anhydride a liquid acetyl compound is produced which boils at 155° under a pressure of 10 mm. The odoriferous constituent of the oil has not yet been investigated."

The New York manufacturers of oil of guaiac wood sell the oil in small quantities to perfumers, mostly in France, the price (1919) being about \$2 an ounce. They inform the writer that they are not familiar with the use the perfumers make of it. According to Gildemeister and Hoffman (17, pp. 436, 454), it is used in the perfume industry for the purpose of producing a tea-rose odor and also as an adulterant of oil of rose.

"*Vera*" or "*Maracaibo Lignum-vitae*"

These names are applied to *Bulnesia arborea* Engl. (= *Zygophyllum arboreum* Jacq., = *Guaiacum arboreum* DC.) which occurs in the coastal region of Colombia and Venezuela. (See plate.) According to Sargent (40, p. 60) this species is "widely distributed through the northern countries of South America from Cartagena to Venezuela." The fact that it was formerly, and occasionally is now, referred to as a species of *Guaiacum* accounts for some of the conflicting statements regarding the range of that genus. Flückiger says (14, p. 102): "This tree, occurring in New Granada (Colombia), has already been noticed (1571-1577) by Francisco Hernandez (Nova plantarum, animal. et mineral. Mexicanor. hist. Romae 1651, fol. 63) under the name of guayacan. He mentions its large umbels with yellow flowers, those of *Guaiacum officinale*, the 'hoaxacan' or lignum sanctum, being blue."

Triana and Planchon (47, p. 362) describe this tree under the name of *Guaiacum arboreum* DC. and call attention to the differences in flowers and fruit between it and *G. officinale*. They report its occurrence in Colombia in the valley of the Magdalena up to an altitude of 2,600 feet above sea level, in Cartagena, the savannas of the valley of Uphar, Santa Marta; and in Estado Carabobo of Venezuela. The common names of "guayacan" and "guayacan polvillo" are given for this species and the wood is described as being of a dark yellow color tending to greenish and with an almost

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pulverulent fracture. There is indication of confusion of species here since the name "guayacan polvillo" is commonly applied to a certain species of *Tecoma* or *Tabebuia* (Bignoniaceae) and the pulverulent nature of the fracture would seem to refer to the lapachol compound which abounds in the wood of this and closely related species.

Stone (46, p. 18) describes the wood of *Bulnesia arborea* under the name of *Guaiacum arboreum* DC., and gives its source as Brazil, citing Miers as authority. The only other reference to the occurrence of this tree in Brazil that the writer has found is by Beauverie (3, p. 248) who apparently follows Stone and it seems probable that this information was incorrect, especially so in view of a statement by Huber (24, pp. 179-180) to similar effect.

The wood of *Bulnesia arborea* is known to the trade as "vera," "vera-wood," and "Maracaibo lignum-vitae." The most common local name for it is vera.⁹ The variations in the color of the wood, attributed to the effect of site, give rise to the names "vera aceituno" (olive), "vera amarilla" (yellow), "vera azul" (blue), and "vera blanca" (white). "Guayacan" and "palosano" are synonyms for vera (1, p. 178). Another native name, a variant of vera, is "bera" or "berra." Humboldt (25, pp. 7-8) says: "On leaving Cumana we enjoyed during the short duration of the twilight from the top of the hill of San Francisco, an extensive view over the sea. the plain covered with *bera* and its golden flowers; and the mountains of the Brigantine." A foot-note referring to the tree reads: "Palo sano, *Zygophyllum arboreum* Jacq. The flowers have the smell of vanilla."

Vera usually grows in places more favorable for its development than is the case of the other zygophyllaceous trees. Consequently it is often comparatively slender, straight-boled, and of rather good timber form. Sargent (40, p. 60) calls it a small tree, but all of the other writers refer to it as attaining large dimensions. Few reliable figures of size are available Sievers (43, p. 194) says that it reaches a height of approximately 100 feet in the Maracaibo region. The present writer has seen logs of this species in New York, transhipped from Curaçao, that were from 14 to 20 inches in diameter and from 8 to 12 feet long. They were smooth, straight, cylindrical and free from knots, indicating that they had come from rather tall trees. The bark was dark gray, smoothish, with longitudinal wrinkles. The bark of a smaller stem was very thin, of a gray-greenish color and showed

⁹ The wood, along with true lignum-vitae, has recently been introduced in the brush-back trade under the fantastic name of "Congo cypress"!

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fine longitudinal wrinkling, crossed at right angles with numerous fine white lines.

Mr. H. M. Curran supplies the following information regarding this tree in Venezuela: "Vera is a common tree of the dry foothills lying between Porto Cabello and the Lake Maracaibo. It does not extend into the extremely dry coastal hills and sand dune areas, but where a little more moisture and better soils are found it is often a very prominent feature in the vegetation. Perhaps four or five trees per acre may be found over considerable areas though the stand would probably be less than 1,000 board feet per acre. The tree as commonly met with is from 40 to 50 feet in height, slender, with a rather small branched crown and is fairly straight, though many individuals are twisted. The tree seldom makes a clear length of more than 15 or 20 feet. The flowers are bright yellow, and the tree is quite ornamental when in bloom. The fruits following the fall of the flowers are rather membranaceous winged pods. The wood is hard, very durable, and is commonly used for fence posts, telegraph poles, and durable construction in general."

The wood of *vera* has many technical properties in common with the true lignum-vitae (*Guaiacum*). In the specimens examined by the writer the heartwood is more or less striped and banded, and varying in color from light olive-green to chocolate-brown. The surface of fresh wood often turns dark green upon exposure to the air and sun. The sapwood is mostly thin and is light yellow except near the heart where the vessels become green upon oxidation of their contents, thus giving a finely striped effect. Generally the color is lighter than in *Guaiacum*. One finds the same arrangement of pores as in *Bulnesia Sarmienti* except that the radial lines are usually narrower and not so inclined to branch. The specific gravity of the heartwood, as determined by the writer on oven-dry material, varies from 1.11 to 1.21. J. Martinex Espino (see 1, p. 178) gives 1.14 as the average density. The heartwood is impregnated with the mildly scented resin typical of the woods of this family.

The heartwood is very durable under exposure and will last indefinitely in the ground. Mr. H. M. Curran found among the ruins of an old Spanish fort on the tip of Araya Peninsula, Venezuela, a pole which was in perfect preservation after some 300 years. A specimen of this wood was examined by the writer and identified as the heartwood of *Bulnesia arborea*. (For features distinguishing the woods of *Bulnesia* and *Guaiacum* see page 19.)

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Guaiacum

This genus, the source of the true lignum-vitae of commerce, is well distributed over the islands and coastal regions of tropical North America. The range in South America seems to be limited to the northern fringe of coast and adjacent islands. Most of the commercial timber is supplied by the West Indies;—Cuba, Haiti, Dominican Republic, Jamaica, and the Bahamas. Considerable material is also obtained from the west coast of Nicaragua.

Description of Species

At least six species¹⁰ are recognized by botanists but very little reliable information is available regarding their respective ranges. There are two species in the West Indies, namely, *Guaiacum officinale* L. and *G. sanctum* L.¹¹ The latter is a small evergreen tree sometimes reaching a height of 30 feet with a small and stout trunk, rarely 12 inches in diameter,¹² clothed with a thin pale or white scaly bark. The slender pendulous branches are enlarged at the nodes and somewhat furrowed. The ovoid, five-cornered fruit is greenish-yellow to bright orange, the seeds dark brown or black and covered with a scarlet exocarp. It is often cultivated for decorative purposes on account of the beauty of its flowers and foliage. It grows naturally in southern Florida, "abundantly on Upper Metacombe and Lignum-vitae Keys and less commonly on Lower Metacombe and Umbrella Keys" (40, p. 63), and is the only representative of the genus reaching the United States. The species occurs throughout the West Indies and, according to Vail and Rydberg (48, p. 106), grows naturally in Yucatan. It has never been of great commercial importance because of its small size and is still less so now than formerly. Flückiger (14, p. 101) says of it: "It is found in southern Florida, the Bahama Islands, Key West, Cuba, San Domingo (including the part called Hayti), and Puerto Rico, and is certainly the source of the small but excellent lignum-vitae exported from the Bahamas as well as some of that shipped from Hayti."

The specific gravity of oven-dry wood of this species from Florida, as

¹⁰ For key to these species see Vail and Rydberg (48, p. 105).

¹¹ Varietal forms of *G. sanctum* exist in Haiti, but have not been described. According to Mr. C. D. Mell, one of these produces a large timber tree, the bera or so-called bastard lignum-vitae of Haiti.

¹² Sargent (40, p. 63) gives maximum diameter of trunk as 2.5 to 3 feet.

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determined by Sharples (see 39, pp. 268-9), varies from 0.9563 to 1.2736, average 1.1432. The variations are in part due to the presence of more or less sapwood in some of the specimens. The specific gravity, oven-dry, of a specimen from Florida was found by the writer to be 1.09 for the sapwood portion and 1.19 for the heartwood. The sapwood of *Guaiacum sanctum* is usually thicker than in *G. officinale*.

In longitudinal compression, the ultimate strength in kilos of two specimens of Florida wood was found by Sharples (see 39, p. 420) to be 11,930 and 11,648, respectively. These values were somewhat in excess of those for the best specimens of hickory but were materially exceeded by, some pieces of Osage orange, black locust, and some less common woods. In resistance to indentation the wood of *Guaiacum sanctum* is given first rank (see 39, p. 253) among 405 woods tested, and is far above any of the common woods of the United States.

Guaiacum officinale is a low or medium-sized evergreen tree with a thick bole often 10 to 12, occasionally 18 to 20, inches in diameter. Its branches are crowded and flexuose and the pinnate leaves are leathery. The fruits are two-cornered and yellowish, bearing seeds light to dark-brown with a cream-colored exocarp. Its range includes all of the West Indies and the northern coast of South America, especially Venezuela and Colombia. Schomburgk (42, pp. 850, 1,012) says it is cultivated in gardens along the coastal region of British Guiana and also grows in the forests along the Essequibo, where it reaches tree size. No other reference to its occurrence in British Guiana has been found. According to Vail and Rydberg (48, p. 106) the species grows naturally in Panama, and Harshberger (21, p. 664) mentions it as occurring in Honduras.

Oviedo (see 14, p. 101), who landed in America in 1514, mentions this tree, under the name of Uguayacan," as a native. (This should dispose of the claim of a **Brazilian** botanist (7, p. 81) that *Guaiacum officinale* L. was introduced into San Domingo from the Matto Grosso by the Spaniards in 1508, and thereafter considered native there). Oviedo appears to have been aware of two species, one of which he found in Espanola (San Domingo) as well as Nagranda (Nicaragua), and the other in the island of Sanct Johan (Porto Rico), whence it was called "**lignum** sanctum." This name is still in use, particularly for the wood of *Guaiacum sanctum*.

Four Mexican or Central American species of *Guaiacum* are described by Vail and Rydberg (48, pp. 106-7), but very little is available regarding their commercial importance and range. *G. guatemalense* Planch. is said

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to be a small tree about 15 feet high with stems clothed with somewhat corky bark. The flowers, which are azure blue, appear before the new leaves; the fruit is reddish or orange, the seeds reddish-brown. The type was collected on the hot plains of Zacapa, Guatemala, and nothing further is known of its range.

Guaiacum Planchoni A. Gray is said to be a much branched shrub, 6 to 10 feet high, with grayish corky bark, leaves crowded or fascicled on short modified branchlets; flowers solitary. The type was collected between Tehuantepec and the Pacific Ocean, Oaxaca.

Guaiacum Palmeri Vail is, according to the same authorities, a shrub or possibly a small tree, with leaves fascicled as in the preceding. The fruit is yellowish-green, leathery, with seeds covered with a dark-red (?) fleshy exocarp. The type was collected at Guaymas, Sonora.

Guaiacum Coulteri A. Gray produces wood of value, though to what extent is undetermined. This tree is known to occur all along the western part of Mexico from Sonora to Oaxaca and it is possible that the commercial lignum-vitae of Nicaragua and the east coast of Mexico is supplied by this species. According to the botanists the tree is small, often reduced to a shrub, with clustered blue flowers and with greenish fruit containing brown seeds covered with a pale yellowish aril.

Hemsley (22, p. 159) suggests the possibility of this and *G. guatemalense* Planch. being the same species, but the material at his disposal was insufficient to decide the question.

In 1913, Dr. H. N. Whitford made an examination of the forest on Maria Magdalena Island, the middle one of the Tres Marias group off the coast of Tepic, Mexico. He found a tree called "guayacan" which was afterward identified as *Guaiacum Coulteri*. In a manuscript report he says:

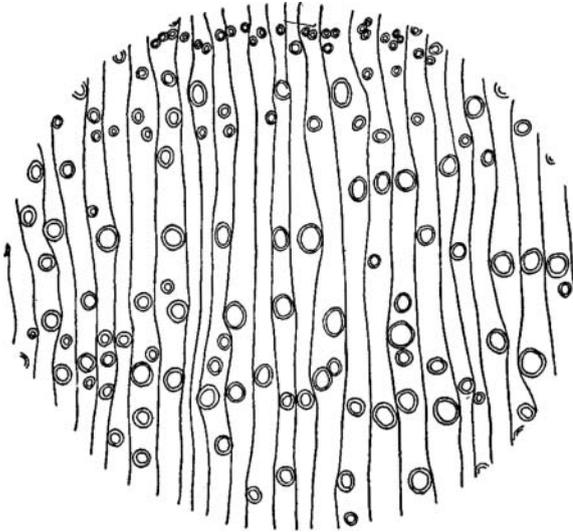
"This species is probably the lignum-vitae of commerce. It occurs growing very scattered with the 'palo prieto' and on the flats near the mouths of the arroyos. The trees are mostly small, between 8 and 12 inches in diameter, yielding logs from 6 to 10 feet in length. One tree was 24 inches in diameter yielding a log only two feet long. It had three branches 8 inches in diameter and 6 feet long that would make good logs. The forests on the main coast are said to produce trees much larger than those on the island. Guayacan is very hard, very durable and very heavy. It is dark greenish-brown in color with concentric rings of nearly black. It is very fine-grained."

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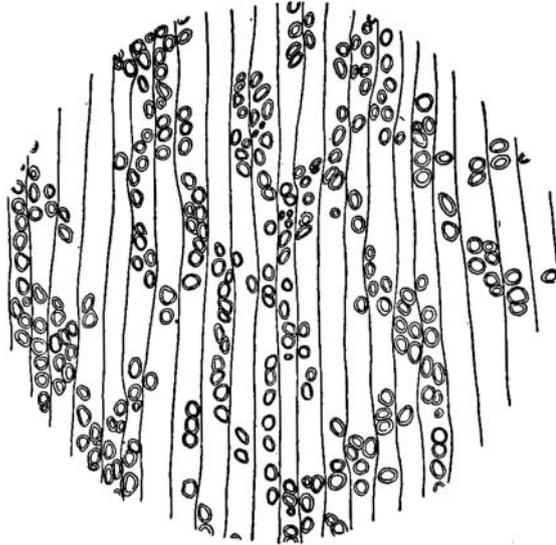
Minute Anatomy of the Wood of Guaiacum

The pores are circular or elliptical and are irregularly distributed, being sometimes abundant and sometimes few and scattering. Usually no definite arrangement can be noted, but occasionally they are in echelon and in some cases a tendency to a ring-porous structure has been observed. There may be considerable difference in the size of the pores in the same specimen while in others they are fairly uniform. In a piece of Cuban lignum-vitae, 14 of the largest pores were found to have an average size of 0.15×0.11 mm.; the maximum was $.18 \times .14$ mm. In a specimen from Nicaragua the pores were nearly all small, the largest measuring about 0.10×0.08 mm. The walls in both cases were about 0.01 mm. thick.

The vessel segments, wood fibers, wood parenchyma strands, and the rays are in horizontal seriation. The bordered pits between contiguous vessels are small, very numerous, and with rounded or hexagonal outlines; the pits between the vessels and rays are small, numerous, and half-bordered. The wood fibers are very thick-walled, very small, short, crowded together without any definite arrangement, and provided with numerous weakly bordered pits. The vessel segments are mostly 0.09 to 0.10 mm. in length, with simple perforations throughout, without tyloses, but with abundant resin (in heartwood) which dissolves readily in alcohol. The rays are from 1 to 8, mostly 5 or 6, cells high and either uni-seriate throughout or two cells wide in the middle portion. The individual cells are very small, thick-walled, sometimes containing crystals, and commonly resinous. Wood parenchyma is present in varying amount in association with the vessels, or diffused, or in tangential lines of irregular length or sometimes in concentric bands several cells wide apparently limiting growth rings. The variations in the amount and arrangement of the parenchyma are very noticeable, not only in different woods but also in different parts of the same specimen.



Cross section of *Guaiacum* from Haiti
Note irregular distribution of the pores



Cross section of *Bulnesia arborea* (Maracaibo)
Note the radial distribution of the pores

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Distinguishing Features of the Woods of Guaiacum and Bulnesia

Guaiacum

Pores irregularly disposed. (See opposite page.)

Pores often widely variable in size; largest sometimes visible without lens.

Pores mostly circular or oval.

Parenchyma paratracheal and meta-tracheal; also often terminal in fine lines distinct with lens.

Crystals present but not abundant in wood parenchyma and rays.

Rays mostly uni-seriate; sometimes 2-seriate in middle portion.

Essential oil not known to be present.

Bulnesia

Pores in radial arrangement. (See opposite page.)

Pores small and fairly uniform in size; not individually distinct without lens.

Pores often angular in outline.

Parenchyma paratracheal and diffuse; indistinct with lens.

Crystals very abundant in wood parenchyma and rays.

Rays commonly 2-seriate (occasionally 3-seriate) in middle portion.

Essential oil known to be present, at least in one species.

Woods of the two genera are alike in being very dense, fine-textured, cross-grained; dark brown or greenish in color with oily appearance and feel; mildly and pleasantly scented when warmed; containing guaiac resin with characteristic color reactions. Woods with very fine and uniform ripple-marks, invisible without lens, averaging about 250 per inch of length. These ripple-marks are likely to be absent in small twigs (0.5 cm. or less) such as one commonly finds in herbarium material. The characteristic alternating or fine-roe grain was not found in stems or twigs less than 1 cm. thick. The interlocked grain is not due, as sometimes supposed, to the crossing of true right and left hand spirals around the stem, but to a weaving back and forth of the fiber layers in an irregular "lazy-S" manner up and down the trunk.

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Check List of Common Names

Guaiacum officinale: Lignum-vitae (U. S.; general trade) ; guaiacum-wood (England); holy wood, wood of life, Indian wood (Lit.); guayacan, guaiacan, guayakan (Spanish); hoaxacan, lignum sanctum, guayacan blanco (Porto Rico) ; guayacan negro, guayacan prieto, palo santo (Cuba) ; gayac jaune vert (Martinique) ; bois de gaiac or bois de gayac, bois sant (Fr.) ; Pockholz, Guaiacholz, Guajak, Guajakholz, Franzosenholz, Lignum Sanctum-holz (Ger.); guaiaco nero, legno santo, legno benedetto, legno nefritico, legno di guaiaco (Ital.); pokhout (Dutch); guaiaco (Port.); "Congo cypress" (Brush-back trade).

Guaiacum sanctum: Lignum-vitae (America; general); Bahama lignum-vitae (Eu. trade) ; palo santo, lignum sanctum, lignum guaici (Spanish); vera, bera (Haiti); vera amarilla, vera prieta, guayacancillo (Cuba); ironwood (Florida); guiaco banco, legno santo, legno benedetto (Ita!). The wood of this species is often not distinguished from the foregoing and the same names maybe used for both.

Guaiacum spp.: Lignum-vitae (Trade); guayacan, palo santo (Mex.).

Bulnesia arborea: Vera, vera aceituna, vera amarilla, vera azul, vera blanca, bera, berra (Venezuela, Colombia); Maracaibo lignum-vitae, vera-wood (Trade) ; guayacan, palo sano (Colombia) ; gayac de Caracas (Fr.) ; Veraholz (Ger.) ; "Congo cypress" (Brush-back trade).

Bulnesia Sarmienti: Palo santo (Argentina); palo balsamo (Trade) ; palo santo negro (Paraguay) ; páo santo (PorL).

Bulnesia retamo: Retama, retamo (Argentina).

Porlieria angustijolia: Guayacan.

Porlieria Lorentzii: Guayacan blanco (Argentina); cucharero, chucarea, chukupi, chuchupi, chucupi (Indian names, Arg.).

Porlieria hygrometrica: Guayaco, palo santo (Chile) ; turucasa (Peru).

PART II: FROM THE COMMERCIAL STANDPOINT

THE TRUE LIGNUM-VITAE OF COMMERCE

General Considerations

THE wood of *Guaiacum* is the true lignum-vitae of commerce. It enters the market in the form of bolts or short logs from 2 to 10 feet in length and 3 inches and upward in diameter. These logs usually retain part or all of their bark and this provides one of the best features for the ready separation of the different kinds recognized by the trade.

The sapwood is usually thin or, if the logs have lain for a long time on the ground or in the water, it may be entirely absent. Logs without sapwood are commonly known as "nigger heads" because they are all black and the surface is etched and channeled in such a way as to expose the criss-crossing grain and give the appearance of being braided or interwoven. It was formerly the practice to hew off the sapwood before shipment, at least for certain grades of wood, but hewn logs are comparatively rare now and such hewing as is done is to remove irregularities.

The logs are cut by natives and carried in some primitive way, often on pack animals (see plate), to a dock to await shipment. They may lie exposed to the weather for months or even years. Under the intense tropical sun they are likely to check and become ring-shaken, at least at the ends, though the various kinds are not equally susceptible to this. Worms often get in and riddle the sapwood, and the writer has seen a few logs with worm holes, the size of a lead pencil, in the heart.

One of the most serious defects of lignum-vitae is heart-rot or "doze." Although the heart is very durable when exposed to decay after the tree is felled, it is subject to rot in the living tree just as in the case of many of our most durable native woods. Although dealers specify strictly sound wood, a certain amount of "dozey" material is likely to be included in every shipment when the demand for lignum-vitae is heavy.

The highest grade logs are smooth, cylindrical, free from knots, checks, shakes, "doze," and worm holes, with very thin sapwood or none at all, with a finely interlocked grain, and heavily impregnated with resin. The preferred lengths and diameters depend upon the uses to which the wood

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is to be put. Thus the Navy Department specifies that "sizes 3 inches average diameter and smaller shall be not less than 2 feet in length; sizes 4 inches and 5 inches average diameter shall be not less than 3 feet in length; sizes 6 inches average diameter and larger shall be not less than 4 feet in length" except in special cases.

The color of the heartwood exhibits a wide variation. The typical is an oily olive-brown with concentric layers of alternately lighter and darker shade. It is very common for the ends of the logs to show a dark blue or green heart as a result of the oxidation of the coloring matter. Upon oven-drying specimens of this color the blue or green was found to disappear.

Several different kinds of lignum-vitae are recognized in the trade and they are usually designated by the name of the country or of the port of origin. The principal kinds now found on the New York market are Cuban, San Domingan, Jamaican, Haitian, and Nicaraguan. Others less common are Bahaman, Mexican, and South American. Buyers usually specify exactly the kind of wood they want and their likes and dislikes are often very pronounced. To what extent these opinions are based on facts and to what extent they are mere prejudices could not be determined, but they do exist and exert a very material influence on the market.

So far as the writer's investigations have gone, specimens from the same region and presumably of the same kind exhibit about as much variation in structure as was found in material of the different kinds recognized by the trade. In general, however, the Mexican, Nicaraguan, and Haitian wood had smaller pores and finer rays than that from Cuba and Florida.

Present Sources of Supply

The following notes are based largely upon data obtained from prominent timber dealers in New York City.

Cuba.—Most of the Cuban lignum-vitae is obtained from Oriente Province in the eastern part of the island and is shipped from Santiago. According to a Government report in 1917 (20, p. 52) not more than 4,000 tons exist in accessible places, not more than one-third of this would repay the cost of getting it out, and the total supply is in danger of early exhaustion. A New York dealer questions this conclusion and cites the fact that a single operator in this region got out 1,000 tons in 1918 and that others were also engaged in the business. During the fiscal years of 1914 and 1915, 3,067 tons, valued at \$127,000, were exported from Santiago. More recent figures are not available. There is some wood in Pinar del Rio, in the western part of the island, but it is not now being exploited.

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Cuban lignum-vitae is considered the standard, at least for the larger sizes. The logs are mostly from 4 to 8 feet long, with a few of the smaller sizes 10 feet. The diameters range from 6 to 24 inches, but only a very small percentage are over 16.

The commercial species is *Guaiacum officinale*, although *G. sanctum* is also present and may enter to a minor extent into the supply. The latter species is locally known as "guayacancillo" to distinguish it from the other which is called "guayacan," "guayacan negro," or "palo santo."

The bark of the Cuban wood is distinctive and is considered typical of high-grade wood in general. It is thin, smooth, and flaky. These flakes are of irregular size and shape and the scars, owing to the laminated structure of the bark and to the variation in depth of different parts of a scale, are marked like a contour map. (See plate.) The fresh scars are glossy and vary in color from reddish-brown to olive-green, the older patches becoming ashy-gray or nearly white. (A large Cuban specimen of *Guaiacum* in the collection of the Yale Forest School is labeled "vera." The color is lighter than that of the typical wood and the bark is ashy gray and granular, suggesting that of logs from Nicaragua.)

A specimen of Cuban wood taken from a storage yard in New York was found to contain a little over 20 per cent moisture. The specific gravity, oven-dry, was 1.17.

Jamaica.-The wood from Jamaica is small and is supposed to be of *Guaiacum sanctum*. The logs are from 2 to 8 feet long and from 3 to 10, mostly 3 to 5, inches in diameter. (See plate.) Not over 5 per cent exceed 8 inches. The sap is usually wide and the bark is smooth as in Cuban logs. The wood is much in demand for mallets for which the small size especially adapts it. It is reputed to be of as high quality as the Cuban and is restricted in its uses only on account of the small sizes now available. Fliickiger (14, p. 102), referring to the wood of this source on the market in the seventies, says that it is small and of only ordinary quality.

Bahama Islands.-This wood is also of *Guaiacum sanctum*, is accordingly of small size, rarely 5 inches thick, and is also largely used for mallets. Almost no stock was obtained from the islands during the war, owing largely to the lack of shipping facilities. The supply remaining is believed to be small. The exports in 1914 and 1915 were valued at \$3,017 and \$5,161, respectively.

Porto Rico.-The wood from this source is small but of good quality. Both *Guaiacum officinale* and *G. sanctum* are native but the latter is "now of only limited occurrence along the south coast" (6, p. 75). Although com-

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paratively little Porto Rican wood has been on the market during the past few years, due principally to lack of shipping facilities, it is believed that the island will continue a source of supply for small stock for many years. The logging conditions in the mountains are very unfavorable. (See 23, pp. 44-45.)

Haiti.—"Lignum-vitae is scattered over the whole of Haiti" (20, p. 136). Most of the wood, however, is considered by dealers and users as non-genuine and is often called "bastard lignum-vitae" in the trade, and "vera" or "bera" locally. It is unquestionably a species of *Guaiaacum* and not of *Bulnesia*, as the name "vera" or "bera" would indicate, since it has blue flowers and the typical fruits of *Guaiaacum*.¹

Prejudice against this material is not of recent origin. Flückiger, following a reference to San Domingan lignum-vitae, which he terms the best on the market in the seventies, says (14, p. 102): "The wood obtained from the Haytian ports (of the western part of the same island) is much less esteemed in the London market."

The logs are from 3 to 5 feet long and from 4 to 14 inches in diameter. The bark is rough, composed of fine scales partly slate-colored and partly ashy-gray, somewhat resembling that of pignut hickory. (See plate.) The sapwood is usually thick and the grain seems to be less interwoven than in the Cuban wood. Several lots were examined by the writer and a high percentage of the logs were found to be "dozey." The specific gravity, oven-dry, of a specimen of Haitian wood was 1.30.

It is believed that a large amount of genuine lignum-vitae exists in Haiti but the transportation facilities in the interior are extremely poor. In 1915, 6,172,853 pounds, and in 1916, 6,226,574 pounds of lignum-vitae were exported from Haiti.

Dominican Republic.—Wood from this region is called San Domingan. It is recognized as genuine and has the characteristic bark and other features of the Cuban. Only occasional logs of the "bastard" variety are included, presumably more because of the small demand for it than because it is not found. Wiesner (50, p. 950) states that the best wood of *Guaiaacum officinale* comes from San Domingo.

The logs now on the market are from 2 to 3 feet long and mostly between 4 and 10 inches in diameter, rarely as large as 16 inches. Some wood-users consider it the best lignum-vitae in the trade, especially for the smaller sizes. It is said that much larger wood than is now being obtained is avail-

¹ Specimens of the leaves and fruits of this tree recently collected by Mr. C. D. Mell have been identified by Dr. Rydberg as an unnamed variety of *G. sanctum*.

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able in considerable quantity in this country but that the natives lack the necessary facilities for getting it out. "Lignum-vitae is plentiful, especially from the bay of Samana southward and westward to the Province of Barahona" (20, p. 181).

The value of this wood shipped from the Dominican Republic during the five fiscal years 1912-1916 was \$157,706.

Nicaragua.-*Nicaraguan* lignum-vitae has been on the market for many years but until recently there has been considerable objection to its qualities on the part of certain users, particularly in France, England, Holland, and Denmark, who claimed that it had too great a tendency to check and split. On the other hand, it has been used without discrimination in Japan, China, Germany, and to a greater or less extent in the United States. The shipyards on the Pacific coast use it exclusively. Makers of bowling balls and of sheaves insist that it is unsuited for their purposes because of the tendency to split. The writer is informed by dealers that the prejudice against this material has been largely overcome through improved methods of handling and manufacture.

The largest log of which record is available was 36 inches in diameter, 9 feet long, and weighed 4,260 pounds (27, p. 3S). Usually the logs are 4 to 8 feet long and from 9 to 24 inches in diameter, with a good percentage over 12 inches. They are straight, smooth, and cylindrical, and free from defects except end checks which give a bad appearance but generally do not extend deeply. The specific gravity, oven-dry, of a specimen of Nicaraguan wood was found to be 1.32.

The species supplying the Nicaraguan wood is not known. The bark is thin, dull gray in color, irregularly flaky, but not smooth or shiny; sometimes pitted and coarsely granular. (See plate.)

The principal port of shipment is Corinto and, according to a consular report, 55 tons, valued at \$1,849, were exported in 1916 and 265 tons, worth \$8,839, in 1917.

Mexico.-The amount of lignum-vitae coming out of Mexico is at present very small. The writer had occasion to inspect a carload of logs from the northwestern part of the country. The sticks were of various lengths up to 6 feet and ranged in diameter from 8 to 11 inches. They were all more or less faulty, being crooked, gnarly, and knotty. Many were double-hearted at one end due to cutting above the fork of the trunk, an undesirable practice. The sapwood was very thick and white, the heart small, oily, and of good color but often affected by spots of dry rot or "doze" of varying size. The bark was very thin, smoothish, granular, and varying in color from

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light to dark gray. The writer was unable to determine the extent to which this shipment was typical of the region.

A specimen of lignum-vitae from the west-central coast of Mexico was found to have a specific gravity, oven-dry, of 1.30. The wood was very dense, highly resinous, and free from defects. The pores were minute.

Future Sources of Supply

West Indies.-The West Indies will probably continue to supply the bulk of the high-grade lignum-vitae for many years if prices remain at a sufficiently high level to warrant the increased expense attending the more and more difficult logging. Improvement of the transportation facilities and logging methods in certain regions will permit the getting out of material now too large and heavy to be handled in the primitive native manner over rough trails.

Central America.-There is believed to be a large supply of accessible lignum-vitae in Nicaragua but the former prejudice against the material from this source has retarded its exploitation. It is reported that the Government of Honduras is taking steps to introduce its wood into the market.

Mexico.-Jordan (27, p. 80S) says that lignum-vitae is very plentiful on the west coast of Mexico from the state of Sonora to Oaxaca, but grows to a greater size and degree of hardness in southern Sinaloa and Nayarit. In the "Catalogo forestal" (9, pp. 16-17) both *Guaiacum sanctum* and *G. officinale* are listed as of quite general occurrence throughout Mexico. Thus the range of the former, known locally as "palo santo," is given as Vera Cruz, Chipas, Oaxaca, Guerrero, Michoacan, Jalisco, Tepic, Sinaloa, Zacatecas, Mexico, Pueblo, Tlaxcala, and Morelos. The range of the other called "guayacan," is given as Yucatan, Tabasco, Vera Cruz, Oaxaca, Guerrero, Michoacan, Colima, Jalisco, Tepic, Sonora, Hidalgo, Pueblo, and Morelos. Although the specific names given are presumably incorrect, the report is of interest in indicating the distribution and possible future sources of lignum-vitae in Mexico.

Northern South America.-There is a very considerable quantity of true lignum-vitae in the coastal region of Colombia and Venezuela. Very little of it is now on the market, partly because the trade fears the substitution of "vera" for the genuine. In 1917, a shipment of a few tons was received by a New York dealer from the Port of Colombia. The logs were 5 or 6 feet long, 4 to 15 inches in diameter, straight and well-shaped and with all of the sapwood trimmed off. It proved to be excellent wood, approximately Cuban quality, according to report.

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It is likely that some of the Venezuelan lignum-vitae will enter the market in the near future. A specimen of the wood which some timberland owners are offering was examined by the writer. It was found to be genuine and apparently of high quality.

Curaçao figures in the commerce reports as a large exporter of various woods, including **lignum-vitae** and vera, but little if any timber is of local origin, although both *Guaiacum officinale* and *G. sanctum* are native of the islands (r9, p. 33r). Vice-consul Gorsica says (r8, p. 1S):

"**Before** the war considerable business in woods was done at **Curaçao**. Woods from the Venezuelan ports, Maracaibo and Carupano, and from Dominican ports were carried to this place for transshipment to the United States and to Europe. Maracaibo relies almost entirely on **Curaçao** for the exportation of woods, owing to a sand bank at the entrance of the Gulf of Manicaibo, which makes it impossible for vessels with a draft of over 12 feet to go into or out of the gulf. Dealers in Maracaibo woods, as a **rule**, own light-draft sailing vessels built to trade with **Curaçao**. . . Restrictive rules, lack of shipping space, the irregular calls of steamers, and the suspension of service of different lines have very nearly killed the wood **business**."

Mr. H. M. Curran supplies the following information regarding true lignum-vitae in Northern Venezuela:

"The dry coastal hills of northern Venezuela have a certain amount of lignum-vitae scattered through them. It has been little exploited probably due to its rather local occurrence, small size and the fact that the region is but little known to anything but small coasting vessels. Only one or two trees per acre are found in the best stands. It seldom reaches a height of over 30 feet, is often much less, and has a broad bushy crown of very dark green foliage. The bole is usually less than 8 or 10 feet in length, and the common diameter of the mature tree is between 8 and 20 inches; rarely 24 inches. It is a very ornamental tree when in blossom and is often completely covered with a mass of violet-blue flowers. These are succeeded by great masses of orange yellow pods which are likewise very ornamental. The **tree** is much used as a shade tree or ornamental shrub in town and about country houses. It has peculiar close dark green mottled bark, and is of very un-symmetrical form. Another variety or species is found with a rather rough bark, though the wood and general appearance of the tree from the forester's point of view is practically the same. The wood is not exploited to any extent and only now and then is seen on the market."

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Value of lignum-vitae imports entered for consumption in the United States

(U. S. Commerce Reports)			
<i>Fiscal year</i>	<i>Value</i>	<i>Fiscal year</i>	<i>Value</i>
19°0	\$123,021	1910	\$ 95,695
19°1	146,834	1911	143,682
19°2	87,399	1912	96,675
19°3	127,262	1913	101,547
19°4	88,234	1914	72,632
19°5	1°3,830	1915	132,411
1906	179,280	1916	73,412
19°7	175,296	1917	222,731
1908	99,796	1918	171,844
19°9	9°,576	1919	<u>308,512</u>
Total value for 20 years			\$2,640,669

Uses Of Lignum-vitae

Bushing blocks.-The most important use for lignum-vitae is in bearings or bushings, particularly for lining the stern tubes of propeller shafts of steamships. In this extremely important and trying position it will last about three times as long as steel or bronze. The great density and tenacity of the wood enable it to withstand the enormous strains upon it, while the resin content serves as a natural lubricant which minimizes the friction and wear of the parts. Although other woods, including beech, and more recently yellow guayacan, have been used, none has proved a satisfactory substitute for the genuine lignum-vitae.

In reference to this use of the wood, Galletley says (IS, p. 384): "It has one remarkable application, namely, its use for the particular bush, or bearing, of the screw shaft of steamships, next to the screw itself, where only a substance able to bear much friction could possibly last for any length of time. Its highly resinous character renders it self-lubricating in a position where no other lubricant is practicable except water."

The stimulation of the shipbuilding industry due to the war occasioned a very large increase in the demand for lignum-vitae. The Navy Department at one time advertised for bids to supply 427,000 pounds of logs of this wood, a large proportion of which were to be from 18 to 24 inches in diameter at the small end.

The Emergency Fleet Corporation was also a large purchaser. A specimen inquiry from this source called for quotations on logs which would cut

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approximately 10,000 board feet edge-grain. These were to be "high-grade lignum-vitae hewed square or rectangular, to be well seasoned, generally sound and straight, free from injurious shakes, worm holes, excessive sap, large or unsound knots, and other injurious defects. Ordinary season checks will not be considered a defect and slight heart and ring-shakes are not considered a defect in pieces 13 inches in the shorter diameter and over." Quotations were also solicited on supplying as an alternate, 6,000 square feet of edge-grain slabs of random lengths (minimum 12 inches) not less than 1-1/8 nor more than 1-1/4 inches in thickness.

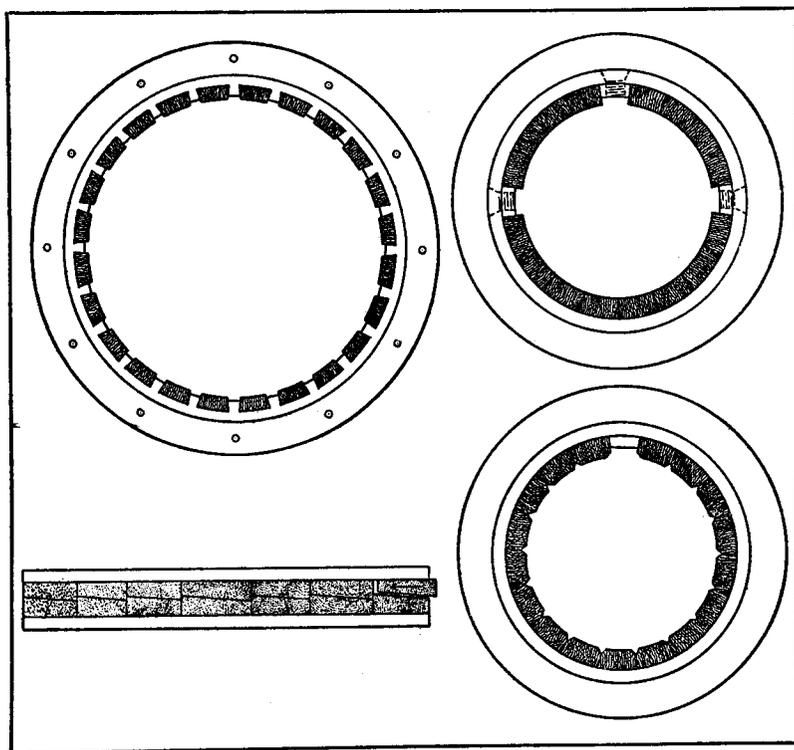
The stern tube, in which the propeller shaft revolves, extends from the peak bulkhead in the after part of the hull to the stern post and, in a large steamship, is from 3 to 7 feet long and from 12 to 22 or even 30 inches in diameter. The forward end, and in some recent instances the after end as well, is made water-tight by means of a stuffing box and flange.

The stern tube is composed of three parts, namely, (1) an outer steel tube with (2) a brass or bronze bushing or sleeve with longitudinal **cleats** or retaining strips which hold in place (3) the lining of end-grain wooden bearing blocks. The number of retaining strips varies in different forms of **construction**. There may be only one in which case it is located at the upper part of the tube; or two, one at each side; or three, one at each side and one at the top; or as many as there are rows of blocks, in some instances 24. In the first methods the lining between the retaining strip is of much the same structure as a wooden-stave pipe, each stave in this case being a row of end-grain blocks placed end to end, beveled along the side and machined on the faces to fit the bore of the tube. (See drawing, p. 30.)

The retaining strips serve not only to hold the blocks in place but also provide grooves into which water enters. The water serves the dual purpose of cooling and lubricating. Where the rows of blocks are arranged in a solid layer it is considered a good practice to cut V-shaped grooves at the joining lines to act as waterways. When ships operate in muddy water, sand is likely to wash into these grooves and cut the bearings. In some of the recent battleships, the *Texas* for example, sea water is excluded by making the after end of the tube water-tight at the stern post.

There are two principal methods of preparing the blocks for stern bearings. In one the logs are cross-cut into short blocks or "**pancakes**," the thickness (in direction of the fiber) varying from 1 to 2 inches according to the size of the stern tube. These "pancakes" are then sawed into **rectangular** blocks from 2 to 4 inches wide, not less than 4 inches long, the maximum lengths being determined by the diameter of the heartwood por-

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Cross sections of stern tubes of different types

At left a large stern tube with waterways between the strips of lignum-vitae blocks. Below a strip of blocks in position showing lengthwise cut to permit wedging into place.

At right: above, section of tube of a steam trawler showing solid lining with 3 retaining strips and waterways; below, section of a small tube, with single retaining strip at top and grooves for waterways cut between the blocks.

tion of the log. As soon as the blocks are sawed out they are dipped in shellac to prevent checking and warping prior to use.

There is a large amount of waste in cutting out these blocks, being about 33 per cent in logs 16 inches and over in diameter, about 50 per cent in those between 12 and 16 inches, and reaching as high as 75 per cent in the smaller sizes. On this account a minimum diameter of 12 inches is usually specified. It is also claimed that logs of the larger diameters yield better and particularly more resinous wood. The wood close to the pith is avoided because of the danger of checking there, while the sapwood is not used because it lacks the necessary resin.

In the second method the logs are cut into cants or planks of the required

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thickness and as wide as the diameter of the heart portion of the log will allow. These cants are then placed edgewise on an adjustable frame, rotating about a fixed center on the table of the band saw. In this way the blocks are cut with the proper degree of curvature to fit exactly into the sleeve. The blocks are then beveled and cut in two lengthwise, with a slight taper to permit wedging into place. (For more detailed description of this method of sawing blocks see *Woodworker*, Apr. 20, 1920, p. 40.)

After the blocks are fitted, wooden strips are temporarily placed in the grooves, and the tube is fixed in a lathe and bored out to the exact diameter required to fit the propeller shaft. To prevent the blocks drying out and checking or getting loose the tube is kept filled with wet sawdust and shavings until permanently installed in the ship.

The life of a lignum-vitae bearing is said to be about ten years. If the propeller shaft is out of alignment it may wear out the bearing in two years or less. The greatest wear is sustained by blocks in the lower part of the bearing since these support the most of the weight, not only of the shaft but also of the propeller which may be as great as nine tons. When to this dead load is added the impact of the waves it is obvious that only the densest and most tenacious woods would be able to withstand the enormous strains produced. Various woods have these properties but none other than lignum-vitae combine with them the natural lubricant indispensable to the prevention of heating and rapid attrition.

Small bushings are sometimes bored from solid wood instead of being built up. The process of manufacture of the so-called "patent feathering wheel bushings" which are used on certain side-wheel steamers is as follows: The logs are cut into bolts 16 to 18 inches long, slabbed to an octagonal form to remove the sapwood, and then turned in a lathe to a diameter of $5\frac{1}{16}$ or $5\frac{7}{8}$ inches. These cylinders are then cut into 7-inch and 8-inch blocks and the centers bored to the required size.

Bearings for water turbines.—"In America the bearings that are by virtue of their position permanently under water are usually made of lignum-vitae. This form of construction is most satisfactory, because the bearings cannot be lubricated and the lignum-vitae contains a quantity of oil which together with the water supplies sufficient lubrication. These bearing discs are made in two parts; the lower one, or so-called step, consists usually of a cylindrical section cut from a sound lignum-vitae log. The shaft bears immediately upon the perfectly smooth end grain of the disc, which withstands the wear and tear of the revolving shaft for many years without lubrication. However, when the water is muddy or contains sand it

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often wears the disc in a relatively short time, but **even** then it lasts considerably longer than steel under similar conditions. Steel or other metal could not be used unless lubrication was properly applied to the bearing parts.

"In addition to the step a collar is fitted around the shaft and on top of the step. This serves the dual purpose of holding the shaft from vibrating, and also prevents the wheel from slipping down in event the step bearing wears too much due to excessive friction and the enormous pressure.

"The collar is cut lengthwise so as to facilitate removing it for repairs. This method of constructing the step bearing is a simple and practical device which supports the lower end of the vertical turbine shaft. Its arrangement is efficient, accessible, interchangeable, and as firm as any of the other bearings in common use. **It** is of the greatest importance, however, that the bearing surfaces of the discs be finished by expert workmen and installed with the greatest care." (32.)

Bowling balls.-*Lignum-vitae* of prime grade is the only- wood which can be used satisfactorily in bowling balls. It was at one time extensively employed for this purpose but now only about one ball in ten is made of wood. **Quebracho** of Argentina, mancono of the Philippines, and various other woods have been tried but with poor success, owing to their tendency to check and split.

For the $8\frac{3}{4}$ -inch regulation ball, choice round logs from 9 to 12 inches in diameter and with the pith in the exact center are required. From such logs are cut 14-inch bolts and the ends immediately coated with shellac. Such a block is placed in a lathe, a ball rough-turned out of the middle portion, and dipped in hot shellac. The ball is then passed to a skilled workman at another lathe for final turning to size. **It** is next placed in a socket chuck and worked down with sand-paper of increasing fineness, followed by polishing with a woolen cloth. The thumb-and-finger holes are then bored, the ball set on pins and shellacked by means of a wide camel's-hair brush. In order to attain an exact weight the ball is tested from time to time during the finishing process and slight over-weight of the finished ball is overcome by increasing the depth of the holes a trifle.

The finishing of the balls requires a high degree of skill, and one man can do about three in a day. If, for any reason, the work is stopped, the wood is immediately coated with shellac to prevent checking.

"Cutting-up" wood.-*This* term is applied to logs of poorer grade which are cut up into small pieces for miscellaneous uses, one of the most important being castor wheels. Large quantities of culls, the crooked, eccentric, and

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variously defective logs, are disposed of for this purpose at a price of from \$25 to \$30 per ton. The advantage of lignum-vitae for casters is that it does not split or splinter and is less likely to mar the floor than metal is.

Mallets.-The largest market for mallet wood is in England. Small round sticks with a rather thick sapwood are preferred for this purpose. Much of this class of material is supplied by *Guaiaecum sanctum*. Lignum-vitae is considered superior to other woods for this purpose because of its hardness and weight together with its freedom from splitting and from brooming at the ends.

Pulleys, dead-eyes, etc.—Lignum-vitae finds a very important application in the manufacture of pulleys where it is used for the sheaves or wheels. Manufacturers prefer cylindrical logs of good quality and 8 inches and up in diameter. The properties which make the wood particularly applicable for this purpose are freedom from checking and splitting and great resistance to wear. According to Galletley (15, p. 384), "sheaves of pulley blocks made of it have been known to last in constant use for seventy years." Wooden sheaves are never used with steel cables or wire rope.

Another use in the shipbuilding industry is for dead-eyes and bull's-eyes. A dead-eye is a round flattish block, a few inches in diameter, with a grooved rim to fit in the bight of a rope or encircled by an iron band, and pierced with three holes to receive a lanyard. It is used to extend the shrouds and stays. A bull's-eye differs from the preceding in having a single hole instead of three. In making these articles the direction of the grain of the wood is not important, though slabs are easier to shape.

A minor use of lignum-vitae in shipbuilding is for the collars of rope guides. The collars noted by the writer in the construction of emergency tillers were about 2 inches thick with rounded corners about a 2-inch opening and bolted in pairs in a frame.

Fuel.-Between 150 and 200 tons of lignum-vitae are used annually in New York for firewood to burn in open grates. It makes a very hot and lasting fire and is said to excel all other woods for this purpose. The selling price per ton, delivered to residence, is about \$25 per ton. Only cull logs are used for this purpose. In some factories the sawdust and refuse are used as fuel under the boilers.

Railroad cross-ties.-The only data available regarding the use of lignum-vitae for cross-ties are contained in a report of the chief engineer of the Panama Railroad on the use and life of hardwood ties laid in the roadbed of the line from 1878 to 1895 (34, p. 85). During this interval more than 100,000 ties were laid. They were procured from the north coast

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of Colombia and were shipped to Colon from the port of Barranquilla. "They were of a variety of wood commonly known as lignum-vitae (*Guayacum recina*), and now spoken of as black guayacum to distinguish it from yellow guayacum, a wood of the same family,² but with less power of resistance to mechanical wear or decay."

In 1891 this note was made: "The exceptional durability of these ties (about 30 years, when of good quality) reduces the number of yearly requirements to small proportions." The report further states that in 1913 many of the early-laid ties were still in use in the roadbed and that others had been removed only because they were too small for the increased traffic. The condition of the ties removed is described as follows:

"The hardwood ties laid in the old track were, generally speaking, in very good condition. There were little, if any, signs of decay, but in many cases, especially with the smaller ties, they were badly worn at the rail seat by the Inechnical action of the base of the rail, no tie plates being used on the ties. They were also 'spike killed,' caused by replacing spikes and changing rail. It will be interesting to note that many of the ties removed from the main track at that time, and later, are now being relaid on the tracks connecting with the new terminal docks at Cristobal. The timber in the ties is practically as good as ever. As their smaller size is not objectionable in the yard tracks, it is expected that they will still have a long life in other services. Tie plates are not necessary with these ties, which results in some saving.

"The mechanical wear on the old hardwood ties in contradistinction to the decay of the wood is demonstrated by the fact that while the base of the rail and the driven spikes have cut into the hardwood and weathered it, the material in the balance is as good as ever. The same experience has, of course, long been encountered and commented upon in the tie records of the United States. The difference between the experience there and here, however, lies in the fact that the ties referred to in the former records have probably not been used for a period longer than 8 to 10 years, while local hardwood ties are from 20 to 25 years old, and have been used in a tropical climate where all other wood decays in from 3 to 5 years.

"The black guayacum cross-tie is probably a thing of the past. Such material is now so valuable for other purposes in connection with machinery and manufacturing arts, that it is not to be expected that it can be procured

² The yellow wood referred to is a species of *Tecoma* or *Tabebuia* of an entirely different family-the Bignoniaceae or catalpa family.

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at reasonable prices for cross-ties. The Panama Railroad Company has procured only 4,000 or 5,000 guayacum cross-ties in the past six years, and most of these have been of the inferior variety known as yellow guayacum."

Miscellaneous.-Among the miscellaneous uses for lignum-vitae may be mentioned stencil and chisel blocks, watch-makers' blocks, mortars and pestles, brush backs, dowels, golf-club heads, wooden cogs, and block guides for band saws. The sawdust or flour obtained in cutting up the wood is in demand by the drug trade at a price varying from \$20 to \$40 a ton.

Medicine.-*Guaiacum*, owing to its reported medicinal virtues, was one of the first plants of the New World to attract the attention of Europeans. . . . One Gonsalvo Ferrand has the reputation of having carried it to Europe about 1508; and three works describing its virtues were published in Germany previous to 1520" (40, p. 60).

The name lignum-vitae (wood of life) originated from the supposition that the wood was possessed of extraordinary remedial power. "It was used in Europe so early as 1508, and attained great celebrity as a remedy for *lues venerea*; but the general professional verdict is that it has no distinct influence in syphilis, nor yet in chronic rheumatism and gout, scrofula, or cutaneous eruptions against which it was formerly much used. It is usually exhibited in decoctions, and in combination with other medicines, as in the compound decoction of sarsaparilla" (10, p. 674).

"The ancient treatment of syphilis by guaiacum, which gained for the drug such immense reputation, consisted in the administration of vast quantities of the decoction, the patient being shut up in a warm room and kept in bed" (14, p. 103). On account of this use the wood is still known in Germany as "Pockholz," and "Franzosenholz"; also "Guaiacholz."

At first only the wood was employed medicinally, there being no known use for the resin. It is now recognized that the medicinal properties are confined to the resin or "concrete juice" which, because of its greater convenience in handling and preparation, is almost the only form of the drug now in the trade. It is a reputed diaphoretic and alterative and is occasionally prescribed in cases of gout and rheumatism.

Resin of Guaiacum: Its Properties and Uses

The following description of the resin, known as "guaiac" or "guaiaci resin," is taken from the latest edition of the American Pharmacopoeia (35, P-211):

"In irregular fragments or in large, nearly homogeneous masses, oc-

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asionally in more or less rounded or ovoid tears, enclosing fragments of vegetable tissues; externally brown, becoming greenish-gray-brown on exposure, the fractured surface having a glossy luster, the thin pieces being translucent and varying in color from reddish to yellowish-brown; odor balsamic; taste slightly acrid.

"Guaiac melts between 80° and 90°C. It is readily soluble in alcohol, ether, chloroform, creosote, and in the solutions of the alkalis or in hydrated chloral T.S. It is sparingly soluble in carbon disulphide or benzene and is not more than 15 per cent insoluble in alcohol; the alcoholic solution, on the addition of an excess of chlorine water or tincture of ferric chloride, becomes blue, changing quickly to green, the color being best seen when the solutions are diluted with an equal volume of water. . . . The powder is grayish, becoming green on exposure to the air."

The resin completely infiltrates the heartwood and makes up about one-fourth its weight. A specimen of the wood tested by Galletley (15, p. 384) has a specific gravity of 1.332 and yielded 30 per cent resin as follows: With naphtha, 9.4 per cent; with ether, 18.37 per cent; with alcohol, 2.22 per cent. The resin for the market is collected in the form of natural exudations ("tears"), by heating sticks of the wood and collecting the melted resin as it runs out, or by boiling the chips and sawdust with a solution of common salt and skimming off the substances which rise to the surface. (14, p. 103; 10, p. 674; 37, p. 694.)

Owing to the difficulty of securing the native resin during the war, New York dealers began its extraction from the sawdust and other waste supplied by factories using lignum-vitae. About 300 pounds of resin can be obtained from a ton of sawdust. The value of the resin varied from about 50 cents a pound before the war to about \$1.50 during that period.

The sawdust is very fine, of the nature of wood flour, and is decidedly yellow or orange-yellow in color. The writer boiled some of it in water to which a small amount of table salt had been added. A sticky and frothy scum formed on the surface and, after being removed and dried, the substance' crumbled to a fine grayish lusterless powder, turning dull green on exposure to the air and light. The water in which the sawdust was boiled was filtered and allowed to stand in the open for two weeks. It was of a rather opaque orange-yellow color, remaining unchanged with exposure, and had the characteristic scent of the heated wood. The coloring principles of the resin is known as "guaiac yellow" and, so far as known to the writer, it is not employed in dyes or stains.

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In oven-drying some specimens of the wood at a temperature of 100° C., a few blocks of fresh wood "bled" rather freely. The exuding resin was a deep reddish-brown in mass, translucent and garnet-colored in thin pieces; very brittle and crumbling readily between thumb and finger. It was very sticky while hot and drew out in long threads when touched with the finger. Left exposed to the air it gradually assumed a very dark green color. The specific gravity of this resin was found to be 1.23. The resin extracted with alcohol assumed a waxy consistency upon volatilization of the solvent but did not harden even after several weeks' exposure.

The composition of guaiacum resin was obtained by Hadelich (1862) to be as follows (see 14, p. 104) :

	<i>Per cent</i>
Guaiaconic acid ($C_{38}H_{40}O_{10}$)	70.3
Guaiaretic acid ($C_{20}H_{26}O_4$)	10.5
Guaiac beta-resin	9.8
Gum	3.7
Ash constituents	0.8
Guaiacic acid, coloring matter (guaiac yellow) and impurities	4.9

The decomposition products of dry distillation are: At 118°C., Guaiacene (C_8H_8O); at 205-210°C., Guaiacol ($C_6H_8.OCH.OH$), and Kreosol ($C_6H_8.OH(CH_3)^2$).

"After the removal by distillation of the liquids just described, there sublime upon further application of heat pearly crystals of pyro-guaiacin ($C_{38}H_{44}O_6$), an inodorous substance melting at 180°C. It is colored green by ferric chloride and blue by warm sulphuric acid. The similar reactions of the crude resin are probably due to this substance (Hlasiwetz)."

According to Lücker (29, p. 290), the formula for guaiac resin acid is $C_{20}H_{24}O_4$ and for guaiaconic acid is $C_{20}H_{24}O_5$. (For additional data on the chemical composition of the resin see Tschirch "Die Harze und die Harzbehälter," pp. 805-811).

Guaiacum resin is used in the preparation of the tincture of guaiac (tinctura guaiaca) and the ammoniated tincture of guaiac (tinctura guaiaca ammoniata).

"The tincture is of a deep-brown color, is decomposed by water, and affords blue, green, and brown precipitates with the mineral acids. It is colored blue by nitric acid, by chlorine, and by tincture of ferric chloride, and usually by spirit of nitrous ether, and is similarly changed when heated successively by diluted hydrocyanic acid and solution of copper sulphate.

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Either in substance or tincture, guaiac gives a blue color to gluten and substances containing it, to mucilage of gum arabic, to milk, and to various freshly cut roots, as to the potato, carrot, and horseradish. This is on account of the fact that oxidizing enzymes or oxidases are present in all of these substances and guaiac resin is one of the most delicate reagents for detecting this class of enzymes." (11, p. 539.)

The tincture of guaiac has also been used in the detection of blood stains. It produces a blue color when, in connection with hydrogen peroxide or other ozonized substance, it is brought in contact with the red coloring matter of the blood. It is also recognized as a valuable aid in distinguishing nucleated red blood disks, such as characterize birds, fishes, and reptiles, from the non-nucleated in man and other mammals. Its use in this connection for demonstration purposes in jury trials is recommended by Bertelot (4, pp. 127-130).

SUBSTITUTES FOR TRUE LIGNUM-VITAE

Woods of the Lignum-vitae Family

"*Maracaibo lignum-vitae*," or *vera*.—The properties which especially adapt lignum-vitae to its most exacting uses are extreme density, durability and toughness, combined with self-lubrication. All of the woods of the family possess these properties to a degree but, as already shown, that of *Guaiacum* alone, and apparently only certain kinds of it, meet the full requirements of the trade. The wood of *Porlieria* is not upon the market because the trees are too small. *Bulnesia*, however, is of comparatively good timber form and can be had in considerable quantity. It is sometimes used as a substitute for the genuine lignum-vitae, but its principal use is said to be for steps and collars for water turbines. (See page 31.)

This "Maracaibo lignum-vitae" or vera-wood is not considered suitable for propeller-shaft bushings and certain other purposes. The objections that have been made to it are that it does not wear well and that the grain is less interwoven than in the best of the genuine wood and accordingly there is more liability to cup-shakes, radial cracks, and similar defects. One New York dealer states that 75 per cent of the vera logs he has seen showed bad ring-shakes. The lower resistance to wear may be due, in part at least, to the large number of crystals present in the wood of this genus since they would act in the nature of a very fine, sharp and hard sand or grit.

The writer has been unable to determine the extent to which these objections are justifiable. The fact remains that the wood is less used now than

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it was a few years ago and is in little demand at a price from one-third to one-half that of the Cuban. The only figures available on the amount of vera exported are for transshipments from Curaçao during the fiscal years 1912, 1913, 1914, 1915, the values being \$4,822, \$3,431, \$4,361, and \$1,941 respectively. These values include an unknown amount of Haitian wood of the same name.

"*Paraguay lignum-vitae.*"— This is the wood of *Bulnesia Sarmienti* locally known as "palo santo" on account of its use for incense in churches. As previously stated, this wood has a place on the market in the manufacture of the "oil of guaiac wood" used by perfumers. It is also used to a small extent in Argentina for chucks and bearings and for various purposes such as small articles of furniture, utensils, and ornaments (31, p. 122).

In Paraguay it occurs scattered among the quebracho trees, and owners of timberlands there are seeking a market for their wood under the name of "Paraguay lignum-vitae." Unless the wood should prove of much better quality than the vera (described above), which is unlikely, the much higher cost of transportation will probably prevent its exploitation.

Woods of Other Families

"*Philippine lignum-vitae.*"—There is no wood on the market which is recognized by the trade as a satisfactory substitute for lignum-vitae. A few have been proposed and advertised. Among these may be mentioned the "mancono," sometimes called "Philippine lignum-vitae" (41, p. 19). The botanical name of this tree is *Xanthostemon verdugianus* Naves, and it belongs to the Myrtaceae or eucalypt family.

The heartwood of mancono is brownish, turning purple when exposed to the air; the sapwood is very narrow and of a pale reddish color. The wood is very heavy and hard, the specific gravity of the oven-dry material being about 1.24. The grain is fine and twisted. The wood checks badly upon exposure to the air, though most of the cracks are said to be superficial (26, pp. 3-4). The writer is informed that the experimental use of this wood for bowling balls proved its unsuitability for that purpose. There are no records of it having been tested for bushing blocks for steamships.

"*Red lignum-vitae.*"— The term "red lignum-vitae" is sometimes used in the trade to designate quebracho when used for articles of turnery. This is an extremely hard reddish wood, becoming claret-red upon exposure, chiefly used as a source of tannin extract. There are two species, *Schinopsis Lorentzii* Engl. (= *Quebrachia Lorentzii* Griseb.) and *Schinopsis Balansae*

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Engl. The principal sources of supply at present are Argentina and Paraguay.

The wood is used for some of the purposes for which true lignum-vitae is employed, for example bowling balls and other turned articles, but is unsuited for bearings. The wood has no resemblance to *Guaiaacum* except in density, which is given by Mell and Brush (33, p. 6) as 1.2 to 1.4. It lacks odor, is not oily, has a reddish color, is without ripple marks, and some of the rays contain intercellular canals.

"*Indian lignum-vitae.*"—The true lignum-vitae does not grow naturally in the Old World but *Guaiaacum officinale* is occasionally cultivated in the tropical regions, as in Calcutta and Madras (15, p. 132). An Indian wood sometimes known as "lignum-vitae of Pegu" (29, p. 35), the "varnish tree" of Burma, is *Melanorrhoea usitata* Wall. of the Anacardiaceae or sumac family. The description of this wood as given by Gamble (16, p. 217) suggests lignum-vitae in that it is highly resinous, fine-textured, very hard and heavy, though the latter statement is hardly consistent with the given weight per cubic foot, namely, 54 pounds. Some authorities give the weight as 59 pounds. A writer in *Hardwood Record* (29, p. 35) says that this wood's "extreme closeness of grain and density of structure suggests a relationship with the true lignum-vitae" but there is no evidence that it is suitable for, or has ever been used as, a substitute for the latter.

"*African lignum-vitae.*"—A New York dealer informs the writer that he has been offered 100 tons of "African lignum-vitae," but the nature of this wood and the species producing it were not known. According to one writer (29, p. 35), "the 'African lignum-vitae' (*Combretum truncatum*) is a large tree which is abundant in lower Guinea and the Mosambique districts. The wood is very hard, heavy, close-grained, and with a deep reddish-brown heartwood and light-colored sapwood." This wood belongs to the family Combretaceae, is not closely related to the true lignum-vitae and, so far as known to the writer, has not been used in bearings.

"*Australian lignum-vitae.*"—Boulger (5) describes six Australian woods which are sometimes called "lignum-vitae," namely, (1) *Acacia falcata* Willd. (Leguminosae), (2) *Myrtus semenoides* F.v.M. (Myrtaceae), (3) *Eucalyptus polyanthema* Schau. (Myrtaceae), (4) *Phyllanthus Ferdinandi* Müll. Arg. (Euphorbiaceae), (5) *Vitex lignum-vitae* A. Cunn. (Verbenaceae), (6) *Dodonaea viscosa* L. (Sapindaceae). He says that the last

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mentioned, which is found throughout the Tropics, is "suited for all the uses of the true lignum-vitae." In India, according to Gamble (16, p. 132), this species is only a shrub, the wood of which is used for engraving, turning, tool-handles, and walking sticks.

Baker (2, pp. 49, 57, 232, 375) mentions four Australian woods as possible substitutes for lignum-vitae, namely, *Elaeocarpus Banero/iii* F. M. & B. (Tiliaceae), *Geijera parviflora* Lindl. (Rutaceae), *Eucalyptus Thozetiana* F. Muell. (Myrtaceae), and *Casuarina Cambagei* Baker (Casuarineae). Of the third he says (p. 232): "The timber of this tree is probably harder than that of any Eucalyptus tree. It is very heavy, close-grained and interlocked, has a chocolate color, and much resembles in texture, color, and hardness, lignum-vitae, *Guaiacum officinale*, Linn., of Central America. In fact it is more deserving the title of Australian 'lignum-vitae' than other trees of the continent passing under that name, and it is so named in the museum specimens." As to the wood of *Casuarina Cambagei* (p. 375): "It is very dark chocolate in color, hard, close-grained, without a figure, ... dresses to hard, firm, even surface, takes a good polish, and ... is the most suitable of all Australian timbers for shaft bearings, being the nearest substitute for lignum-vitae so extensively used for this purpose." There is no evidence that any Australian wood has actually been used for such a substitute.

Other woods called lignum-vitae.-*Boulger* (5) also reports that the name lignum-vitae is applied to the following additional woods: *Metrosideros scandens* B. & S. (Myrtaceae), a tall creeper in New Zealand; *Ixora ferrea* Benth. or *Siderodendron triflorum* Vahl. (Rubiaceae) of British Guiana; also known as "hackia," "West Indian ironwood" and "Martinique ironwood";³ also to an unknown species shipped from Guayaquil and called "Guayaquil lignum-vitae," though "having nothing in common with the true lignum-vitae, to which it is inferior." Further this author (5, p. 289) states that "among the ancients and in France the name (lignum-vitae) has been applied to *Tetraclinis articulata* Vahl."

"*Guayacan.*"-The generic name *Guaiacum* (also spelled *Guayacum*) is derived from the vernacular name "guayacan." The latter, or some variant of it, is applied by Spanish-speaking people not only to all the woods of the lignum-vitae family (Zygophyllaceae) but to many others as well. It seems to be the equivalent of the English term "ironwood" and is

³ These names are applied to *Tabebuia* sp. (Bignoniaceae) according to Stone and Freeman (44, p. 31).

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likely to be used to designate any hard and heavy timber, particularly one which is not well known by some other name.

In Argentina, the names "guayacan" or "guayakan," and "guayacan negro" are applied to *Caesalpinia melanocarpa* Griseb. of the Leguminosae or pea family. This tree reaches a height of 65 feet and a diameter of 20 inches (44, p. 354). The wood varies in color from chocolate-brown to nearly black, is very hard, heavy, durable, and more or less cross-grained. It is in local demand for turnery but apparently is not exported.

uYellow guayacan."-The fallacious contention that because true lignum-vitae is called "guayacan," any wood called "guayacan" is true lignum-vitae, has resulted in much confusion and in the substitution of inferior material for the genuine.

A most conspicuous instance of this is described in *Hardwood Record* (28, p. 22). It appears that in 1918 the Navy Department accepted the bid of the officials of the Panama Railroad, Canal Zone, for over 300,000 pounds of lignum-vitae logs. A specimen of the wood supplied was examined by the writer and found to be (as reported) a species of *Tecoma* (or *Tabebuia*) of the Bignoniaceae or catalpa family, though locally known as "yellow guayacan" or "yellow guayacum." (See "Uses of lignum-vitae; Railroad cross-ties.") It is also reported that considerable of this wood was purchased by the Emergency Fleet Corporation, and used for stern bearings but with what success the writer is unable to determine. In order to prevent checking the logs were stored under water, shipped in wet sawdust kept wet while cutting and fitting into the tubes, a practice which might be followed with the more refractory kinds of genuine material with success. The wood in question seems to be lacking in the essential properties of the genuine and it will be very surprising if it proves to be a satisfactory substitute.

"Yellow guayacan has never been used anywhere for bearings," says a writer in *Hardwood Record* (28, p. 22), "and only the slightest knowledge of the structure of the wood is required to convince anyone that it is not suitable for any part of a vessel coming in contact with water and subjected at the same time to great wear and tear, as in the case of bushing blocks."

The Bureau of Construction and Repair of the Navy Department advises

*Castro (8, p. 47) gives the specific gravity of this wood as ranging from 1.113 to 1.811. Another leguminous wood, "guaycuruzu," is reported by Castro to have a density of 1.655. Since the specific gravity of dry wood substance is between 1.50 and 1.56, it seems impossible for any wood to have so great a density as these larger values, even allowing for infiltrated substances.

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the writer in a letter dated March 29, 1919, that it "made one purchase of *Tabebuia* with the expectation that this material would be suitable for the same uses for which the genuine lignum-vitae is required. Tests have proven that this material has sufficient strength and hardness but is lacking in oil content which prohibits its use for stern tube bearings which require wood of self-lubricating properties."

The writer found some of this material in the New York Navy Yard and was informed that it has been used to a small extent for stern bearings either alone or in connection with genuine lignum-vitae. In the latter case the lower half of the tube would be lined with the genuine wood, the upper, where wear is less, with the substitute. The workmen had no difficulty whatever in recognizing this substitute and were outspoken against its employment where the genuine could be had.

The "yellow guayacan" grows also in Mexico and is sometimes called "Mexican lignum-vitae." The writer saw about 200 tons of it in New York where it had been stored for several months owing to the inability of the owners to dispose of it profitably. A wood of the same or, more likely, a closely related species grows in Colombia and is called "guayacan polvillo." One in British Guiana is, as stated elsewhere in this paper, called "hackia" or "lignum-vitae." These woods are hard and heavy and more or less cross-grained, sometimes decidedly so. They are of a yellow color due to the deposits of a crystalline substance called "lapachoL" They bear so little resemblance to the true lignum-vitae that there is no occasion for confusing them with it.

The writer was recently informed by a person familiar with the timbers of Central America that at least 40 different kinds were locally called "guayacan." While this may be an exaggeration it serves to emphasize the need for discrimination on the part of the buyers and users of lignum-vitae if they would avoid being imposed upon, whether intentionally or otherwise.

uPalo santo" or "páó santo."-The woods of the Zygophyllaceae are often called "palo santo" in Spanish America. The equivalent Portuguese term is "páó santo." The wood of *Zollernia paraënsis* Huber (Leguminosae) of Brazil is known by this name and, presumably on this account, it has been exported as a substitute for the wood of *Guaiacum officinale* which, according to Huber (24, pp. 179-181), it resembles in its physical properties. He describes the tree as tall with a cylindrical trunk and light gray and scaly bark. The heartwood, which is relatively large and distinctly differentiated from the light yellow sapwood, varies in color from light gray or greenish to almost black. Sometimes it is spotted like "snakewood" (*Brosi-*

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mum Aublettii P. & E.) and is then called "muirapinima preta." A specimen, said to have been a part of the Huber collection, was examined by the writer and found to be hard, heavy, and fine-textured, but perfectly straight-grained, fissile, and non-resinous.

SUMMARY AND CONCLUSIONS

(1) The true lignum-vitae of commerce belongs to the family Zygo-phyllaceae, of which only three genera, namely, *Guaiacum*, *Porlieria*, and *Bulnesia*, have representatives of tree size, and these are confined to the tropical and sub-tropical regions of the Western Hemisphere. *Porlieria* is of no commercial importance.

(2) The genus *Bulnesia*, with its several species, is confined to South America. *Bulnesia arborea* Engl., the only species of present commercial importance, grows in Colombia and Venezuela, and supplies the wood known as "vera" or "Maracaibo lignum-vitae." It is sometimes used as a substitute for the genuine but is considered inferior.

(3) The true lignum-vitae is produced only by species of *Guaiacum*, of which six have been described by botanists. The commercial range of this genus includes the West Indies, Mexico, Central America, and the coastal region of northern South America. It is not definitely known which species supply the Mexican and Central American wood of commerce.

(4) Lignum-vitae is one of the heaviest woods in the world. The weight (oven-dry) per cubic foot of the heartwood is usually between 75 and 80 pounds. The wood has been an article of trade for more than four centuries. It was formerly supposed to possess remarkable curative powers but is now little employed in medicine. Its principal uses are for bearings (especially for lining the stern tubes of steamships), sheaves, castor-wheels, bowling balls, and miscellaneous articles of turnery. During the war there was an unusual demand for this wood in the shipbuilding industry.

(5) The properties which make lignum-vitae valuable are great density and hardness, extreme toughness, and resistance to wear. The large resin content of the wood acts as a preservative and a natural lubricant, thus making it especially adapted for service under water, as in the case of propeller bushings and water-wheel work.

No wood has been found which is a satisfactory substitute for the more exacting uses to which true lignum-vitae is so eminently suited.

(6) The woods of the Zygophyllaceae can be readily distinguished from all others by the fineness of the "ripple marks" (about 250 per inch), the density and grain of the wood, and the peculiar fragrant resin content. The

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woods of *Guaiacum* and *Bulnesia* can be readily separated by noting the arrangement of the pores as they appear under a hand lens. The different kinds of true lignum-vitae logs can best be separated by their size and by the appearance of the bark.

(7) Dealers have no difficulty in getting an abundant supply of genuine lignum-vitae logs. Although the more conveniently located timber has in many places been cut out, increased prices have made it possible to secure timber previously considered inaccessible. The supply appears adequate to meet the demands for a great many years.

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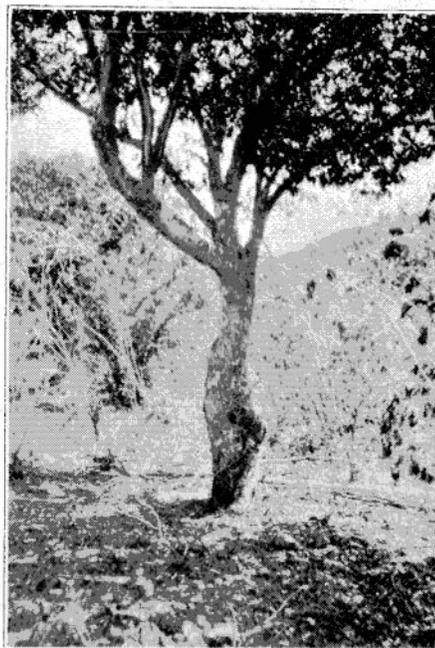


Photo by Pittier

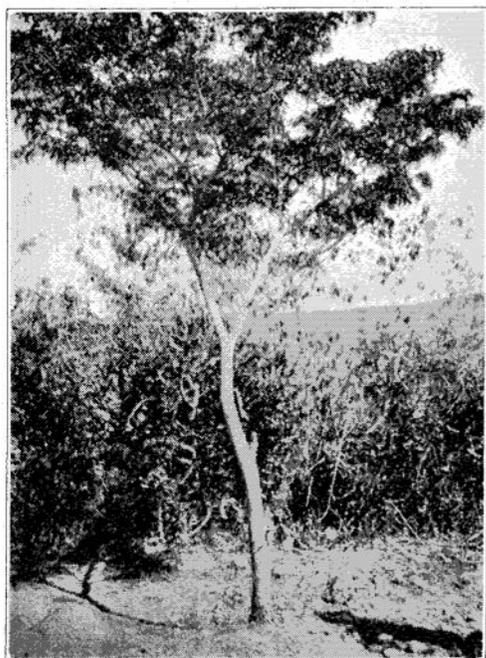
BULNESIA ARBOREA NEAR PORTO CABELLO. VENEZUELA



GUAIACUM OFFICINALE



GUAIACUM SANCTUM



YOUNG TREE



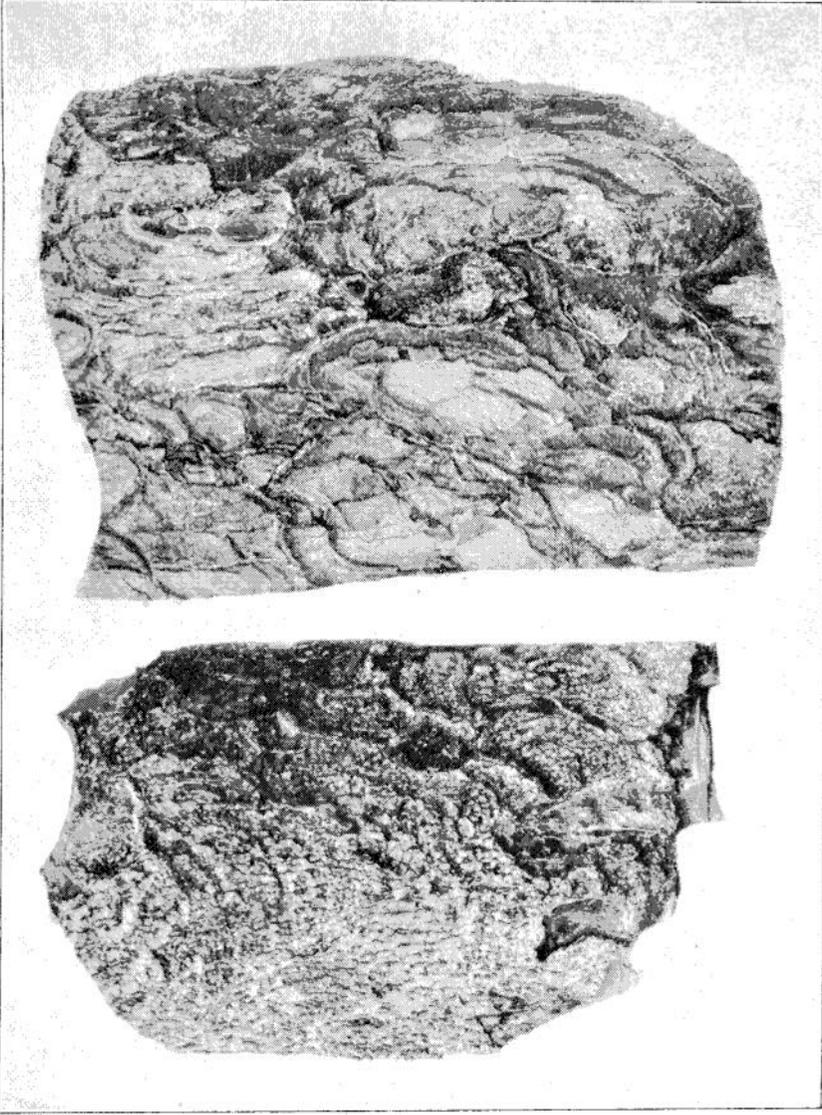
MATURE TREE

Photos by Mell

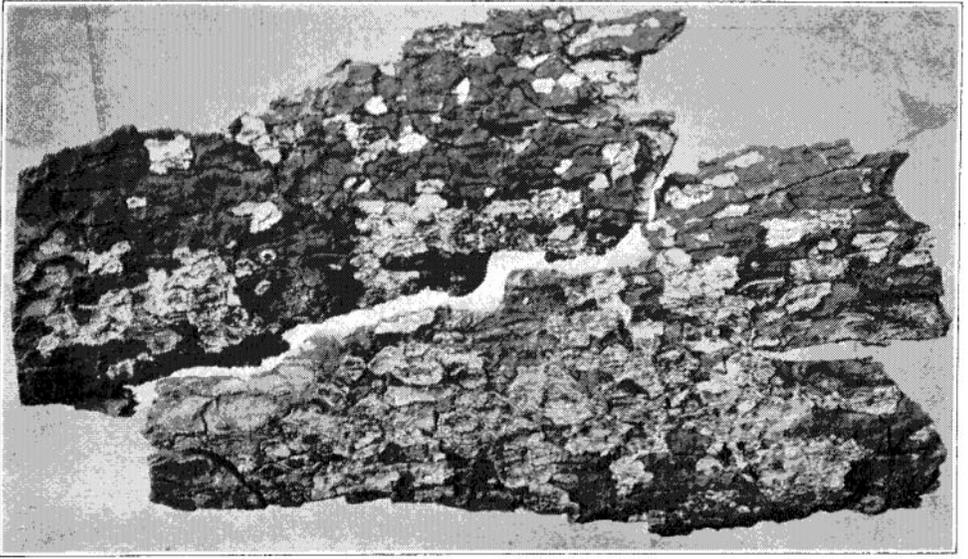
GUAIACUM SANCTUM VAR. OF HAITI



TYPICAL BARK OF CUBAN LIGNUM-VITAE.
(GUAJACUM OFFICINALE) $\times\frac{1}{2}$



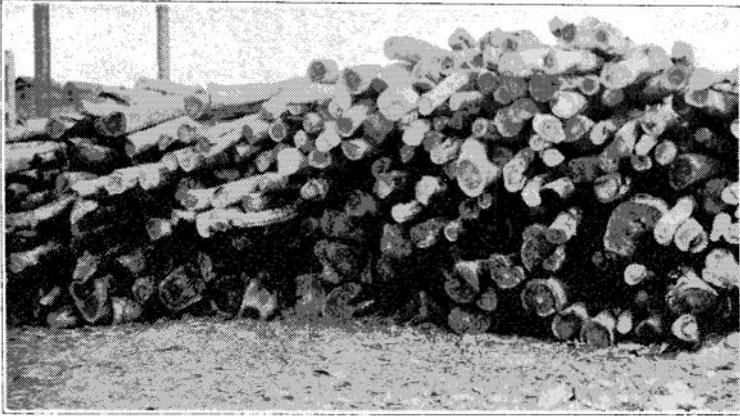
BARK OF NICARAGUAN LIGNUM-VITAE (GUALACUM SP.) X $\frac{1}{2}$



BARK OF HAITIAN VERA (*GUAIACUM SANCTUM* VAR.) $\times\frac{1}{2}$



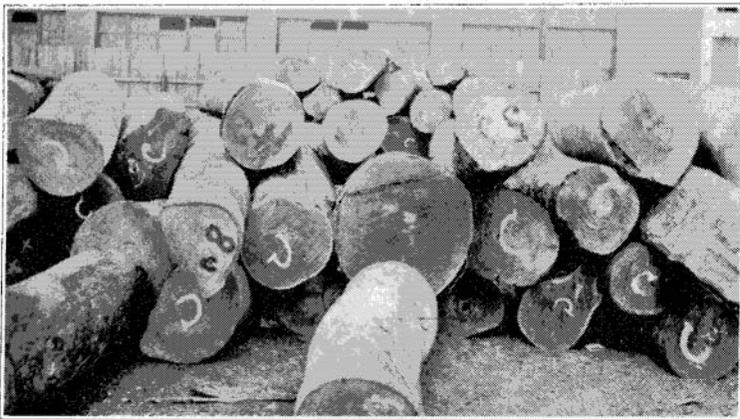
LOGS OF *GUAIACUM* ST. FROM NTCARAGUA



LoeSOF GUALACUM SANCTUM FROM JAMAICA



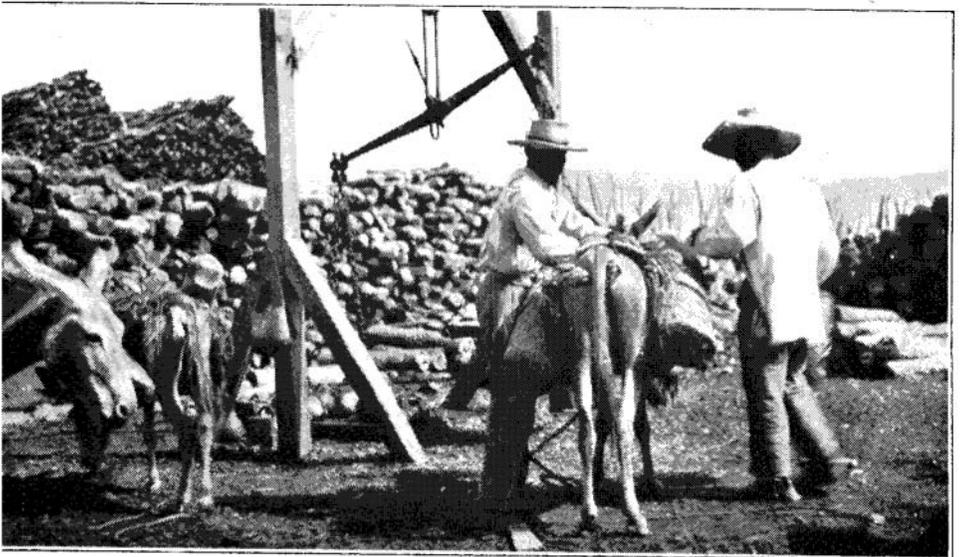
LOGS OF GUALACUM SANCTUM VAR. FROM HAITI



LOGS OF GUALACUM OFFICINALE FROM CUBA



METHOD OF TRANSPORTING LIGNUM-VITAE LOGS IN HAITI
(In the background is a large pile of logwood.)



Photos by Mell

A WOOD YARI IN HAITI SHOWING METHODS OF TRANSPORTING,
WEIGHING, AND STORING LIGNUM-VITAE LOGS

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