CHAPTER 5. ANATOMY OF THE 2^{ND} PHLOEM OF *THUYA PLICATA* (WESTERN RED CEDAR-WRC) Figs 5.1a- 5.5c

5.1 Introduction

Tissues in perennial plants that are produced in the plants first year growth are called primary tissues and those that are formed after one year's growth, are called 2nd tissues. The two tissues are anatomically different.

Secondary (2^{nd}) phloem of WRC is commonly called bark. The so called cedar bark used for artifacts is not true bark tissue, it is 2^{nd} phloem tissue.

The term bark is generically divided in all stems into inner and outer bark. Outer bark is made up of the tissues (Fig.5.1a) from the outside inwards, the surface epidermis, the complex periderm, and the cortex. Details of branch outer bark are discussed in Chapter 4 The outer bark is seen on trees such as maple trees as a colored epidermal or in the case of white birch bark where the phellem cork cells (see Figs.3.4a-c) have replaced the epidermis..

In tree trunks the inner bark may have fragments of the primary phloem but is mainly 2^{nd} phloem. Next to the 2^{nd} phloem is the central heartwood, the 2^{nd} xylem cells.

In some coniferous trees the outer bark is sloughed off and the inner bark remains on the outside of the tree trunk. It is seen as fragments of secondary phloem tissue, and is called a rhytidome as is seen on WRC.

In all plants, living phloem tissue is the metabolic tissue that stores starch and may hydrolyse the starch to glucose for transport. When glucose is needed, it is transported in the phloem along with water, up and down the tree branch or trunk and radially to adjacent xylem sapwood. The fluid is called sap. The nutrients are from photosynthesis in chlorophyll containing leaves. Some young branches may also have chlorophyll and also produce sugars. The nutrients in phloem tissue in tree trunk sapwood were used as a food source in many ethnographic cultures.

2^{nd} phloem tissue is made up of three types of cells: the parenchyma cells that store the nutrients and water; the inert sieve cells that transport the water solution to sapwood cells and 2^{nd} phloem fibers for structural strength. It is the 2^{nd} phloem fibers that are important in artifacts.

The 2^{nd} phloem groups are often seen in a pyramidal shape because the cambium, from which it grows, grows laterally to keep up with the increase in circumference of the tree trunk. Thus in older trunks the new phloem, next to the cambium and 2^{nd} xylem, has a broader base than the older phloem, thus making a pyramid. In WRC as the tree trunk increases the outer bark (epidermis, periderm, cortex and phloem) cannot keep up with its inner circumferential growth and splits lengthwise and is sloughed off.

There are thin walled parenchyma cells between the 2^{nd} phloem groups that continuously grow between the groups of phloem fibers. The parenchyma cells enlarge greatly and form grotesque, gargoyle like shaped cells but they still are attached to the phloem fiber bands and that keep the groups of phloem fibers together as they are pushed outwards. When exposed at the surface these parenchyma cells eventually die and then the groups of phloem fibers easily fragment and may fall off. This fragmented surface on the tree trunk is called the rhytidome (rhinoceros skin).

In the ethnographic use the WRC bark is striped off the tree trunk by making a cut across the bark at the base of the tree and a cross cut t the height they want. This cut piece is pulled off upwards and is easily separated from the tree trunk at the delicate, thin, living cambium region.

Different growth rings of 2nd phloem at the various stages of growth are used for specific ethnographic artifacts. The newly formed young 2nd phloem, close to the cambium, still is in flat intact groups and is used in weaving baskets and textiles. The outside of old 2nd phloem is highly separated and fragmented into small groups of fibers. These are used as fragments for ceremonial decoration or coiled together to make rough cordage.

In most dicot trees, such as maple trees, the 2nd phloem fibers form circular bands that are protected by the outer bark. These groups of phloem are used ethnographically after alteration such as pounding and retting to make, artifacts of cloth, paper, cordage etc., for example, the textile, tapa cloth, maple cordage etc.

The primary phloem of dicot annual plants -not trees-, i.e., jute, nettle, linen, ramie, etc., produce fibers used for textiles, string and cordage etc. These fibers are commonly called bast fibers. The fibers are in groups located in the cortical region between the periderm and secondary phloem. They give the plant stem its structural strength.

5.2 2nd phloem bark anatomy of *Thuja plicata* (western red cedar). .

5.2.1 Cross (transverse) section of a branch and outer tree trunk bark (rhytidome) surface of 2nd phloem of *Thuya plicata* (WRC). Figs. 5.1a-b, Figs. 5.2a-e

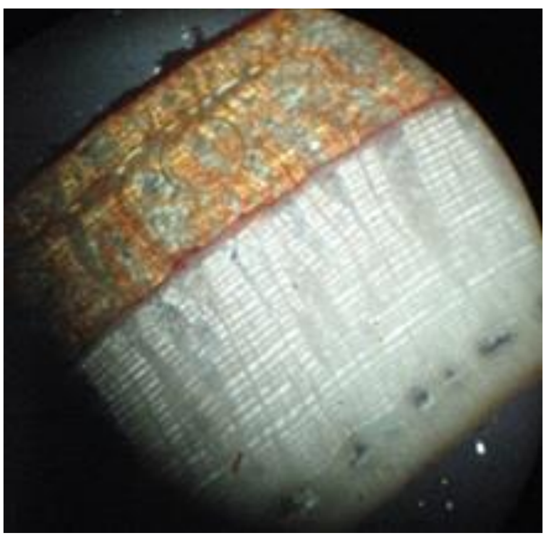

Fig.5.1a

Fig.5.1b

Fig.5.1a photomicrograph taken under polarizing light, of the cross section of outer part of young WRC branch. The outer two brown cells are dead, 2nd phloem groups and the white

are living groups. The brown in the phloem bands is a polyphenolic that acts as a biocide. The 2nd phloem groups are separated by a red layer of a purple nonanthocyanic phlobaphene. Below it are some empty traumatic axial resin canals at the 2nd xylem region.
photomlf

Fig.5.1b is a photograph, of the outer surface of an old tree trunk. The surface bark is made up of dead 2nd phloem, called the rhytidome. It fractures-is split- to compensate for the increase in girth of the tree trunk as it grows. Seen at the bottom of the image of the fragmented phloem is a smooth lighter brown piece of heart wood with some beetle tracks.
photomlf

The cross section of the outer portion of a three year old WRC branch is shown in Fig.5.1a. The complete cross section would have show further xylem wood tissues at the bottom edge of the 2nd phloem. At top left, the thin dark red outer surface is the location of the true bark. The true bark on a tree trunk of a WRC is sloughed off after about ten year's growth and replaced by only growing 2nd phloem.

In Fig.5.1a below the surface outer bark, there are two different colored groups of cells, light brown, triangular wedges of dead 2nd phloem and living younger white functional 2nd phloem of the present years growth. The white functional 2nd phloem will become brown after another year growth occurs.

The light brown phloem is in two groups showing the growth of two years. The dark line between these two groups and the red line separating them from the white region of 2nd phloem demarks the annual rings – 3 years growth. These lines are parenchyma cells filled with a red dye called phlobaphene. Phlobaphene is a mixture of red pigments with biocidal features and functions to protect the phloem tissue from fungal activity. They are common in many coniferous trees. Non functional –dead- 2nd phloem fibers are brown because resinous polyphenolic chemicals are produced to protect the cells from insect and fungal attack and also to water proof them.

Fig.5.1b is a photograph of a piece of WRC outer, external 2nd phloem-the rhytidome. It shows the fragmentation of the 2nd phloem that is a result of the increase in circumference growth of the tree's trunk.

The living 2nd phloem stores nutrients and transport organic nutrients and water to other parenchyma cells in the sapwood and in branches.

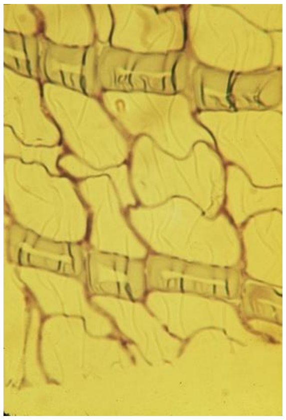

Fig.5.2a

Fig.5.2b

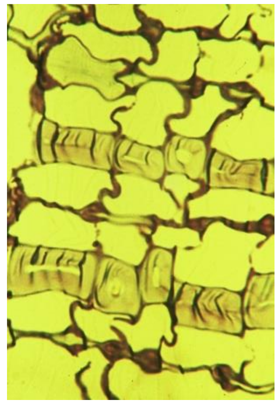

Fig.5..2c

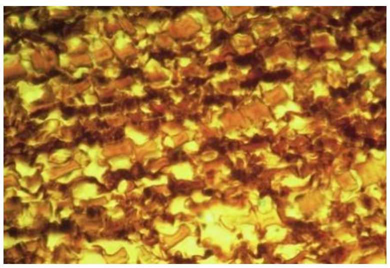

Fig.5.2d

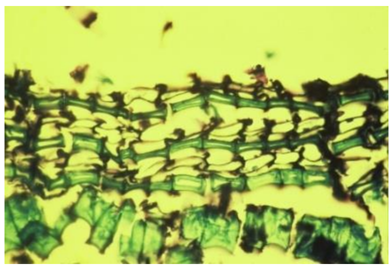

Fig.5. 2e

Figs.5.2a-e cross sections of 2nd phloem tissue showing collapsing cells over aging. It shows that as the tree grows, the phloem tissue ages, the thin walled parenchyma cells fracture easily and the tissue is crushed by continuous growth. The fibers still remain in rows but the tissue becomes disorganised. Figs.5.2, a, c and e are stained with methyl blue for visible enhancement. Fig. 5.2.b is stained with phloroglucinol to show the presence of lignin in the phloem fibers. Fig.5.2.d is natural brown colour of the polyphenolic in an artifact. Fig.5.2e show the beginning of fragmentation. The phloem fibers vary in size in diameter averaging 7x15μm (height x width). photos Fig.5.2a and 2c Arlene Bramhall, Western Forest Products Laboratory 1978. Figs.5.2b, d and e photomlf,

Fig.5.2a is a photomicrograph of a thin cross section of a histological stained sample of living phloem. The dark blue rectangular cells are 2nd phloem fibers that have been stained with methyl blue. Between the fibers are three thin walled cells. The two outer sieve cell that transport water, nutrient, and the central parenchyma cells that are involved in storing starch from leaves and converting them- when needed -into glucose that is passed to the sieve cells for transport to sapwood in branches, tree trunks and stems

Figs.5.2a-e show the progress changes in the 2nd phloem tissue due to aging. Fig.5.2d shows the natural color in the aged tissue. Fig.5.5e shows the complete collapse that would occur in some artifacts where the tissue was purposely crushed for weaving.

5.2.2 Radial section of 2ndphloem of *Thuya plicata (*WRC). Figs.5.3a-f.


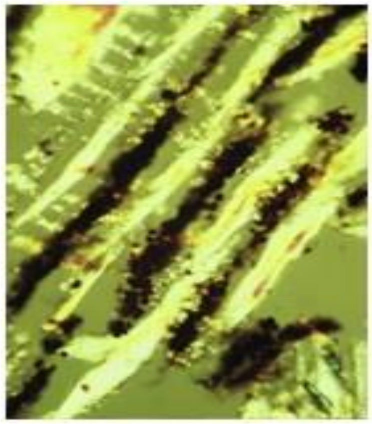
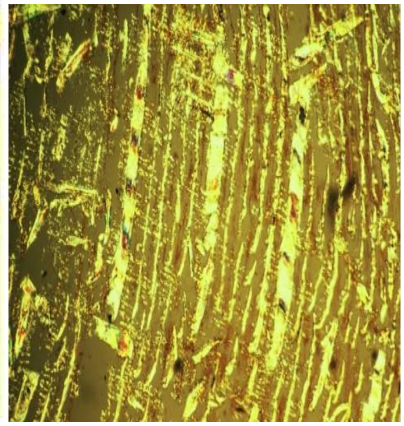

Fig.5.3 a Fig.5.3 b Fig.5.3c

Figs.5.3 a-c, -left to right- show the radial surface of the secondary phloem tissue under different staining and photographic light. Figs.5.3a and b, are stained for the presence of starch. The black starch is shown in parenchyma cells between the outer two sieve cells and that are next to the 2nd phloem fibers. Figs.5.3b and c are shown under polarizing light. They show the presence of calcium oxalate crystal and the birefringence of the 2nd phloem fibers. The two different sizes of the fibers shown in (Fig.5.3c) is the result of annual, seasonal, growth rings. photomlf

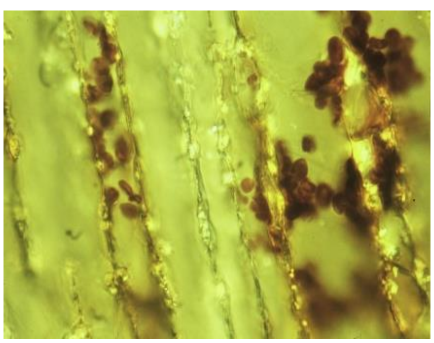
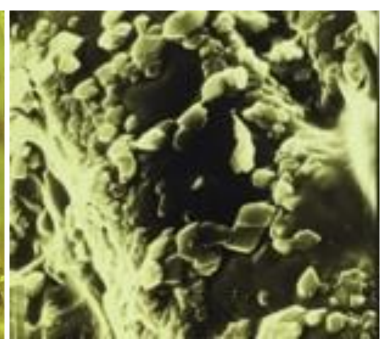


Fig. 5.3d Fig. 5. 3e Fig. 5.3f

Fig. 5.3.d is a radial section of WRC 2nd phloem under polarizing light and stained for starch show the presence of starch grains and groups of birefringent calcium oxalate crystals. photomlf

Fig.5.3e is a radial section of WRC 2nd phloem scanning electron image of the irregular rectangular calcium oxalate crystal shapes commonly called rhombohedron. photo Arlene Bramhall, Western Forest Products Laboratory 1978

Fig.5.3f is a calcium elemental map of the image in Fig.5.3e, taken by an electron dense ex-ray (EDX) to show the map of the presence of calcium outlining the calcium oxalate cystals. **photo Arlene Bramhall, Western Forest Products Laboratory 1978**

Figs.5.3a,b and c shows the radial view of the 2nd phloem and the contents of the different cells under different methods of preparation and show the presence of starch grains and calcium oxalate crystal. Fig.5.3a is the natural colour under normal lighting and b and c using polarizing light. Figs.5.3a and b. have been stained for the presence of starch. Figs.5.3b and c is shown under polarizing light.

Under polarizing light the fibers and calcium oxalate crystal show birefringence. The crystals are deposited outside the parenchyma cells. Calcium oxalate is like a waste product of metabolism. It is very common in barks. Chemically it is found in the crystalline monohydrate and dihydrate state suggesting a role in metabolic water relationships. It is a water insoluble chemical and stays in the tissues. In the bark it functions in catabolic disposal, primarily sequestering extra calcium and also discourages grazing of the bark by herbivores and bark beetles.

Figs.5.3b and d, have been stained for starch. The starch grains are present in the central phloem parenchyma cells located between the sieve cells. The starch is used during metabolic activity and is rarely present in dead 2nd phloem. During a year's growth the growth rings are obvious by the large and small 2nd phloem fibers. In early –spring- growth the 2nd phloem fibers are wide and narrow during the remaining of the year. This is obvious in Fig.5.3c.

Fig.5.3e show details of the calcium oxalate crystal under scanning electron microscopy to show their shape and Fig.5.3f electron dense x-ray (EDX) to show the presence of calcium in the crystals. EDX can be used to map the presence of specific elements in materials. In dead 2nd phloem the crystals may be still present and commonly free from the cells. The shapes in some plants are characteristic and assist in identification of the plant species.

5.2.3 Sieve plates in 2nd phloem of *Thuya plicata* (WRC). Fig.5.4a.

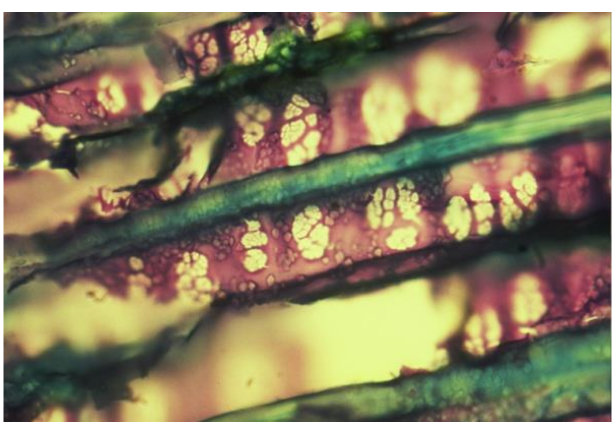

Fig.5.4a

Fig.5.4a is a photomicrogaph that shows two groups in a growth ring of WRC 2nd phloem. The sample was stained with saffranin and fast green and shows the purple marginal sieve cells and their sieve plate design and central small brown parenchyma cells and blue 2nd phloem fibers. Each group is made up of two outer, purple seive cells and a brown central parenchyma cell. photomlf

Fig.5.4a is stained with stained with saffranin and fast green. The phloem fibers are blue. Between two blue phloem fibers are two rows of purple sieve cells separated by a brown narrow parenchyma cell. The tissue has been fractured during sectioning showing incomplete sieve cells at the bottom of the photo. The sieve cells have a number of irregular oval shaped sieve plates through which the cytoplasm flows to carry organic nutrients to living cells. The shape of the sieve plates varies with species and it can be used for identification.

2nd phloem transports glucose and amino acids from leaves and water from 2nd xylem up and down and radially through sieve plates to were ever it is needed for growth.

5.3. Ethnographic use of 2nd phloem of *Thuya plicata* (WRC). Figs.5.5a-c.

Fig.5.5.a.

Fig.5.5b

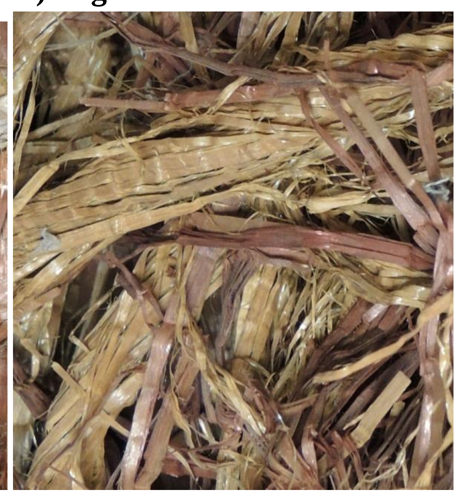

Fig.5.5c

Figs.5.5 a and b WRC 2nd phloem show two examples of the intact, inner, young 2nd phloem used for weaving in ethnographic objects. Fig.5.b photo with permission from Grant Keddie Curator Royal BC Museum

Figs.5.5 c WRC 2nd phloem shows shredded outer 2ndphloem than can be used as cordage. It comes in strips as may be very easily rubbed into shreds because of it is naturally fragmented. In conservation we call it inherent vise. Fig.5.5c photo with permision from by Grant Keddie Curator Royal BC Museum.

When the tree has grown for decades of growth, the 2nd phloem tissue is then functioning as what we call bark. In WRC the outer growth is fibrous and fractures into in strips, shown in Fig.5.1b. The fracturing of the 2nd phloem tissue is caused by continuous increase in the girth of the trunk of the coniferous tree. The youngest 2nd phloem closest to the interior of the tree trunk the phloem tissue is intact. It can be used for weaving baskets as shown in Figs.5.5a and b.

The outer fragmented surface can be easily removed, beaten, and cleaned to produce just the 2nd phloem fibers shown in Figs.5.5c and d. This is used in ceremonial costumes as decoration; cordage coils of different strengths; and as an adsorptive material.

The 2nd phloem fiber chemicals and fragrance of WRC have longevity. The anatomical relationship of weak thin walled cells of the sieve cells and parenchyma cells against thick walled phloem fiber cells also makes it prone to fragmentation under any mechanical agitation. As well the fibers are heavily lignified and brittle and calcium oxalate crystal can act as an abrasive to enhance fragmentation. Thus it has an inherent characteristic to self destruct. Because of this it is a difficult material to stabilize in term of conservation.

There are have biocidal chemicals that may prevent biodeterioration when dry and also may remain under an extensive time immersed in water .