96° F., and that at 104° F. (40° C.) there is no break in the curve as there would have been had there been a melting point at this temperature.

It is therefore obvious that the really significant temperature in this connection is about 36° C. (95° to 96° F.) where the transition from dodekahydrate to heptahydrate takes place. The temperature 40° C. (104° F.) is without significance.

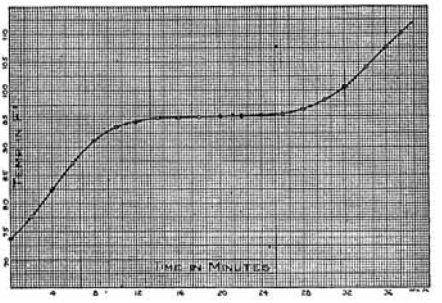


Fig. 1.

It is not possible to prevent caking when sodium phosphate is subject to temperatures of over 35° C. unless sodium phosphate heptahydrate is substituted for the present U. S. P. material. Sodium phosphate heptahydrate is stable up to 48° C. (about 118° F.). This material is stronger than sodium phosphate U. S. P. as it contains 53% anhydrous sodium phosphate as against the present U. S. P. limits of 39.25 to 44%.

SUMMARY.

The "fusing point" of 40° C. given in the U. S. P. is without significance. Sodium phosphate will cake if heated above 35° C. The only way to prevent this is to market sodium phosphate heptahydrate which is stable up to 48° C.

LABORATORIES OF E. R. SQUIBB & SONS.

STRUCTURAL VARIATIONS IN ERYTHROXYLON LEAVES.

BY C. W. BALLARD.

(*Continued from p. 359, May* JOUR. A. PH. A.)

HISTOLOGICAL CHARACTERS OF ERYTHROXYLON LEAVES.

As noted in the section dealing with the morphology of several varieties of Erythroxylon, chief attention has been directed to the few species used as sources of cocaine. Comparative data is hardly available except in the form of brief notations in connection with the histological descriptions of the cocaine-yielding species. Necessarily the modifications due to environment must be apparent in histological structure and this part of the study was undertaken in the hope that the data accumulated might be of service in ascertaining the botanical identity of closely related species, or even varieties of the same species. With the constant multiplication of species or new names for slightly varying forms of the same species it is often a problem to decide whether or not the variations are sufficiently extensive to warrant the coining of new specific titles. Still more perplexing is the practice of considering these slight differences as variations and so naming them. Carried to the extreme this would result in each plant being a variety unto itself, for surely each has minor points of difference from others of the same species. While it is admitted that plants of a given genus, or even family, have certain histological characters common to all members, the points of variation in histological structure are, as a rule, just as apparent as the gross differences and perhaps more so. While modification in gross characters is necessarily accompanied by modification of minute structure it is questionable which occurs first.

It may well be remarked by the systematist that dependence upon leaf characters as a means of classification is faulty and this is admitted, but in pharmacognostical work one seldom receives flowering and fruiting specimens. The difficulties of securing flowering and fruiting specimens must also be taken into account and if leaf characters can be successfully used in paleobotanical classifications there appears no good reason why they cannot be used here. Again, it has been suggested that many of the Erythroxylons are dimorphic and perhaps trimorphic and this fact alone would bring leaf characters, as an aid to classification, into greater prominence than usual.

It is not to be expected that variants of the same species will not show resemblance in histological as well as gross characters but there appears the possibility of considering both gross and histological characters in dealing with so closely related forms as those of Eyrthroxylons. Where the morphological variations are very slight, histological characters might well be made more use of.

General Anatomical Characters of Erythroxylon (Leaves).—The leaves are bifacial; epidermal cells with straight to undulated lateral walls; stomata accompanied by subsidiary cells parallel to the pore; smaller vascular bundles of the veins accompanied by small amounts of sclerenchyma (*E. Coca*); gelatinized epidermal cells on the upper side of the leaf in many species; certain lower epidermal cells contain solitary calcium oxalate crystals (*E. Coca*), these cells being sometimes arranged in pairs; papillose differentiation of the lower epidermis is of frequent occurrence (*E. ovatum* and *E. subrotundum*); in *E. Bolivianum*, Burck, certain cells of the lacunar spongy tissue are sclerosed; typical sclerenchymatous ideoblasts, usually assuming the shape of a T, occur in *E. acutifolium, E. citrifolium, E. mucronatum* and *E. squamatum;* these ideoblasts traverse the palisade tissue and then continue their course between the latter and the epidermis; "sclerites rameuses" are also recorded in *E. Amplum, E. campestre, E. lucidum* and *E. suberosum;* cystolith-like bodies appear as small peg-shaped structures arising from the upper epidermal cells in *E. obtusum* (15).

Hartwich deduces the following characters as the result of a study of the general characters and histological structure of commercial coca leaves and several substitutes (3). This work is the only available reference wherein the histological characters of several species have been studied in detail and, although the number of species included is rather limited, it is an admirable presentation.

1. The leaves are of bilateral structure. 2. The midrib is prominent on the upper surface of all species studied excepting *E. obtusum.*

3. Meristele structure is variable.

4. Pericyclic fibers occur in all species studied excepting *E. campestre.*

5. Papillae occur only in *E. Coca, E. ovatum,* and *E. subrotundum.*

6. Stomata on the lower surface with two subsidiary cells.

7. Trichomes absent in all species studied. 8. Ideoblasts occur in *E. Coca, E. mucronatum, E. acutifolium, E. squamatum* and *E. citrifolium.*

Aside from these general characters Hartwich also notes that the best distinctions between Bolivian leaves (*E. Coca,* Lam.) and the others examined were the presence of strongly thickened but slightly lignified branched cells among the spongy parenchyma (termed ideoblasts by Hartwich) and also T-shaped ideoblasts, the arms being between the palisade and epidermal layers with the leg inserted in the palisade. Of these specific histological characters the first is perhaps the best, for while every specimen of *E. Coca* examined showed these branching cells, comparatively few showed the latter form of ideoblast, and this has also been the experience of Greenish (1).

Examination of *E. obtusum* confirms Hartwich's statement but the prominence on the upper side of the midrib was also lacking in *E. brevipes*, *E. minutifolium* and *E. alaternifolium*. It must also be borne in mind that the distinction between this midvein ridge and a slight thickening of the leaf in the midvein region is sometimes difficult to establish, especially when reduced to actual measurements. Thus one sample of Truxillo coca showed a midvein ridge of the same height as that occurring in Huanuco leaves despite the statement that this ridge is not as prominent in the former. Reference to Table 2, (in next issue) will show elevations in the midvein region ranging from 42 to 283 microns and a question arises whether the small elevations should be considered as ridges or mere local thickenings common in many leaves.

Pericyclic fibers were found to occur in the midvein structure in every species examined with the exception of a specimen marked *E. areolatum*.

In addition to the three species above named as showing papillae I find these structures present in the following species of Erythroxylon: *subracemosum*, *cumanense*, *Popayanense*, *areolatum*, *obovatum*, *Truxillense*, *carthagenense*, *Novagranatense* and *Spruceanum*.

Ideoblasts occurred in several of the species examined but they are not a constant character and were lacking in several specimens of *E. Coca* of undoubted authenticity.

The histological part of this study consisted in the examination of several specimens of various species of Erythroxylon divided as follows:

Erythroxylon	Coca, Lam.	4 specimens
"	Novagranatense, Mor.	2 "
"	Truxillense, Rusby	3 "
"	Spruceanum, Peyr.	1 "
"	carthagenense, Jacq.	1 "
"	subracemosum, Turcz	1 "
"	pauciflorum, Rusby	2 "
"	Bangii, Rusby	2 "
"	cumanense, H. B. & K.	1 "
"	Popayanense, H. B. & K.	2 "
"	areolatum, Linn.	4 "
"	anguifugum, Mart.	7 "
"	brevipes, DC.	2 "
"	Urbanii, O. E. Schulz	1 "
"	havanense, Jacq.	2 "
"	minutifolium, Griseb.	1 "
"	alaternifolium, A. Rich	1 "
"	obovatum, Macfad.	2 "
"	Pelletierianum, A. St. Hil.	1 "
"	nitidum, Spreng	1 "
"	Columbianum, Mart.	1 "
"	orinocense, H. B. & K.	1 "
"	unidentified or uncertain	5 "

These materials were selected from specimens used in determining the gross characters of the leaves and in many instances represent type specimens. While the objections to basing descriptions and comments upon the examination of limited amounts of material are fully realized, it must be borne in mind that in work of this sort it is impossible to obtain large specimens. Many of these species are

not commercial articles and herbarium material is limited. Undoubtedly similar conditions would be encountered in a histological study of many of the more common genera occurring naturally in this vicinity. If we are to be deterred from comparative studies because large amounts of material are not at hand we immediately check or greatly limit this field of research. But even though the amount of material be limited, if it is possible to obtain specimens from different sources and find that they agree in structural characters this at least should serve to combat the danger of drawing false conclusions. In a few instances but a single leaf was available and it has been thought more advisable to complete the study, even with this small amount of material, than to accept the alternative of passing it over entirely.

Sections were made by the usual methods and cut from 20 to 40 microns in thickness. As far as possible the material for sectioning was taken from the middle portion of the leaf. In studies of the arrangement of midrib tissues this is especially

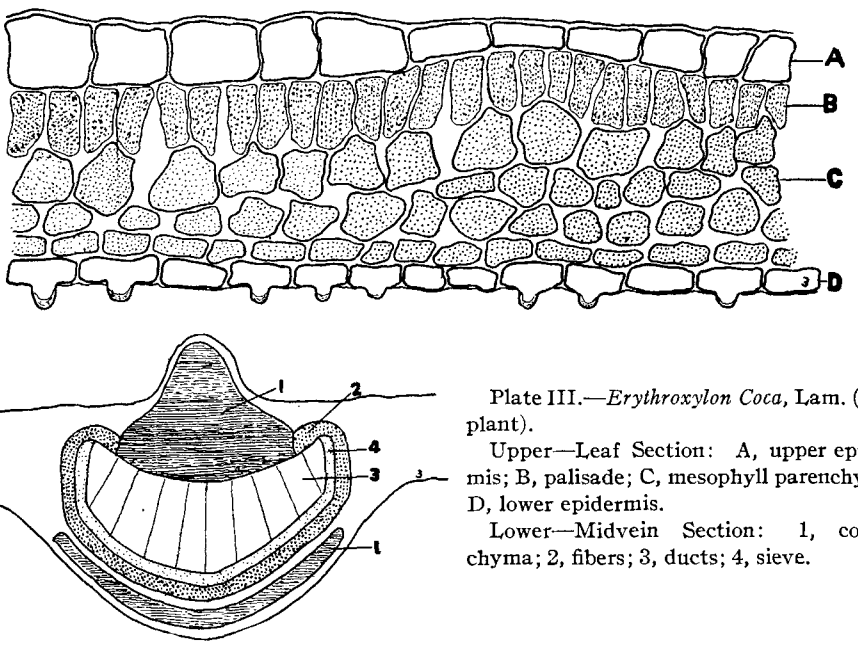


Plate III.—*Erythroxylon Coca*, Lam. (wild plant).

Upper—Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis.

Lower—Midvein Section: 1, collenchyma; 2, fibers; 3, ducts; 4, sieve.

important, as Greenish (1) has called attention to the fact that the arrangement of these tissues varies in different regions of the leaf and criticizes the conclusions of Hartwich based upon the form of the xylem. The illustrations showing transverse sections of the different leaves are all drawn to the same scale and at a magnification of 375 diameters. The illustrations showing the arrangement of tissues in and about the midrib are also drawn to a definite scale but owing to space limitations this is rather smaller than that used for the leaf sections. These midrib illustrations are semidiagrammatic and an effort has been made to show the comparative amounts of each tissue as well as the arrangement. The magnification of these midrib sketches is 100 diameters, excepting where otherwise noted. Cell contents (as chloroplastids and crystals) have been purposely omitted in the illustrations and the shading is indicative of depth of coloration in the different specimens.

Erythroxylon Coca, Lam. (Wild Growing).—(Plate III.) Sections of this leaf average 126 microns in thickness. The upper epidermal cells are variable, especially in height, ranging in form from nearly square to tangentially elongated and bearing a moderately thick cuticle on the free surface. These size differences appear to be due to a pushing outward of the palisade layer by the fibrous tissue of the veinlets. Cells of the lower epidermis are one-half to two-thirds the size of those of the upper epidermis and many bear prominent papillae with a thickened apical portion. Palisade cells are nearly uniform in height but variable in form and contain a brownish green material. Two to three of these cells abut on each epidermal cell. Mesophyll parenchyma is not very extensive, comprises three to five layers of cells, is rather compact and lacking in large aerating chambers. Crystalline calcium oxalate occurs in moderate amounts in addition to a brownish green content.

The primary branch veins are surrounded by a heavy fibrous sheath which appears to force a portion of the palisade outward and the epidermal cells in the vicinity of the veins are reduced in size to make way for the palisade which has been so displaced.

A distinct ridge appears above the midvein on the upper surface of the leaf. This ridge is of the same type as in *E. Coca* but not as extensive. Collenchyma occurs within the ridge and extends inward to the duct region. A narrow band of collenchyma also occurs between the lower epidermis and the fiber zone, although separated from the latter by a thin layer of parenchyma. Fibrous tissue extends but part way around the vascular elements and is lacking on the upper side of the midvein, at which point the collenchyma adjoins the ducts. The sieve region is well marked and extends around the ends of the duct zone. The ducts occur in double rows with a strip of parenchyma intervening and a small amount of the latter tissue is present on the upper face of the duct zone.

A second specimen of this material, collected by Dr. Rusby in a different locality, was found to agree excepting as regards thickness of leaf, which averaged 157 microns, and in midvein characters. The fibrous tissues completely surround the vascular elements and the sieve is located only on the lower side of the duct zone.

Erythroxylon Coca, Lam. (Cultivated).—(Plate IV.) Leaves from four specimens of this species range from 120 to 180 microns in thickness. The upper epidermis is a single layer of nearly rectangular cells, the outer surface being rather strongly cutinized. The lower epidermal cells bear large papillae with thick-walled apical portions. The cells of the lower epidermis, including the projecting papillae, are about equal in size with those of the upper epidermis. Palisade consists of a single layer of slightly irregular cells, approximately three times longer than broad and filled with chlorophyll. The number of palisade cells abutting on each epidermal cell varies from two to three. Mesophyll parenchyma is arranged in five to eight layers of cells ranging in form from isodiametric to elongated rectangular containing chlorophyll and numerous prismatic calcium oxalate crystals. Large aerating chambers occur in this region. Many of the fibrous elements are irregularly branched and with white thick walls.

Primary veins are placed more toward the upper side of the leaf and the fibrous elements surrounding them penetrate the palisade and extend to the upper epider-

mal layer, which is slightly raised above the vein. There are one or two layers of mesophyll parenchyma between the vein and the lower epidermis. The areolae or lateral lines are marked by pads of collenchyma occurring within the lower epidermis at these points.

The midvein ridge on the upper leaf surface is well developed and consists of a mass of slightly collenchymatized cells which interrupt the palisade and extend inward to the duct region. Collenchyma also occurs in contact with the lower epidermis but is separated from the fiber zone by a layer of elongated thin-walled parenchyma and two or three layers of isodiametric parenchyma. The pericyclic fibers extend around the vascular elements with the exception of the middle portion of the upper side of the duct zone which is in contact with collenchyma. The amount of fibrous tissue is rather smaller than in other species and the ducts are more irregularly disposed, the sieve projecting into the duct zone at several points.

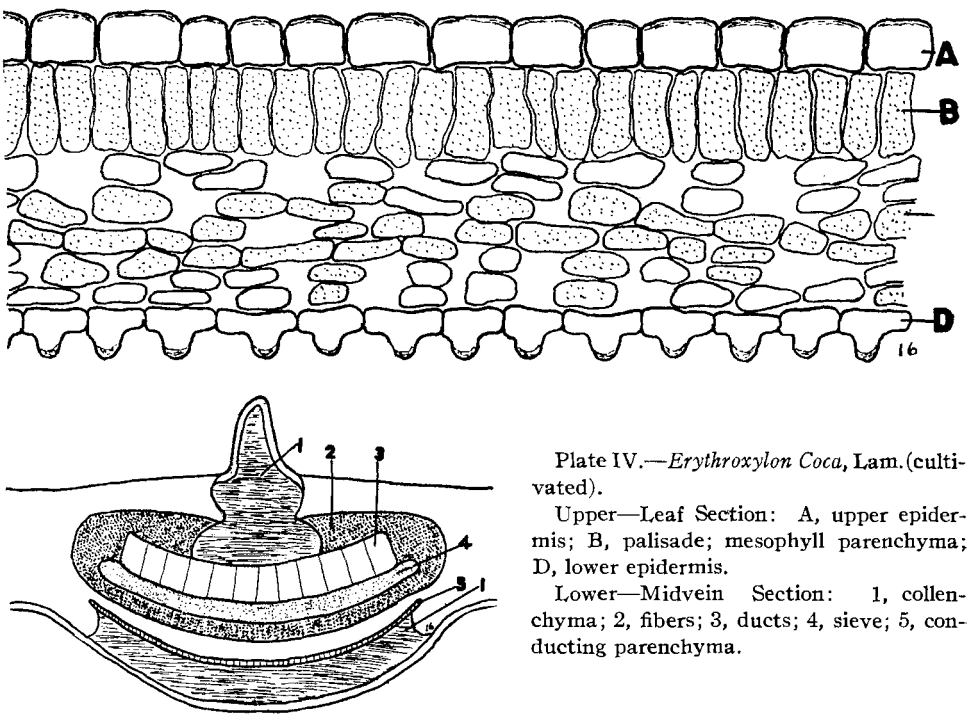


Plate IV.—*Erythroxylon Coca*, Lam. (cultivated).

Upper—Leaf Section: A, upper epidermis; B, palisade; mesophyll parenchyma; D, lower epidermis.

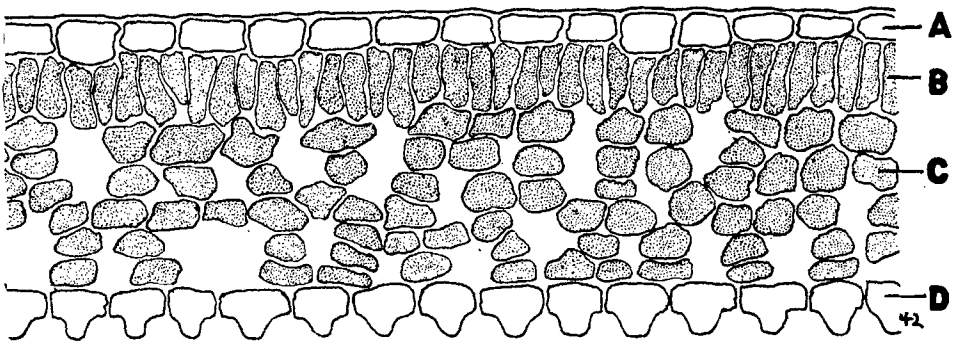
Lower—Midvein Section: 1, collenchyma; 2, fibers; 3, ducts; 4, sieve; 5, conducting parenchyma.

Hartwich (3) illustrates the general arrangement of the fibrous elements, sieve and ducts of the midvein. This illustration does not include the collenchyma but is substantially identical with Plate IV.

The illustrations of Bolivian Coca appearing in *Pharm. Jour. and Trans.* p. 485, (May 27, 1899), are very similar to Plate IV, thus supporting Rusby's view (14) that *E. Coca* var. *Bolivianum*, Burck, is identical with *E. Coca*, Lam.

Erythroxylon Novagranatense, Mor.—(Plate V.) Sections of this specimen show considerable variation in thickness, ranging from 84 to 147 microns. The cells of the upper epidermis are slightly variable as regards height, some appearing

but one-half the size of others, are nearly uniform in length and but slightly elongated. A thin cuticle is present on the free surface. Lower epidermal cells are somewhat larger and bear prominent papillae, with slightly thickened apical portions. The palisade layer is thinner than in other leaves of the same thickness and the cells vary in size and shape. These variations are but partly due to the difference in size of the overlying epidermal cells. Chloroplasts in a fair state of preservation fill the palisade cells and the number of the latter in contact with each epidermal cell ranges from two to four. The proportion of height to width is two or three to one. Mesophyll parenchyma consists of five to seven layers of cells surrounding large aerating chambers. The uppermost layer is of the collecting or funnel type and the lower layers are flattened. Prismatic calcium oxalate occurs freely. Small numbers of branched but non-thickened cells also occur in this region.



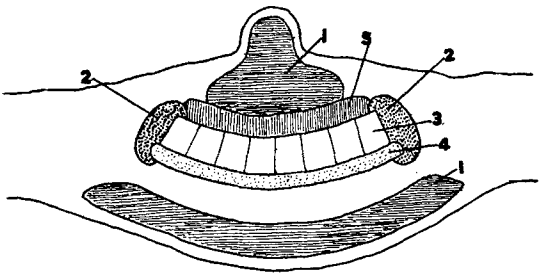


Plate V.—*Erythroxylon Novogranatense*, Mor.

Upper—Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis.

Lower—Midvein Section: 1, collenchyma; 2, fibers; 3, ducts; 4, sieve; 5, conducting parenchyma.

The fibrous tissue of the primary vein branches partially displaces the palisade at points of occurrence and the entire leaf blade shows a slight thickening in the vicinity of these veins. This fibrous sheath is separated from the lower epidermis by one or two layers of parenchyma.

The crest over the midvein on the upper surface of the leaf varies in height and is more prominent in the thinner specimens. There is a gradual thickening of the midpart of the leaf leading up to the crest which rises above the surface of midvein. The collenchyma of the midrib region is greatly increased and fibrous elements are correspondingly reduced. Collenchyma occurs both within the crest and as a broad band between the midvein and the lower epidermis, although parenchyma intervenes between this tissue and the sieve. The sieve zone is rather larger than in other species and the usual surrounding sheath of fibrous elements is lacking. Distinct fibers are only apparent at the sides of the vascular elements. Ducts are large,

with thicker walls than usual and with very little conducting parenchyma between them, the bulk of the latter tissue being massed on the side of the duct zone toward the upper epidermis.

The midvein tissues as pictured by Hartwich (3) for this species are quite different from those shown in Plate V. His illustration does not show collenchymatic zones and conducting parenchyma. The fibrous tissues are shown as almost completely surrounding the vascular elements, similar to the arrangement in *E. Coca*, and in fact the chief difference between his illustration of *E. Coca* and *E. Novagranatense* is the lack of a midvein ridge in the latter. In my specimen of this species I find a distinct ridge, although smaller than that in *E. Coca*.

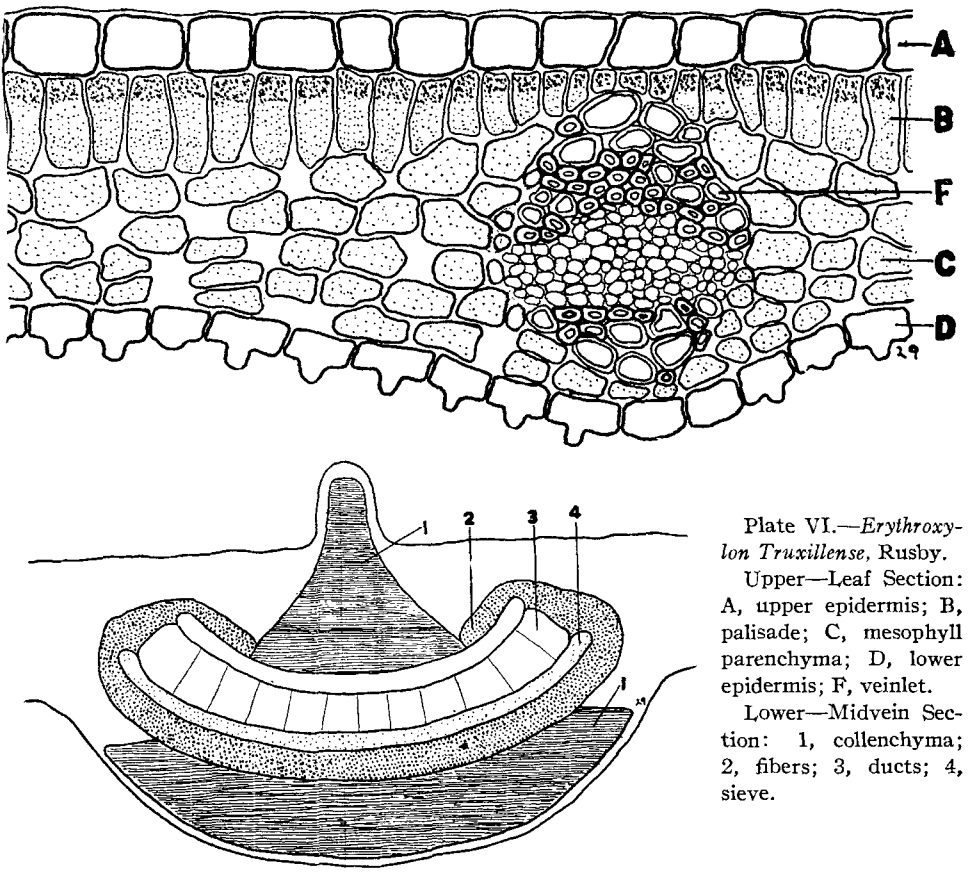


Plate VI.—*Erythroxylon Truxillense*, Rusby.
Upper—Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis; F, veinlet.
Lower—Midvein Section: 1, collenchyma; 2, fibers; 3, ducts; 4, sieve.

Erythroxylon Truxillense, Rusby.—(Plate VI.) Specimens of this species range from 100 to 138 microns in thickness. The upper epidermis consists of a single layer of cells, varying in form from tangentially elongated to nearly square, and bearing a thin cuticle on the free surface. The cells of the lower epidermis are almost the same size as those of the upper and bear well developed papillae which are rather broader than those of other species. Palisade cells are uniform in height and the proportion of height to width is about 3 to 1. The chlorophyll appears to have accumulated in the portion in contact with the epidermis. Mesophyll parenchyma consists of three to six layers of cells. The upper layers of parenchyma

cells are of flattened form while the others are isodiametric. Prismatic calcium oxalate is very abundant and many of the cells retain their chloroplasts in a good state of preservation. Large aerating chambers occur, especially toward the lower side of the leaf.

Primary branch veins occupy nearly the entire space between lower and upper epidermal layers, extending through the palisade on one side and in many instances to the lower epidermis on the other. While in other species these primary veins are massive it is seldom that they are so extensive.

The midvein ridge shows considerable variation in height above the general leaf surface, averaging about 75 microns. The tissue within the ridge is collenchyma and this tissue extends inward to the midvein bundle. A broad area between the lower side of the bundle and the lower epidermis also consists of collenchyma which apparently replaces, at least in part, the fibrous tissue occurring in the corresponding location in most species. While fibrous tissue surrounds the vascular elements it is poorly developed, being greatest in amount at the sides of the bundle. Sieve occurs below the ducts, but there is an area on the upper side of the bundle which has every appearance of being a secondary sieve zone.

Plate VI, showing the arrangement of tissues in the midrib region of Peruvian coca, differs from the illustration in *Pharm. Jour. and Trans.*, p. 485 (May 27, 1899), in that a distinct crest appears in my specimens of Truxillo leaves. According to Holmes (2) Peruvian and Truxillo cocas are identical, both being from *E. Novagranatense* and the latter having little sign of a midvein crest. My observations would confirm the latter part of his statement but would conflict with his conclusion that Truxillo leaves are identical with *E. Novagranatense.*

Erythroxylon Spruceanum, Peyr.—(Plate VII.) Sections of this leaf range from 115 to 190 microns in thickness, the variations resulting from local thickenings due to the presence of large amounts of fibrous tissue in connection with the veins. The epidermis consists of a single layer of tangentially elongated cells of approximately even size and bearing a thin cuticle on the free surface. Lower epidermal cells bear very large thick-walled papillae. The palisade cells are somewhat irregular as regards form and size and this layer is frequently interrupted by the fibrous sheaths of the veins. Three palisade cells are in contact with each epidermal cell. Mesophyll parenchyma occurs in about six layers of cells, the lower layers being slightly flattened and enclosing small aerating chambers. A brownish content occurs in both palisade and mesophyll parenchyma cells. Prismatic calcium oxalate occurs rather sparingly. Branched thick-walled fibrous elements are found scattered amongst the mesophyll parenchyma cells.

The fibrous sheaths surrounding the veins in this leaf show a greater degree of development than in any of the other species examined. This fibrous tissue not only displaces the palisade but also causes an elevation of the epidermal surface at the points of occurrence. In the case of primary branch veins, the fibrous and vascular tissues occupy the entire area between upper and lower epidermis.

The midvein region shows but little sign of a ridge or crest on the upper surface. Narrow zones of partially collenchymatized cells occur on both upper and lower sides of the midvein. Fibrous tissue encircles the vascular elements with the exception of a small area on the upper side of the ducts which is occupied by conducting parenchyma. In addition to the main sieve region on the lower side

of the ducts two smaller zones appear within the fibrous tissue on the upper side of the duct region.

The Hartwich illustration (3) of the midvein tissues of this species differs from Plate VII in that the fiber zone is shown as extending but part way around the sides of the vascular elements. Collenchymatic tissue, conducting parenchyma and the small secondary sieve groups on the upper side of the ducts are not shown in this figure. The elevation over the midvein appears similar to that in Plate VII.

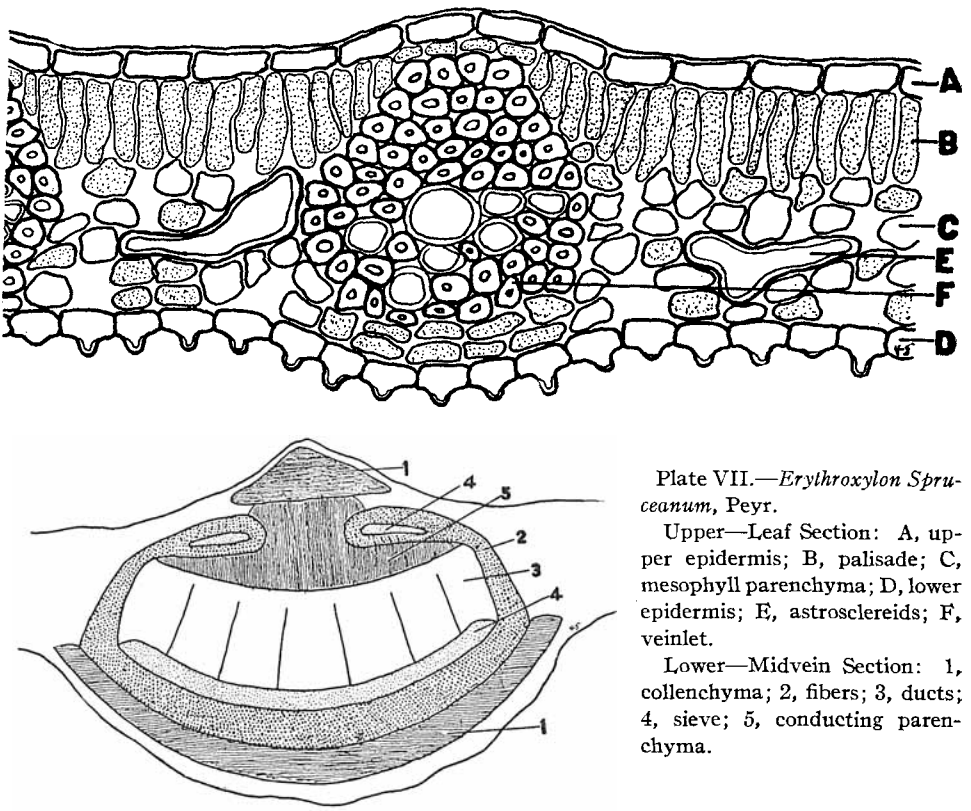


Plate VII.—*Erythroxylon Spruceanum*, Peyr.

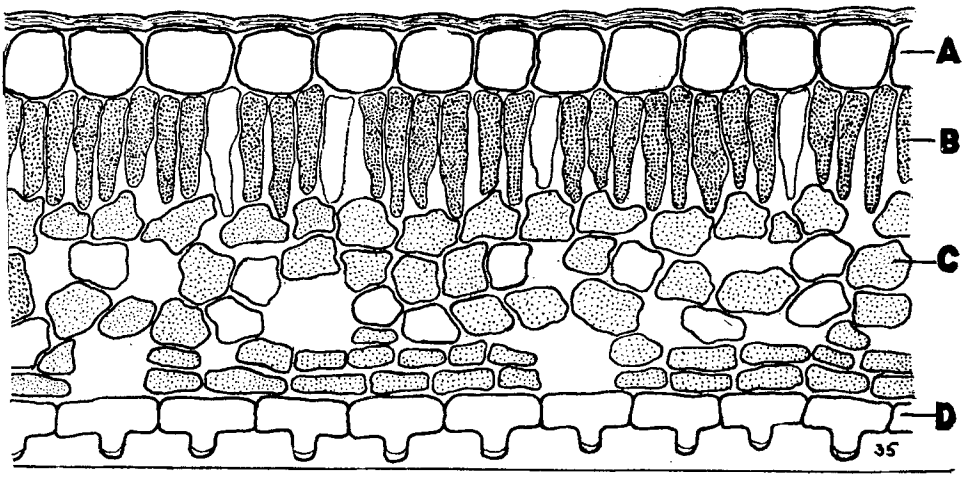
Upper—Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis; E, astrosclereids; F, veinlet.

Lower—Midvein Section: 1, collenchyma; 2, fibers; 3, ducts; 4, sieve; 5, conducting parenchyma.

Erythroxylon carthagenense, Jacq.—(Plate VIII.) This leaf is comparatively thick, sections averaging 230 microns. The upper epidermis is a single layer of large, nearly square cells, bearing a thick cuticle on the exposed surface. The inner walls of these cells are but slightly convex and the outer ends of the palisade cells are nearly straight. Cells of the lower epidermis are large and bear large papillae with extremely thick walls. Palisade consists of radially elongated cells many of which taper toward the mesophyll parenchyma, thus leaving spaces of varying sizes between the individual cells. Many of the palisade cells are filled with brown content while others appear clear. The proportion of height to width averages five to one and two to four palisade cells underlie each epidermal cell. Mesophyll parenchyma consists of four to six layers of various types of cells. The uppermost layer consists of funnel or collecting cells adjoining the palisade. The lowermost layers are flattened while those in between are irregular. A brownish

content similar to that noted in the palisade occurs in many of these cells and, owing to large aerating chambers, the entire texture is loose. Prismatic calcium oxalate and large chloroplastids in a fair state of preservation are apparent in the parenchyma cells.

Fibrovascular bundles representing the primary veins are placed toward the upper surface of the leaf and the fibrous tissue displaces the palisade. Two or three layers of parenchyma intervene between the lower side of the vein bundle and the lower epidermis.



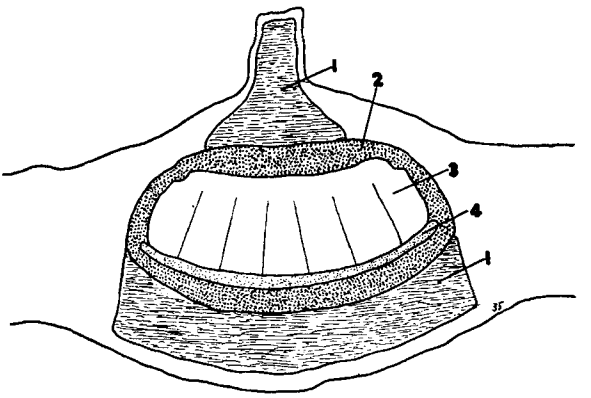


Plate VIII.—*Erythroxylon carthagenense*, Jacq.

Upper—Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis.

Lower—Midvein Section: I, collenchyma; 2, fibers; 3, ducts; 4, sieve.

A distinct ridge appears on the upper leaf surface above the midvein but the summit of the ridge is a flat surface and not rounded as in the majority of species. Collenchyma occupies the interior of the ridge and extends inward to the fibrous layer. A broad band of collenchyma is also located between the lower epidermis and the lower layer of fibrous tissue. Besides the thickened white walls, typical of collenchymatic tissue, these cells contain a brown content similar to that occurring in the palisade and the mesophyll parenchyma. Pericyclic fibers completely encircle the vascular portions, being greatest in number on the upper side. Sieve cells are filled with brown content. Ducts are arranged in radiating rows

separated from each other by one or two layers of porous or woody parenchyma cells, and this tissue is continued as a zone on the upper surface of the ducts.

Erythroxylon subracemosum, Turcz.—(Plate IX.) Sections of this leaf average 230 microns in thickness. The upper epidermis consists of a single layer of large rectangular cells fairly symmetrical as regards form and with the free surfaces thickened to form a cuticular covering for the leaf. The cells of the lower epidermis are about one-third the depth of those of the upper epidermis, showing rather scattered papillae and a light brown coloration which in several instances extends into the papilla. No evidence of a distinct cuticular layer is apparent. The palisade cells are of a light brown color but chromatophores are not apparent. The cells of this

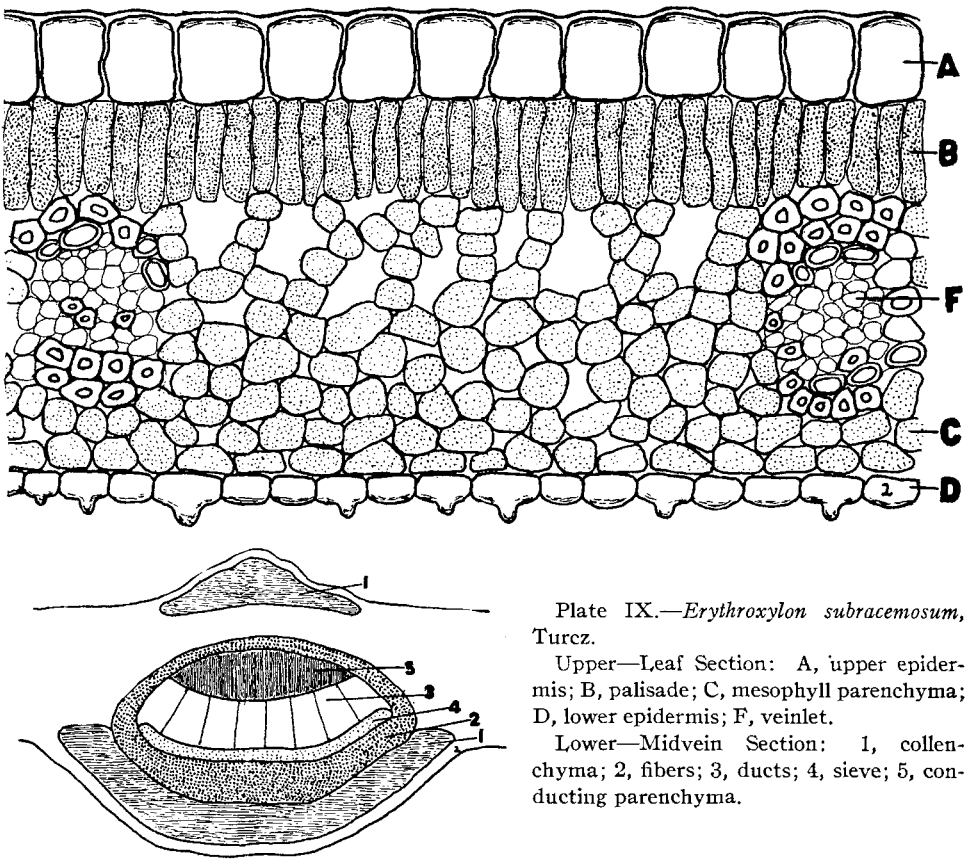


Plate IX.—*Erythroxylon subracemosum*, Turcz.

Upper—Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis; F, veinlet.

Lower—Midvein Section: 1, collenchyma; 2, fibers; 3, ducts; 4, sieve; 5, conducting parenchyma.

region are of the usual radially elongated type, the average ratio of length to width being four to one. The number of palisade cells abutting on an epidermal cell ranges from two to four. The mesophyll consists of five to nine layers of parenchyma cells of a light brown color, many of which contain prismatic crystals of calcium oxalate. Viewed in surface preparations the lowermost layers of mesophyll cells appear as branching or interlacing forms. The fibers ramifying in this loose parenchyma may assume slightly branched form.

The fibrovascular bundles representing the primary vein branches are placed

more toward the upper leaf surface and partially displace the palisade tissue where they occur.

The midvein shows but little evidence of the ridge so marked in several species of Erythroxylon. While sections show a thickening of the leaf on the upper as well as the lower side of the midvein, this thickening is hardly greater than that occurring in the leaves of many other plants. The sieve portion of the fibrovascular bundle is a thin zone of light brown cells with two to four layers of lignified cells on the lower surface. These fibers extend around the ends of the duct region and appear in reduced amount toward the upper surface of the latter. Thus the entire midvein is encircled by fibers. The ducts occur in irregular radiating lines

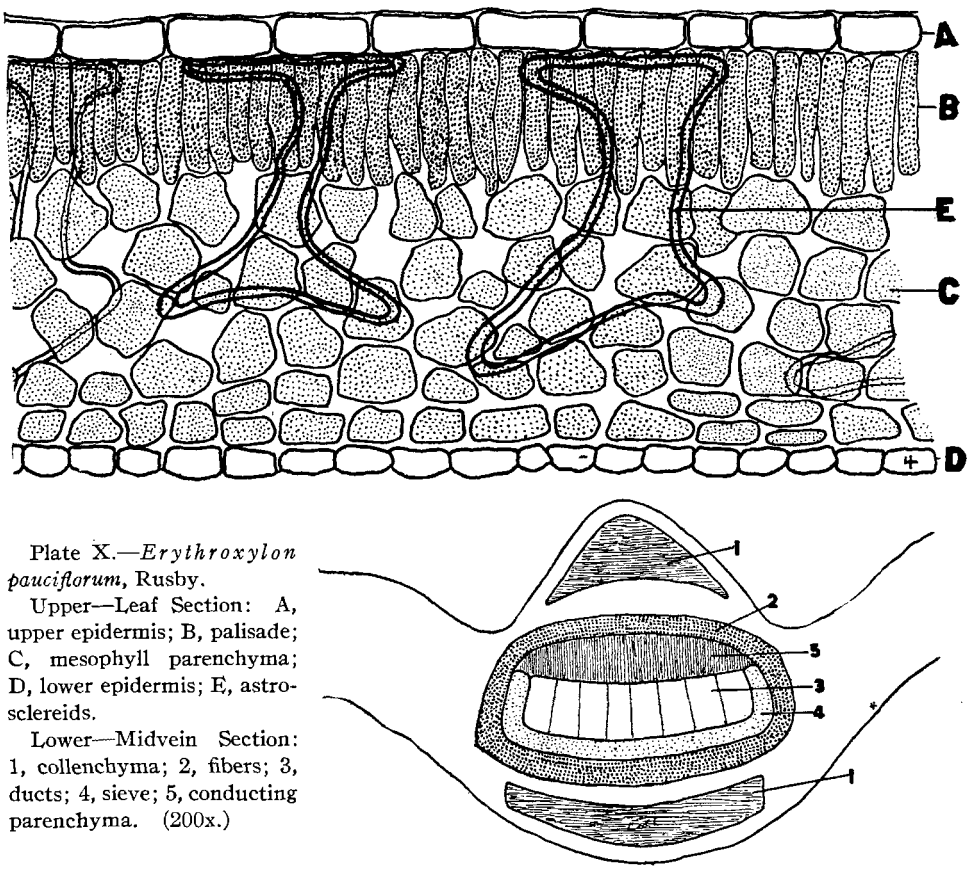


Plate X.—*Erythroxylon pauciflorum*, Rusby.

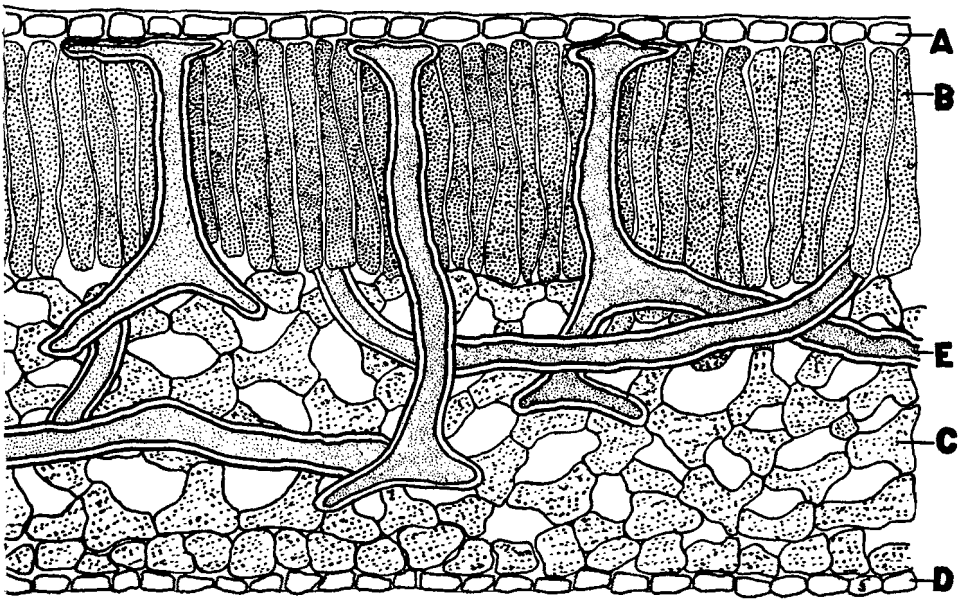
Upper—Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis; E, astrosclereids.

Lower—Midvein Section: 1, collenchyma; 2, fibers; 3, ducts; 4, sieve; 5, conducting parenchyma. (200x.)

interspersed with fibers and gradually giving way to larger parenchymatic cells toward the upper side of the leaf. A broad collenchyma zone occurs between the lower epidermis and the fiber zone, and a small area of collenchyma is present immediately within the upper epidermis.

Erythroxylon pauciflorum, Rusby.—(Plate X.) Two specimens of this species were examined and sections of the leaf averaged 195 microns in thickness. The upper epidermis consists of a single layer of tangentially elongated cells, the length being two to four times the height, with a thin cuticle on the free surface. The lower

epidermal cells are entirely devoid of papillae and are about one-half the length of those of the upper epidermis. Prismatic crystals of calcium oxalate occasionally occur within the lower epidermal cells. The palisade cells are brownish in color, the outer half of each cell being deeper in color than the portion in contact with the mesophyll parenchyma. The cells of the palisade region are four to five times longer than broad and rather irregular in form. The number of palisade cells abutting on an epidermal cell averages four. At certain points the palisade tissue is interrupted by astrosclereids of the buttress type, which are in contact with the upper



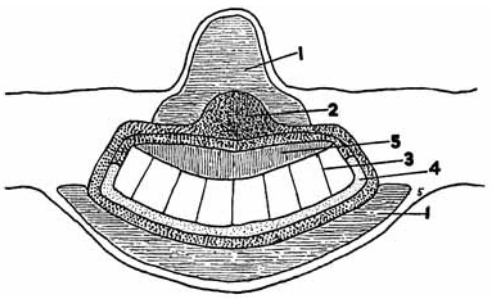


Plate XI.—*Erythroxylon Bangii*, Rusby.
Upper—Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis; E, astrosclereids.
Lower—Midvein Section: 1, collenchyma; 2, fibers; 3, ducts; 4, sieve; 5, conducting parenchyma. (200x).

epidermis by a flat surface and which extend well into the mesophyll parenchyma. The mesophyll parenchyma consists of five to six layers of cells, nearly devoid of coloration, and in many instances containing prismatic calcium oxalate crystals. Branched sclerenchymatic elements ramify amongst the parenchyma cells.

The fibrovascular bundles representing the primary vein branches are centrally located and the palisade at the points of occurrence is but slightly reduced.

The upper leaf surface shows a fairly pronounced ridge over the midvein. Within both upper and lower epidermal layers is a zone of collenchymatic tissue.

The pericyclic fibers extend in an unbroken layer around the vascular portions of the midvein and the fiber zone is equally thick at all points. The sieve zone is brownish in color and about equal in thickness to the duct region. The circle of pericyclic fibers also encloses a large parenchyma zone placed toward the upper side of the leaf.

Erythroxylon Bangii, Rusby.—(Plate XI.) Sections of this leaf average 280 microns in thickness. The upper epidermis is a single layer of comparatively small rectangular cells, the free surface bearing a thin cuticle. Both upper and lower epidermal layers are much thinner than the corresponding tissues in the other leaves examined and comprise but one-thirteenth to one-sixteenth the entire thickness of the leaf, this proportion being smaller than in any other specimen. Papillae do not occur upon the lower epidermal cells. The length of the palisade cells is about eight times the width and they are extremely irregular in form, not more

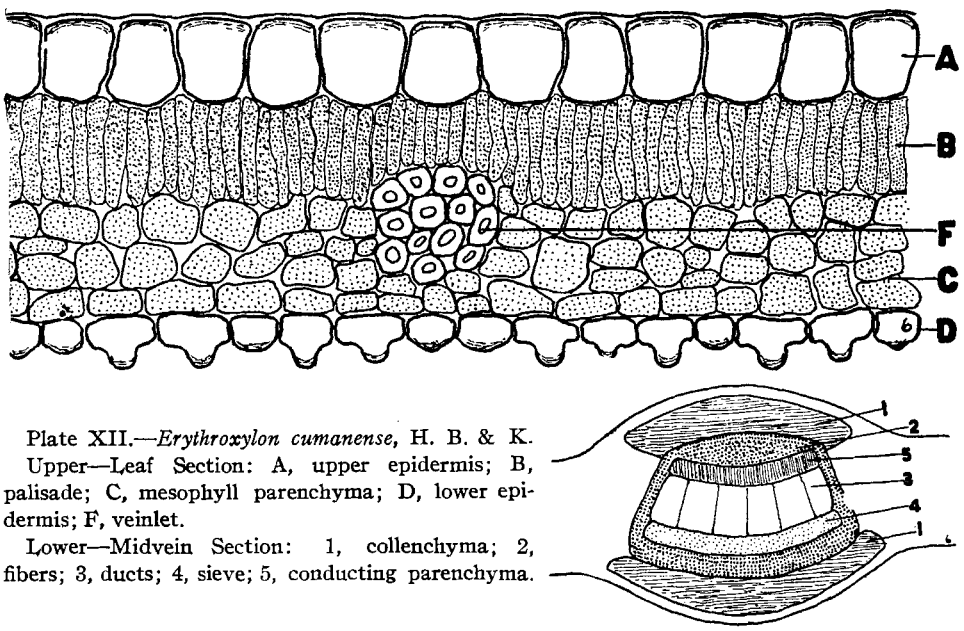


Plate XII.—*Erythroxylon cumanense,* H. B. & K.
Upper—Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis; F, veinlet.
Lower—Midvein Section: 1, collenchyma; 2, fibers; 3, ducts; 4, sieve; 5, conducting parenchyma.

than two abutting on each epidermal cell. The buttress type astrosclereids are very prominent in this species, being larger and more extensive in branching than in any other species examined. These sclereids penetrate the palisade, presenting a flat surface in contact with the upper epidermis and extending deeply into the mesophyll parenchyma, an arrangement similar to that in *E. Coca.* The mesophyll parenchyma consists of six to eight layers of branching cells with brown contents. Comparatively few calcium oxalate crystals are present in the specimen.

The fibrovascular tissue of the primary veins is located centrally and thus does not materially reduce the depth of the palisade layer.

The ridge on the upper leaf surface over the midvein is very pronounced, being even more prominent than in *E. Coca.* The ridge is a mass of collenchymatic tissue and several layers of this tissue are placed on each side of the vascular strand which is completely surrounded by fibers. The fibrous tissue is greatest in amount

on the upper side of the bundle and immediately beneath the ridge. The sieve region extends part way around the xylem and is light colored. A mass of collenchyma appears on the upper surface of the xylem.

Erythroxylon cumanense, H. B. & K.—(Plate XII.) The sections of this leaf average 160 microns in thickness. The upper epidermis is very thick, averaging about one-fourth the thickness of the entire leaf and consisting of a single layer of large rectangular cells, the outer surfaces being covered with a moderately thick cuticle. The lower epidermal cells bear prominent papillae which in many instances contain greenish contents, and the wall of the papilla is of even thickness throughout. The palisade cells are very regular in arrangement and uniform in size, being about five times longer than wide. Five or six palisade cells abut on each epidermal cell. The inner wall of the upper epidermal cells is convex and there is a slight variation in length of palisade cells to meet this irregularity. The mesophyll parenchyma consists of four to five layers of flattened or irregular cells containing chlorophyll. Prismatic calcium oxalate occurs within a few of the paren-

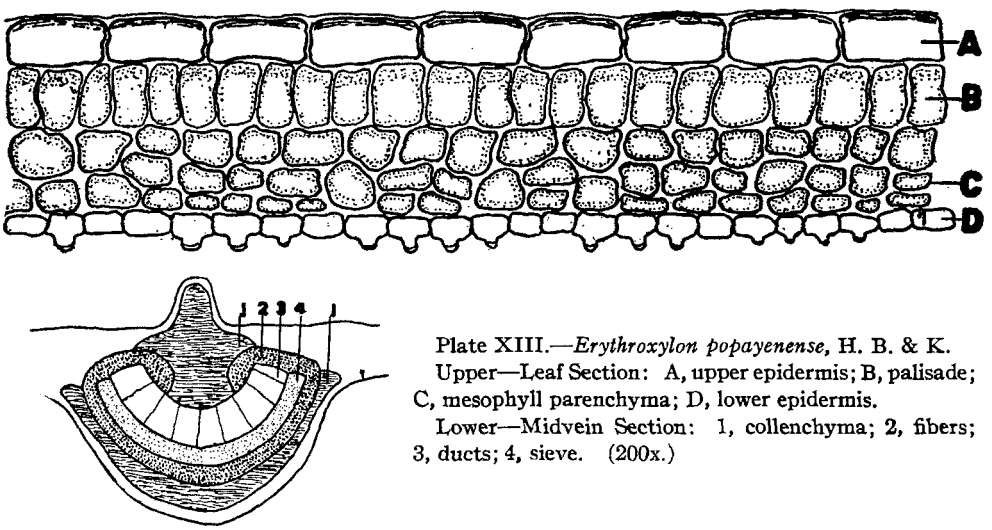


Plate XIII.—*Erythroxylon popayenense*, H. B. & K.
Upper—Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis.
Lower—Midvein Section: 1, collenchyma; 2, fibers; 3, ducts; 4, sieve. (200x.)

chyma cells but a greater amount occurs in connection with the fibrous tissue of this region. The lower layers of parenchyma consist of branching cells which appear circular in sectional view and resemble the "tube cells" in cereals.

Although the primary veins are located centrally, they are so abundantly provided with fibrous tissue and the upper epidermis occupies so much of the total area of the leaf, that both palisade and upper epidermis are reduced in size in the vicinity of these structures.

The midvein region of the leaf is about twice the thickness of the lamina but no ridge occurs on the upper surface. Collenchyma occurs in greatest amount on the lower side of the midvein bundle, being almost lacking on the upper surface. Pericyclic fibers encircle the vascular tissues, being greatest in amount on the upper surface. Sieve and duct tissues are about equal in amount, with a small mass of collenchyma placed between the upper side of the duct group and the fibrous zone.

Erythroxylon Popayenense, H. B. & K.—(Plate XIII.) Sections of this leaf

range from 105 to 160 microns in thickness. The upper epidermis is about one-fifth the thickness of the entire leaf, the cells appearing elongated rectangular in sectional view, with the outer surface thickly cutinized. Papillae with extremely thick walls and a greenish content are prominent on the lower surface of the leaf. The palisade cells are broad, being almost as wide as long, and of light green color. Two or three palisade cells abut on each epidermal cell. The mesophyll parenchyma consists of but a few layers of isodiametric to irregular cells of light color in which crystals occur but sparingly. Many of the fibers in this region are decidedly branched.

Owing to the fact that the leaf blade is rather thin and the primary veins of large size, the leaf is thickened at the points of occurrence of these veins and the palisade layer is much reduced in thickness.

The midvein ridge is fairly prominent although not very large. Collenchyma occurs within the ridge and also in a narrow band between the fiber zone and the

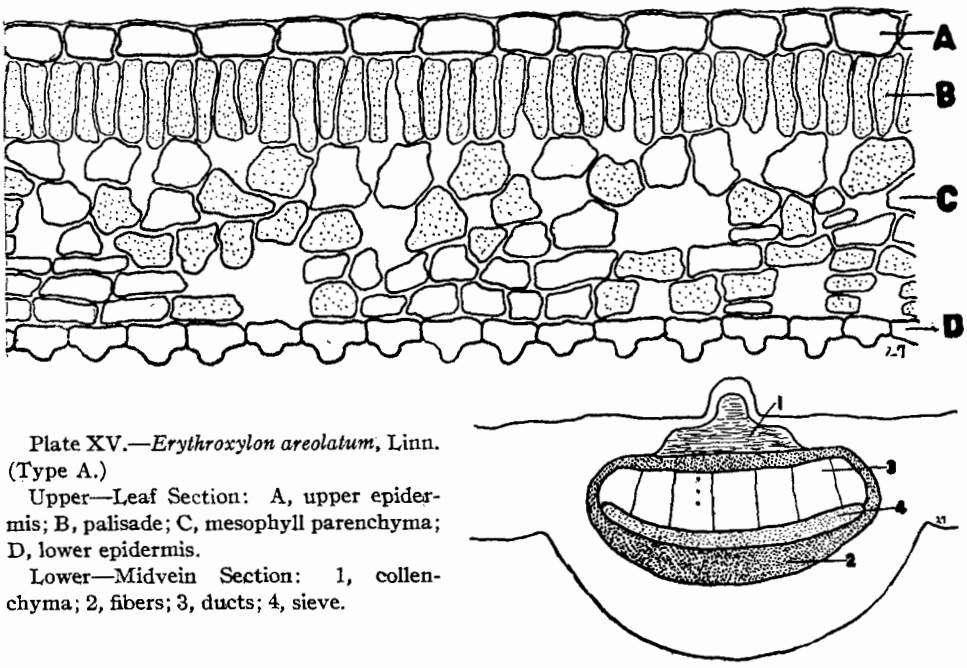


Plate XV.—*Erythroxylon areolatum*, Linn. (Type A.)

Upper—Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis.

Lower—Midvein Section: 1, collenchyma; 2, fibers; 3, ducts; 4, sieve.

lower epidermis. The vascular elements are surrounded by fibers excepting a small area on the upper side of the duct region which is occupied by collenchyma. The ducts occur in radiating rows with strips of parenchyma intervening.

Erythroxylon areolatum, Linn.—As noted in the section dealing with the morphological characters of the leaves of this species, the specimens are of three types.

Type A.—(Plate XV.) Specimens from three sources were examined and two of these were exactly the same thickness, 157.5 microns. The third specimen was 139.5 microns in thickness. Aside from this difference in thickness of lamina and slight differences in the height of the ridge over the midvein, the leaves were identical in histological structure. The upper epidermis consists of tangentially elon-

gated cells, rather regular in size and form and with a thin cuticle on the exposed surface. The lower epidermal cells bear papillae, are but slightly smaller than those of the upper surface and show a brownish or a greenish coloration. Palisade cells are fairly regular in form and size, with the greater number of chloroplasts appearing at the end in contact with the upper epidermis. The proportion of height to width averages four to one and the number of palisade cells in contact with an epidermal cell ranges from two to four. Mesophyll parenchyma consists of four to seven layers of cells, differing in form in different portions of this region. Funnel or collecting cells are especially prominent immediately beneath the palisade and these communicate with isodiametric cells in the midportion of the mesophyll. The lower portions of mesophyll parenchyma appear as flattened elongated cells arranged in layers and some of these cells are of branched type. Chloroplasts and prisms of calcium oxalate occur within the mesophyll cells and aerating cham-

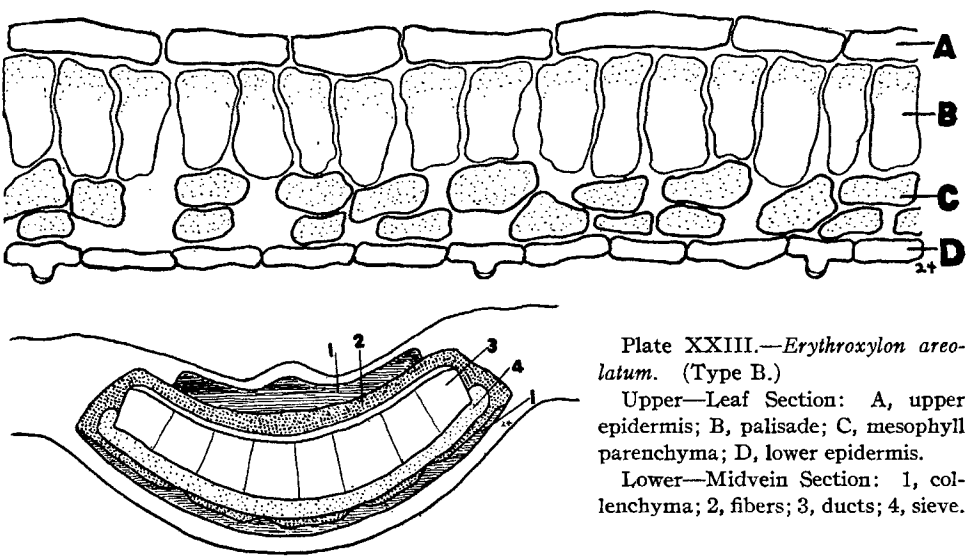


Plate XXIII.—*Erythroxylon areolatum.* (Type B.)
Upper—Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis.
Lower—Midvein Section: 1, collenchyma; 2, fibers; 3, ducts; 4, sieve.

bers are frequent. Fibrous elements show a slight tendency toward branched form.

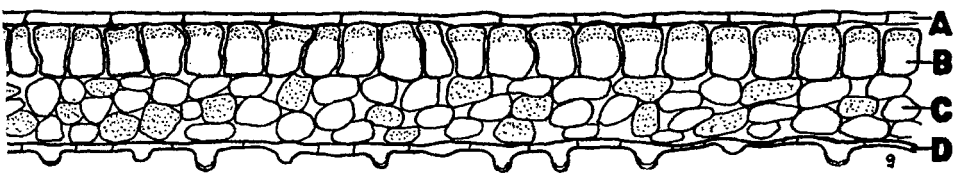
Primary vein branches are placed more toward the upper leaf surface and the fibrous tissue displaces the palisade cells at the points where the veins occur. The vein does not entirely displace the mesophyll parenchyma and two or three layers of this tissue underlie each vein.

The ridge on the upper leaf surface varies in height from 73.5 to 115.5 microns. Collenchyma occurs within the ridge and extends internally to the fiber zone. The region below the midvein shows little trace of collenchyma. Pericyclic fibers extend completely around the vascular elements, being best developed on the lower side. The ducts occur in radiating rows, each row being separated from the others by a line of woody parenchyma.

Type B.—(Plate XXIII.) Leaves of this specimen average 105 microns in thickness but are variable in that the blade is noticeably thicker over the veinlets. The upper epidermal cells appear in tangentially elongated form, being three to

seven times longer than wide. In sections of some leaves and in different portions of the same leaf this epidermis is reduced in thickness and in one instance appeared as a thick cuticle, details of cellular structure not being apparent. The lower epidermis is sparsely provided with papillae and also shows peglike projections from some of the cells. These projections are much narrower than papillae and do not show a distinct cavity as do the latter. Palisade cells are exceedingly large as compared with the other tissues, are very irregular both in size and form and show a thicker wall than is usually present in this type of tissue. The number of palisade cells abutting on an epidermal cell is two or three. Mesophyll parenchyma consists of two to four layers of elongated irregular cells with a brown content and enclosing large aerating chambers. Fibrous elements of decidedly branched form are numerous in this portion. Branched forms of parenchyma occur toward the lower epidermal surface.

The locations of primary, and even the smaller branch veins, are marked by an increase in thickness of the leaf blade at the points of occurrence. In the case of primary veins the fibrous sheath narrows down to a wedge of one or two fibers



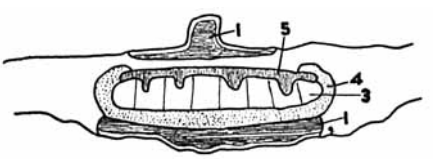


Plate XIV.—*Erythroxylon areolatum*, Linn. (Type C.)

Upper—Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis.

Lower—Midvein Section: 1, collenchyma; 3, ducts; 4, sieve; 5, conducting parenchyma.

which extends to the upper epidermis, usually displacing but a single palisade cell. At least one layer of parenchyma intervenes between the vein and the lower epidermis.

The upper surface of the leaf is depressed over the midvein but at the midpoint of the depression there is a slight elevation which can hardly be termed a ridge. Collenchyma occurs within this elevation and for a short distance on each side of the depression. A narrow zone of collenchyma also occurs on the lower side of the vein. Fibrous tissue encircles the vascular elements but is incomplete on the lower face, as collenchyma intervenes between the groups of fibers and at best the fibrous layer is thin at this point. There is a corresponding increase in the amount of fibrous tissue on the upper side of the vascular elements. A narrow zone, apparently sieve, occurs on the upper side of the ducts in addition to the main body located below the latter.

Type C.—(Plate XIV.) This leaf is the thinnest of any examined, averaging but 75 microns. The upper epidermis appears as elongated very narrow cells which are four to eight times longer than broad and the outer wall is not strongly cutinized. Although papillae occur upon the lower epidermis, they are scattered and not very large. Palisade occurs as large, nearly rectangular cells, coloration

being deepest on the side toward the epidermis. One to two palisade cells abut on each epidermal cell. The mesophyll parenchyma occupies but little more of the total area of the leaf than the palisade. This tissue is fairly compact with but small aeration spaces and hardly exceeding four layers of cells. Calcium oxalate occurs sparingly.

The leaf blade is slightly thickened in the vicinity of the primary veins and the latter completely fill the space between the upper and lower epidermal layers, mesophyll tissues being lacking at these points.

Although the ridge over the midvein is small, it is well developed when one considers that the leaf blade is very thin. In fact the ridge rises 52 microns above the general surface and the leaf blade is but 75 microns in thickness. The support-

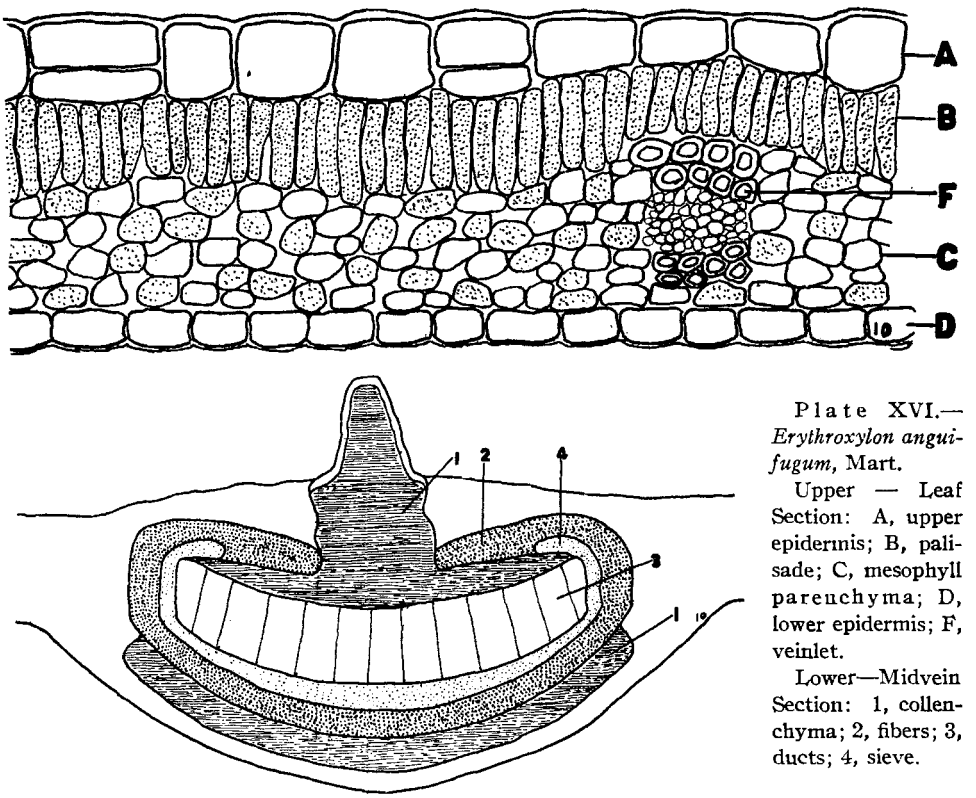


Plate XVI.—*Erythroxylon anguifugum*, Mart.

Upper — Leaf Section: A, upper epidermis; B, palisade; C, mesophyll parenchyma; D, lower epidermis; F, veinlet.

Lower—Midvein Section: 1, collenchyma; 2, fibers; 3, ducts; 4, sieve.

ing tissues of this region are mainly collenchyma, fibers being reduced to a minimum and only occurring as isolated cells in connection with the ducts. The tissues of the ridge and a zone in contact with the lower leaf surface are collenchymatic. Sieve is better developed than ducts and extends well around the ends of the duct region. A narrow zone of parenchyma occurs on the upper side of the ducts, projecting between groups of the latter cells and causing a segmented appearance in the xylem zone.

Erythroxylon anguifugum, Mart.—(Plate XVI.) Leaves from six samples of this species average 155 microns in thickness. A seventh sample, identical in histological structure, was about 250 microns in thickness. The upper epidermis

consists of large square cells occurring in both single and double layers, the cells in the latter case being reduced in height so that the two occupy but little more space than the single layer. The free surfaces bear a moderately thin cuticle. The lower epidermis is devoid of papillae and the cells are about one-half the height of those of the upper epidermis. Cuticle is less prominent on the lower surface. Palisade consists of regularly arranged and fairly symmetrical cells containing chloroplasts in great number. Variations in length of these cells are chiefly due to a slight convexity of the inner wall of the epidermal cells. Four to five palisade cells abut on each epidermal cell. The mesophyll parenchyma consists of four to six layers of isodiametric cells with but little sign of large aeration cavities. The parenchyma in contact with the lower epidermis may assume rectangular form in-

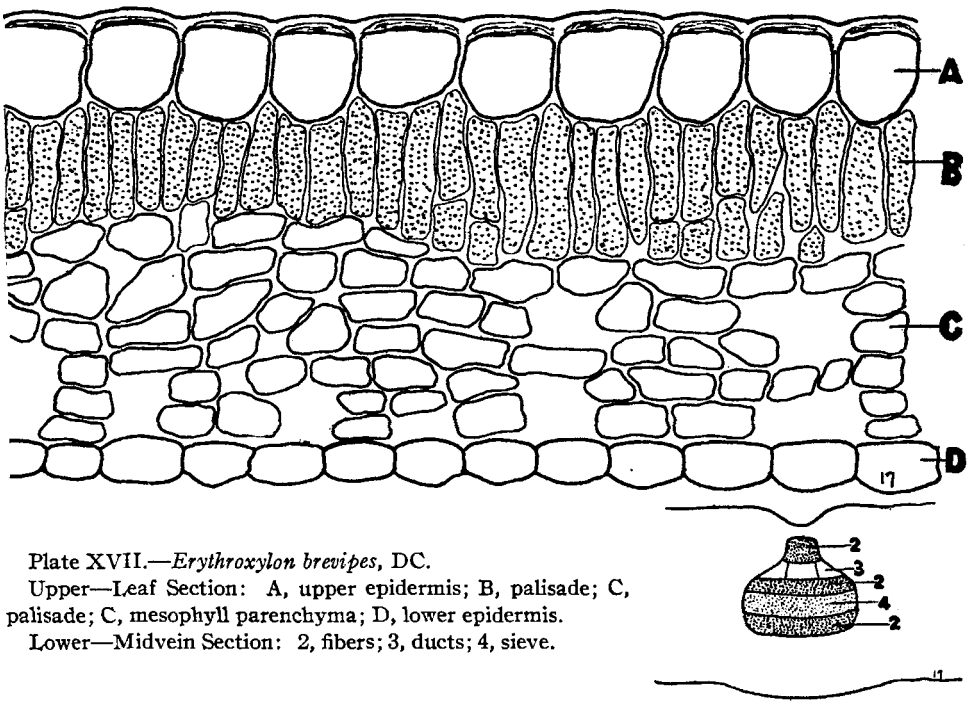


Plate XVII.—*Erythroxylon brevipes*, DC.
Upper—Leaf Section: A, upper epidermis; B, palisade; C, palisade; C, mesophyll parenchyma; D, lower epidermis.
Lower—Midvein Section: 2, fibers; 3, ducts; 4, sieve.

stead of isodiametric. The lower parenchyma cells occasionally occur as branched forms. Most of the mesophyll cells are deeply colored by chlorophyll. Prismatic calcium oxalate occurs sparingly and for the most part as fiber crystals.

The leaf blade is about the same thickness in the vicinity of the primary veins as elsewhere, but at the points where these structures occur, the fibrous sheath encroaches largely upon palisade and mesophyll parenchyma, leaving but a small strip of each between the vein and the respective epidermal layers.

The midvein ridge on the upper leaf surface is well developed and very similar to that of *E. Coca* in proportions and form. The midvein vascular tissues are completely or almost completely encircled by pericyclic fibers, in the latter case the circle being broken on the upper side of the bundle by a mass of collenchyma and conducting parenchyma. Collenchyma also occurs on the lower side of the bundle external to the fiber zone and also extends into the ridge.

(To be concluded)