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I hereby recommend that the thesis prepared under my supervision by Arthur Harry Blicke
entitled "Ohio Psaronii"

be accepted as fulfilling this part of the requirements for the degree of Doctor of Philosophy

Approved by:

OHIO PSARONII

A dissertation submitted to the

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requirements for the degree of

DOCTOR OF PHILOSOPHY

1940

by

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OHIO PSARONII

HISTORICAL

The genus Psaronius was instituted by Cotta (2), in 1832 for certain silicified stems from the Carboniferous and Permian rocks of Europe.

Our knowledge of the anatomy and taxonomy of the European species of the genus Psaronius has in the main been presented by Cotta (2), Stenzel (23), Zeiller (26), Rudolph (18), Solms-Laubach (22), and more recently by Bertrand (1), Scott (214), Hirmer (8) and Sahni (15). The literature concerning the non-American species is well reviewed by Hirmer in his "Handbuch Der Palaobotanik" (1927). Since that time Sahni (15), has discussed the secondary cork tissue in Psaronius roots. Schoute (21), has recently discussed at considerable length many of the fundamental concepts of the structure and organization of the Psaronius stem.

In 1858 Lesquereux (13), reported numerous finds of silicified logs from the Pennsylvanian of Ohio, Virginia, and Pennsylvania, some of which based on later geological survey reports, were without doubt the petrified stems of Psaronius. In 1880 Lesquereux (14), described a specimen from Illinois as Caulopteris giffordi which Potonie (17), later referred to Psaronius because of the occurrence of internal structure.

from the McLeansboro formation of Illinois. Hoskins' specimen consisted of a portion of a stem and part of the peripheral inner zone of adventitious roots. The normal arrangement of the vascular strands of the stem could not be determined, this stem must therefore be classed along with Macbride's specimen in the Psaronii Incertae Sedis.

Gillette (4), has presented the first major contribution on the morphology and the anatomy of American Psaronii, based on fragmentary silicified sections of stems from the glacial drift in the vicinity of Peoria, Illinois. He described four specimens of Psaronius. Gillette assigned two of his specimens to the species Psaronius septangulatus. These specimens were studied in considerable detail from a series of transverse sections of one of the stems, the second stem presumably was not sectioned serially because of its poor preservation. The third specimen was assigned by Gillette to the new species Psaronius peoriensis, and the last specimen was ascribed to the species Psaronius giffordi Potonie. The latter specimen agreed rather closely with Caulopteris giffordi. A comparison of the external characters only was possible between the type specimen of Psaronius giffordi and Gillette's specimen, which possessed smaller leaf scars than the type specimen of the species. It is apparent that Gillette considered the two specimens conspecific even though the internal anatomy of Psaronius giffordi was never elucidated.

Schopf (20), reported several large polystichous trunks of Psaronia from the middle McLeansboro formation of Richland County, Illinois. Concerning the material Schopf says the following:-

" Largest and most obvious are trunks of polystichous Psaronia. Three species may be represented, two of which appear similar to Psaronius peoriensis and Psaronius septangulatus described by Gillette in 1937. However, since Gillette's material was discovered in glacial deposits, the discovery of comparable species in place is doubly significant. The species which may be compared with P. septangulatus shows an aerenchymatous ground parenchyma between the stelar strands similar to that in the cortex of the free growing Psaronius roots. The third species not only shows the typical small internal roots forming a dense cortical mass, but also shows them distributed in the ground parenchyma between the stelar strands. Some roots apparently show their original connection with strands of the stelar complex."

One of the above mentioned specimens was partially investigated by Miss Moon (16), however, specific reference of this specimen was not made at the time. She states that "this specimen is notable for the presence of secondary growth in the stem meristemes and the absence of spiral or annular tracheids in the protoxylem areas of its free roots, the last two features being unreported for American Psaronia."

Although Miss Moon's Figure 1 shows an incomplete stem, it appears from its vascular organization to fall within the group bearing leaves spirally arranged in ten ranks similar to Psaronius multivascularis described below. However, specific reference of this specimen must be deferred until a

thorough analysis of a more complete specimen has been made. Pending such inquiry it should, as Miss Moon first suggested, and in the estimation of the writer, be tentatively considered as a distinct species.

LOCALITIES AND HORIZONS

Collection of the silicified Psaronius stems which comprise the materials for the present study was begun in 1930 by Dr. J. H. Hoskins who brought together many of the finest specimens in the collection. Additional excellently preserved materials, some of which had been highly polished, were kindly loaned to the writer from the Hildreth collection at Marietta College, the Herzer collection at Baldwin Wallace College, and the collections of the Geology Museum of the Ohio State University and the Geology Museum of the University of Cincinnati.

Over one hundred specimens were added to the paleobotanical collection of the Botany Department by Hoskins and the writer during the years 1937-1939, in addition to the numerous stems which had been previously collected, making a total of some three hundred portions of trunks of Psaronius. Not all of these are perfect specimens, to be sure, but the majority of them possess well preserved central axes and root tissues.

The specimens considered in the present research were derived from the horizon of the Pittsburgh Coal or No. 8 seam, which, according to Stout (252), marks the base of the Monongahela system in Ohio; from the horizon of the Arnoldsburg sandstone of middle Monongahela age; and from

the horizon of the Connellsville sandstone and closely associated clays, coal, and shales, of upper Conemaugh age.

Exposures of the Pittsburgh horizon were studied at several localities in Lodi township, Athens County. The Pittsburgh horizon is represented at intervals by a vein of coal which varies from a thin carbonaceous streak to a thickness of ten or twelve inches, overlain by a bed of bluish-gray clay two to three feet in thickness which is heavily impregnated with iron pyrite. Above this bed for approximately twenty feet are varicolored beds of fine-grained clay shales which are locally interbedded with thin lens-shaped layers of non-fossiliferous limestone and which are overlain by massive sandstone strata. These shales are extremely fossiliferous, containing many plant compressions.

Beneath the coal there are approximately eight feet of dark carbonaceous shales which contain numerous flattened trunks of Psaronius. These often measure as much as three feet in diameter. The shales are in turn underlain by the prominent Connellsville sandstone which according to Condit (1^a), "lies only a few feet below the Pittsburgh coal in Lodi township and occupies all of the interval to the bed of the Middle Branch of Shade River, and is the cause of the narrow canyon-like valleys frequent in that area."

Three large specimens of Psaronius were found in situ in different localities in the same township at the Pittsburgh

horizon. At each place of collection the strata dip to the southeast and tributaries of the Middle Branch of Shade River known locally as Fossil and Harris Creeks, have cut through the clays and clay shales and have locally exposed the coal beneath. This seam is quite variable in thickness. Two of the three large specimens were exposed by the downcutting action of the stream, the third was accidentally exposed by the writer. The basal portions of these trunks were embedded in the clay which forms the uppermost stratum of the creek bed and in the coal beneath the clay to a depth of thirty inches or more. Two of the trunks were very carefully excavated along with vertical sections of the investing clays, coals and shales. The largest of these trunks is approximately six and one half feet long and has a greatest diameter of seventeen and one half inches.

This trunk constitutes the basal portion of a Psaronius stem, which in the estimation of the writer, must have been about twenty five feet in height. Two upper sections of the same tree were found lying loose a short distance from the upright trunk. All of the tissues of this specimen of Psaronius are very well preserved and show little evidence of distortion or compression.

The bluish-gray clay which immediately invested the tree trunks above the coal was found to contain quantities of Pecopterid foliage bearing numerous well-preserved fruiting structures of the form-genera Asterotheca and Scolecoperis.*

* A detailed study of these form genera is now in progress.

This association may be significant. The fact that these fertile fronds occur in such quantity and proximity to the Psaronius stems and constitute the only plants, with the exception of the genus Sphenophyllum, found within a radius of six feet or more from the base of the tree, again suggests that this foliage may have belonged to Psaronius. However, the association must be considered as suggestive only, for in the shales immediately overlying the blue clay there is a large assortment of frond genera such as Neuropteris, Mariopteris, Odontopteris, Lesqueropteris, Sphenophyllum, Annularia, and Asterophyllites. *

Several additional obconical basal portions and numerous middle and upper sections of Psaronius were collected from the shales and clays of the creek bottoms. Fragments of trunks which had obviously been eroded free from the strata above and below the coal were found lying loose in the stream beds.

Fifteen additional specimens of Psaronius were collected in Morgan County by Hoskins and the writer during the period 1936-1939. All of these stems were derived from the horizon of the Arnoldsburg Sandstone which immediately overlies the Arnoldsburg limestone and shale in the vicinity of Hackney, Morgan County, Ohio. The Arnoldsburg members are immediately underlain by the Fulton sandstone which is

* A detailed study of these form-genera is now in progress.

well known for its amphibian dinosaur tracks. The siliceous Uniontown shale outcrops in hillside gullies above the Arnoldsburg members. These strata belong to the Middle Monongahela series.

Six of the Arnoldsburg stems were found embedded horizontally in the sandstone. Some of the stems had weathered out of the exposed sandstone and were lying in nearby gullies. These stems constitute the basal, middle, and upper portions of Psaronius trunks, and though some of the stems are well preserved, many of them are large flattened slabs of compressed root material.

Approximately two miles northeast of Shade, Athens County, the Middle Branch of Shade River has downcut through the Connellsville sandstone as well as the strata underlying it. Twenty five fine specimens were taken from this locality, some of them had already weathered free of the strata and were lying in the creek bottoms, some were excavated from the shale beneath the massive Connellsville sandstone, while still others were discovered in ravines which were formed in the sandstone by the action of downcutting streams.

CRITERIA

The features originally employed by Stenzel (23), in his classification of Psaronii were shown to be incidental features of subordinate importance by Zeiller (26), who correctly emphasized the organization of the vascular tissues of the stem as more nearly constant characters of paramount importance. Examination of a great many specimens of Psaronius emphasizes the systematic value of the vascular system of the axis. It is fortunate also that it is more consistently well preserved than any other stem tissue, and therefore presents convenient criteria.

Zeiller (26), instituted a classification of the various groups of Psaronii based on the arrangement of the leaves on the axis as determined either by a consideration of the vascular system as seen in section or by the position observed on casts and impressions. On this basis the Psaronii were divided into three primary groups, the Distichi, those with leaves in two vertical rows; the Tetrastichi, those with alternating pairs of leaves, thus having four vertical rows; and the Polystichi, those with five or more vertical rows of leaves. The Polystichi were further subdivided into groups having whorled and spirally arranged leaves. Hirmer (9), modified this classification by combining the Tetrastichi with that portion of the Polystichi having leaves in whorls, calling the assemblage the Psaronii polystichi verticillati.

The polystichous stems with spirally arranged leaves were called the Psaronii polystichi spirales.

When the stems of Psaronii preserved either as casts, impressions or petrifications, bear upon their surfaces leaf scars or bundles scars, they have been described under other form genera, based on conditions of preservation in addition to the arrangement of leaf scars. The genus Megaphyton Artis has been assigned to stems with alternating distichous leaf scars and is usually correlated with Psaronii distichi. The genus Caulopteris Lindley and Hutton has been assigned to stems with polystichous leaf arrangement of both whorled and spiral types, and is usually correlated with Psaronius polystichi verticillati* and Psaronius polystichi spirales. Caulopteris includes many variations in the size and pattern of the leaf scars and bundle scars. The genus Ptychopteris Corda has been assigned to certain Psaronius stems which have undergone decortication but is not easily separated from Caulopteris and should not be separated from it. On occasion the Caulopteris and Ptychopteris organizations occur on opposite sides of the same specimen. Stipitopteris Gram¹ Eury is considered to be the rachis of a Psaronius leaf. This genus is correlated with a leaf scar of the Caulopteris

* Recent discoveries of a number of specimens of Caulopteris with well preserved internal structure may give additional information concerning the organization of Psaronii with whorled leaves. These specimens are now being investigated.

type as well as with its bundle scar.

It is with Psaronii polystichi spirales with which, in the main, this paper is concerned. The criteria which usually have been employed in distinguishing the separate species of this group include the following:- The number of leaf traces appearing at the periphery of any transverse section of the stem; the presence or absence of gum canals in the parenchyma of the axis; the presence or absence of sclerenchymatous tissue, and if present whether the sclerenchyma forms an entire cylindrical sheath or is variously interrupted.

In applying these criteria to a considerable number of specimens of Psaronii polystichi spirales from Ohio, it appears that certain modifications of their application must be made. In some instances factors which have been assumed to be constant are found to be quite variable within a single stem, as for instance, the nature of the sclerenchyma; and thus cannot be used arbitrarily. Others after inquiry, assume greater or lesser importance. The criteria used in separating the species described below will be discussed.

1. The number and arrangement of leaf traces appearing at the periphery of the stem in any transverse section.

Here the problem is to distinguish between vascular strands which are leaf traces, and vascular strands from which the leaf traces either have already separated or from which

they will later separate. In some instances there is a significant size difference, the tangential thickness of the trace being consistently less than the thickness of other peripheral vascular strands. However, the width of a peripheral vascular strand from which the trace has not yet diverged is remarkably uniform throughout its length. The actual radial thickness of the leaf trace and the size of the cells which compose it are not found to be sufficiently constant for any species to be used as specific characters.

The number of leaf traces may not readily be apparent in any one section, and may become assured only by a consideration of serial transverse sections. The actual number of leaf traces--which represent, of course, the leaf arrangement on the stem, are, in the various species, hereinafter described, 5, 7, 8, and 10. Evidence derived from sections taken at intervals through Psaronius stems indicate that the number of leaf traces is constant for a species. This does not mean that a given section is sufficient to determine this number. Examinations of additional sections of one specimen, which showed but seven leaf traces in the first section observed revealed the fact that all sections but the first had eight well-defined leaf traces. This threw doubt temporarily on all specimens which had been described as having seven leaf traces in section until additional sections of stems with seven leaf traces were studied sufficiently to indicate that

this number is constant for this particular species.

The leaf trace may assume a variety of shapes in a given species and is not a serviceable factor in specific determination. The form varies from V- shape to a broad U shape with lateral margins straight; or from horse-shoe shaped to J- shaped, with free ends slightly or strongly involute; or W-shaped with the free ends so incurved as to be contiguous.

This variety of pattern of the leaf trace may be obtained in a series of transverse sections cut in sequence from that level where the leaf trace has just diverged from the peripheral strand to the level where the trace is lost at the stem periphery.

2. The Internal vascular strands.

The number of vascular strands lying internal to those at the periphery of any stem vary in number from very few to over a hundred. Serial transverse sections indicate that the number is variable within rather definite limits for any species. That this is true is further indicated by the fact that a larger axis may have only one third as many internal strands as an axis of a different species but half the diameter of the first. These internal strands may appear, then, regardless of the actual diameter of the axis, either very loosely arranged within the axis, or very compactly arranged. In the extreme condition of compactness the strands

are scarcely separated one from another by fundamental tissue.

The position of these strands within the axis is related to the phyllotaxy of the stem and follows the pattern indicated by the peripheral strands. In general it may be said here that the internal strands, while forming a complex anastomosing framework, show in any transverse section few to many concentric cylinders, depending upon the species, each composed of a number and arrangement of strands based again on the phyllotaxy of the stem. The general disposition of internal strands is the same for all the members of the Spirales studied.

The actual radial width of the internal strands is quite uniform throughout a single section and throughout a single strand. There is a noticeable and consistent difference in thickness, however, between internal strands of different species, some being twice the thickness of others. This feature cannot well be used arbitrarily, however, in the separation of species, because we have as yet insufficient evidence to compare such measurements from the oldest and youngest parts of a single specimen. It is probable that the actual measurements in millimeters of both the radial thickness of these strands and their tangential width will vary as much from the very oldest (basal portion) of the axis to the youngest (apical portion) than will be found between distinct species.

3. The occurrence and position of sclerenchymatous tissue and its relation to the vascular tissue of the axis.

Sclerenchymatous strands are present in all of the Ohio specimens studies. In a majority of forms the vascular tissues of the axis are completely surrounded by a sclerenchymatous sheath broken only at the points of outgoing leaf traces. There are in addition, internal strands in most stems which occur even in the very center of the axis. In other specimens the strands are absent in the central region. The internal sclerenchyma strands vary greatly in size, the more internally placed ones usually being quite small. They also differ materially in position, some evidently having a definite position in relation to internal vascular strands, others not being definitely placed.

In a series of sections of another species of Psaronius a continuous external sclerenchymatous band is absent. However elongated strands, sometimes forming an almost continuous band, weave in and about the internal vascular strands in a definite pattern, separating them from the peripheral vascular tissue. In this specimen at the position of an outgoing leaf trace only does sclerenchyma appear at the periphery of the axis, and then only internal to the trace itself. While this condition of the sclerenchyma is in sharp contrast to that seen in other specimens, and in this instance does occur in

a different species, the variations seen in serial sections suggest the possibility that an essentially continuous peripheral sclerenchymatous band may occur in all adult stems and that its absence may be an age factor rather than a specific difference. Additional sections of the very basal portions of stems should add much needed information on this point.

Serial sections indicate that in all of the stems studied the sclerenchymatous tissue forms a continuous anastomosing tissue with a definite relationship between peripheral and internal strands. This relationship is more clearly shown at the position of outgoing leaf traces.

The actual radial thickness of bands of sclerenchyma is fairly constant in the species studied, and in the absence of entire specimens may be serviceable as a specific character. However, in stems of considerable length the thickness is observed to increase in sections taken nearer the stem apex, suggesting the probability that in all complete stems there would be a size variation, depending upon the level of the sections observed.

4. The parenchymatous fundamental tissue.

The parenchymatous cells of the fundamental tissue are, in the main, compact, isodiametric, thin walled cells which vary in size from 40 μ - 60 μ in smaller specimens and from 75 μ - 150 μ in larger ones. However, in specimens belonging to a different species, this tissue is definitely

lacunar, forming the familiar network of cells so characteristic of the cortex of Psaronius free roots.

The distribution of this lacunar tissue in the species in which it occurs, may be quite variable in the same stem. When the distribution is general, the lacunae show little variation in size, and are uniformly separated from the phloem of the vascular strands by a narrow layer of normally compact parenchymatous cells; in other instances the lacunae are larger and more prominent in the central areas of the axis, and become smaller and less definite as the periphery is approached, finally grading into the more compact fundamental tissue at the periphery.

Several specimens have, at the periphery of the axis, inside the sclerenchymatous band, a gradation of thin walled fundamental tissue into thick-walled cells. These are isodiametric and of the same size as the adjacent thin-walled cells, and are apparently lignified. The juncture of this layer with the sclerenchymatous sheath is abrupt and definite.

From a consideration of the Ohio specimens of Psaronius it appears that lacunar tissue is not a common feature of most Psaronii axes, but is a feature of at least one distinct species.

5. The number of xylem arms in the radial steles of the adventitious roots of the inner root zone.

The number of xylem arms in the polyarch stele of the root is not significant when the counts involve a small

number of roots. There is always some variation found in any section of any stem. When a large number of roots are examined differences which may be significant are found.

The method employed was that of drawing straight lines at random through the inner root zone, examining each root along these lines until a minimum of one hundred roots had been examined. The nature of the results is indicated by the following examples: In one species the number of xylem arms of the roots are 7, 8, or 9. An examination of a large number indicates that some 65% of all the roots in this root zone have 7 xylem arms. In another species the variation in number is much larger, ranging from 7 - 12. Here again about two-thirds of all roots have 9 xylem arms. In still another species the number of xylem arms are 5, 6, or 7. Here over half of the roots have 6 xylem arms. It is probable that used in conjunction with other factors, the xylem organization of the inner root zone may be a useful factor in species determination.

6. The occurrence of tannin sacs and gum canals.

In all specimens examined tannin sacs and often gum canals as well occur in the tissues of the axis. By far the most abundant are the tannin cells which occur generally distributed throughout not only the fundamental tissue but also in even greater numbers in the phloem. Sometimes these cells occur here so closely ^{packed} together that

they obscure the enclosing tissue.

The size of the tannin sacs varies according to the size and nature of the cells of the tissue within which they occur. Those in the phloem, for instance, are usually, but not always, smaller than are those in the adjacent fundamental tissue. In transverse section these cells vary from 100 μ - 150 μ in diameter, and in longitudinal section from 100 μ - 180 μ .

Larger gum canals also are present sparingly in some specimens but not in all. In no instance, however, does the number of canals equal the number of tannin sacs present in the same stem. Because of the definite but very infrequent occurrence of gum canals in some stems, it is uncertain whether they are actually absent from other stems, or only absent from observed sections of those stems.

From the literature it appears that the tannin sacs have been interpreted as gum canals in some instances. There is a marked difference both in size and appearance between the two structures. The gum canals are larger, varying in transverse section from 180 μ - 260 μ in diameter in the specimens studied, and with the surrounding walls thickened. In longitudinal section they appear as longer structures.

Because tannin sacs occur rather uniformly in all of the Ohio specimens their occurrence is not in itself significant for species identification. As for the gum

canals, our material has not afforded any satisfactory conclusions based on their occurrence.

7. The divergence of the leaf trace.

In all of our specimens the leaf traces are derived from the central sections of the peripheral vascular strands, the lateral portions of which persist as peripheral cauline strands.

In most of our specimens divergence of the leaf trace from the two peripheral cauline strands which remain is simultaneous. However, in some cases now one inner margin of the leaf trace and now another lags behind in its divergence from the accompanying cauline strands.

Hirmer (9), has described another type of leaf divergence as exemplified by Psaronius quadrangulus. This type acts just the reverse of the diverging leaf traces in our specimens. In Psaronius quadrangulus the leaf traces were formed from the lateral portions of the peripheral vascular strand, while the central section made up the so-called peripheral cauline xylem bundle.

This type of leaf trace divergence has not been found in any Ohio specimens.

METHODS

All of the Psaronii described below are silicified portions of stem. Some of these possess organic material sufficiently well preserved to permit an examination of the cellular structure by the nitrocellulose peel technique.

Others less well preserved were sectioned, fine ground, etched in hydrofluoric acid, and examined in reflected light.

Abundant thin sections were prepared from the various specimens which form the bases of these descriptions.

DESCRIPTIONS OF THE SPECIES

The application of the criteria discussed above to the large number of specimens from Ohio has resulted in the recognition of a number of groups of specimens, each of which is believed to be of specific rank. Not all of the Ohio specimens fall within the species to be described. The remainder will be considered in later papers. However, five species are sufficiently known as to warrant description. These follow.

Psaronius lacunosus sp. nov.

DIAGNOSIS:- (Numbers- B-202, B-206, B-237, B-208, B-229).

In transverse section eight foliar vascular strands alternate with eight peripheral vascular bundles. Within this peripheral vascular zone lie 18-27 internal vascular strands loosely arranged in spiral fashion. A definite sclerenchymatous sheath, interrupted only at the position of the outgoing leaf traces surrounds the vascular axis. Small sclerenchymatous islands occur internal to the central portion of each of the internal vascular strands nearest the stem periphery. Fundamental tissue of the axis definitely lacunar, becoming compact near the phloem of the vascular strands, and near the periphery of the axis, where at the juncture with the peripheral sclerenchymatous sheath, the cells are thick-walled, appearing lignified. Steles of roots of the inner root zone possess

5-8 xylem arms, approximately sixty five percent having 7
sylem arms. Leaves spirally arranged. Phyllotaxy 3/8.

Horizons:- Pittsburgh Coal or Number 8 seam, Lower Monongahela
formation. Arnoldsburg Sandstone, Upper Monongahela
formation.

Name:- Psaronius lacunosus - after the lacunar fundamental tissue

DISCUSSION:-

Number B-202 is designated the Holotype. Numbers B-206,
B-237, B-208, and B-229 the Paratypes.

Sections of trunks of this species of Psaronius vary
from 17-50 centimeters in length and have suffered little or
no distortion during preservation. The basal portions of the
specimens including root zones and stems vary from 23-36
centimeters in diameter, while the upper portions of the
specimens measure 25-43 centimeters in diameter. The specimens
consist for the most part of an extensive root mantle which
varies from 5.5-20 centimeters thick. This mantle of roots
surrounds the slightly off-centered vascular axis which may
be oval or cylindrical in shape and varies from 5 x 7
centimeters at the basal portion of the axis to 7 x 12
centimeters at the upper end. As all of the surface of the
axis was covered by a massive mantle of adventitious roots,
it was impossible to determine either leaf scars or bundle
scars on the stem surface. However, when the root zone was
removed, the general course of most of the leaf vascular

strands could be determined. Many small adventitious roots were observed at their places of emergence from the peripheral vascular bundles and it was possible to trace their vascular systems from the point of origin on the lateral involute margins of the peripheral bundles for a distance of 3 millimeters. From studies of 12 serial transverse sections as well as from thin sections totaling some 28 faces, the following anatomical observations may be made!

The leaf traces vary from 10-14 millimeters from outer margin to outer margin in tangential diameter. The distance from the centers of the leaf traces at the periphery of the stem to the centers of the adjacent strand lying next internal to the leaf trace, varies from 10 to 32 millimeters. The distance between adjacent leaf traces as seen in transverse section varies from 15-20 millimeters.

Not all of the eight foliar traces may be distinguished as free traces at the periphery, for, when they are in anastomosis with the peripheral bundles, they form a continuous peripheral vascular strand which is uniform in thickness. When in this condition the leaf traces may appear to be fewer than eight in number at the stem periphery. Those portions of vascular strands at the stem periphery which become foliar traces are usually indicated by inwardly projected finger-like extensions of the sclerenchymatous sheath.

The foliar traces may be strap-shaped or U-shaped,

or if sectioned as they are curved towards the stem periphery may appear as two paired J-shaped strands, or as a single small W-shaped strand. This appearance of the foliar strands depends on the position of the transverse cut in relation to the inwards-bent divergent leaf traces. These foliar traces are always derived from the center sections of long strap-shaped peripheral vascular strands. Endarch protoxylem areas appear placed in regular order on the inner or concave border of the foliar traces and are distinguished from other vascular cells in transverse section by their very small size and their aggregation into wedge-shaped groups of cells, the smallest cells constituting the narrowest portion of the wedge.

When the leaf trace is diverged from the center section of the peripheral vascular strand, two lateral margins of the peripheral strand remain as peripheral cauline bundles. These peripheral cauline bundles alternate with the leaf traces at the periphery of the axis and exhibit a considerable variation in size varying from 10-17 millimeters from outer margin to outer margin in their tangential diameters. These strands are distinctly arched towards the axis periphery with their concavities towards the center of the axis. Their lateral margins are normally involute. The distance from the lateral margin of one peripheral bundle to that of another varies from 15-25 millimeters. On the inner borders of the peripheral vascular strands, small wedge-shaped groups of

xylem cells are identified as protoxylem areas. The smallest cells in this group are innermost. The stem is thus endarch and the development centrifugal. Eight peripheral bundles alternate with the eight foliar traces, but the peripheral bundles also may appear fewer in number because of their anastomosis with the foliar traces. When free of the leaf traces the peripheral cauline bundles are usually C-shaped in transverse section.

The preparation of serial sections demonstrates the fact that 18-27 internal vascular strands occupy various positions in the fundamental tissue of the axis and are spirally arranged in four roughly concentric circles or coils and thus appear to make up a complex dissected polycyclic vascular system. In transverse section as many as four and occasionally five of these elongate, strap-like internal strands may make up one irregular circle. Nearly all of these internal strands are more or less arched with their concavities towards the center of the vascular axis and as the center of the axis is approached, they become shorter and shorter tangentially and are more closely associated with one another. The center of the axis is occupied by a number of small internal vascular strands which vary from 1-10 millimeters in their tangential diameters. These strands present a variety of shapes, being now crescentic, now solid cylinders, or even rod shaped. Serial sections substantiate the fact that these small central vascular strands anastomose with and

diverge from one-another, thus changing in size, shape, and position from section to section throughout the length of the axis. All of the internal strands are observed to be somewhat modified in size, shape, and arrangement in the various serial sections of the axis.

The various vascular strands of the axis, which are thus observed to fall into the above three categories, consist in the main of large, long scalariform pitted xylem tracheids which taper and whose extremities are pointed. These may vary from 110μ - 220μ in diameter. Smaller cells which make up the protoxylem may be as few as 9μ in diameter. Parenchymatous cells occasionally lie between the tracheids of the xylem.

Poorly preserved, thin-walled phloem parenchyma cells surround each of the vascular strands in the axis, forming a small-celled tissue which is usually compact and is easily differentiated from the surrounding lacunar fundamental tissue. Tannin sacs and occasional gum canals may be seen in this tissue, the former in great numbers occasionally obscuring cellular detail. White opaque chalcedony has entirely replaced the phloem around some of the vascular strands. The cells of the phloem vary in size from 95μ to 112μ in diameter.

The fundamental tissue of the vascular axis is definitely lacunar and cannot be distinguished in form from the lacunar cortical tissue of the free roots of Psaronius. The lacunae

vary in diameter from 50 μ to 407 μ . This tissue consists of large usually thin walled, isodiametric cells which vary in diameter from 75 μ - 150 μ and occasionally appear somewhat flattened as the result of pressures from adjacent cells. These cells include scattered tannin sacs and other opaque materials. Near the phloem the fundamental tissue is more compact but still lacunar and contains a large number of tannin sacs here. Just inside the sclerenchymatous sheath, the fundamental tissue is made up of a zone of thick-walled cells from fifteen to thirty cells wide, which are apparently lignified and are in sharp contrast to the small thick-walled cells of the sheath. These cells do not vary in size from the other cellular elements of the fundamental tissue.

A sclerenchymatous sheath is present completely surrounding the vascular axis. Interruptions occur in this sheath only at the positions of the outgoing leaf traces. This sheath is made of thick-walled cells varying in diameter from 110 μ - 150 μ , which are definitely smaller than any of the cells of the fundamental tissue. Here they are compactly arranged and are compressed together appearing angular in transverse section. However, in the sclerenchymatous islands which lie between the central portions of each of the internal vascular strands nearest the stem periphery, these cells are nearly round or are oval-shaped, and in longitudinal section appear as long, slender cells which taper to a sharp point.

These islands may vary from one to fifteen cells thick.

The root mantle which surrounds the axis is differentiated into two zones, a zone of smaller, inner roots, and an outer root zone consisting of larger free roots which usually have lacunar cortical tissues. The inner roots of this species evince but few instances of lacunar cortical tissues. Their steles may have from 6-8 xylem arms, but approximately sixty five percent of one hundred roots have 7 xylem arms. These inner roots vary in size from 3-10 millimeters, and their sheaths may vary from six to twenty five cells in width.

Roots of both outer and inner zones have been observed to include the sheaths and vascular axes of other roots within their cortices. In one case (Fig.), an outer root included as many as five smaller roots within its cortical tissue.

COMPARISON

This species compares with and at first glance somewhat resembles Psaronius septangulatus Gillette, but it may be distinguished from that species by its greater number of peripheral vascular bundles, foliar traces, and internal vascular strands. The axis of our specimen is considerably larger, the root zone more extensive, and the foliar traces are separated from the central section of each of the internal vascular strands nearest the stem periphery by islands or plates of sclerenchyma. In addition to this, our specimen possesses a definite lacunar fundamental tissue, while that

of Gillette's specimen is definitely non-lacunar.

Psaronius euvascularis originally described but unnamed by Farr (3), possessed the same number of foliar strands, but fewer internal strands than our specimen, and if Farr's illustration of the face of his specimen is correct and accurate, it must have been a stem of the Psaronius polystichous verticillati type. It could not compare further with our specimen were this true, and, moreover, since its tissues were undescribed in detail, a further comparison is not possible.

Psaronius Klugei Stenzel was a much smaller stem and had many more internal vascular strands than our specimen. It also possessed a compact parenchyma and had no gum canals or tannin sacs. This species is known only from polished section.

Psaronius octostichus sp. nov. No.'s B-216, C-P1-32.

DIAGNOSIS:

In transverse section 8 foliar strands alternate with 8 peripheral vascular bundles. Within this peripheral vascular zone lie 35-55 internal vascular strands arranged very compactly in spiral fashion. A definite, thick, sclerenchymatous sheath surrounds the vascular axis and is interrupted only at the places of outgoing leaf traces. Definite sclerenchymatous bands occur internal both to the leaf traces and the central sections of the next internal vascular strands. Scattered small groups of sclerenchymatous cells are common between most of the outer vascular strands, but are rare in the central plexus of these strands. Thin zones of compact fundamental tissue occur between vascular strands. A broad zone of compactly arranged, thick-walled and apparently lignified fundamental tissue occurs just within the sclerenchymatous sheath at the stem periphery. Phloem tissues of adjacent vascular strands often appear confluent. Separatory fundamental tissues usually thin between adjacent vascular strands. The majority of the steles of the inner roots have 6 xylem arms. Leaves spirally arranged. Phyllotaxy 3/8. Horizon: Pittsburgh Coal or No. 8 seam; Lower Monongahela formation. Name - Psaronius octostichus on the basis of the eight peripheral foliar strands.

DISCUSSION:- No.'s B- 216 Holotype, No. C-P1-32 Paratype

In this species of Psaronius sections of the trunk vary from 2-38 centimeters in length and have suffered no distortion during preservation. These specimens, in transverse section, appear nearly cylindrical. The longer specimen ranges from 20 centimeters in diameter at the base to 32 centimeters at the top, much of the basal root zone having been lost before preservation took place. The greater portion of the trunk consists of a root mantle varying from 6-21 centimeters in diameter. This surrounds an eccentric vascular axis which is 7 x 8 centimeters in diameter in the upper portion of the trunk and 6 x 6.5 centimeters in the lower portion.

The massive root mantle obscures all of the external features of the vascular axis. The vascular organization was determined from the several transverse cuts, polished surfaces, and thin sections.

In a transverse section, the axis contains vascular strands which fall into three separate categories. These are the 8 foliar traces, the 8 cauline bundles and the internal vascular strands. Six of the 8 foliar traces usually are free from the peripheral bundles, and in various stages of divergence from the vascular axis. Two of the 8 foliar traces usually are not separated from the peripheral bundles, but this separation is characterized by a definite

thinning of the bundle at the points indicated by the indent, finger-like projections of the sclerenchymatous sheath. The peripheral, C-shaped vascular bundles are well arched with their concavities towards the center of the axis. In each case they alternate with the foliar traces. Where the two are still in anastomosis, the bundles are distinguished as thickened lateral parts of the long, peripheral, strap-shaped vascular strand.

The foliar traces at the periphery of the vascular axis vary in form. They may be crescentic, strap-shaped, V-shaped, U-shaped, formed as two separate J-shaped strands, or W-shaped. The appearance of these strands in this sequence varies with the level of the section and the degree of the divergence from the vascular axis. The distance from the center of a leaf trace to the center of the next internal vascular strand varies from 13-23 millimeters in the lowest section of the specimen, and from 23-33 millimeters in the highest section. The characteristic, horseshoe-shaped leaf traces vary in their greatest width from 5-8 millimeters in the lower section of the axis and from 7-10 millimeters in diameter in the upper section. The distance from the center of one peripheral bundle to the center of an adjacent peripheral bundle varies from 20-25 millimeters in the upper section. The lateral margins of these bundles are involute.

Within the peripheral vascular zone, there are from

35-55 internal vascular strands compactly and spirally arranged in irregularly concentric circles. These vary in form from long, strap-shaped strands in the outer part, to short oval, rod or crescent-shaped and occasionally circular strands in the central portions of the axis. Here the latter are very closely associated and freely anastomose with and diverge from one another. Thus their number varies considerably from the bottom of the specimen to its top-most portion. The internal strands adjacent to the peripheral strands vary from 18-25 millimeters in tangential width in the lower section of the axis and from 25-35 millimeters in the upper section. The smallest centrally located internal strand measures 1 millimeter in diameter in the lower section and 2 millimeters in the upper section.

The vascular strands of this axis are composed largely of xylem elements of unusually good preservation. Large, scalariform-pitted tracheids make up the bulk of the xylem. No xylem parenchyma has been found in these strands. The tracheids vary in diameter from 111μ to 185μ . The smaller tracheids making up the protoxylem measure 17μ to 37μ in diameter. The protoxylem was identified as wedge-shaped groups of small xylem cells on the inner borders of the various vascular strands.

The phloem tissues completely encircle each vascular bundle. In some regions in both lower and upper sections the

phloem tissues of adjacent bundles appear to be confluent with fundamental tissue not discernable. The phloem consists of thin-walled elements which vary from 22 μ to 37 μ in diameter, which may be obscured by the presence of numerous tannin sacs. Gum canals were not observed in this specimen.

The fundamental tissue of the axis, as seen in thin section, is definitely non-lacunar, appearing compactly arranged. The individual parenchyma cells appear much smaller than in Psaronius lacunosus, varying from 74 μ to 107 μ in diameter. Tannin sacs are frequent in occurrence in this tissue.

A thick walled fundamental tissue appears just inside the sclerenchymatous sheath and in certain areas in this specimen may not be readily separated from it. However, in just as many places it is sharply demarcated.

Surrounding the vascular axis is a well developed sclerenchymatous sheath varying from 2-4 millimeters in thickness. This sheath is made up of numerous thick-walled cells which vary in diameter from 37 μ to 111 μ in thickness.

Sclerenchymatous islands from 10-15 cells thick occur between the leaf traces and the center sections of the internal vascular strands. Other scattered sclerenchymatous areas occur without definite arrangement between the outer vascular strands.

Adventitious roots form the characteristic mantle

about the axis. In transverse thin section of the axis, root traces may be seen in connection with the peripheral vascular bundles. Near the periphery of the axis the roots are small, varying from 1 to 3 millimeters in length. The steles of the inner roots, based on 100 counts, possess from 5-8 xylem arms. Approximately sixty-five percent of these have 6 xylem arms. The sheaths and vascular axes of these roots are well preserved, but the cortical tissues have, for the greater part, been replaced by opaque chalcedony. Some of these inner roots contain much pyrite and have non-lacunar cortices. In this species, the inner root zone is larger than the outer root zone. Roots of the outer zone usually demonstrate greater size and have definitely lacunar cortices. The sclerenchymatous sheaths of these adventitious roots vary from 15-30 cells in thickness. The phenomenon of intra-penetration of roots one within another is also observed in this specimen.

COMPARISON

Psaronius Klugei Stenzel from the Middle Rötliegende (Lower Permian) of Chemnitz in Saxony is the only known specimen which resembles P. octostichus closely. They differ, however, in the following ways. Psaronius octostichus has a much larger axis and possesses many more internal vascular strands. In these the radial thickness of the strands is uniform throughout the entire axis, whereas in Psaronius Klugei the strands in the central portion of the axis are

much narrower than those more peripherally placed. Psaronius Klugei possesses no internal sclerenchymatous areas such as those found in Psaronius octostichus.

Although Psaronius lacunosus and Psaronius octostichus possess the same number of foliar traces, the latter stem is only two thirds as large as the former and possesses nearly three times as many internal strands in compact arrangement. The fundamental tissue of Psaronius octostichus is very compact. That of Psaronius lacunosus is definitely lacunar.

Psaronius quinquefolius sp. nov. specimen no. 203.

DIAGNOSIS:-

In serial transverse sections five foliar traces alternate with five peripheral vascular bundles. In a single transverse section usually only 2 but sometimes 3 leaf traces appear at the periphery of the axis. The remaining 3 or 2 of the five leaf traces are still in anastomosis with adjoining peripheral strands. Within this peripheral zone few (4-7) strands are spirally arranged. No definite sclerenchymatous sheath surrounds the vascular axis.

Elongated sclerenchymatous strands forming an almost continuous band weave in and about the internal vascular strands in definite pattern separating them from the peripheral vascular tissue. At the position of an out-going leaf trace only, does sclerenchyma appear at the periphery of the axis, and then only internal to the trace itself. The fundamental tissue is compact and dense with tannin sacs. Leaves arranged spirally on the axis. Phyllotaxy 2/5. Steles of adventitious roots of the inner root zone having 7-12 xylem arms, with approximately fifty-five percent of these having 9 xylem arms. Root sheaths very thick. Horizon - Pittsburgh coal. No. 8 Seam - Lower Monangahela. Named Psaronius quinquefolius on the basis of its phyllotaxy.

DISCUSSION:- No. 203 - Holotype.

This species consists of a single specimen, No. 203, which is an oval-shaped section of Psaronius trunk 11.5 centimeters long and 23 x 32 centimeters in diameter. It

is composed largely of root mantle which surrounds a small central vascular axis but 3 centimeters in diameter.

The vascular axis was removed from the root mantle and was cut into 11 sections at intervals of approximately one centimeter. It was thus possible to examine 22 serial faces. Thin sections were also made.

As seen in transverse serial section, the vascular tissue is divided into three categories, the leaf traces, the peripheral bundles, and the internal vascular strands, all of which traverse the fundamental tissue of the vascular axis.

The leaf traces are small and vary in their greatest width from 4-6 millimeters. Usually only two, but sometimes three leaf traces may be visible in a single transverse section. Other traces diverge later from peripheral vascular strands and can be definitely designated only in serial transverse sections.

The distance from the centers of the leaf traces at the periphery of the stem to the centers of the strands next internal to them varies from 5-13 millimeters. The distance from the border of one leaf trace to that of an adjacent leaf trace, as seen in transverse section, varies from 5-10 millimeters.

Peripheral strands from which leaf traces have not diverged form continuous irregularly thickened peripheral

vascular plates which extend half way around the vascular axis. Thus at intervals throughout the axis, these long peripheral strap shaped plates give the vascular system of the axis an asymmetrical aspect.

The vascular tissues of the leaf traces are not well preserved. The tracheids of the trace vary in diameter from 95u to 130u.

The peripheral vascular bundles also are small, varying in tangential width from 6 millimeters to 8 millimeters and are radially thin. In a single orthostichy only one or two of the five peripheral bundles may be visible in any one transverse section.

Within the peripheral vascular zone are 4-7 internal vascular strands, an extraordinarily small number of Psaronius, very loosely organized in spiral fashion. These vary in form and may be small-circular, crescentic, v-shaped, hook-shaped, u-shaped, strap-shaped, or irregular in outline. These strands are not closely associated with one another but do freely anastomose with and diverge from one another. The number of internal strands varies with the section. Some circular strands which traverse the fundamental tissue of the axis enclose central masses of fundamental tissue. One to three small centrally located strands vary in diameter from 1-2 millimeters.

A feature peculiar to a number of the internal strands is the disintegration or poor preservation of the xylem cells in the involute bundle margins. The cells here are disorganized and without definite outline. It was not possible to recognize protoxylem areas in this stem.

The nature of phloem tissue of the vascular bundles could not be determined because of the occurrence of dense masses of tannin cells which obscure it.

Tannin sacs occur in great numbers throughout the fundamental tissue. This consists entirely of small, thin-walled, closely packed, isodiametric parenchyma cells which vary in diameter from 40 μ to 80 μ . Gum canals are not present.

No well developed sclerenchymatous sheath is observed in this specimen. Elongated strands of sclerenchyma sometimes forming an almost continuous band of sclerenchyma weave in and about the internal vascular strands in a definite pattern, separating them from the peripheral vascular tissue. In this specimen at the position of outgoing leaf traces only does sclerenchyma appear at the periphery of the axis and then only internal to the traces themselves. In serial sections of the vascular axis the position of these internal sclerenchymatous bands varies accordingly with the anastomoses and divergences of the internal vascular strands.

Adventitious roots form the characteristic mantle about the axis. In transverse thin section of the axis root

traces may be seen lying within the zone of outer peripheral vascular strands. Near the periphery of the axis the roots are both large and small and vary in diameter from 1-10 millimeters. The steles of the inner roots, based on 100 counts, possess from 7-12 xylem arms. Approximately fifty-five percent of these have 9 xylem arms. The sheaths of these roots are extraordinarily thick and vary in diameter from 2-4 millimeters. The cortices of the inner roots are thin.

COMPARISON:

Psaronius punctatus Stenzel from the Middle Rotliegendes (Lower Permian) of Chemnitz in Saxony is the only known specimen which closely resembles Psaronius quinquefolius. They differ, however, in the following ways: P. quinquefolius has a smaller axis and internal vascular strands of uniform radial thickness throughout the entire axis, whereas in Psaronius punctatus the central strands are very narrow. Thick bands of internal sclerenchymatous tissue were not observed in Psaronius punctatus and do occur in Psaronius quinquefolius. Gum canals occur in Psaronius punctatus but are not present in the axis of Psaronius quinquefolius. In Psaronius punctatus the number of leaf traces at the periphery of the axis is 5. In Psaronius quinquefolius only 2 or 3 leaf traces are visible at the periphery in any single transverse section.

PSARONIUS MULTIVASCULARIS sp. nov. No.'s C-P1-31,
B-210, B-244.

DIAGNOSIS:-

In transverse section 10 foliar strands alternate with 10 peripheral vascular bundles. Within this peripheral vascular zone lie 30-70 internal vascular strands in an extremely compact spiral arrangement. A definite, very thick, sclerenchymatous sheath surrounds the vascular axis and is interrupted only at the places of outgoing leaf traces. Definite sclerenchymatous bands occur internal both to the leaf traces and to the central sections of the two next internal vascular strands.

Scattered small groups of sclerenchymatous cells occur occasionally between the outer vascular strands, but do not occur in the central plexus of these strands.

Narrow zones of loosely arranged non-lacunar fundamental tissue occur between the vascular strands. A narrow zone of compactly arranged fundamental tissue occurs just within the sclerenchymatous sheath at the stem periphery. The majority of the steles of the inner roots have 6 xylem arms. Leaves spirally arranged. Phyllotaxy uncertain. Horizon: Connellsville sandstone, Upper Conemaugh formation. Name: Psaronius multivascularis, on the basis of the numerous internal strands.

DISCUSSION. No.'s C-P1-31, B-210, B-244. Paratypes.

In this species of Psaronius, our specimens vary from 15-48 centimeters in length and appear undistorted. In transverse section these vary in shape from irregular to cylindrical. The longer specimen ranges from 22 centimeters in diameter at the base to 26 centimeters at the top, some of the root zone having been lost before preservation took place. The greater portion of the sections consist of root mantle which surrounds a central axis 4-7 centimeters in diameter.

Two of the vascular axes of these specimens were sectioned serially, and one was given a high polish. The longest specimen was cut into 7 sections which presented 14 faces. Each section was cut approximately three centimeters from the next. A second specimen was cut into 2 sections, presenting 4 faces. Sections of both of the above specimens were peeled, using the nitro-cullulose peel method. Thin sections also were made.

As seen in transverse section the vascular strands of the axis fall into three categories, the leaf traces, the peripheral bundles, and the internal vascular strands, all of which traverse the fundamental tissue of the vascular axis.

The leaf traces vary in their greatest width from 7-9 millimeters. The distance from the centers of the leaf traces at the periphery of the axis to the centers of the strands next internal to them varies from 6-15 millimeters.

They vary greatly in shape, assuming a broad V-shape, strap-shape, U-shape or W-shape, and, when they appear as 2 separate strands, may be J-shaped or straight. The xylem of the leaf traces is well preserved and consists mainly of large tracheids of scalariform pitted type. Occasional xylem parenchyma cells lie between the tracheids of the leaf traces.

Ten peripheral vascular bundles alternate with the ten peripheral leaf traces. In one specimen all of the peripheral bundles except two are free of their accompanying leaf traces. These bundles are often C-shaped but sometimes appear narrowly U-shaped. In tangential width they measure 3-8 millimeters. In other specimens, two or more of these strands as seen in any one section are non-diverged from the leaf traces. But in serial sections the alternation of ten peripheral strands with ten leaf traces is a constant feature.

The anastomosis of one of the peripheral bundles with the central section of a vascular strand of the next inner irregular circle of strands gives the outer peripheral zone of vascular strands an irregular appearance and demonstrates the fact that in this species the divergence of the central sections of inner vascular strands from the accompanying lateral sections is not simultaneous as in other species.

Within the peripheral vascular zone are 30-70 internal vascular strands. These are extremely compact in their arrangement and evince a very complex spiral pattern. They

exhibit a great diversity in form, and, as determined by serial transverse sections, freely anastomose with and diverge from one another. The number of internal strands varies accordingly with the number of anastomoses and divergences of these strands.

In some sections of the vascular axis doughnut-shaped vascular strands occur in the central plexus of internal strands. These anastomose with adjacent internal strands.

The phloem tissues of this species, as in some others, are obscured by closely packed tannin sacs. Other structures occur in this tissue which could not be positively identified.

The cells of the fundamental tissue are loosely arranged. They vary in diameter from 60 μ -80 μ . Because of the compactly arranged internal strands, only narrow zones of fundamental tissue occur between the internal vascular strands. The narrowness of these zones is accentuated when internal bands of sclerenchyma occur between the internal strands. Gum canals could not be determined, but tannin sacs are numerous throughout this tissue.

A very thick, much convoluted sheath of sclerenchymatous tissue surrounds the vascular axis and is interrupted only at the place of outgoing leaf traces. This sheath varies from 2-5 millimeters in thickness. In some sections it may be seen in anastomosis with internal bands of sclerenchyma. At this point a leaf trace appears completely isolated

from tissues internal to the sheath. Thus, the sheath and internal bands of sclerenchyma form a network. Additional smaller areas of sclerenchyma occur scattered between internal strands nearest the periphery of the axis.

The root mantle characteristic of Psaronii surrounds the vascular axis. The steles of roots of the inner root zone have 6-8 xylem arms. Approximately seventy-five per cent of these roots have 6 xylem arms.

A striking peculiarity occurs in the longest specimen. Three adventitious roots, distorted, and with convoluted sheaths, are found to traverse the central portion of the vascular axis for a distance of 48 centimeters.

COMPARISON:-

No previously described species of the sub-group Psaronii polystichi spirales demonstrates as many as ten leaf traces and ten peripheral vascular bundles at the periphery of the vascular axis. Certain features of Psaronius Klugei, Stenzel from the Middle Rötliendes of Chemnitz, Saxony (Lower Permian), a form having eight peripheral leaf traces and eight peripheral bundles, are, however, in common with Psaronius multivascularis. P. Klugei had a stem 5 centimeters in diameter and a heavily developed sclerenchymatous sheath. In P. multivascularis a thick sheath is also present, and the stem varies from 4-7 centimeters in diameter. In P. multivascularis the fundamental tissue is loosely arranged, not compact as in P. Klugei. Many more internal

strands occur in the Ohio specimen, 30 to 70 internal strands being present, while the Chemnitz specimen contains but 30 internal vascular strands. The occurrence of internal areas of sclerenchymatous tissue, some of which has a definite position in relation to the leaf traces in P. multivascularis, is significantly different from P. Klugei, in which internal sclerenchymatous areas do not occur.

When compared with the better known species Psaronius octostichus, many of these differences may be noted. In P. octostichus there are fewer peripheral traces and peripheral strands than in P. multivascularis. The fundamental tissue of P. octostichus is compact, while that of P. multivascularis is loosely arranged but non-lacunar. P. octostichus also possessed fewer internal strands.

PSARONIUS PAUCIVASCULOSUS sp. nov. Specimen no.'s
C-P1-28, B-249, B-256.

DIAGNOSIS:-

In transverse serial sections eight peripheral foliar strands alternate with eight peripheral vascular strands. In any single transverse section, however, only four or five of the foliar strands are usually visible at the periphery of the axis. Within the peripheral vascular zone lie 10-15 internal vascular strands in a loose spiral arrangement. A definite well-developed sclerenchymatous sheath surrounds the vascular axis and is interrupted only at the places of outgoing leaf traces. Many sclerenchymatous bands occur between the various vascular strands. These bands become both radially and tangentially wider as the periphery of the axis is approached. The fundamental tissue of the vascular axis is compact.

Over 50 percent of the steles of roots have 6 xylem arms; other roots have 5-7 xylem arms. Leaves spirally arranged. Phyllotaxy 3/8. Horizon: Connellsville sandstone; Upper Conemaugh Formation. Name: Psaronius paucivasculosus on the basis of the small number of few internal vascular strands.

DISCUSSION:- No.'s C-P1-28, B-249, B-256, Paratypes

In this species of Psaronius the specimens vary from

2.5 to 30 centimeters in length and are but slightly distorted. They vary in transverse section from oval to cylindrical. The larger specimen has a diameter of 25 centimeters at the base, and 23 centimeters at the top, while the smaller specimens are 14.5 to 15.5 centimeters in diameter.

The root zones surrounding these axes are intact and make up the greater part of the diameter. This mantle surrounds a central axis which varies from 3.5 centimeters in diameter in the smallest specimen to 5.5 centimeters in the largest specimen.

All of the specimens were either cut and polished or cut and ground smooth with Aloxite powder, etched, and then peeled, using the nitrocellulose technique. Thin sections were also employed.

As seen in transverse section, the loose organization of the vascular tissues is immediately apparent, and in this character it contrasts sharply with those species having compactly arranged vascular systems.

The leaf traces are uniform and only half as thick in their radial widths as are the peripheral bundles and the internal strands. They measure approximately .5 millimeters. At the place of their greatest tangential width, the leaf traces vary from 5-8 millimeters.

The distance from the centers of the leaf traces at the periphery of the axis to the centers of the strands

next internal to them varies from 7-12 millimeters. The distance from the border of one leaf trace to that of an adjacent leaf trace as seen in any single transverse section, varies from 8-14 millimeters. The leaf traces are V-shaped, U-shaped, or as 2 separate J-shaped strands.

The xylem of the leaf traces is not well preserved. The metaxylem vary in diameter from 182 μ to 225 μ . Small protoxylem areas are visible at varying distances along the inner border of the leaf traces. The small protoxylem cells are 25 μ to 50 μ in diameter. Xylem parenchyma occurs between the larger, scalariform-pitted tracheids.

In any single transverse section usually one to three peripheral bundles only are visible, as such, at the periphery of the axis. This may be due either to their anastomoses with the more centrally placed vascular strands, or, to the vertical distance between superimposed leaf traces. In this case the leaf traces have not diverged from their particular strands. Thus, in serial transverse sections, in either circumstance it can be demonstrated that eight peripheral vascular bundles alternate with the eight leaf traces at the periphery of the axis.

After their separation from the long strap-shaped strands at the periphery of the axis, the peripheral vascular bundles assume a characteristic C-shaped form.

Within the peripheral vascular zone lie from 10-15

internal strands which are loosely spiral in arrangement. The majority of these internal strands form anastomoses with one another, appearing in transverse section, convoluted; strap-shaped strands. These vary considerably in radial width. In higher sections these strands have shorter tangential widths, parts of these having diverged and fused with adjacent strands. The number of internal strands varies accordingly with the number of anastomoses and divergences at these strands.

In transverse section strands of the central internal plexus appear Y-shaped, S-shaped or L-shaped. Their ends are invariably involute.

The phloem tissues of the vascular bundles have been crushed beyond recognition, and in addition, are obscured by numerous tannin sacs.

The cells of the fundamental tissue are closely packed together and are very thin walled. The preservation of this tissue prevents accurate interpretation of the cellular outlines. Tannin sacs occur in great numbers. Gum canals cannot be identified definitely.

A thick sclerenchymatous sheath surrounds the vascular axis and is interrupted only at the places of outgoing leaf traces. The sheath varies in thickness from 1.5 - 5 millimeters and may at the place of an outgoing leaf trace be continuous with the sclerenchymatous bands lying internal to it.

Irregularly thickened bands of sclerenchyma occur

between the vascular strands from the periphery of the axis to its center.

The root mantle characteristic of Psaronius surrounds the central vascular axis. The number of xylem arms in the steles of roots of the internal zone varies from 5-7 with the majority having 7 xylem arms. A count of more than fifty roots was not possible due to the large quantity of iron pyrite which obscured the vascular tissues. The roots of both inner and outer zones appear greatly flattened. Some of the roots of the inner root zone may lie within the sclerenchymatous sheath, or lie partly within and partly without that tissue.

COMPARISON:-

Psaronius paucivasculosus differs from Psaronius lacunosus in the following ways: It has a much smaller vascular axis, fewer internal vascular strands, a compact fundamental tissue. The leaf traces are thinner in their radial widths than are those of P. lacunosus. P. octostichus possesses many more internal vascular strands, a greater development of root zone, a larger vascular axis, and a more compactly spiral arrangement of its internal vascular strands.

None of the European species of Psaronius showing similarities with P. paucivasculosus with the exception of Psaronius punctatus Stenzel and Psaronius helmintholithus Stenzel are sufficiently well known structurally to be

compared accurately. P. punctatus Stenzel from the Middle Rotliegendes (Lower Permian), of Chemnitz, possesses only five leaf traces at the periphery of the vascular axis, while P. paucivasculosus has eight leaf traces, but of these only four or five appear as diverged foliar traces in any single transverse section. The fundamental tissues of both the Chemnitz stem and the Ohio specimen are compact and the axes have the same diameter.

Psaronius helmintholithus Stenzel, Middle Rötliedendes (Lower Permian) from Chemnitz and New Paka (Bohemia), had a vascular axis 4 to 6 centimeters in diameter, a compact parenchyma, and no gum canals. All of the above features are common to P. paucivasculosus. P. helmintholithus, however, had but five leaf traces at the periphery of the vascular axis, while the Ohio specimen has eight. Nothing is known concerning the number of internal strands of the vascular axis of the Chemnitz specimen and the details of the individual tissues of these specimens is not known from thin sections.

SUMMARY

1. From a collection of over 300 specimens of Psaronius, from the Connellsville sandstone of the Upper Conemaugh formation, the Pittsburgh coal of the Lower Monongahela formation, and the Arnoldsburg sandstone of the Upper Monongahela formation, 13 specimens have been selected for detailed description.
2. Criteria for the identification of species are discussed.
3. These specimens fall into 5 groups which are considered to be of specific rank, and which have not previously been described. These are: Psaronius lacunosus sp. nov., Psaronius quinquefolius sp. nov., Psaronius multivascularis sp. nov., and Psaronius paucivascularis sp. nov.

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Psaronius lacunosus sp. nov.

Fig. 1. Transverse section of the vascular axis. x1

Fig. 2. Lacunar fundamental tissue of the vascular axis.

x 750

1037

Psaronius lacunosus sp. nov.

Fig. 3. Transverse section of a free root from the outer root zone demonstrating the lacunar cortex and the phenomenon of root intra-penetration. x 10

Fig. 4. Radial section through the metaxylem showing the scalariform-pitted tracheids. x 750

Fig. 5. Transverse section of tracheids of the metaxylem. x 200

Psaronius lacunosus sp. nov.

Fig. 6. Tangential section through the involute margin of a peripheral bundle showing a root trace in connection. x 10

Fig. 7. Transverse section of a vascular strand showing protoxylem groups at X. x 75

Fig. 8. Transverse section of the lacunar cortex of a root of the outer root zone. x 45

Psaronius lacunosus sp. nov.

Fig. 9. Transverse section of roots from the
inner root zone. x 10

Psaronius octostichus sp. nov.

Fig. 10. Transverse section of the vascular
axis and part of the inner root zone.

X 1.5

Psaronius octostichus sp. nov.

- Fig. 11. Transverse section of a vascular strand
showing a protoxylem group. x 250
- Fig. 12. Radial section through a vascular strand
showing scalariform-pitted tracheids. x 200
- Fig. 13. Transverse section of the fundamental tissue.
x200

Psaronius quinquefolius sp. nov.

Fig. 14. Transverse section showing the internal vascular strands. x 10

Fig. 15. Transverse section of the vascular axis showing a portion of the surrounding root zone. x 3

Fig. 16. Transverse view of the vascular axis from thin section. x 1.5

Psaronius multivascularis sp. nov.

Fig. 17. Transverse section of the trunk showing root zone and vascular axis. x $\frac{1}{4}$

Fig. 18. Transverse section of the vascular axis. x 1

Fig. 19 Transverse section of the vascular axis. x 1+

Psaronius multivascularis sp. nov.

- Fig. 20. Radial section through the metaxylem of a peripheral vascular bundle showing scalariform- pitted xylem. x 550
- Fig. 21. Transverse section of a peripheral vascular bundle showing an outgoing root trace. x 50
- Fig. 22. Transverse section of the sclerenchymatous sheath of the vascular axis x 75.

Psaronius paucivasculosus sp. nov.

Fig.'s 23 & 24. Transverse sections of the vascular axes showing a small portion of the accompanying root zone. x about 2

Psaronius paucivasculosus sp. nov.

Fig. 25. Enlargement of a thin section showing a portion of the vascular axis, its sheath, and surrounding root zone in transverse section. x 16

- a. leaf trace.
- b. peripheral vascular bundle
- c. sclerenchymatous sheath
- d. roots of the inner root zone
- e. root lying partly within the sclerenchymatous sheath.
- f. internal band of sclerenchyma.