

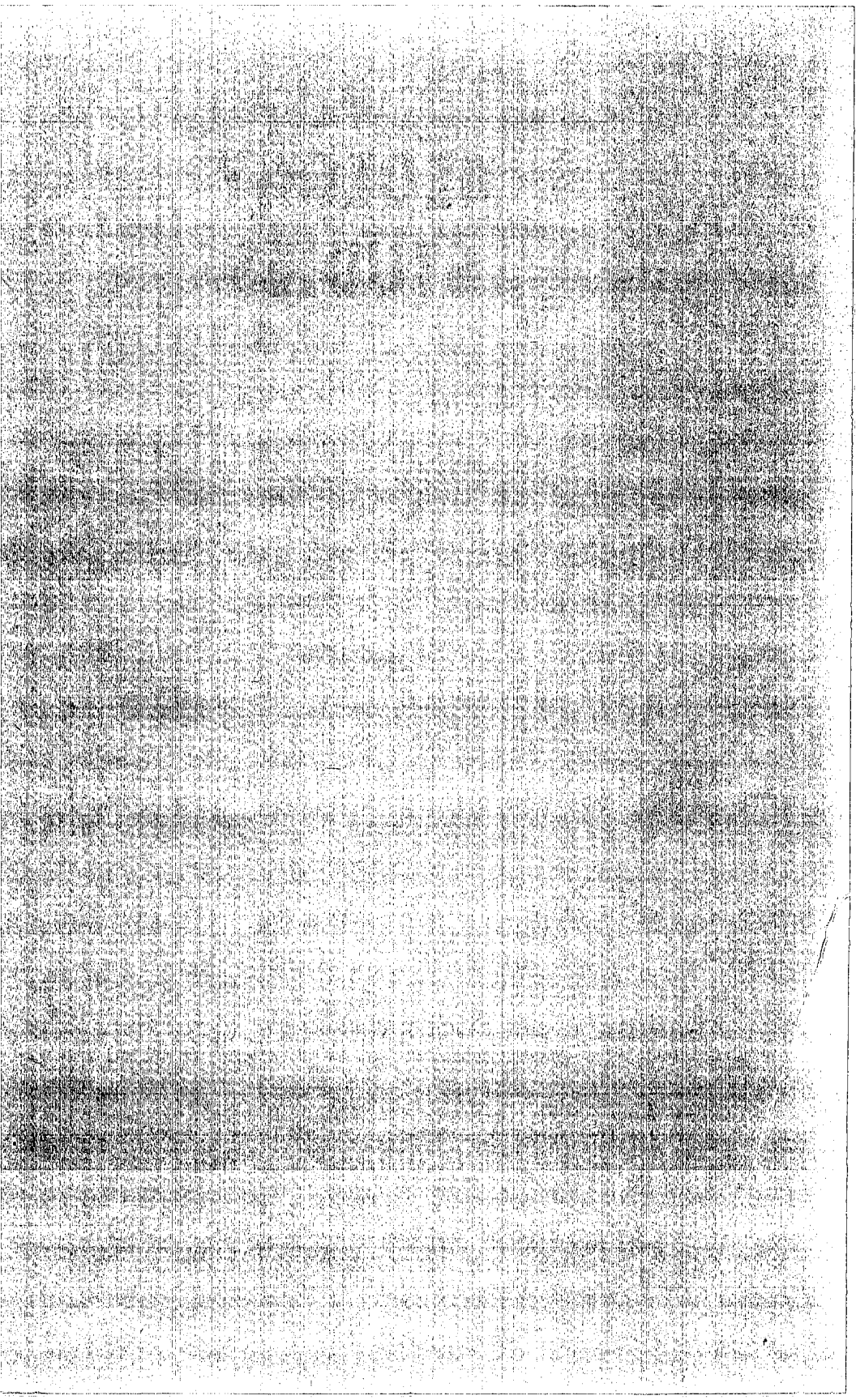
GEOLOGY STUDIES

Volume 14

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FLORA OF MANNING CANYON SHALE

Part I:

A Lowermost Pennsylvanian Flora from the Manning Canyon Shale, Utah, and Its Stratigraphic Significance.

WILLIAM D. TIDWELL

Department of Botany, Brigham Young University

ABSTRACT.—The Manning Canyon Shale on the eastern slopes of Lake Mountain in central Utah contains a unique, lowermost Pennsylvanian flora within its upper shales. This flora contains both Mississippian and Pennsylvanian plant species. *Crossopteris* gen. nov. is the most abundant form with *Calamites* (*Mesocalamites*) also occurring with relatively high frequency.

The flora consists of thirty-three genera and fifty-eight species. Fourteen new species and two new genera, *Crossopteris* and *Rigbyocarpus*, are described. The new species are *Neuropteris ampelina*, *Crossopteris utahensis*, *Crossopteris undulata*, *Crossopteris mc-knightii*, *Sphenopteris dipblebia*, *Sphenopteridium zaitzeffii*, *Tingia placida*, *Cordaicarpus globosus*, *Cordaicarpus jaysbulerii*, *Cordaicarpus manningcanensis*, *Cordaicarpus binutus*, *Cornucarpus longicaudatus*, *Lagenospermum discissium*, and *Rigbyocarpus ebracteatus*. Three new combinations are proposed.

The occurrence of *Sphenopteridium dissectum*, *Diplothmema arnoldi*, *Lepidostrobus obovatus*, and *Gnetopsis anglica* is reported for the first time from North America. This is also the first record of *Telangium affine* in the United States.

The Manning Canyon Shale is composed of shale with quartzite, sandstone, and limestone which appear to have been deposited in an embayment with transgressive-regressive cycles alternating between lagoonal and paludal environments. The flora indicates a fresh or brackish swamp environment.

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INTRODUCTION

The Manning Canyon Shale is a time-transgressive formation in central Utah. Previous geologic investigations and studies of the fossil fauna of this formation indicate a late Chesterian and early Springerian age (Moyle, 1958).

The presence of plants in the Manning Canyon Shale has been previously mentioned by Gilluly (1932), Moyle (1958), Hyatt (1956), and Calderwood (1951, *ms.*). A reconnaissance of the flora and its related stratigraphic position was attempted previously by the author (Tidwell, 1962). The present study is a re-evaluation and enlargement of that study with special emphasis on the systematics of these fossil plants and correlation of the assemblage with other known fossil floras of this age.

The flora from the Manning Canyon Shale as described in this study has two aspects of paramount importance.

(1) Other floras of this approximate age are rare in western United States. Only two other Lower Pennsylvanian floras and one Upper Mississippian flora are known from this vast region. The state of preservation of these floras is generally too poor to allow detail differentiation. Consequently, the number of species from each is small. In comparison, the flora from the Manning Canyon Shale is well preserved and constitutes a relatively diverse assemblage of plants.

(2) The flora occurs in rocks situated stratigraphically between strata containing a fossil invertebrate fauna of Lower Pennsylvanian age near the top of the formation and a Mississippian assemblage near the middle. The flora is transitional and probably the time boundary between these two periods is located near the plant horizon.

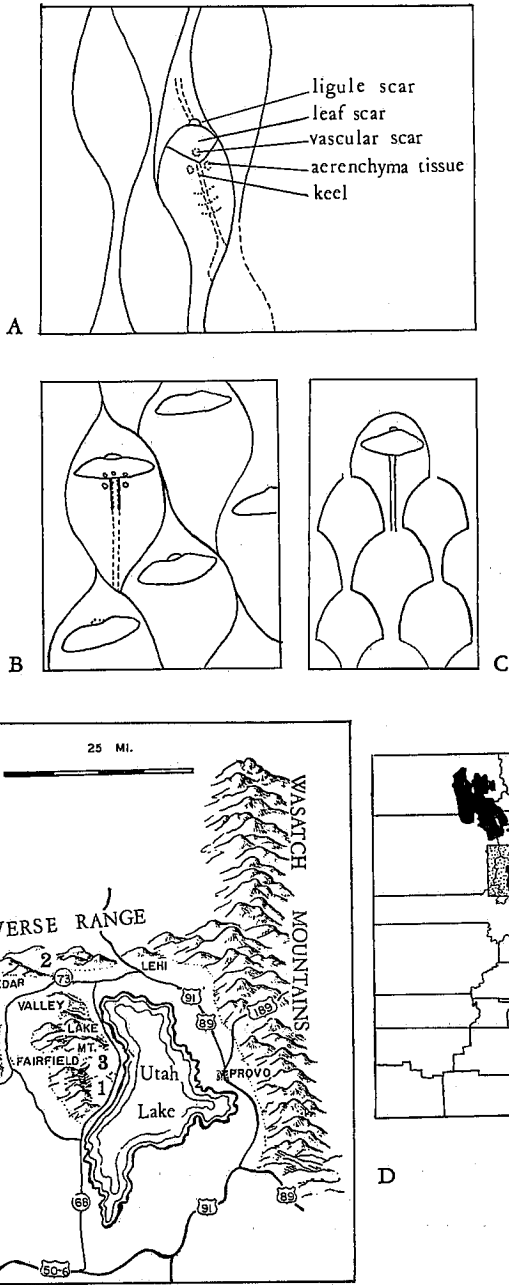
Type specimens of fossil plant material from the Manning Canyon Shale used in this study will be on deposit at the U. S. National Museum, Washington, D. C., and a representative suite of specimens is also placed in the repository at Michigan State University, East Lansing, Michigan. The U.S. National Museum numbers are cited as USNM following the discussion.

LOCATION AND AREA

The Manning Canyon Shale from which the described flora was collected is exposed in central and northern Utah. Most of the fossil plant collections were made from this formation in exposures on Lake Mountain and the Traverse Mountains which are located directly west of the Wasatch Range (Text-fig. 1). Lake Mountain parallels the western shore of Utah Lake and is separated by the undrained basin of Cedar Valley from the southern Oquirrh Mountains to the west. The Traverse Mountains are located to the north and northeast of Lake Mountain and are a small, subdued, east-west range separating Utah Valley from Salt Lake Valley.

Lake Bonneville occupied the valleys adjoining Lake Mountain during the Pleistocene, and many well-developed shoreline features of the lake remain, particularly along the eastern face of Lake Mountain.

Manning Canyon Shales may be overlain by Bonneville sands and gravels, or by quartzite, sandstone, and limestone talus which is derived from overlying strata. The only reasonably unweathered exposures of the shale are in quarried "clay pits." The "clay pits" on Lake Mountain are approximately thirteen miles southwest of Lehi, Utah, near State Highway 69. The "clay pits" on Traverse Mountains are about nine miles west of Lehi and about two miles north of State Highway 73 (Text-fig. 1).



TEXT-FIGURE 1.—A.—*Lepidodendron aculeatum* Sternb. (1X); B.—*Lepidodendron obovatum* Sternb., (1X); C.—*Lepidodendron volkmannianum* Sternb. (2.5X); D.—Index map of collecting localities.

PREVIOUS WORK

The Manning Canyon Shale is the name given to a certain sequence of rocks exposed in Manning Canyon on the western slopes of the Oquirrh Mountains by Gilluly (1932). Various sections of the formation, some of them essentially complete, have been measured and reported by Nolan (1935), Bissell and Hansen (1935), Baker (1947), Bullock (1951), Calderwood (1951, *ms.*) and others.

Other studies of the formation include: sedimentation study (Herbertson, 1950), selenium studies (Robertson, 1950; Brimhall, 1963), a study of the Mississippian and Pennsylvanian boundary (Sadlick, 1955), clay studies (Orneales, 1953; Hyatt, 1956), a paleoecological study (Moyle, 1958), a study of its cyclothems (Prince, 1963), and a preliminary study of the flora and its stratigraphic position by Tidwell (1962).

Very little is known about the megascopic fossil plants from rocks of the Mississippian and Pennsylvanian systems of the western continental United States. Five Upper Paleozoic leaf floras besides the preliminary survey of the Manning Canyon Shale flora (Tidwell, 1962) have been described with some detail from the region west of the Great Plains. These studies include the Permian Hermit Shale flora of northern Arizona (White, 1929); a Permian (?) flora from Colorado (Arnold, 1941; an Early Pennsylvanian flora from the Weber (?) formation of Central Colorado (Read, 1934); a Pennsylvanian flora from the Spotted Ridge Formation of central Oregon (Read and Merriam, 1940; Arnold, 1953; Mamay and Read, 1956), and a Mississippian flora from the Uinta Mountains of Utah reported by Arnold and Sadlick (1962).

GEOLOGY

Stratigraphy and Lithology.—The exposures of the Manning Canyon Shale at the type locality designated by Gilluly (1932) are poor (Text-fig. 1). Therefore, Moyle (1958) designated Soldier Canyon, located a few miles north in the Oquirrh Range, as a reference section.

The formation is composed predominantly of shales with interbedded limestones, orthoquartzite and some siltstone. The shales are black, grey, brown, and red, weathering to black, purple, brown, and yellow. They are fissile, calcareous, and platy in many localities. The limestones are thin to thick-bedded, light blue-grey to dark blue-grey, usually weathering light-grey and brown to yellow, and contain abundant fossils. The light-grey to light-tan orthoquartzites show variable characters of grain size, cementation and porosity as well as cross-bedding and ripple marks.

The lower part of the formation on Lake Mountain is essentially shale with some limestone and quartzite, whereas the upper half is predominately quartzitic with a few shale and limestone beds.

The formation is underlain by the ridge-forming Chesterian Great Blue Limestone and overlain by the limestones of the Morrowan portion of the Oquirrh Formation.

FLORAL COMPOSITION

Plant fossils in the Manning Canyon Shale consist of stems, impressions, portions of fronds and detached pinnules, isolated seeds and other disassociated plant remains. Nearly all of these fossils are compressions with very little of the

original carbonaceous materials having been preserved. The remains have been secondarily replaced with limonite and hematite, resulting in the compressions having reddish or brownish coloration. This type of replacement preserves very little of the cellular structure and cuticle of the original plants.

Minute, siliceous, crack fillings, arranged in box-like structures which are filled with limonite and hematite, occur on the stem and leaf remains. The silica appears to have filled minute joints or cracks which developed in the replacing minerals.

The Manning Canyon Shale flora is represented by fifty-eight species and thirty-three genera. Twenty species are of fern or fern-like foliage. Ten species of lycopods, eight species with calamitian affinities, thirteen species of seed types, four cordaitan species, and three species related to microsporangiate structures are included.

The synopsis in Table I reveals that the most common groups to be represented are crossopterids, calamitian forms, and seed types. These comprise the majority of the compressions. *Crossopteris utabensis*, the most abundant fossil form present, accounts for at least seventy percent of the total number of collected specimens. The lycopods, although represented by many form genera of stems, leaves and fructifications, account for less than 10% of all the material collected. Of these, the majority of compressions are *Lepidocarpon* and *Lepidophyllum*. The sphenopterids are frequent and diversified. Their associated genera, *Rhodea* and *Adiantites*, are also present in small quantities. Other species are relatively rare and any collections from the Lake Mountain or Traverse Mountain "clay pits" would result in an accumulation of ten or twelve specimens of the more common types, particularly *C. utabensis*.

TABLE I
Floral List and Relative Abundance of the Manning Canyon Shale Flora

	AB	F	R
<i>Lepidodendron aculeatum</i> Sternberg		X	
<i>Lepidodendron obovatum</i> Sternberg		X	
<i>Lepidodendron volkmannianum</i> Sternberg			X
<i>Lepidostrobus obovatus</i> Němejč		X	
<i>Lepidostrobus variabilis</i> L. & H.			X
<i>Lepidocarpon linearifolium</i> (Lesq.) Schopf	X		
<i>Lepidostrobus majus</i> (Brongt.) Hirmer			X
<i>Lepidophyllum longifolium</i> Brongniart		X	
<i>Lepidophyllum</i> sp.		X	
<i>Stigmaria ficoides</i> (Sternb.) Brongniart		X	
<i>Archeocalamites radiatus</i> (Brongt.) Stur			X
<i>Calamites</i> (<i>Mesocalamites</i>) <i>hesperius</i> Arnold	X		
<i>Calamites</i> (<i>Mesocalamites</i>) <i>cistiiformis</i> Stur	X		
<i>Asterophyllites equisetiformis</i> (Schloth.) Brongniart	X		
<i>Asterophyllites longifolius</i> (Sternb.) Brongniart			X
<i>Asterophyllites charaeformis</i> (Sternb.) Goepfert		X	
<i>Calamostachys</i> (?) sp.			X
<i>Tingia placida</i> Tidwell, sp. nov.			X
<i>Rhodea vespertina</i> Read			X
<i>Sphenopteridium dissectum</i> (Goepf.) Schimper		X	
<i>Sphenopteridium zaitzeffii</i> Tidwell, sp. nov.		X	
<i>Adiantites</i> (<i>Wardia</i>) <i>tenuifolius</i> (Goepf.) var.			
<i>defoliolatus</i> (White) comb. nov.			X
<i>Mariopteris muricata</i> (Schloth.) Zeiller			X
<i>Sphenopteris dipblebia</i> Tidwell, sp. nov.		X	

TABLE I (Continued)

<i>Corynepteris angustissima</i> (Sternb.) Němejč		X
<i>Diplothmema trifoliolata</i> (Artis) White		X
<i>Diplothmema obtusiloba</i> (Brongt.) White	X	X
<i>Diplothmema arnoldi</i> Stockmans & Williere		X
<i>Neuropteris gigantea</i> Sternberg		X
<i>Neuropteris</i> cf. <i>pocabontas</i> White		X
* <i>Neuropteris heterophylla</i> Brongniart		X
<i>Neuropteris ampelina</i> Tidwell, sp. nov.		X
<i>Crossopteris utahensis</i> Tidwell, gen. and sp. nov.	X	
<i>Crossopteris undulata</i> Tidwell, gen. and sp. nov.	X	
<i>Crossopteris mcknightii</i> Tidwell, gen. and sp. nov.		X
* <i>Cyclopteris dilatata</i> Lindley & Hutton		X
<i>Odontopteris</i> sp.	X	
<i>Cordaites principalis</i> (Germer) Geinitz		X
<i>Cordaites</i> sp. A		X
<i>Cordaites</i> sp. B	X	
<i>Cordaianthus pseudofluitans</i> Kidston		X
<i>Cordaicarpus elongatus</i> (Newberry) Tidwell, comb. nov.		X
<i>Cordaicarpus globosus</i> Tidwell, sp. nov.		X
<i>Cordaicarpus cordatus</i> (Jackson) Tidwell, comb. nov.	X	
<i>Cordaicarpus jaysbulerii</i> Tidwell, sp. nov.	X	
<i>Cordaicarpus manningcanensis</i> Tidwell, sp. nov.	X	
<i>Cordaicarpus binutus</i> Tidwell, sp. nov.	X	
<i>Trigonocarpus noeggerathii</i> (Sternb.) Brongniart		X
<i>Trigonocarpus</i> sp.	X	
<i>Holcospermum</i> sp.		X
<i>Cornucarpus longicaudatus</i> Tidwell, sp. nov.	X	
<i>Rigbyocarpus ebracteatus</i> Tidwell, gen. and sp. nov.	X	
<i>Lagenospermum discissum</i> Tidwell, sp. nov.	X	
<i>Gnetopsis anglica</i> Kidston	X	
<i>Telangium affine</i> (L. & H.) Benson		X
<i>Aulacotheca campbellii</i> (White) Halle		X
<i>Aulacotheca hemingwayi</i> Halle	X	

*not included in systematic botany

ABundant = 25 or more Frequent = 5 to 25 Rare = 5 or less

FLORAL COMPARISON WITH OTHER NORTH AMERICAN FLORAS
OF MISSISSIPPIAN AND PENNSYLVANIAN AGE

The following comparison of floras between the Manning Canyon Shale flora and those fossil floras already described from North America and Europe may possibly be biased. This conclusion is based upon the concept that the study of the Manning Canyon flora is not complete, and that due to the abundance and diversity of the flora, our program of continued collecting may eventually uncover genera and species presently presumed to be missing.

Comparison of the Manning Canyon Shale flora with other Mississippian and Pennsylvanian floras in the United States is very difficult because of the inadequate knowledge of these floras. Not only are floras associated with many of the important coal seams virtually unknown, but the existing information is often of little value for comparative purposes. Lesquereux's *Coal Flora* is essentially the only reference available for much of the Appalachian region and many of his figures and descriptions are inadequate. Thus it becomes necessary to rely upon the European literature for modern sources of information on Carboniferous floras. The inherent disadvantages of this were pointed out by Arnold (1949). He states (p. 152) that "It not only reflects the serious lag

in the development of American paleobotany, but it renders the task of correctly interpreting the smaller and more isolated American floras unduly difficult."

Comparison of the Manning Canyon Shale flora with the Chesterian plant materials from the Uinta Mountains of Utah (Arnold and Sadlick, 1962); with the Spotted Ridge flora of central Oregon (Arnold, 1953; Mamay and Read, 1956); and with the Mosquito Range flora from Colorado (Read, 1934) is of particular interest because of their geographic proximity. Fossil plant localities in the Manning Canyon Shale are located approximately midway between the Spotted Ridge flora (500 miles northwest) and the Mosquito Range flora (400 miles east). The Mississippian Uinta flora lies about 50 miles northeast of the Lake Mountain clay pits.

The Uinta flora contains the genera *Cardiopteris* (= *Fryopsis*) and *Caulopsis* which are not found in the Manning Canyon Shale collections, and with the exception of *Archeocalamites*, *Rhodea*, and *Lepidodendron*, none of the 33 genera represented in the Manning Canyon Shale flora have been reported from the Uinta Mountains locality.

If Lacey and Eggert (1964) are correct in referring the *Lepidodendron* form from the Uinta flora to *L. volkmannianum*, then the floras would have three species in common. However, after examining Arnold's specimens, the author believes their preservation is too poor for specific identification.

Species common to the Manning Canyon Shale and the Spotted Ridge flora are *Calamites* (*Mesocalamites*) *hesperius* and *Asterophyllites equisetiformis*. However, there are striking generic differences between these two floras. The genera *Dicranophyllum*, *Pecopteris*, and *Phyllothea* in the Oregon flora have not as yet been recognized in the Manning Canyon Shale, and conversely, no *Neuropteris*, *Corynepteris* (= *Alloiopteris*), clearly identifiable lycopods, *Sphenopteris*, *Mariopteris*, and other forms found in the comparatively well-preserved Manning Canyon Shale flora have been found in the Oregon flora.

The Spotted Ridge flora is considered to be Pennsylvanian in age (Mamay and Read, 1956), particularly Lower (Arnold, 1953).

Four species are common to the Mosquito Range flora and the Manning Canyon Shale flora from a total of seventeen species described from the Mosquito Range. Read (1934) places this flora in the Lower Pennsylvanian.

Thus these floras are floristically distinctive, as well as geographically separated. The distinctive difference is probably due to their time of growth, for the Manning Canyon Shale flora appears to be older. The Oregon and Colorado Carboniferous floras are relatively poorly preserved and depauperate. Many of the plants which grew in these areas and which may have been represented by plant fragments deposited during the accumulation of these sediments, have not been preserved. Therefore these fossil floras, as they are known today, may give a biased record of the Pennsylvanian vegetation of those areas.

The two Mississippian floras from Arkansas, the Stanley-Jackfork and the Wedington as reported by White (1937a, 1937b), have no species correlative with those found in the Manning Canyon Shale. The Stanley-Jackfork flora, thought to be Pennsylvanian by White (1937a), is now considered as Mississippian by Mamay (in Miser and Hendricks, 1960).

Rhodea verspertina is the only species common to the Mississippian Pocono and Price floras of eastern United States (Read, 1955) and the Manning Canyon Shale. These Appalachian floras contain the characteristic Mississippian

genera: *Triphylopteris*, *Fryopsis* (= *Cardiopteris*), and *Lepidodendropsis* which do not occur in the Manning Canyon Shale.

The Michigan Coal Basin flora (Arnold, 1949) has nine forms, from a total of forty-five species, in common with the Manning Canyon Shale. Arnold (1949) considers the Michigan Coal Basin flora to be late Westphalian A or B in age.

Jongmans (1937), in his subdivision of the Pottsville, interprets the Pocahontas seams to be equivalent to the European Namurian age and subdivides its coal seams into Namurian A, B, or C. The coal seam underlying seam #1 which he attributes to Namurian A has one species in common with the Manning Canyon Shale. Seams 1-3 (Namurian B) and seams 4-6 (Namurian C) have five species and one species comparable, respectively. The New River Series (Westphalian A) has two species in common, whereas Kanawha (Westphalian B) has five and Alleghany (Westphalian C) has one.

The number in common may not be as important as the particular species involved. Coal seams 1-3 contain *Alloiopteris sternbergi* and *Sphenopteris obtusiloba* which are characteristic of this and higher stratigraphic horizons in Europe. *Neuropteris gigantea* and *Sphenopteris schatzlarenensis* are found in the Kanawha (Westphalian B) and Alleghany (Westphalian C). They are indicative of Upper Namurian and Westphalian age in Europe.

Jongmans (1937) states that the Pocahontas seam #3 on the basis of principal plant components, *Neuropteris pocahontas*, *N. schlehani*, and *Alloiopteris sternbergi*, has a Namurian or older Westphalian A character. He places the Pocahontas Coal in an age equivalent to the middle and upper portions of the Namurian or perhaps as late as the transition into the lowest Westphalian A.

Upper Carboniferous strata of Nova Scotia in Canada have been divided into three groups based on their distinctive floral components (Bell, 1938, 1943). The lowest of these, the Canso Group has three species, *Telangium affine*, *Archaeocalamites radiatus* (= *Asterocalamites scrobiculatus*), and *Calamites (Meso-calamites) cistiiformis* in common with the Manning Canyon Shale flora. According to Bell (1943) the poorly preserved calamitean stems are fairly abundant in the Canso Group, but other fossil plant remains are scarce. Bell (1943) states that the flora of the Canso Group is possibly equivalent to Dix's (1933) floral zone A of southern Wales which is comparable to Lower Namurian.

The Riversdale Group contains seven species in common with the Manning Canyon Shale flora; whereas, the Cumberland Group has nine. Bell (1943) placed the Riversdale Group in Upper Namurian or Lower Westphalian A. The flora of the Cumberland Group he cites as indicative of Late Westphalian A or Early Westphalian B (Bell, 1943).

COMPARISON WITH EUROPEAN CARBONIFEROUS FLORAS

Crookall (1934) outlined three factors to be used in comparing fossil floras: (1) the occurrence of certain assemblages of species, (2) the frequency of individual forms composing the assemblages, and (3) the absence of other assemblages. The problem encountered in using his second criteria is the lack of uniform quantitative data for the various described floras. Occasionally an author will enumerate relative abundance, but generally only a floral list is given.

Great Britain.—Crookall (1934) summarized the Carboniferous floras from Great Britain. He reports a total of 132 species from the Radstockian (Table II) of which 6 are in common with the Manning Canyon Shale flora. Twelve species are in common from 168 species reported from the Staffordian, sixteen species in the Yorkian from a total of 392, and nine species in common from 91 for the Lanarkian.

Pecopterids as a body are characteristic of the Radstockian Series; an abundance of *Lonchopteris* species marks the Staffordian; and *Lonchopteris*, though rare, is typical of the Yorkian. The Lanarkian has several typical forms of *Sphenopteris* (Crookall, 1931-32). None of these forms occur in the Manning Canyon Shale.

Three species of the 51 reported by Dix (1933) from Namurian A of Great Britain have also been collected from the Manning Canyon Shale; whereas, 5 species from the Namurian B, from a total of 26 (Dix, 1933; Lacey, 1951), correspond.

From the Lower Carboniferous of Great Britain (Crookall, 1934) the species *Calamites cistiiformis*, *Asterocalamites scrobiculatus* (= *Archeocalamites radiatus*), *Sphenopteris affine* (= *Telangium affine*), *Sphenopteridium dissectum*, and *Lepidodendron volkmannianum* are also encountered in the Manning Canyon Shale flora.

The largest number of common species are located in Dix's floral zones C, E, and G (Table II). These species as well as many of those already enumerated are composed largely of long-ranging species (Table III) found throughout either the Lower or Upper Carboniferous.

Belgium.—The Namurian of Belgium as studied by Stockmans and Williere (1952-53) has a few species in common with the Manning Canyon Shale. The Assise de Chokier (Namurian A) has 3 species in common from a total of 77 species. The Assise d'Andenne (Namurian B) has 10 in common from 176 species. These are *Lepidodendron obovatum*, *Lepidostrobus variabilis*, *Trigonocarpus noeggerathi*, *Gnetopsis anglica*, *Lepidostrobophyllum majus*, *Sphenopteris* (= *Diplothmema*) *obtusiloba*, *Corynepteris angustissima*, *Neuropteris gigantea*, *Cantheliophorus* aff. *linearifolius* (= *Lepidocarpon linearifolium*), and *Aulacotheca hemingwayi*.

Ancion and Leckwijck (1947) described a flora from Zone de Gilly (Uppermost Namurian B) with 5 species, *Asterophyllites equisetiformis*, *Alloiopteris* (= *Corynepteris*) *angustissima*, *Neuropteris gigantea*, *Sphenopteris* (= *Diplothmema*) *obtusiloba*, and *Aulacotheca hemingwayi*, having also been collected from the Manning Canyon Shale.

France.—Of the 34 species reported by Carpentier (1928) from the Namurian A of the Passe-loire, two species from the Manning Canyon Shale are in common.

The species common to the Valenciennes flora (Carpentier, 1907) and the Manning Canyon Shale flora are only long-ranging species, with the exception of *Lepidodendron volkmannianum* which appears out of place in the Valenciennes flora. The number of species corresponding to those from the Manning Canyon Shale is fairly small (13 of about 50) in the lower coal beds, becoming less numerous upward, indicating very little relationship between these two floras.

TABLE II
GENERALIZED STRATIGRAPHIC NOMENCLATURE OF THE CARBONIFEROUS
IN EUROPE & NORTH AMERICA

Europe	Dix*	Kidston-Crookall*	Belgium**	Goniatites Zone**	Nova Scotia*	West Virginia*	Pennsylvanian
D	"H"	Radstockian			?	Allegheny Series	
C	"G"	Staffordian	Assise de Flenu		Pictou Group	Kanawha Group	
B	"F"	Yorkian	Assise de Charleroi	<i>Gastrioceras</i> (G)	Riversdale Group	New River Group	
	"E"						
A	"D"						
	"C"	Lanarkian	Assise de Chatelet				
C	"B"	Upper part of Lower Carboniferous (Kidston)	Assise d'Andenne	<i>Reticuloceras</i> (R)	Canso Group	Pottsville (Pocahontas Group)	
B							
A	"A"		Assise de Chokier	<i>Homoceras</i> (H) <i>Eumorphoceras</i> (E)	?		
Viscan Tournaisian							Miss.
Upper Carboniferous							
Lower Carboniferous							

*Modified from Crookall, 1955 **Modified from Delmer and Graulich, 1954 +Modified from Wood, 1963

Germany.—Gothan (1931) listed 6 species for the Namurian A in the Westphalian-Rhine basin. None of these are found in the Manning Canyon Shale. The Namurian B and Lower Namurian C of this same region has *Lepidodendron aculeatum*, *Asterophyllites longifolium*, *Alloiopteris* (= *Corynep-teris angustissima*) *sternbergi*, *Cordaites principalis*, *Neuropteris gigantea*, and *Sphenopteris schatzlarensis* in common from a total of 38 species.

Leggewie (1933) lists *Asterophyllites charaeformis*, *Cordaites principalis*, and *Lepidodendron obovatum* among 24 other species from the upper Namurian. These three are also present in the Utah material.

Zimmermann (1958) reports 62 species from the Culm of Waldenburger. Of this number, *Sphenopteridium dissectum*, *Asterocalamites scrobiculatus* (= *Archeocalamites radiatus*), and *Stigmaria ficoides* are found in the Manning Canyon Shale flora. In a second list for his Namurian flora, he lists 52 species of which *Asterocalamites scrobiculatus*, *Lepidodendron volkmannianum*, *L. aculeatum*, and *Stigmaria ficoides* are also present in the Utah flora.

He reports *Sphenopteridium dissectum* as only from the Culm, and *Lepidodendron volkmannianum* and *L. aculeatum* as only from the Namurian.

Netherlands:—Jongmans (1955) summarized the coal flora from the Anatolie region. Sixteen species from this flora are in common with the Manning Canyon Shale flora (Table III).

TABLE III

Species in common between the Manning Canyon Shale Flora and Floras of the Anatolie Region of the Netherlands (Jongmans, 1955)

	Diant	Namurian A	Namurian B	Namurian C	Westphalian A	Westphalian B	Westphalian C	Westphalian D
<i>Asterocalamites scrobiculatus</i> (= <i>Archeocalamites radiatus</i>)	x	?						
<i>Calamites</i> (<i>Mesocalamites</i>) <i>cistiiformis</i>		x						
<i>Asterophyllites charaeformis</i>					x	x	x	
<i>A. equisetiformis</i>					x	x	x	x
<i>A. longifolius</i>					x	x	x	
<i>Lepidodendron aculeatum</i>					x	x	x	
<i>L. obovatum</i>					x	x		x
<i>Lepidostrobophyllum majus</i>						x	x	x
<i>Lepidostrobus variabilis</i>					x	x	x	
<i>Alloiopteris sternbergi</i> (= <i>Corynep-teris angustissima</i>)					x	x	x	
<i>Neuropteris gigantea</i>				x	x	x	x	
<i>N. heterophylla</i>					x	x	x	
<i>Renaultia schatzlarensis</i>					x	x	x	x
<i>Sphenopteris obtusiloba</i>				x	x	x	x	x
<i>Sphenopteris trifoliolata</i>				x				
<i>Cordaites principalis</i>					x	x	x	?
Jongmans total species		25	19	30	132	147	124	123

AGE OF THE MANNING CANYON SHALE FLORA

The Mississippian-Pennsylvanian boundary, which has not been accurately determined in the type section of the Manning Canyon Shale, could be determined by using fossil fish, fossil invertebrates, or fossil plants.

The occurrence of fossil fish in the Manning Canyon Shale is not well enough known to be of any value.

Sadlick (1955) identified as Springerian an assemblage of fragments of the fossil invertebrates *Schizophoria* cf. *S. texana* and *Spirifer* cf. *S. occidentalis* in the uppermost unit from the Soldier Canyon section. He also reports a Chesterian assemblage 702 feet lower stratigraphically than this Springerian unit. Helen Duncan of the U. S. Geological Survey (personal communication) writes:

According to Gordon (Mackenzie Gordon, Jr.), the lower 400 feet of the Manning Canyon in the type area contains an upper Mississippian fauna as pointed out by Girty. Fossil invertebrates are generally poorly preserved and relatively uncommon in the upper part of the Manning Canyon, but a diagnostic Pennsylvanian fauna has been found near the top of the formation. A considerable thickness of the Manning Canyon in the type area has not been precisely dated on evidence from invertebrate fossils.

The Mississippian-Pennsylvanian boundary has been placed by some workers at the top of the dark gray-blue limestone, commonly termed the "medial limestone" which lies about 450 feet above the base of the formation. Others place the boundary 200 to 300 feet higher in the formation at the arkosic and graywacke zone.

The fossil plant horizon is located within the zone between the Springerian fauna and the Chesterian assemblage. However, the plants occur near the top of the section, stratigraphically closer to the position of the Springerian fauna.

In order to establish the age of this flora, the stratigraphic ranges of its various species were studied and are plotted on Table IV. In compiling the stratigraphic ranges, floral lists were studied as well as ranges recorded by Gothan and Remy (1957) and Dix (1932b). The chart shows the probable ranges for all but new species and species not frequently reported.

TABLE IV

Stratigraphic Ranges of 30 Plant Species of the Manning Canyon Shale

	Mississippian			Pennsylvanian					
	Diant	Namurian			Westphalian				
		A	B	C	A	B	C	D	
<i>Archeocalamites radiatus</i>	—————								
<i>Asterophyllites charaeformis</i>					— — — — —				
<i>Asterophyllites equisetiformis</i>			— — — — —	—————					
<i>Asterophyllites longifolius</i>			— — — — —	—————		— — — — —		—————	
<i>Calamites (Mesocalamites) hesperius</i>					—————				
<i>Calamites (Mesocalamites) cistiiformis</i>	—————	— — — — —							
<i>Lepidodendron obovatum</i>		— — — — —	— — — — —	—————	—————				

<i>Lepidodendron</i>	
<i>aculeatum</i>	-----
<i>Lepidodendron</i>	
<i>volkmanianum</i>	-----
<i>Lepidostrobus</i>	
<i>variabilis</i>	-----
<i>Lepidostrobophyllum</i>	
<i>majus</i>	-----
<i>Stigmaria</i>	
<i>ficoides</i>	-----
<i>Mariopteris</i>	
<i>muricata</i>	-----
<i>Sphenopteris</i>	
<i>schatzlarensis</i>	-----
<i>Corynepteris</i>	
<i>angustissima</i>	-----
<i>Diplothemema</i>	
<i>obtusiloba</i>	-----
<i>Diplothemema</i>	
<i>trifoliolata</i>	-----
<i>Diplothemema</i>	
<i>arnoldi</i>	-----
<i>Sphenopteridium</i>	
<i>dissectum</i>	-----
<i>Rhodea</i>	
<i>vespertina</i>	-----
<i>Adiantites</i> (<i>Wardia</i>)	
<i>tenuifolius</i> var.	
<i>defoliolatus</i>	-----
<i>Neuropteris</i>	
<i>gigantea</i>	-----
<i>Neuropteris</i> cf.	
<i>pocabontas</i>	-----
<i>Cordaites</i>	
<i>principalis</i>	-----
<i>Cordaianthus</i>	
<i>pseudofluitans</i>	-----
<i>Trigonocarpus</i>	
<i>noeggerathi</i>	-----
<i>Gnetopsis</i>	
<i>anglica</i>	-----
<i>Telangium</i>	
<i>affine</i>	-----
<i>Aulacotheca</i>	
<i>campbellii</i>	-----
<i>Aulacotheca</i>	
<i>bemingwayi</i>	-----

Eighteen of the thirty-five species listed on Table IV have stratigraphic ranges throughout all or most of the Carboniferous. Therefore, species like *Asterophyllites longifolius*, *A. equisetiformis*, *Cordaites principalis*, and *Neuropteris gigantea* would only indicate a probable Upper Carboniferous age.

First appearances of so many species, however, is important. The two vertical columns on Table IV, Namurian A and Namurian B, contain the majority of first appearances.

Index species are also important. *Sphenopteris* (?*Renaultia*) *schatzlarensis* and *Corynepteris angustissima* are indicative of uppermost Carboniferous of

Europe. Bell (1943) reported both from Canada. He reports *Sphenopteris schatzlarensis* from the Riverdale Group of Late Namurian or younger Westphalian A, and *Alloiopteris sternbergi* (= *C. angustissima*) from the Cumberland Group which he considers to be late Westphalian A or early Westphalian B. Jongmans (1937) reports *A. sternbergi* from the Pocahontas coal seams 1-3 which he equates to Namurian B.

Neuropteris pocahontas and *Mariopteris muricata* are also important index forms for the lower Pennsylvanian and Upper Carboniferous. *N. pocahontas* characterizes the lower Pottsville, whereas *M. muricata* is important in the lower Upper Carboniferous of Europe.

The Manning Canyon Shale flora appears to be transitional between Mississippian and Pennsylvanian ages.

Excluding the ubiquitous *Stigmara ficoides*, there are five species in this flora which are known to characterize the Mississippian. Two of these, *Sphenopteridium dissectum* and *Telangium affine* are fairly common, whereas three, *Rhodea vespertina*, *Lepidodendron volkmannianum*, and *Archeocalamites radiatus* are rare. Twenty-one Pennsylvanian species are present. Ten of these are rare in the Manning Canyon Shale flora and eleven are common.

In this transitional flora, other typical Mississippian genera such as *Fryopsis* (= *Cardiopteris*), *Triphyllopteris*, *Rhacopteris*, and *Lepidodendropsis* are lacking; but also conspicuously missing are *Pecopteris*, *Sphenophyllum*, *Bothrodendron*, *Caulopteris*, *Megaphyton*, and *Lonchopteris* which are genera found in the Pennsylvanian or younger strata.

Sphenopteris and *Diplothmema* forms are highly diversified, although only two species, one Mississippian and one Pennsylvanian, are common. *Rhodea* is limited, as is *Adiantites*. *Sphenopteridium* is represented in the flora by two relatively abundant species. *Mesocalamites*, the dominant calamitean form, is, in itself, transitional between *Archeocalamites* and true *Calamites*. *Calamites*, abundant in the Middle and Upper Pennsylvanian, is rare in the Mississippian, whereas *Archeocalamites* is common. *Odontopteris*, fairly common in the Manning Canyon flora, is reported by Crookall (1931-32) as generally characterizing the Radstockian (Table II); and although *Lepidodendron aculeatum* and *L. obovatum*, two of the *Lepidodendraceae* in the flora, range throughout most of the Pennsylvanian, they are more frequent in the lower series.

Crossopteris utahensis, however, suggests an older flora. White (1900) considered *Neuropteris pocahontas* to be a relatively primitive form of the neuropterids. He based this upon the partial basal attachment of the uppermost pinnules on the pinnae. He considered this form to be one of the intermediate types between *Neuropteris* and an ancestral form common to the alethopterids and neuropterids. White considered it to be significant that *Neuropteris pocahontas* was common only in the lowermost Pottsville. *Crossopteris utahensis* is similar to *N. pocahontas* in the manner of its small pinnule attachment, but appears to be more primitive in its more persistent half-basal attachment and its lobing which is more alethopteroid-pecopteroid than neuropteroid. If White's hypothesis is correct, then *Crossopteris utahensis* should be from a horizon older than Lower Pottsville. However, intermediate forms would be expected to occur in a transitional flora. Also since this is a form not previously identified, its range has not been established.

The Mississippian form *Archeocalamites radiatus* is known to extend into Westphalian A. *Telangium affine* had only been previously reported from the Lower Carboniferous of Europe and from the Lower Namurian of Canada (Bell, 1943). *Rhodea vespertina*, reported by Read (1955) from the basal Mississippian Pocono Formation, is like *Sphenopteridium dissectum* and the other Mississippian forms in that they are perhaps "hold-overs" from an older, diversified flora, some species of which were still extant at the time the Manning Canyon Shale flora was being deposited.

In summary, the plants indicate a lowermost Pennsylvanian age, and the horizon from which they were collected is close to Mississippian-Pennsylvanian boundary. The flora occupies a zone between Read and Mamay's (1964) floral zone 3 which is characterized by *Fryopsis* (= *Cardiopteris*) and *Sphenopteridium* and their floral zone 4 with *Neuropteris pocahontas* and *Mariopteris eremopteroides* as the zonal species.

The presence of *Sphenopteridium*, *Telangium*, and *Archeocalamites* from the Mississippian in association with components of a Pennsylvanian flora indicate a very early Namurian age for this flora, probably Namurian B, or possibly as old as Namurian A.

SUMMARY

The fossil flora from the Manning Canyon Shale of central Utah is important because of its floral content, stratigraphic position and geographical location. The flora contains 58 species of Mississippian and Pennsylvanian age, indicating that these strata are transitional between these two periods. Five species have a Mississippian range, 22 are known Pennsylvanian species, 10 have no definite ranges, 6 are long-ranging species, and 14 are new species. This flora contains 2 new genera, and one genus (*Tingia*) which has been previously reported only from the Lower Permian of China.

Stratigraphically, the flora lies near the Mississippian and Pennsylvanian boundary, with a Springerian fauna above and a Chesterian fauna below. The plants indicate a lowermost Pennsylvanian age and probably represent Namurian B, possibly extending downward into Namurian A, in European terminology. The flora is compared with other Carboniferous floras in Europe and North America, but none of these floras appear to be similar to the Manning Canyon Shale flora. There is similarity in long-ranging species present in these floras, but none has the overall aspect of the Utah flora. The flora of the Canso group in maritime Canada may prove to be the most closely related, but further study of both floras will be required to demonstrate this.

The flora is located geographically between the Spotted Ridge flora of Oregon and the Mosquito Range flora of Colorado. These three represent essentially the only known Pennsylvanian floras from the western United States. One small Mississippian flora is reported by Arnold and Sadlick (1962) from the Uinta Mountains of Utah.

The flora from the Manning Canyon Shale exhibits a number of significant paleobotanical features. Further study of this flora and other potential Pennsylvanian floras in western United States is necessary if a more comprehensive understanding of the Pennsylvanian paleobotany of this vast region is to be attained.

SYSTEMATIC PALEOBOTANY

Order LEPIDODENDRALES

Genus LEPIDODENDRON Sternberg 1820

(Versuch der Flora der Vorwelt, v. 1, fasc. 1, p. 23)

Lepidodendron obovatum Sternberg

Pl. 2, fig. 6; Text-fig. 1b

1820 *Lepidodendron obovatum* STERNBERG—Versuch der Flora der Vorwelt, v. 1, fasc. 1, p. 20, 23, pl. VI, fig. 1, pl. VII, fig. 1A.

1875-77 *Lepidodendron obovatum* STERNBERG, STUR—Culmflora II Abh. k. k. Geol. Reichsanst., p. 283, pl. XXIV, figs. 1, 2, 3.

1951 *Lepidodendron obovatum* STERNBERG, STOCKMANS, AND WILLIERE—Quelques Vegetaux Namuriens et Westphaliens du Carbone d'Aiseau-Presle, pl. 2, fig. 11.

1962 *Lepidodendron* sp. A. TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 99, pl. 5, fig. 2.

Discussion.—Specimens of *Lepidodendron obovatum* are composed of prominent transversely "diamond-shaped" bolsters with elliptical leaf scars located in the upper one-half of the bolsters. The ligule scar is visible on the upper edge of the leaf scar, and the vascular strands and parichnos occur in the lower portion of the scar. Although the keels are generally observable, the transverse markings on the keels are rather obscure.

This form frequently occurs in the Manning Canyon Shale. Fragments of this species often occur as isolated bolsters or as specimens with a small number of bolsters being present.

In discussing *Lepidodendron mosaicum*, Jongmans (1938) states, "These figures show that they can be compared with *Lepidodendron obovatum* Sternb. with which *L. rhodeanum* Sternberg is very nearly related, if not identical."

Figured specimen.—USNM 42869.

Lepidodendron aculeatum Sternberg

Pl. 1, fig. 5; Text-fig. 1a

1820 *Lepidodendron aculeatum* STERNBERG—Versuch der Flora der Vorwelt, v. 1, fasc. 1, p. 20, 23, pl. VI, fig. 2, pl. VIII, figs. 18a, b.

1962 *Lepidodendron* sp. B. TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 99, pl. 5, fig. 4.

Discussion.—The bolsters of *Lepidodendron aculeatum* are large with the elongated ends passing beyond the one directly above and below, causing the top and bottom ends of the same bolster to curve in opposite directions, thus giving the bolsters a rather sinuous appearance.

The leaf scar is cuneate with acute lateral angles and basal angles. The top of the scar is obtusely rounded. The leaf scar appears to be situated toward the right side of the bolster. Vascular scar appears in the lower portion of leaf scar. Parichnos areas are not generally preserved, although the aerenchyma tissue is present. Keels are obscure, but present. One specimen has faint transverse irregular lines.

The preservation of *Lepidodendron aculeatum* (Pl. 1, fig. 5) is relatively poor. The leaf scars, ligule scars, and the keels are present. A composite figure (Text-fig. 1a) made from several specimens illustrates a more complete bolster.

L. aculeatum is separated from *L. obovatum* by its more elongated bolster, although they often intergrade and are at times very difficult to distinguish from one another.

Figured specimen.—USNM 42868.

Lepidodendron volkmannianum Sternberg

Pl. 1, fig. 4; Text-fig. 1c

1957 *Lepidodendron volkmannianum* STERNBERG, GOTHAN & REMY—Steinkohlenpflanzen, p. 36; pl. 25.

1964 *Lepidodendron volkmannianum* STERNBERG, LACEY & EGGERT—Am. Jour. Bot. 51(9), p. 979, figs. 5-13.

Discussion.—Specimens of this species were collected from the principal plant horizon in the Manning Canyon Shale and from a quartzite bed approximately 200 feet below the principal plant horizon.

The somewhat inverted "pear-shaped" bolsters of this species are aligned horizontally and vertically. Elliptical to rhomboidal leaf scars are located in the upper portion of the bolsters.

Lacey and Eggert (1964) reported specimens of *Lepidodendron volkmannianum* showing gradations of leaf cushion shape and size on a single stem, making it impossible to assign species to it which were originally considered to be distinct. Using this criterion, they were able to assign most of White's (1937b) new *Lepidodendron* species from the Wedington Shale to *L. volkmannianum*.

Lepidodendron volkmannianum is characteristic of the Lower Carboniferous and rarely extends into Namurian A. Namurian A is roughly equivalent to Chesterian age.

Figured specimen.—USNM 42870.

Genus LEPIDOSTROBUS Brongniart 1828

Lepidostrobus variabilis Lindley & Hutton

Pl. 2, fig. 8

1831 *Lepidostrobus variabilis* LINDLEY & HUTTON—The Fossil Flora of Great Britain, v. 1, pls. 10 & 11.

1963 *Lepidostrobus variabilis* L. & H. WOOD—Indiana Geol. Surv. Bull. 29, p. 37, pl. 2, figs. 4, 5, and 6.

Discussion.—No spores are present. Specimen is preserved as limonite with minute quartz box-like cracks or joint structures transcending the sporophylls obliquely across the surface of the strobilus.

Lepidostrobus variabilis as discussed by Wood (1963) is an extremely variable form. Into this group are placed *Lepidostrobus* cones which have sporophylls resembling sterile leaves, and are often difficult to separate from one another as to species.

In 1880 Lesquereux wrote "From the figures of the species given by European authors, it seems evident that different kinds have been described under the common name." Zeiller (1888) also found this species to vary as to size and disposition of the sporophylls.

Specimens from Greene County, Indiana, housed at the University of Missouri (Wood, 1963), and the Geological Survey of Canada agree favorably with the Utah material. Bell (1943) thought that his specimens of *Lepidostrobus variabilis* from the Cumberland Group, the Riverside Group, and the Stellarton Group may have included more than one species, but examination of his types does not indicate any great variation.

Gothan and Weyland (1959) discuss *L. variabilis* and mention that its axis corresponds to the structure of *Lepidostrobus oldhamius* Williamson. Its axis

also shows a central stele with pith similar to *Lepidodendron vasculare* Binn. Hirmer (1927) also notes *L. variabilis* may be related to *L. oldhamius*.

Stockmans and Williere (1953) report that the strobili of the arborescent lycopodiales are relatively common in the Namurian of Belgium. In the quarry at Rieudotte in particular, they found perfect types of *L. variabilis* associated with *Lepidodendron obovatum* and *Lepidophloios laricinus*.

Figured specimen.—USNM 42872.

Lepidostrobus obovatus Němejč
Pl. 2, fig. 7

1963 *Lepidostrobus obovatus* NĚMEJC—Paleobotanika II, p. 188, pl. 16, fig. 1.

Description.—Strobilus oblong with parallel margins tapering to a pointed apex, strobilus incomplete, basal portion is missing. Axis 2 mm wide. Sporophylls crowded and crushed; spirally arranged, normal to the axis. Bracts long-linear to linear-lanceolate, 11 mm long, 2 mm wide at base, overlaps 3-6 distal sporophylls. Pedicel 6-7 mm long with sporophylls on upper surface, crestline about horizontal with slight rise toward bract.

Discussion.—No spores are present. This type varies from *Lepidostrobus variabilis* by bract length and shape, more compact structure, sporophylls more nearly perpendicular to the axis, and pointed apex of strobilus.

Lepidostrobus obovatus Němejč is similar to *Lepidostrobus butleri* Lesq., but *L. butleri* is smaller, more oblong, oval shape, and the apex is not as pointed. *L. obovatus* Němejč has been reported from the Westphalian of central Bohemia.

Figured specimen.—USNM 42871.

Genus LEPIDOCARPON Scott 1900
(Proc. Roy. Soc. London, v. 67, p. 309)

Lepidocarpon is a genus of seed-bearing lycopods founded by Scott (1900, 1901) for petrified cones of both Upper and Lower Carboniferous age. However, Schopf (1941) emended Scott's original description to include all such compressions within the genus. Schopf (1940) transferred to *Lepidocarpon* twelve compression species previously assigned to *Cantheliophorus* by Bassler (1919).

Bassler (1919) based his genus upon (1) two sac-like sporangia borne on short sporangiophoric stalks per sporophyll; and (2) a plate of sterile sporophyll tissue ascending from the ventral midline of the pedicel and to which the sporangiophores were attached laterally and distally. Schopf (1941) states Bassler had not properly shown that the two sac-like bodies exist and the "median" plate to be other than the compressed form of the *Lepidocarpon* integument.

Lepidocarpon linearifolium (Lesq.) Schopf
Pl. 2, fig. 2

1880 *Lepidophyllum linearifolium*. LESQUEREUX—Coal Flora, 2nd Geol. Surv. Pennsylvania Rpt. of Prog. P., v. 1, p. 452-454, pl. 69, fig. 39.

1919 *Cantheliophorus linearifolium* (LESQ.) BASSLER—Bot. Gaz. v. 68(2) p. 978, pl. IX, fig. 1, 8-10.

1940 *Lepidocarpon linearifolium* (LESQ.) SCHOPF—in Janssen, Illinois State Museum Sci. Papers, v. 1, p. 43.

1949 *Lepidocarpon linearifolium* (LESQ.) SCHOPF, ARNOLD—Univ. Mich. Contr. Mus. Paleont., v. 7, p. 174, pl. IX, figs. 2-3.

Discussion.—The isolated sporophylls of *Lepidocarpon linearifolium* are very abundant in the Manning Canyon Shale. These sporophylls are nearly exact duplicates of specimens described by Arnold (1949) from the Lower Pennsylvanian of Williamston, Michigan.

Arnold (1949) states the most conspicuous feature of *Lepidocarpon linearifolium* is the long, slender terminal bract (lamina) which generally extends horizontally, but in many cases is at a 45° angle to the pedicel. The latter form is the general type encountered in the Manning Canyon Shale.

The specimen described by Lesquereux (1880) consists of the distal lamina and part of the pedicel. If a megasporangium was present, he did not illustrate it.

The stratigraphic range of *Lepidocarpon linearifolium* is at present undefined.

Figured specimen.—USNM 42873.

Genus LEPIDOSTROBOPHYLLUM Hirmer 1927
(Handbuch der Palaobotanik, v. I, p. 231)

Lepidostrobophyllum majus (Brongniart) Hirmer
Pl. 1, fig. 2

1866 *Lepidophyllum majus*, BRONGT., LESQUEREUX—Fossil plants of Illinois, Geol. Surv. Illinois, v. II, Paleont., p. 456.

1880 *Lepidophyllum majus* BRONGT., LESQUEREUX—Coal Flora, 2nd Geol. Surv. Pennsylvania Rept. of Prog. P., v. 1, p. 449.

1927 *Lepidostrobophyllum majus* (BRONGT.) HIRMER—Handbuch der Paleobotanik, v. I, p. 193, fig. 213.

Discussion.—Lamina of the sporophyll of this species are large and rather oblong with parallel margins tapering to a lanceolate shape with an acute apex.

Lesquereux (1880) states that the blades are generally 7-9 cm long and 13-16 cm wide. He reports them as rare in the American Coal Measures. They are also comparatively rare in the Manning Canyon Shale.

Crookall (1925) in comparing the specimens of *Lepidostrobophyllum majus* he had collected with *L. missouriensis* as figured by White (1899), states that the later species should be combined with *L. majus*. Abbott (1963) in discussing her new genus *Lepidostrobopsis*, in which she places *L. missouriensis*, reports the difference between the two as the sporophyll of *L. majus* having hair or cilia along its margins, whereas the margins of *L. missouriensis* are smooth.

Crookall (1925) reports *L. majus* as occurring throughout the Coal Measures of Great Britain.

Figured specimen.—USNM 42874.

Genus LEPIDOPHYLLUM Brongniart 1828

Prod. d'une Hist. des. Veg. Foss., p. 87

Lepidophyllum longifolium Brongniart

Pl. 1, fig. 3

1939 *Lepidophyllum longifolium* BRONGT., JANSSEN—Leaves and Stems from Fossil Forests, p. 62, fig. 44.

Discussion.—A large number of the sterile leaves of the ancient lycopods are found isolated and in fragmental condition in the Manning Canyon Shale.

Some specimens are similar to *Lepidophyllum longifolium* Brongniart as reported by Janssen (1939). Although incomplete, these measure 4 mm wide and over 20 cm long. Their complete lengths are indeterminable. A single midrib traverses the length of this linear, grass-like leaf.

Janssen (1939) refers this species to Brongniart, but doesn't give a reference, and the author was unable to locate Brongniart's original description. Therefore these specimens are placed tentatively with *L. longifolium*.

Figured specimen.—USNM 42875.

Lepidophyllum sp.

Pl. 2, fig. 9

Discussion.—These sterile leaves are smaller than *Lepidophyllum longifolium*. They are 5-6 cm long and 4 mm wide. The leaves are elongate-triangular in shape with a flat, truncated base and an acute apex. A single vein is continuous from base to apex. Stomatal grooves parallel the vein.

Leaves of this type have been collected attached to *Lepidodendron obovatum* where they may constitute the base of a strobilus with sporangia in the axils or they may be sterile foliage. The preservation is not sufficient to determine if spores are present.

Figured specimen.—USNM 42876.

Genus STIGMARIA Brongniart 1822

(Memoirs du Museum d'Histoire Naturelle, v. 8, p. 209)

Stigmaria ficoides (Sternb.) Brongniart

Pl. 1, fig. 1

1820 *Variolaria ficoides* STERNBERG—Versuch der Flora der Vorwelt, v. 1, fasc. 1, p. 23-26, pl. XII, figs. 1-3.

1822 *Stigmaria ficoides* (STERNB.) BRONGNIART—Memoirs du Museum d'Histoire Naturelle, v. 8, p. 209, pl. I, fig. 7.

1877 *Stigmaria verrucosa* MILLER—Amer. Paleozoic Fossils, p. 40.

1899 *Stigmaria verrucosa* MILLER, WHITE—U. S. Geol. Surv. Prof. Paper 185-D, p. 82.

1962 *Stigmaria verrucosa* MILLER, TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 99, pl. 5, fig. 1.

Discussion.—A few rather large-sized specimens were uncovered from a clay pit in the Manning Canyon Shale northwest of Fairfield, Utah. These show the spirally disposed circular rootlet scars with several appendages (rootlets) still attached.

The species name *Stigmaria verrucosa* is invalid as the species term was derived from *Phytolithus verrucosus* Martin 1809, a term used prior to 1820, which is the priority date for paleobotanical nomenclature.

Figured specimen.—USNM 42877.

Order EQUISETALES

Genus ARCHEOCALAMITES Stur, 1875

(Culmflora I, Abh. k. k. Geol. Reichsanst, v. 8)

Archeocalamites radiatus (Brongt.) Stur

Pl. 8, fig. 9

1828 *Calamites radiatus* BRONGNIART—Prod. d'Hist. Veg. Foss. I, p. 122, pl. 26, figs. 1, 2.

1875 *Archeocalamites radiatus* (BRONGT.) STUR—Culmflora I, Abh. k. k. Geol. Reichsanst, v. 8, pl. 1, figs. 3-8, pl. 2, 3, 4; pl. 5, figs. 1, 2.

1964 *Archeocalamites radiatus* (BRONGT.) STUR, BOUREAU—Sphenophyta, Noeggerathio-phyta, *Traite de Paleobot.* III, p. 209, figs. 186, 187, 188.

Discussion.—*Archeocalamites radiatus* is the only species of *Archeocalamites* from which the leaf-bearing shoots are known. The dividing of the leaves by repeated bifurcations is contrary to the general leaf types found in the Equisetales. Both the unbranched part of the archeocalamitean leaf and its segments are extremely narrow; more or less filiform. Halle (1925) points out that the leaves are given off in great numbers in radially symmetrical nodes. They are ascending or slightly spreading, attaining lengths of 10 to 12 cm or more. They regularly bifurcate (Pl. 8, fig. 9) into two similar halves with the entire leaf having a uniform appearance. Halle (1925) states that the branching of this species is sparse, and its lateral shoots are finely divided.

Lestikow (1959) demonstrated that *Calamites scrobiculatus* Schloth. and *Asterocalamites scrobiculatus* (Schloth.) Zeiller should be assigned to *Archeocalamites radiatus*.

Lacey and Eggert (1964) placed all of White's (1937b) asterocalamitean species from Arkansas, Bell's Canadian asterocalamitean forms, and Arnold's (1962) specimens from the Uinta flora, Utah, with *Archeocalamites radiatus*.

Archeocalamites radiatus is reported from the Lower Carboniferous up into Namurian A.

Figured specimen.—USNM 42878.

Genus CALAMITES Suckow, 1784

(Hist. Comm. Acad. Elect. Sci. Litt. Theod.-Palat. v. 225, Mannheim)

Calamites (*Mesocalamites*) *hesperius* Arnold

Pl. 8, figs. 6, 11

1953 *Calamites hesperius* ARNOLD—*Palaeontographica*, v. 93B, p. 62-63, pl. 24, figs. 1, 6-8.

1956 *Mesocalamites hesperius* (ARNOLD) MAMAY AND READ—U. S. Geol. Surv. Prof. Paper 274-I, p. 215, pl. 34, figs. 4, 4a.

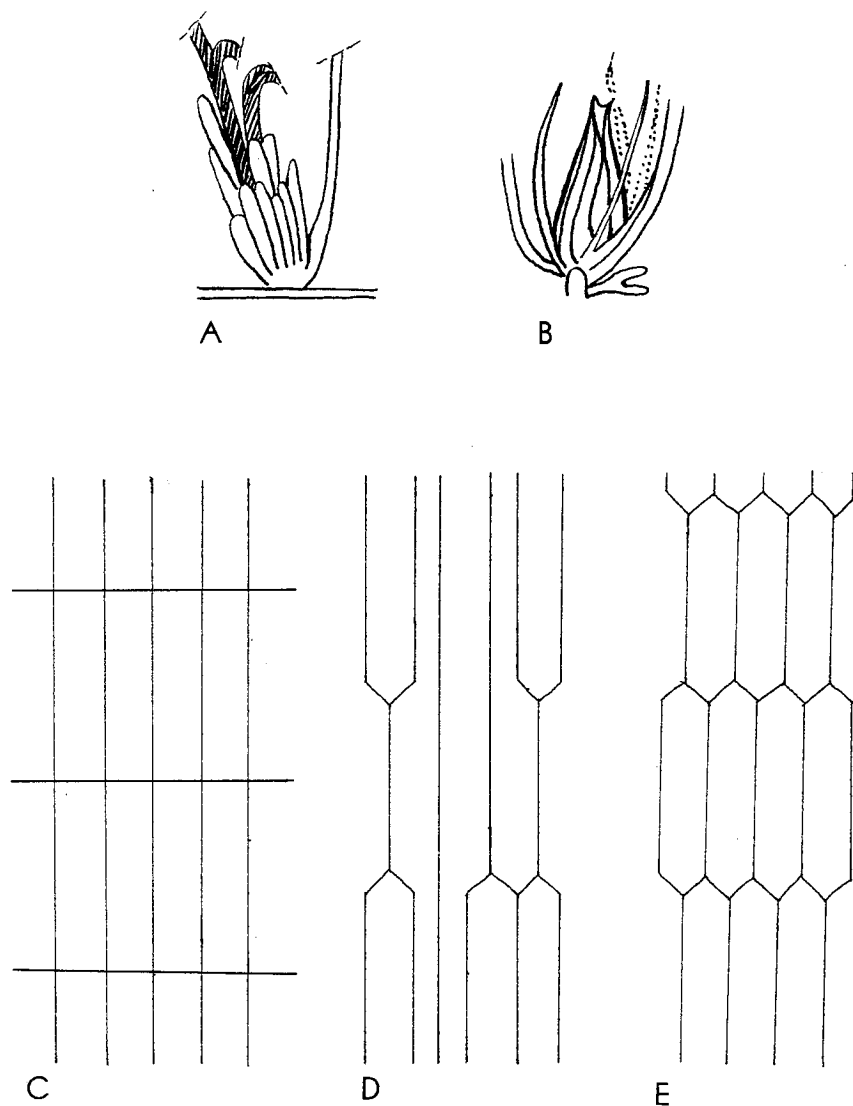
1964 *Calamites* (*Mesocalamites*) *hesperius* ARNOLD, BOUREAU—Sphenophyta, Noeggerathio-phyta, *Traite de Paleobot.* III, p. 247, fig. 217.

Discussion.—Specimens are pith cast compressions. Ribs on the specimens are nearly straight with rounded or flattened surfaces. Some ribs terminate in acute or rounded points and alternate, whereas others are truncated but appear to pass directly across the node. Internodes are 2.4 to 3.0 cm in length. No branch scars are present.

Arnold (1953) informally discussed the affinities of this species with the *Mesocalamites* group of Hirmer. Mamay and Read (1956) recombined it into *Mesocalamites*. Boureau (1964), however, reduced the genus *Mesocalamites* to a subgeneric position.

The mesocalamitian group, because of its series of alternating ribs and ribs which appear superficially to cross directly through the node, occupies a morphological and stratigraphic position between *Archeocalamites* and the other subgenera of *Calamites*.

Archeocalamites with its ribs terminating at the node, and not alternating in successive internodes, is considered to be a primitive calamitean form. The other subgenera of *Calamites*, such as *Stylocalamites* Weiss, *Diplocalamites* Gothan, *Crucicalamites* Gothan, and *Calamophyllites* Grand'Eury have most of their ribs alternating.



TEXT-FIGURE 2.—A.—*Cordaianthus pseudofluitans* Kidston. A.—strobilus in axis of a bract. Note bifurcated sporophylls. B.—*Rigbyocarpus ebracteatus* Tidwell, gen. and nov. C.—Schematic diagram of the ribs of *Archeocalamites* passing directly through the nodes. D.—Schematic diagram of *Mesocalamites* illustrating the alternation of ribs that pass through the node with those that alternate at the nodes. E.—Schematic diagram of the alternating ribs of true *Calamites*.

Mesocalamites resembles a mixture of these two types, with the opposing ribs more or less predominant over the alternating ribs (Text-fig. 2). The vertical range of *Archeocalamites* is essentially Lower Carboniferous through Namurian A, whereas *Calamites* ranges through the Carboniferous and Permian. *Mesocalamites* is positioned more or less traditionally from Namurian A. into Westphalian A.

Figured specimen.—USNM 42880.

Calamites (Mesocalamites) cistiiformis Stur
Pl. 9, figs. 10, 11

1877 *Calamites cistiiformis* STUR—Culmflora II, Abh. k. k. Geol. Reichsanst., v. 8, p. 200, pl. IV, figs. 5, 6.

1917 *Calamites cistiiformis* STUR, KIDSTON AND JONGMANS—Monograph of *Calamites* of western Europe, Riipsop. van Delfst. Meded., v. 1, p. 192-195.

1964 *Calamites (Mesocalamites) cistiiformis* STUR, BOUREAU—Sphenophyta, Noeggerathioophyta. Traite de Paleobot. III, p. 245.

Discussion.—The width of the specimen illustrated is 24 mm and its internodes are 42 mm long.

There is a strong similarity between *C. cistiiformis* and *C. cisti* Brongt. Jongmans and Kukuk (1913) stated that these two species might eventually be united.

Kidston and Jongmans (1917), however, state that although many authors would unite *C. cistiiformis* and *C. cisti*, *C. cistiiformis* differs from *C. cisti* in the constant occurrence of some of the ribs passing through the nodal line and some alternating. The ends of the alternating ribs are sharp pointed in *C. cistiiformis*, whereas they are rounded in *C. cisti*.

The specimens from the Manning Canyon Shale do not have as many non-alternating ribs as those illustrated for *C. cistiiformis*, but they have too many to be placed with *C. cisti*.

C. cistiiformis is a typical Namurian form, especially for Namurian A; however, Gothan, Leggewie, and Schonefeld (1959) frequently encountered it in Namurian B and C. They state that *C. cistiiformis* is not found in the Lower Westphalian. Leggewie and Schonefeld (1961) report its occurrence in the *Homoceras* zone (H_1 & H_2).

Figured specimens.—USNM 42878, 42879.

Genus ASTEROPHYLLITES Brongniart 1822
(Memoirs du Museum d'Histoire Naturelle, v. 8, p. 210)

Differentiating between the genera *Asterophyllites* and *Annularia* is often very difficult. They are similar in that both have linear-lanceolate, single-veined leaves which are more or less united at their bases with a sheath.

Abbott (1958), in her comprehensive work on these genera, separates them on width-length ratios and the position of the leaves in the whorl in relation to their axis. In *Asterophyllites* the leaves, which are of equal length, are usually cupped around the axis. In *Annularia* the leaves, of equal or unequal length, radiate from the node. She states that these orientations are not always constant, but a contrary orientation would be an exception and probably due to preservation.

She defines the margins of the leaves from *Asterophyllites* as essentially parallel or straight, gradually tapering to an acute apex, whereas the leaves of *Annularia* are lanceolate to obovate or spatulate.

Asterophyllites equisetiformis (Schloth.) Brongniart
Pl. 4, fig. 1; Pl. 9, fig. 2

1828 *Asterophyllites equisetiformis* (SCHLOTH.) BRONGNIART—Prod. d'Hist. Veg. Foss. I, p. 159, 176.

1958 *Asterophyllites equisetiformis* (SCHLOTH.) BRONGNIART, ABBOTT—Bull. Amer. Paleont., v. 38 (174), p. 299, pl. 35, fig. 4; pl. 36, figs. 12, 15, 19, 30; pl. 39, figs. 46, 47, 49-51; pl. 43, fig. 63; pl. 47, fig. 78; Chart I.

1962 *Asterophyllites* sp. A. TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 98, pl. 4, figs. 6, 8.

Discussion.—The leaves occur in whorls with an average of 12 per whorl. The nodes from which the whorls originate appear to shorten toward the end of the branch causing the leaves from each proceeding whorl to overlap the succeeding whorl, giving the tip a "paint brush" effect which is characteristic of this species.

Asterophyllites equisetiformis is the most abundant calamitean foliage found in the Manning Canyon Shale. However, it appears to be a somewhat smaller form than normal *A. equisetiformis* in both size and number per whorl.

Abbott (1958) lists the stratigraphic range for this species as Pottsville through Allegheny, although Stockmans and Williere (1952) report it from the Namurian of Belgium.

Figured specimen.—USNM 42882, 42883.

Asterophyllites charaeformis (Sternb.) Goepfert
Pl. 9, fig. 1

1825 *Bechera charaeformis* STERNBERG—Versuch der Flora der Vorwelt, v. 1(4), p. 30, pl. 55, figs. 3, 5.

1844 *Asterophyllites charaeformis* (STERNB.) GOEPPERT—in Wimmer, Flora von Schlesien Preuss; und Oster. Onth., p. 198.

1958 *Asterophyllites charaeformis* (STERNB.) GOEPPERT, ABBOTT—Bull. Amer. Paleont., v. 38 (174), p. 296, pl. 35, fig. 2; pl. 48, figs. 85, 86; Chart I.

Discussion.—This form is rare in the Manning Canyon Shale. Its distribution as given by Abbott (1958) is Pottsville to lower Allegheny. According to Leggiewie and Schonefeld (1961), *Asterophyllites charaeformis* should not occur in Namurian C, but one would encounter *Asterophyllites unguis* Jongmans and Stockmans, with which *Asterophyllites charaeformis* is often confused. Because the difference between these two is not clear, the Utah specimens were placed with *A. charaeformis*.

Figured specimen.—USNM 42881.

Asterophyllites longifolius (Sternb.) Brongniart
Pl. 4, fig. 6

1825 *Bruckmannia longifolia* STERNBERG—Versuch der Flora der Vorwelt, v. 1, no. 4, p. 45, pl. 59, fig. 1.

1828 *Asterophyllites longifolius* (STERNB.) BRONGNIART—Prod. d'Hist. Veg. Foss. I, p. 159-176.

1880 *Asterophyllites longifolius* (STERNB.) BRONGNIART, LESQUEREUX—Coal Flora, 2nd Geol. Surv. Pennsylvania Rpt. of Prog. P., v. 1, p. 36.

1958 *Asterophyllites longifolius* (STERNB.) BRONGNIART, ABBOTT—Bull. Amer. Paleont., v. 38 (174), p. 303, pl. 40, fig. 53; pl. 42, fig. 60; chart 1.
 1962 *Asterophyllites longifolius* (STERNB.) BRONGNIART, TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 98, pl. 4, fig. 7.

Discussion.—*Asterophyllites longifolius* is very rare in the flora from the Manning Canyon Shale. The specimen illustrated on Pl. 4, fig. 6 is very fragmental with incomplete whorls, although the length of the leaves is clear.

Lesquereux (1880) states that *Asterophyllites longifolius* bears some resemblance to *Asterophyllites rigidus* Geinitz, and gives the broader stems with shorter internodes and more rigid leaves of *A. rigidus* as the major distinctions. Miklaussen (1949) illustrates how these factors are not constant, and concludes by using *Asterophyllites longifolius* forma *rigida* Weiss for at least one of his specimens.

The age range of *Asterophyllites longifolius* is Pottsville to Upper Allegheny (Abbott, 1958).

Figured specimen.—USNM 42884.

Genus CALAMOSTACHYS Schimper 1869
 (Traite, v. 1, p. 328)
Calamostachys (?) sp.
 Pl. 8, fig. 1

Discussion.—A description of this species is as follows: Small, incomplete cone, 15 mm long, with alternating sterile and fertile sporophylls which are associated with foliage of the *Asterophyllites equisetiformis* type. Fertile whorls are situated midway between the sterile whorls. The sporangiophores are of a cruciate shape and are borne at right angles to the cone axis. No spores were obtained from this specimen.

No illustrations or descriptions were found in the literature of a calamitean cone which are similar to the form described here. However, the form is too incomplete to give it a new species name or to assign it any other species.

Figured specimen.—USNM 42885.

Genus TINGIA Halle 1925
 (Geol. Surv. China, Bull. 7, p. 4-6)
Tingia placida Tidwell, sp. nov.
 Pl. 7, fig. 2

Description.—Fronde-like. Leaves obocuneate to linear-oblong with rather truncated apices. These apices are dissected through narrow incisions to form 2 to 3 linear lobes with obtuse apices which may again be divided near their apices. Leaves alternate, oblique, attached with a broad base. Veins fine, bifurcating mostly in the lower part, supplying one to two veinlets to each lobe.

Discussion.—The genus *Tingia* is characterized by frond-like anisophyllous shoots with a thick axis. The leaves are arranged in four rows, two on the upper and two on the lower side of the axis. The leaves on the upper side are broadly obocuneate-obovate to oblong or linear, deeply lobed. Those on the lower side are similar but narrower and often more deeply dissected. The venation of this genus is nearly parallel to the margins.

These characters fit *Tingia placida* except for the anisophyllous structure and the broad axis. The anisophyllous structure, although not present, may

eventually be discovered with further collecting. However, this structure is rarely uncovered, even in known species (Stockmans, personal communication).

Tingia placida is extremely close to *Tingia carbonica* Halle, the type species for the genus, and differs only on the size and the slender axis of *Tingia placida*. In fact, they are so close that *Tingia placida* looks like a small replica of the specimen figured by Halle (1927) on Pl. 62, fig. 6. *Tingia placida* may be from near the apex of a frond which may account for its smaller size.

The genus *Tingia* is presently known only from the Lower Permian of China. Darrah (1938) has reported *Tingia* from the Permian of Texas, but Mamay (1964) believes Darrah's specimens belong to another genus unrelated to *Tingia*.

Figured specimen.—Holotype: USNM 42886.

Orders FILICALES and CYCADOFILICALES

Genus SPHENOPTERIS Brongniart 1822

(Memoirs du Museum d'Histoire Naturelle, v. 8, p. 233)

The genus *Sphenopteris* constitutes a heterogeneous group and assignment here does not imply systematic relationship between the species which are included in it. Brongniart (1822) defined the genus as "pinnules cuneiformes, arrondies ou lobees a' l'extremite' et a' nervures palmees ou rayonnantes de la base de la pinnule."

Sphenopteris includes the sterile leaves of species with general similarity in shape, their pinnule attachment, and their venation. It is simply a provisional group which probably includes both ferns and pteridosperms.

The pinnules are mostly small, wedge-shaped, often rounded, generally more or less contracted at the base. They are rarely simple and are generally divided into angular or rounded lobes with obtuse or acute apices. A single midvein in each pinnule gives rise to simple or dichotomizing secondary veins which extend into each segment or lobe.

Sphenopteris originally included species whose fructifications are now known. These species have been placed with genera based upon the structure and arrangement of their fructifications.

Sphenopteris is distributed throughout the Mississippian and Pennsylvanian.

Sphenopteris schatzlarensis (Stur) Zeiller

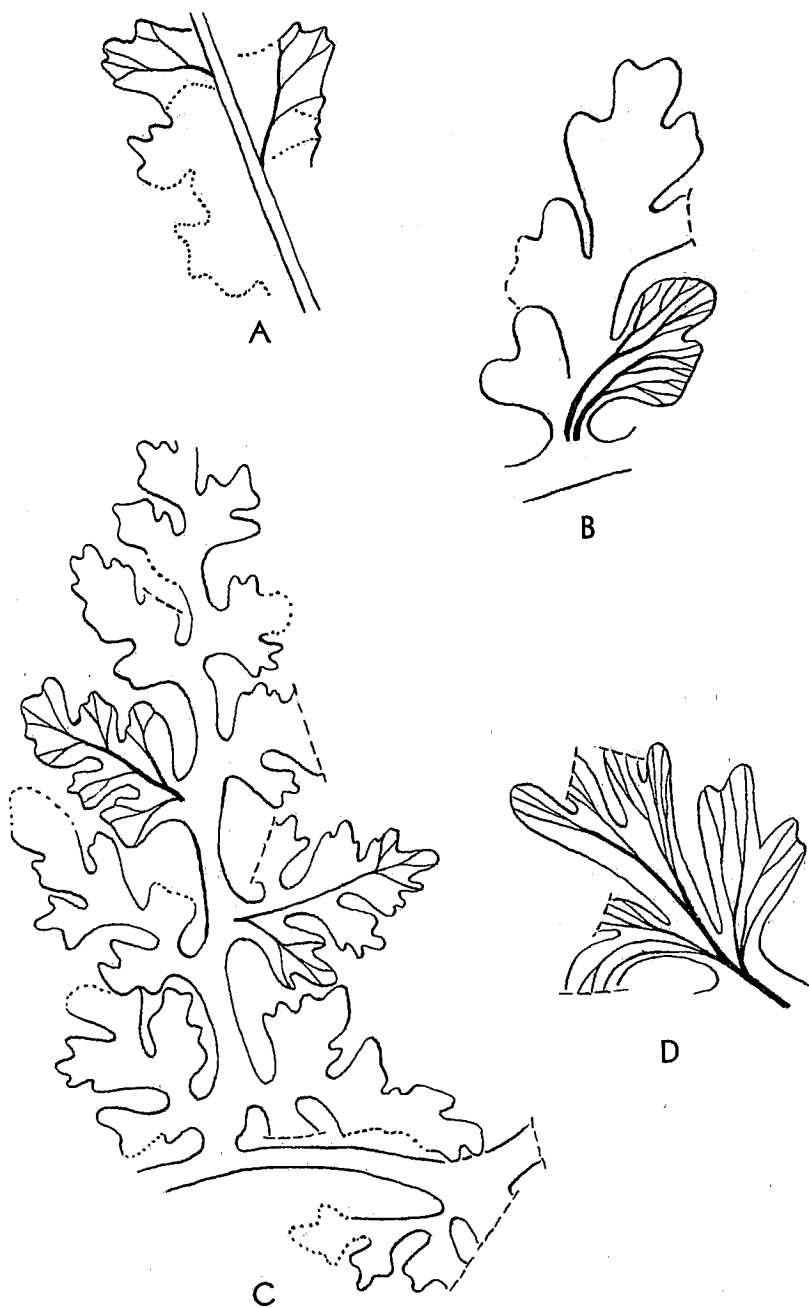
Pl. 5, fig. 1

1885 *Hapalopteris schatzlarensis* STUR—Die Farne: Carb.-Flora d. Schatzlarer Schichten, I Farne: K. k. Geol. Reichsanst., v. 11, p. 58, text-fig. 2, pl. XXXIX, figs. 7, 7a; pl. XL, figs. 2-6.

1923 *Sphenopteris* (*Renaultia*) *schatzlarensis* STUR, KIDSTON—Mem. of Geol. Surv. Great Brit., Paleont. v. 2, pt. 2, p. 123, pl. 29, fig. 4; pl. 30, figs. 1, 1a.

Discussion.—*Sphenopteris schatzlarensis* belongs to the narrow, delicate-leaved sphenopterids. Its fertile remains belong to the *Renaultia* type. The structure of its sporangia is still not certain. Zeiller (1899) reported a fertile specimen which Kidston (1923) notes as being imperfectly preserved and therefore having insufficient characters to warrant placing *S. schatzlarensis* in *Renaultia*.

Boweria schatzlarensis has larger pinnules with segments wider in proportion to their length and is generally entire as compared with *S. schatzlarensis*.



TEXT-FIGURE 3.—A.—*Corynepteris angustissima* (Sternb.) Němejč (10X); B.—*Sphenopteridium dissectum* Geopp. (2.5X); C.—*Sphenopteris schatzlarensis* (Stur) Zeiller (5X); D.—*Sphenopteris dipblebia* Tidwell, sp. nov. (2X).

According to Bell (1943), the frond of *S. schatzlarensis* is more delicately cut than that of *Boweria schatzlarensis*, and the two species should no longer be confused with one another.

Kidston (1923) restricts this species to the Westphalian; whereas Daber (1955) places it from Namurian to Westphalian D. Bell (1943) records occurrences of *Sphenopteris schatzlarensis* in Cumberland and Riversdale Groups in Canada.

Figured specimen.—USNM 42892.

Sphenopteris dipblebia Tidwell, sp. nov.

Pl. 3, fig. 6

Description.—Frond at least tripinnate. Penultimate pinnae not complete, rachis flexuous. Ultimate pinnae: somewhat oblong with constricted base, alternate,

EXPLANATION OF PLATE 1

STIGMARIA, LEPIDOSTROBOPHYLLUM, LEPIDOPHYLLUM, AND LEPIDODENDRON

- FIG. 1.—*Stigmara ficoides* (Sternb.) Brongniart. Portion of rhizome with rootlets attached. (1X). USNM 42877.
FIG. 2.—*Lepidostrobohyllum majus* (Brongt.) Hirmer. Broad, lanceolate leaf with fertile portion missing. (1X). USNM 42874.
FIG. 3.—*Lepidophyllum longifolium* Brongniart. Basal portion of leaf illustrating the central midvein and the two stomatal grooves on each side. (1X). USNM 42875.
FIG. 4.—*Lepidodendron volkmannianum* Sternberg. Specimen showing the characteristic horizontal and vertical alignment of the leaf bolsters. (1X). USNM 42870.
FIG. 5.—*Lepidodendron aculeatum* Sternberg. Bolsters with leaf scar visible. Ligule scar is deep indentation at the top of the leaf scar. (1X). USNM 42868.

EXPLANATION OF PLATE 2

ODONTOPTERIS, LEPIDOCARPON, TRIGONOCARPUS, GNETOPSIS, LEPIDODENDRON, LEPIDOSTROBUS, AND LEPIDOPHYLLUM

- FIG. 1.—*Odontopteris* sp. Ultimate pinnae. (1X). USNM 42907.
FIG. 2.—*Lepidocarpum linearifolium* (Lesq.) Schopf. Specimen of the megasporangium with the sporophyll still attached. (1X). USNM 42873.
FIG. 3.—*Trigonocarpus* sp. Sarcotesta with a portion of the micropyle present. (1X). USNM 42924.
FIGS. 4, 5.—*Gnetopsis anglica* Kidston. Seed, with appendages. Note longitudinal folding of envelope along right edge of seed. Fig. 4 (1X), Fig. 5 (approx. 3X). USNM 42930.
FIG. 6.—*Lepidodendron obovatum* Sternberg. Leaf bolsters on a stem. Note broad-as-long size of bolsters with elliptical leaf scar in upper one-half of bolster. The bolster near base of stem portion shows the vascular and parichnos scars. (1X). USNM 42869.
FIG. 7.—*Lepidostrobus obovatus* Němejč. Strobilus showing its compacted sporophylls and its general shape (pointed apex) incomplete. (1X). USNM 42871.
FIG. 8.—*Lepidostrobus variabilis* Lindley and Hutton. Strobilus demonstrating its oblong shape, its axis and crowded sporophylls. Note the quartz box-work near its apex. (1X). USNM 42872.

- FIG. 9.—*Lepidophyllum* sp. Sterile leaf; midvein and stomatal grooves are visible. The base of the leaf is near the base of the specimen, tapering to a pointed apex. (2X). USNM 42876.

EXPLANATION OF PLATE 3

DIPLOTHMEMA, ADIANTITES, NEUROPTERIS, CORDAICARPUS,
SPHENOPTERIS, AND CROSSOPTERIS

- FIG. 1.—*Diplothmema arnoldi* Stockmans and Williere. Pinnules and ultimate pinnae. (1X). USNM 42891.
- FIG. 2.—*Adiantites (Wardia) tenuifolius* var. *defoliolatus* (White) Tidwell, comb. nov. Penultimate segment of a frond. (1X). USNM 42898.
- FIG. 3.—*Neuropteris gigantea* Sternberg. Fragment showing four falcate pinnules. (1X). USNM 42899.
- FIG. 4.—*Cordaicarpus manningcanensis* Tidwell sp. nov. Seed showing rounded shape, distinct micropyle. (1X). Holotype: USNM 42919.
- FIG. 5.—*Diplothmema trifoliata* (Artis) White. Specimen showing several ultimate pinnae. (1X). USNM 42890.
- FIG. 6.—*Sphenopteris dipblebia* Tidwell, sp. nov. Antepenultimate segment. Note the distinctly visible two veinlets per lobe. (1X). Holotype: USNM 42893.
- FIG. 7.—*Crossopteris utahensis* Tidwell, gen. and sp. nov. Penultimate segments illustrating one-half basal attachment, alethopteroid-pecopteroid lobing and odontopteroid-neuropteroid venation. (1X). Paratype: USNM 42903.

EXPLANATION OF PLATE 4

ASTEROPHYLLITES, TELANGIUM, CROSSOPTERIS, MARIOPTERIS,
AND NEUROPTERIS

- FIG. 1.—*Asterophyllites equisetiformis* (Schloth.) Brongniart. Stem with branches arising from each node. The leaves are whorled at each node with internodal area becoming shorter, eventually achieving the "bottle brush" effect near the tips of the branches. (1X). USNM 42882.
- FIG. 2.—*Telangium affine* (L. & H.) Benson. Specimens showing branching of fertile frond and sporangia. (1X). USNM 42931.
- FIG. 3.—*Crossopteris undulata* Tidwell sp. nov. Penultimate segment. (1X). Holotype: USNM 42905.
- FIG. 4.—*Mariopteris muricata* Schloth. Pinnules from near apex of penultimate pinnae. (1X). USNM 42887.
- FIG. 5.—*Neuropteris ampelina* Tidwell sp. nov. Penultimate segment. (1X). Holotype: USNM 42901.
- FIG. 6.—*Asterophyllites longifolius* (Sternb.) Brongniart. Branch or small stem with leaves attached at nodes. Note how leaves overlap the node above. (1X). USNM 42884.

EXPLANATION OF PLATE 5

SPHENOPTERIS, CORYNEPTERIS, DIPLOTHMEMA, AND NEUROPTERIS

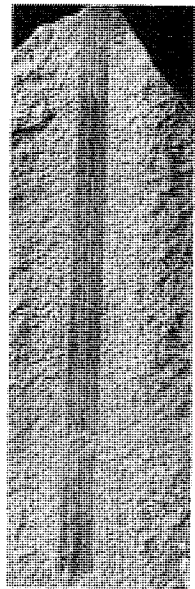
- FIG. 1.—*Sphenopteris schatzlarensis* (Stur) Zeiller. This species is illustrated in the lower right portion of the figure. *Asterophyllites equisetiformis* occupies the remainder of the figure. (1X). USNM 42892.
- FIGS. 2, 3.—*Corynepteris angustissima* (Sternb.) Němec. 2. Specimen, enlarged, showing the toothed aspect of this species. (2X). 3. Specimen showing natural size. (1X). BYU 1481.
- FIG. 5.—*Diplothmema obtusiloba* (Brongt.) White. Portion of an antepenultimate pinnae. (1X). USNM 42889.
- FIGS. 4, 6.—*Neuropteris* cf. *pocabontas* White. 4. Enlargement of fig. 6 showing the single point attachment. (1.5X). USNM 42900. 6. Penultimate pinnae. (1X).



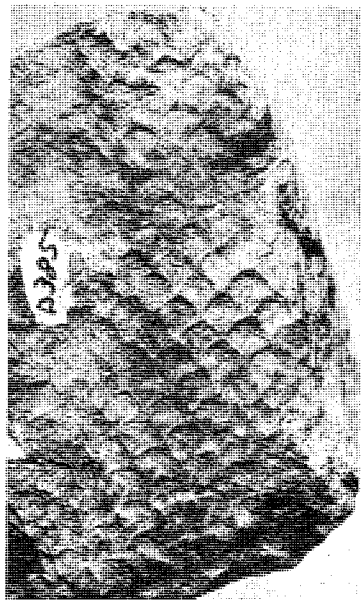
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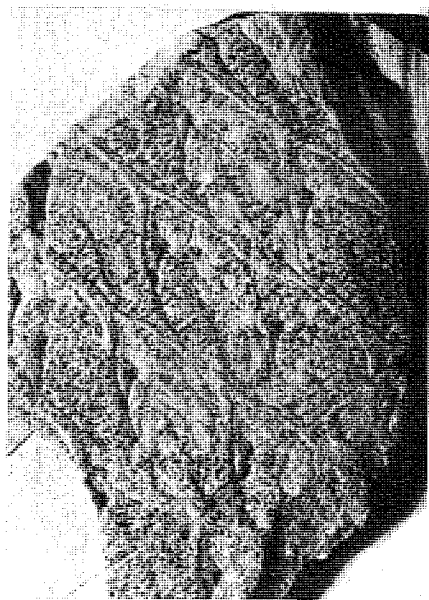
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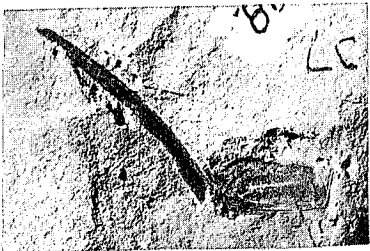
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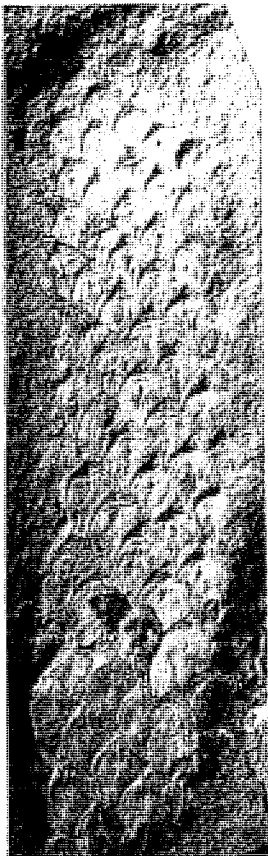
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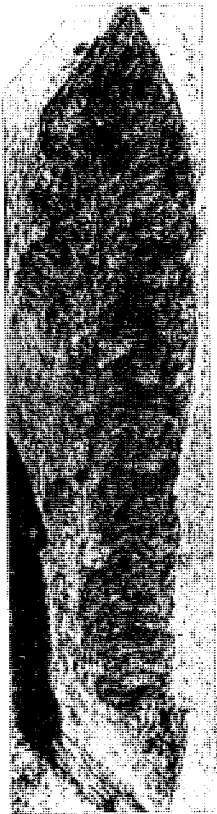
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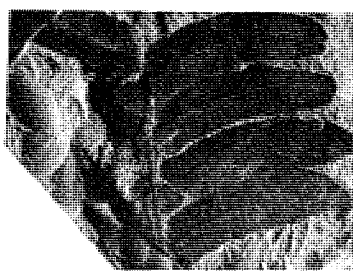
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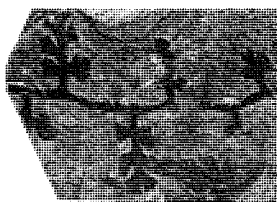
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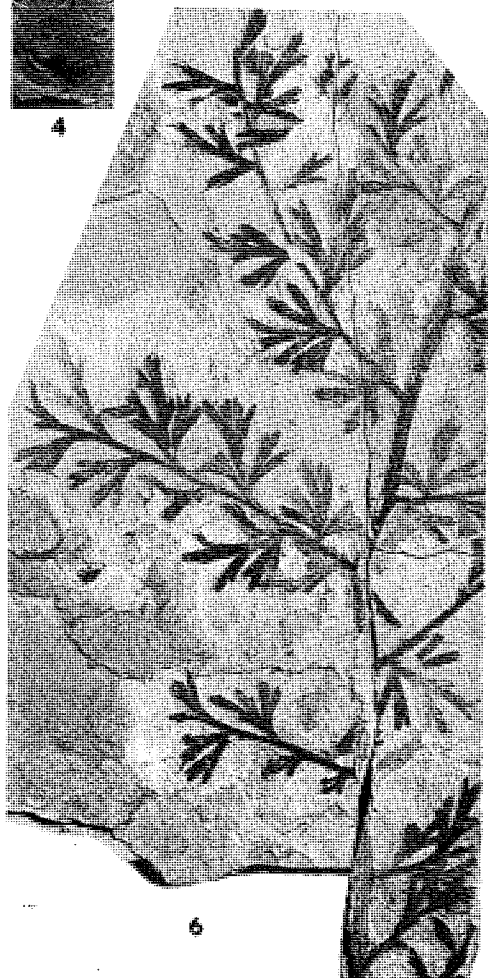
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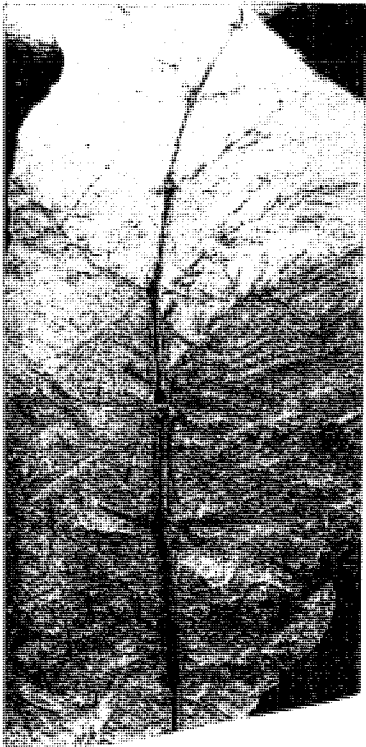
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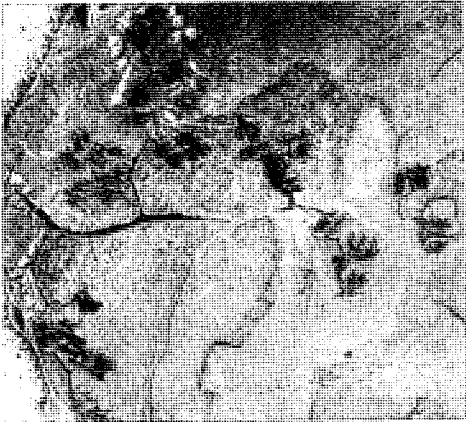
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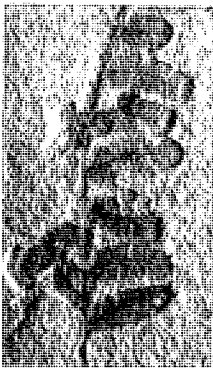
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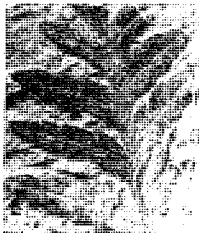
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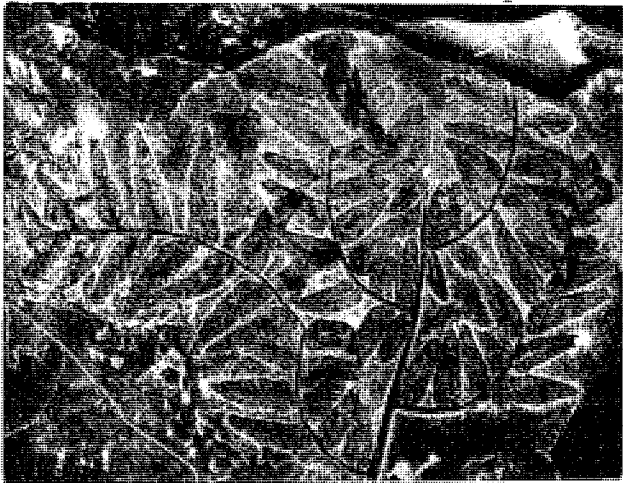
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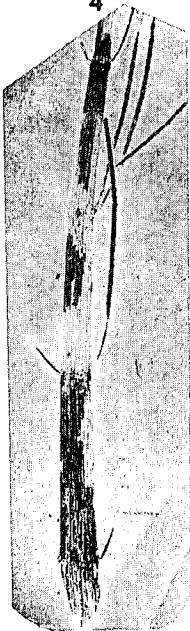
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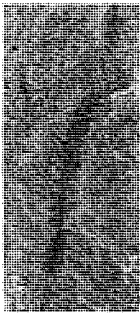
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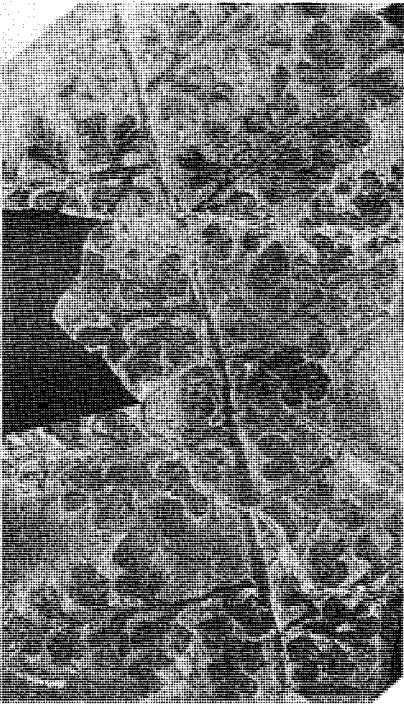
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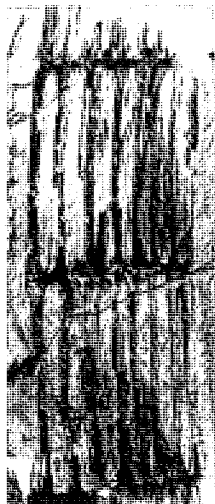
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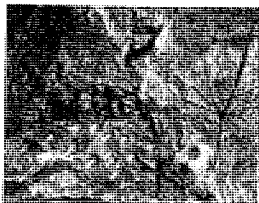
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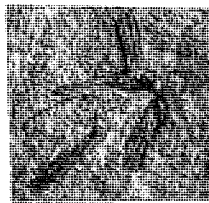
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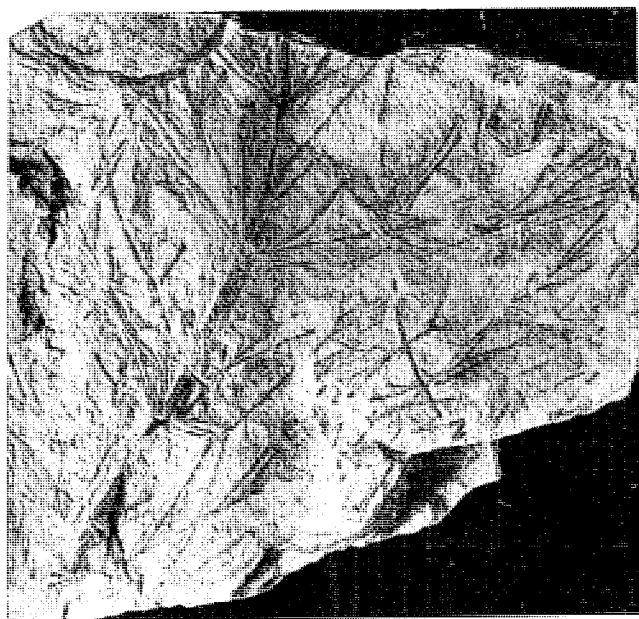
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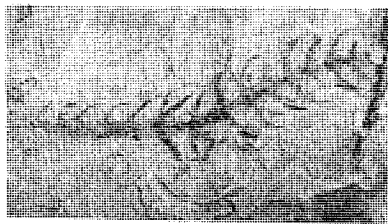
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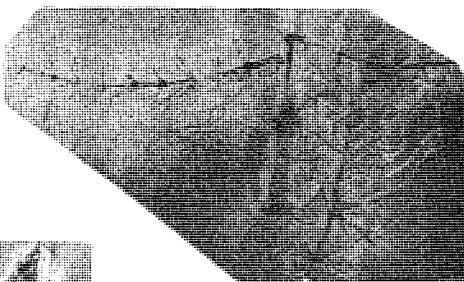
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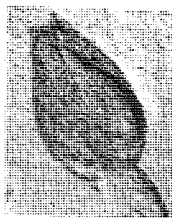
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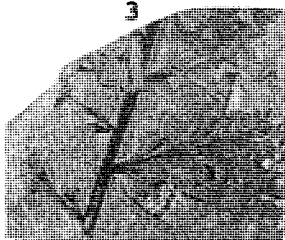
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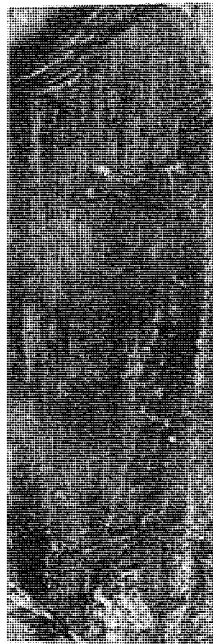
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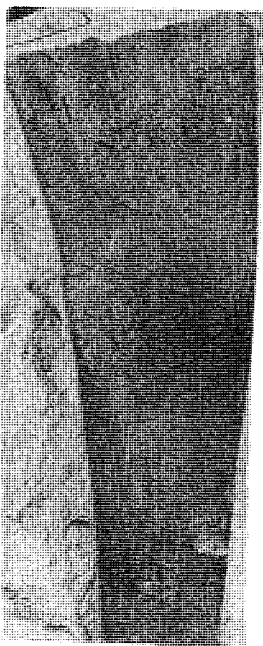
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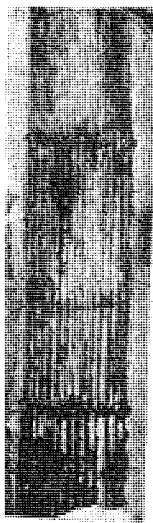
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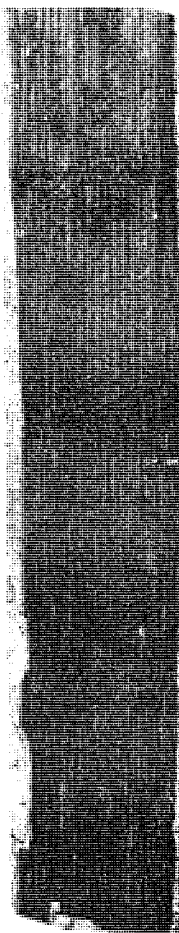
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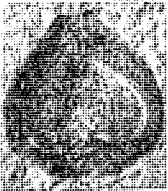
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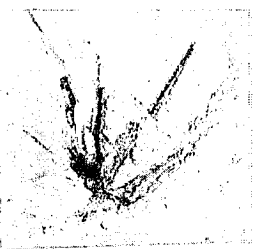
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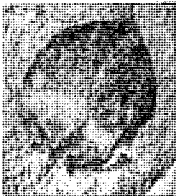
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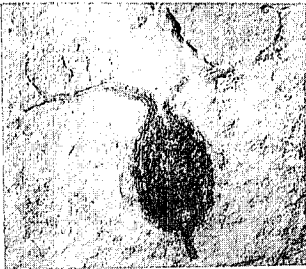
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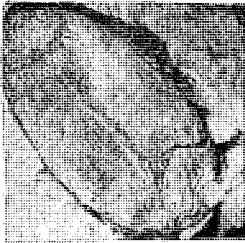
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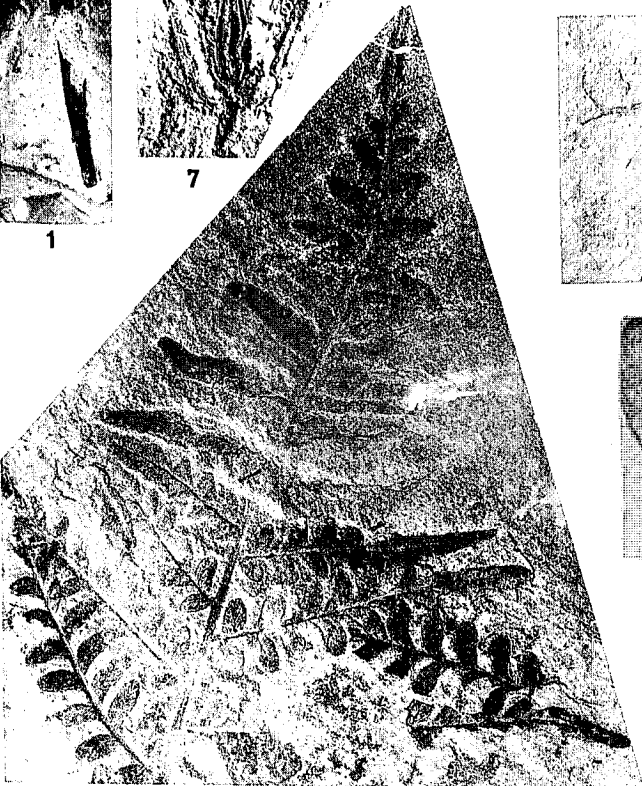
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EXPLANATION OF PLATE 6

CROSSOPTERIS UTAHENSIS TIDWELL

- FIG. 1.—*Crossopteris utahensis* Tidwell, gen. and sp. nov. An antepenultimate frond illustrating the various characters of the genus. The polymorphous aspect of this species can be seen by comparing the pinnules from various pinnae. The terminus of this frond is missing. ($\frac{1}{2}$ X). Holotype: USNM 42902.

EXPLANATION OF PLATE 7

LAGENOSPERMUM, *TINGIA*, *CORDAICARPUS*, *CROSSOPTERIS*,
AND *SPHENOPTERIDIUM*

- FIG. 1.—*Lagenospermum discissium* Tidwell, sp. nov. Seed cupules, some with seed still present. (1.5X). Holotype: USNM 42929.
- FIG. 2.—*Tingia placida* Tidwell, sp. nov. Upper pinnules from an antepenultimate or a penultimate segment. The deeply dissected lobing can be observed in pinnules on right side of rachis. (1X). Holotype: USNM 42886.
- FIGS. 3, 4.—*Cordaicarpus elongatus* (Newberry) Tidwell, comb. nov. These specimens illustrate general shape and size of wings. (2X). USNM 42913, 42914.
- FIG. 5.—*Crossopteris mcknightii* Tidwell sp. nov. Antepenultimate or penultimate pinnae. One-half basal attachment, alethopteroid-pecopteroid lobing and neuropteroid venation can be seen. (1X). Holotype: USNM 42906.
- FIG. 6.—*Sphenopteridium zaitzeffii* Tidwell, sp. nov. Antepenultimate segment. Notice the flabellate, lax pinnules. (1X). Holotype: USNM 42896.

EXPLANATION OF PLATE 8

CALAMOSTACHYS (?), *AULACOTHECA*, *CORDAICARPUS*, *CALAMITES*,
AND *ARCHEOCALAMITES*

- FIG. 1.—*Calamostachys* (?) sp. The strobilus is associated with *Asterophyllites equisetiformis*. (1X). USNM 42885.
- FIG. 2.—*Aulacotheca campbelli* (White) Halle. Three micro-sporangiate structures on the specimen illustrating the ribbing. (1X). USNM 42932.
- FIG. 3.—*Cordaicarpus jayshulerii* Tidwell, sp. nov. Illustration showing striated surfaces of seeds and lack of wings. (2X). Holotype: USNM 42916.
- FIGS. 4, 5, 7, 10.—*Cordaicarpus cordatus* (Jackson) Tidwell, comb. nov. 4. Seed illustrating shape with wings attached. (1X). USNM 42920. 5. Enlargement of fig. 7 (2X). 7. Nucellus with wings missing. (1X). USNM 42921. 10. Enlargement of fig. 4. (2X).
- FIGS. 6, 11.—*Calamites* (*Mesocalamites*) *besperius* Arnold. 6. An enlargement of fig. 11 showing the alternation between some ribs going directly across the nodes and others alternating. (1.5X). 11. Two nodes of a stem showing the broad, straight ribs, some of which alternate at nodes while others appear to go directly across. (1X). USNM 42880.
- FIG. 8.—*Aulacotheca hemingwayi* Halle. Specimen of the sporocarp. (1X). USNM 42933.
- FIG. 9.—*Archeocalamites radiatus* (Brongt.) Stur. Stem with the bifurcating leaves arising from each node. The straight ribs are visible at upper portion of the stem, but the non-alternation of these ribs cannot be seen. (1X). USNM 42878.

EXPLANATION OF PLATE 9

ASTEROPHYLLITES, *RHODEA*, *CORDAICARPUS*, *SPHENOPTERIDIUM*,
MARIOPTERIS, *CORDAITES*, AND *CALAMITES*

- FIG. 1.—*Asterophyllites charaeformis* (Sternb.) Geoppert. Branch with whorled leaves. (1X.) USNM 42881.

- FIG. 2.—*Asterophyllites equisetiformis* (Schloth.) Brongniart. Branches with whorls of leaves attached. (1X). USNM 42883.
- FIG. 3.—*Rhodea vespertina* Read. (1X). USNM 42897.
- FIG. 4.—*Cordaicarpus elongatus* (Jackson) Tidwell, comb. nov. (1X). USNM 42915.
- FIG. 5.—*Sphenopteridium dissectum* Goeppert. Specimen illustrating general pinnule shape and venation. Note veins arise direct from rachis. No central midvein is present. (1X). USNM 42895.
- FIG. 6.—*Mariopteris muricata* Schloth. Fragment of ultimate pinnae. (1X). USNM 42888.
- FIG. 7.—*Cordaicarpus jaysbulerii*, Tidwell, sp. nov. (1X). Paratype: USNM 42917.
- FIG. 8.—*Cordaites* sp. A. Portion of a leaf illustrating the poor preservation. (1X). USNM 42909.
- FIG. 9.—*Cordaites* sp. B. Leaf, illustrating the broad, spatulate shape. (1X). USNM 42910.
- FIGS. 10, 11.—*Calamites* (*Mesocalamites*) *cistiiformis* Stur. 10. Stem with two nodes and part of another showing straightness of ribs and how some ribs alternate at the node while others appear to pass through the nodes, particularly at the middle node. (1X). USNM 42894, 42879.

EXPLANATION OF PLATE 10

CORDAITES, CORDAICARPUS, RIGBYOCARPUS, CORDAIANTHUS,
CROSSOPTERIS, CORNUCARPUS, TRIGONOCARPUS, AND HOLCOSPERMUM

- FIG. 1.—*Cordaites principalis* (Germar) Geinitz. Spatulate leaf. ($\frac{1}{2}$ X). USNM 42908.
- FIG. 2.—*Cordaicarpus binutus* Tidwell sp. nov. Seed with a depression showing where the reniform bodies were harbored. (1X). Holotype: USNM 42922.
- FIGS. 3, 7.—*Rigbyocarpus ebracteatus* Tidwell gen. and sp. nov. 3. Bracts with the seed missing. (2X). Paratype: USNM 42928. 7. Seed surrounded by bracts. (2X). Holotype: USNM 42927.
- FIG. 4.—*Cordaicarpus globosus* Tidwell sp. nov. Figure illustrating shape and relationship of nucellus to the wings. (2X). Holotype: USNM 42912.
- FIG. 5.—*Cordaicarpus jaysbulerii* Tidwell, sp. nov. (1X). Paratype: USNM 42918.
- FIG. 6.—*Cordaianthus pseudofluitans* Kidston. Cordaites strobilis without seeds attached. (1X). USNM 42911.
- FIG. 8.—*Crossopteris utahensis* Tidwell, sp. nov. (1X). Paratype: USNM 42904.
- FIG. 9.—*Cornucarpus longicaudatus* Tidwell, sp. nov. Seed with bifurcating "horns." Note recurving of the bifurcations. (1X). Holotype: USNM 42926.
- FIG. 10.—*Trigonocarpus noeggerathi* (Sternb.) Brongniart. Specimen showing a single longitudinal ridge. (1X). USNM 42923.
- FIG. 11.—*Holcospermum* sp. (1X). USNM 42925.

slightly decurrent to secondary rachis. Terminal pinnule missing. Pinnule: triangular, deltoid or rhomboidal, dividing into 2-4 spreading cuneate segments which are in turn split into 2-3 cuneate, rounded lobes; margins of outer segments tapering toward base, attached with a short, broad stalk; constricted base; decurrent, acute, rarely obtuse apex on each segment, alternate, oblique, rarely normal to the rachis. Venation: distinct, decurrent, arises from rachis acutely to enter the pinnules at a sweeping angle, bifurcates to supply each segment with two veinlets.

Discussion.—*Sphenopteris dipblebia* is similar to *Adiantites gothanica* Dolianiti reported from the Lower Carboniferous of Brazil.

Gothan (1928) states that Berry's (1922) *Palmatopteris furcata* from Peru was incorrectly identified and that it resembles a narrow-leaf *Adiantites* and re-names it *Sphenopteris paracasica* Gothan. Dolianiti (1954) reported Gothan believed his *S. paracasica* is really *Adiantites* and requested that he use *Adiantites paracasica* rather than create a new species. However, Dolianiti separated his species from Gothan's on the basis of the small "nervils" on his specimens.

Gothan's description is incomplete and his illustration is too poor to determine venation or anything else about his species except size and shape. It appears to be smaller and more flabellate than Dolianiti's species. Gothan's specimen has truncated apices, whereas *Adiantites gothanica* Dolianiti has more slender pinnules and lobes with acute apices. Gothan's form does resemble an *Adiantites*, but Dolianiti's appears to be a *Sphenopteris*.

Sphenopteris dipblebia is fairly abundant in the Manning Canyon Shale flora, and although closely related to *Adiantites gothanica*, it lacks the "nervils" which are so important in Dolianiti's description. This may be due to preservation or they may have never been present. These "nervils," as defined by Dolianiti (1954) in his species, may also be due to some vagary of preservation. They do not appear to be consistent along the main veins and seem to cross one another rather than anastomosing into networks which Dolianiti describes. Dolianiti gives no idea as to how consistent these "nervils" are.

A similar form is *Sphenopteris pseudo-furcata* Kidston which also has two veinlets per lobe. The pinnules of *S. pseudo-furcata* are not as deeply incised or as spread out as those of *Sphenopteris dipblebia*.

Figured specimen.—Holotype: USNM 42893.

Genus CORYNEPTERIS Baily 1860

(Explan. to Accomp. sheet 142 of the Maps of the Geol. Surv. of Ireland, p. 16, fig. 8)

Corynepteris was founded for unique fertile foliage placed with the leptosporangiate ferns. Their sporangia are united in sori with 6-8 sori situated along the axis. The axes are represented by the form genus *Zygopteris*. Zeiller (1883) created the genus *Grand Eurya* for fructifications similar to those included in *Corynepteris*, but *Grand Eurya* also included fructifications belonging to *Asterotheca*. Daber (1955) provided a new interpretation of *Saccopteris* which would have included *Corynepteris*, but Danze (1956) comments that Stur considered *Saccopteris* as not only a fructification, but a complete genus in the botanical sense, and therefore, *Saccopteris* should be placed in synonymy with *Corynepteris*.

Potonie (1899) proposed *Alloiopteris* for the sterile foliage, but according to Danze (1956) *Alloiopteris* and *Corynepteris* can now be united. However, Kidston (1923) states that "most probably the fossils placed in *Alloiopteris* are only sterile examples of members of the genus *Corynepteris*, but until their fructification is known, they cannot be placed in the latter genus." Therefore, new species of this type with unknown fructifications should be placed with *Alloiopteris* until their fructifications become known. Those species with known fructification may be properly assigned to *Corynepteris*.

Corynepteris angustissima (Sternb.) Némecj
Pl. 5, figs. 2, 3

- 1823 *Aspidium angustissimum* STERNBERG—Versuch einer geognostischen botanischen Darstellung d. Flora d. Vorwelt, v. 1, fasc. 2, p. 29, pl. 23, fig. 1a & b.
 1854 *Asplenites sternbergi* ETtingshausen—Die Steinkohlenflora von Radnitz, K. k. Geol. Reichsanst., Abh., v. 2, p. 42, pl. XX, figs. 2, 3.
 1899 *Alloiopteris sternbergi* POTONIE—Lehrbuch der Pflanzen Palaontologie, p. 139.
 1899 *Sphenopteris (Corynepteris) sternbergi* ZEILLER—Mem. Soc. Geol. France No. 21, p. 24, pl. 2, figs. 8, 9.
 1923 *Corynepteris (Zygopteris) sternbergii* KIDSTON—Mem. Geol. Surv. Great Brit. Paleont., v. 3, p. 301, pl. LXXIV, figs. 1, 5; pl. LXXVII, figs. 1, 2.
 1955 *Saccopteris sternbergi* DABER—Pflanzengeograph. Besopd. Karbonflora Zwickzu-Laquauer. Geologia Beih., No. 13, p. 22, pl. IV, fig. 2.
 1956 *Corynepteris angustissima* DANZE—Contribution L'etudes des *Sphenopteris*, fourgeres sphenopteridiennes; Etudes Géologiques, Houill. du Bassin du Nord et du Pas-de-calais, p. 325-331, pl. LII, figs. 4-6; pl. LIV, fig. 1, 2; pl. LV, fig. 3, 3a.

Discussion.—The French authors use *Corynepteris angustissima* which Sternberg figured as *Pecopteris*, and as Danze (1956) points out, it has pinnules similar to those for which Ettingshausen created *Asplenites sternbergi*. The Germans use *Alloiopteris sternbergi* designated by Potonie (1899) for this form. White (1899) created *Alloiopteris winslovii* for similar forms. *A. winslovii* has often been reported in North America, but according to Jongmans (1937) *A. winslovii* is merely a synonym of *A. sternbergi*. Thus we have three names with the specific differences appearing to be whether you speak French, German, or English. However, *Alloiopteris winslovii* may be a valid species, based on its fairly consistent larger size.

Corynepteris angustissima differs from *Corynepteris erosa* on smaller pinnules which have fewer and more rounded lobes or teeth.

Corynepteris angustissima has a wide distribution and is a readily recognized species. It has been reported from Asia Minor, Canada, central and western Europe.

This species ranges from Namurian B through Westphalian, although it is rare in the Namurian, becoming fairly abundant in the younger Carboniferous strata.

Figured specimen.—BYU 1481.

Genus RHODEA Presl ex Sternberg 1838
(Versuch der Flora der Vorwelt, v. 2, p. 109)

The genus *Rhodea* was proposed by Presl (1838) for sterile, fernlike forms which resemble *Sphenopteris*, but are separated from it by having more deeply incised, linear, decurrent, delicate pinnules containing a single vein which is not always visible. The segment is greatly reduced, giving the appearance of vascular strands surrounded by thin lamina. Kidston (1923) arbitrarily separated *Rhodea* from *Sphenopteris* on the basis of the width of the lamina that borders the single central vein of the segment.

Presl (1838) placed *Rhodea* together with *Hymenophyllites* in *Hymenophyllaceites*, and subsequently had it placed in a synonymy with *Hymenophyllites*. Stur (1879) reestablished it as a separate genus.

Kidston (1923) assigned the fertile forms to *Zeilleria*, *Urnapteris* and some species of *Telangium*. A. Carpentier (1929) reported a fructification for *Rhodea guthieri* and considered it a pteridosperm. Gothan and Weyland (1954)

placed *Rhodea* among the Sphenopteridaceae and among the pteridosperms, although they included the fern *Zeilleria frenzli*. Danze (1956) preferred limiting *Rhodea* to pteridosperms and reserved *Zeilleria* for the ferns. This further complicates this group by mixing fertile and sterile forms. *Rhodea*, like *Sphenopteris*, is a heterogeneous genus and should perhaps be handled the same way by separating the species as their fructifications are discovered.

Rhodea was originally considered to be restricted to the Lower Carboniferous; but, although it is more common in the Mississippian and Lower Carboniferous rocks, species belonging to this genus also occur stratigraphically higher.

Rhodea vespertina Read
Pl. 9, fig. 3

1955 *Rhodea vespertina* READ—Floras of the Pocono Formation and Price Sandstone, etc., U. S. Geol. Surv. Prof. Paper 263, p. 22; pl. 3, figs. 3, 4; pl. 4, figs. 1-4, pl. 16, fig. 6.

Discussion.—Read (1955) reports this species as the most widely distributed and most abundant plant species in the Lower Mississippian of the Appalachian trough. Arnold and Sadlick (1962) report a *Rhodea* sp. which they suggest may be conspecific. Their figured specimen is similar to those from the Manning Canyon Shale.

Figured specimen.—USNM 42897.

Genus SPHENOPTERIDIUM Schimper 1874
(Traite Pal. Veg., v. 3, p. 488)

Sphenopteridium is a form genus which includes fern-like foliage with laterally dichotomizing fronds which are simply pinnate. Ultimate pinnae of these fronds are sessile or slightly petioled. They are largely oval near frond base, becoming more elongate and lanceolate near frond center. Pinnules are short and subtrilobed to trilobed. They are wedge-shaped with truncated or rounded apices. Veins parallel the margins of the pinnule and dichotomize.

Foliage attributed to this genus was initially described by Goeppert (1852) under *Cyclopteris* and attached to the neuropterids. Schimper (1874) re-described them under *Sphenopteridium* and placed them with sphenopterids. Potonie (1899) and Gothan and Weyland (1954) have placed this genus with Archeopteridales. Gothan and Weyland (1954) placed *Sphenopteridium* with pteridosperms and assign *Calathiops*-like fructifications to this genus.

Sphenopteridium differs from *Sphenopteris* because its veins radiate from the pinnule base and it lacks a distinct midrib.

Sphenopteridium dissectum (Goepp.) Schimper
Pl. 9, fig. 5

1852 *Cyclopteris dissecta* GOEPPERT—Foss. Fl. des Ubergangesgebirge Nova Acta Acad. Caes. Leop. Car. Nat. Cur., p. 161, taf. XIV, fig. 3.

1874 *Sphenopteridium dissectum* (GOEPP.) SCHIMPER—Traite Pal. Veg. v. 3, p. 488, pl. 107, fig. 12.

1875 *Archeopteris dissecta* (GOEPP.) STUR—Culmflora I, Abh. k. k. Geol. Reichsanst., v. 8, p. 61.

1899 *Sphenopteridium dissectum* (GOEPP.) SCHIMPER, POTONIE—Lehrbuch der Pflanzen Palaeontologie, p. 130, text-fig. 119.

1962 *Diplothemema subdecipiens* WHITE, TIDWELL—Brigham Young University Geol. Studies v. 9(2), p. 97, pl. 3, fig. 6.

Discussion.—*Sphenopteridium dissectum* differs from *Sphenopteridium pachyrrhachis* (Goepp.) Schimper by having narrower ultimate pinnae and from *Sphenopteridium colombianum* (Schimper) Potonie by having more triangular pinnules.

The specimens of *Sphenopteridium dissectum* from the Manning Canyon Shale are similar to the polymorphous *Diplothemema subdecipiens* White which has elongated, lobed, truncated to rounded pinnules; but they differ from it on the midrib which *D. subdecipiens* has and *S. dissectum* lacks.

Sphenopteridium dissectum is considered to be Lower Carboniferous in age. Danze-Corsin (1960) gives its age as Dinantian (Mississippian). Daber (1959) states its age as Middle Visean or Upper Mississippian.

Figured specimen.—USNM 42895.

Sphenopteridium zaitzeffii sp. nov.

Pl. 7, fig. 6

1962 *Sphenopteris* (*Diplothemema*) *spinosa* GOEPPERT, TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 97, pl. 3, fig. 5.

Description.—Tripinnate (?). Pinnae flabellate, deltoid to lanceolate, alternate, attached by broad, although rather constricted footstalk. Pinnules constricted above, decurrent below on the pinnae rachis, attached with a somewhat constricted base, alternate, deltoid, flabellate, divided into two spreading lobes which in turn divide into three to four cuneate segments with obtuse apices, most are entire. Venation: veins often obscure in the lamina. No midvein is present. Veins enter pinnules as a cluster from the rachis, dichotomously divided to fill each lobe and segments with finer veins.

Discussion.—This form from the Manning Canyon Shale has some similarities with *Diplothemema furcatum* (= *Palmatopteris furcata*), but differs from it by having more rounded and spread-out pinnules, and also in the venation. *D. furcatum* has a single vein per lobe.

Sphenopteridium zaitzeffii varies from the other *Sphenopteridium* species by its more flabellate shape of both pinnules and pinnae, and its somewhat broader base. This species was named for the author's colleague, Dr. James B. Zaitzeff of the Office of Naval Research.

Figured specimen.—Holotype: USNM 42896.

Genus ADIANTITES Goeppert 1836
(Die foss. farnkrauter, p. 216, 217)

This genus has a rather confused history. According to Danze (1956), Goeppert (1836) had originally placed his new genus with the neuropterids, and had used it again in 1852 for a division of *Cyclopteris* in opposition to the division of *Neuropteroides*. White (1904) stated that Goeppert had originally proposed *Adiantites* to include species of *Ginkgo*. Geintz (1854) and Zeiller (1883) both used *Adiantites* in synonymy with *Neuropteris* and *Cyclopteris*.

Schimper (1869) proposed the new genus *Adiantides* for foliage similar to Goeppert's *Adiantites*. *Adiantides* was subsequently placed in synonymy with

Adiantites by Kidston (1887) who had also created *Macrosphenopteris*, a closely related genus.

Adiantites, as presently used, appears to be synonymous with *Aneimites*. Ettingshausen (1865) raised the subgenus *Aneimites*, described by Dawson (1860), to a generic level. The usage of *Aneimites* as a genus persists in North America. White (1904) rejected *Adiantites* as being "untenable in its restricted application as employed by Schimper, Stur, and others and as now generally recognized." He stated that "the emended genus is indistinguishable from the American plant to which Dawson gave the name *Aneimites*" and concluded to use *Aneimites* rather than *Adiantites*.

Danze (1956) comments that the European paleobotanists have dropped *Aneimites* into synonymy with *Adiantites*. To illustrate how confusing this has become, Read and Mamay (1964) mention "*Aneimites*-like *Adiantites*."

Gothan and Weyland (1954) describe *Adiantites* as a valid genus, and retained Potonie's (1899) concept of placing it in the Archaeopteridales.

It would seem that *Adiantites* should be conserved over *Aneimites*.

Adiantites (*Wardia*) *tenuifolius* (Goepp.) Tidwell, comb. nov.
var. *difoliolatus* (White) Tidwell, comb. nov.
Pl. 3, fig. 2

1943 *Aneimites* (*Wardia*) *tenuifolius* (GOEPP.) var. *difoliolatus* WHITE—U. S. Geol. Surv. Prof. Paper 197-C, p. 101, pl. 36, figs. 8, 11.

1962 *Aneimites* (*Wardia*) *tenuifolius* (GOEPP.) var. *difoliolatus* WHITE, TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 98, pl. 2, fig. 4.

Discussion.—Specimen very small and delicate, having both difoliate and trifoliate lobation. White (1943) reports this species as being Lower Pennsylvanian in age.

Figured specimen.—USNM 42898.

Genus DIPLOTHMEMA Stur 1877

(Die Culmflora II, Abh., k. k. Geol. Reichsanst., v. 8, p. 130 (236).)

Stur (1877) proposed *Diplothmema* to include many unrelated species which he regarded as an absolutely natural genus. White (1943) in his discussion of this genus enumerates the complications and restrictions imposed upon it by various authors which have resulted, in White's opinion, in a genus without any of its original components. He concludes that *Diplothmema* should include not only the round-pinnuled species placed in it by Zeiller (1888), but other round-pinnuled species with bipartitely divided, but not distinctly quadripartite fronds, which are not definitely referable to *Mariopteris* as originally defined.

Corsin (1932) pointed out that he could see no fundamental differences between the frond structure of *Diplothmema* and *Mariopteris* and that they were intergradational.

Danze-Corsin (1953) reserved the term *Diplothmema* "(diplo = two, thmema = section)" for those plants whose frond is definitely composed of two symmetrical sections bearing the primary rachis and lacking a quadripartite aspect. She considered the primary rachis in general to be naked, but occasionally partially covered with pinnae. The pinnae of this genus have sphenopteroid pinnules.

White (1943) in his synopsis states that *Diplothemema*, *Mariopteris*, and *Palmaopteris* were similar in their major structural features and habit of growth. They were apparently climbers or lianas with relatively slender, flexuous, aerial trunks or axes.

Diplothemema trifoliolata (Artis) Stur
Pl. 3, fig. 5

1825 *Filicites trifoliolatus* ARTIS—Antediluvian Phytology, p. 11, pl. XI.

1828 *Sphenopteris trifoliolata* (ARTIS) BRONGNIART—Prod. d'une Hist. des Veg. Foss., v. 8, p. 50.

1880 *Pseudoplectopteris trifoliolata* (ARTIS) LESQUEREUX—Coal Flora, 2nd Geol. Surv. Pennsylvania Rept. P., v. 1, p. 217.

1875 *Diplothemema trifoliolata* (ARTIS) STUR—Culmflora I, Abh. k. k. Geol. Reichsanst., v. 8, p. 346, pl. 19, figs. 1-4.

1943 *Diplothemema trifoliata* (ARTIS) STUR, WHITE—U. S. Geol. Surv. Prof. Paper 197-C, p. 98, pl. 32.

1962 *Diplothemema trifoliolata* (ARTIS) STUR, TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 96, pl. 3, fig. 7.

Discussion.—The pinnules of *D. trifoliolata* are smaller and more distant than those of *D. obtusiloba* Brongt. and the plant is more lax. The trifoliate segmentation of the pinnules frequently occurs on specimens of *D. obtusiloba*, but these are probably dependent upon their position within the frond. This has led to some possible erroneous conclusions (Kidston, 1923). Kidston (1923-25) doubted that *Sphenopteris trifoliolata* existed on continental Europe but that the various authors using this taxon were actually misidentifying *S. obtusiloba*.

Kidston (1923-25) reports *S. obtusiloba* (= *D. obtusiloba*) as occurring in Westphalian.

Figured specimen.—USNM 42890.

Diplothemema obtusiloba (Brongt.) Stur
Pl. 5, fig. 5

1829 *Sphenopteris obtusiloba*, BRONGNIART—Prod. d'Hist. Veg. Foss. I, p. 204, pl. LIII, fig. 2.

1877 *Diplothemema obtusilobum* (BRONGT.) STUR—Culmflora II, Abh. k. k. Geol. Reichsanst., v. 8, p. 230.

1943 *Diplothemema obtusiloba* (BRONGT.) STUR, WHITE—U. S. Geol. Surv. Prof. Paper 197-C, p. 97, pl. 30, fig. 4; pl. 35, figs. 7, 9.

1962 *Diplothemema spectabilis* WHITE, TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 96, pl. 3, fig. 8.

1962 *Diplothemema obtusiloba* (BRONGT.) STUR, TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 97, pl. 3, fig. 9.

Discussion.—The similarity between this form and *D. trifoliolata* (Artis) Stur was discussed under the latter species.

Figured specimen.—USNM 42889.

Diplothemema arnoldi Stockmans & Williere
Pl. 3, fig. 1

1956 *Diplothemema arnoldi* STOCKMANS & WILLIERE—Vegetaux de la Zone d'Oupeye d'Argenteau-sarolay. Pub. Assoc. Etud. Paleont. No. 25, pl. A.

Discussion.—A description of *Diplothemema arnoldi* is as follows: Penultimate pinnae about 2 cm wide. Rachis appears to be slightly winged. Ultimate pinnae;

parallel borders, $10+$ mm long, 4-6 mm wide, alternate, normal to the rachis. Pinnules: triangular, some more or less circular, divided into lobes which are subdivided into digitate segments. The number of lobes per pinnule diminish to two in direction of pinnae-apex. Venation: midvein distinct, divides twice supplying each digitate segment and lobe with one lateral vein.

This is the first reported occurrence of this species in North America, and perhaps the first outside of d'Argenteau-Sarolay where it was originally described. Stockmans and Williere (1956) report this form from the "Zone d'Oupeye" which is equivalent to lowermost Westphalian A.

Figured specimen.—USNM 42891.

Genus MARIOPTERIS Zeiller 1878

(Explication Carte Geol. France v. 4 (Atlas), (text, 1879), p. 68)

Mariopteris was created by Zeiller (1878) as a genus to include certain ferns which, among other characters, are distinguished by a peculiar dichotomizing of their pinnae.

The frond of *Mariopteris* is composed of quadripartite pinnae, that is, they are divided into four parts. The primary pinnae are attached to the rachis by a naked stalk which bifurcates, dividing the frond into two equal segments. These two, short, primary petioles are also naked, and again divide, forming the secondary pinnae. On the secondary pinnae are borne the tertiary pinnae, which in turn support the pinnules.

The pinnules of *Mariopteris* are pecopteroid to sphenopteroid, generally subtriangular, with complete basal attachment or constricted at their base. They are always decurrent and sometimes confluent. The pinnules are entire, lobed, or with margins undulated, or more or less toothed. The basal pinnule on the posterior side is usually distinctively larger than the others and divided into two prominent lobes which may be entire or dentate.

The nervation is sphenopteroid with oblique ascending veins. It is generally immersed and often difficult to trace. The midvein extends to near the apex of the pinnule. The secondary or lateral veins arise acutely and divide once or twice before reaching the margins.

The fructification of *Mariopteris* is at present essentially unknown. Gothan (1935) reported *Calathiops bernhardti* as having affinity with *Mariopteris acuta*. Danze-Corsin (1953) accepts this as confirming the hypothesis that *Mariopteris* belongs to the pteridosperms. Daber (1955) states the clarification of this relationship has not been demonstrated and that the type of fructification belonging to *Mariopteris* is still unknown, although *Mariopteris* is undoubtedly a pteridosperm.

White (1943) discusses the difficulty of differentiating *Mariopteris* species due to the variation of size and form of the pinnules in different positions within the quadripartite frond and in younger as compared to older fronds of the same plant. The species also are very intergradational. White thought one could distinguish the various species by arranging them according to their stratigraphic position. He considered the forms to be confined to and even to be characteristic of these stages. To do this, however, would require very fine and subtle differentiation in order to divide the long-ranging species. To use these forms stratigraphically would require an expert to differentiate these subtle differences

between the newly created species. These differences also may not be of sufficient magnitude on which to base a specific distinction.

Mariopteris muricata (Schloth.) Zeiller

Pl. 5, fig. 4; Pl. 9, fig. 6

1836 *Pecopteris muricata* BRONGNIART—Prod. d'Hist. Veg. Foss. I, p. 352, pl. XCV, figs. 3, 4.

1880 *Pseudopecopteris muricata* (BRONGT.) LESQUEREUX—Coal Flora, 2nd Geol. Surv. Pennsylvania Rpt. P., v. 1, p. 203, pl. XXXVII, fig. 2.

1886-88 *Mariopteris muricata* (SCHLOTH.) ZEILLER—Flore fossile du bassin houillier de Valenciennes, Étude Gites Minéraux de France, pl. XX, fig. 2, 3; pl. XXI, fig. 1.

1953 *Mariopteris muricata* (SCHLOTH.) ZEILLER, DANZE-CORSIN—Les *Mariopteris* du Nord de La France, Études Geol. Houill. du Bassin du Nord et du Pas-de-calais, p. 122-135, pl. XXII to XXXVIII.

Discussion.—The pinnules of *Mariopteris muricata* are toothed, but this dentation presents a peculiar aspect in that it is irregular. The typical *M. muricata* pinnule will have two to six teeth which are slightly developed except for the basal pinnule which is relatively well-developed. The pinnules of *M. muricata*, as can be seen in Pl. 9, fig. 6 are clearly symmetrical due to the uneven development of the teeth with those below being better developed than the teeth above.

Mariopteris muricata is very similar to *Mariopteris acuta* and *Mariopteris nervosa*. Lutz (1938) described the fundamental difference between *M. muricata* and *M. acuta* as the stratigraphic level in which one finds these plants. White (1899) proposed much the same difference for *M. muricata* and *M. nervosa*. He confined *M. muricata* to the Pottsville series, while *M. nervosa* characterized the Allegheny series, rarely being found within and near the top of the Pottsville series.

Kidston (1923-25) distinguished *M. nervosa* from *M. muricata* by the more or less triangular or sub-triangular form of its decurrent pinnules, with the pinnules of *M. nervosa* being invariably united and with the exception of the posterior basal pinnule and occasionally the corresponding pinnule on the anterior side, they rarely have lateral lobes.

The definition of *Mariopteris nervosa* as given by Danze-Corsin (1953) illustrates the difference between *M. nervosa* and *M. muricata* as basically: *M. nervosa* has entire margins and the margins of *M. muricata* are toothed.

Danze-Corsin (1953) separates *M. muricata* from *M. acuta* by the pinnules of *M. muricata* (1) being closer on the rachis; (2) being broader and slightly contracted at the base; (3) having slightly fewer teeth; (4) having more apparent venation, illustrating clearly the finer secondary veins; and (5) having its tertiary pinnae slightly distant. The fourth difference however, is dependent largely upon preservation. If the preservation of both is excellent, then the clearness of the venation may be a specific difference. Kidston (1923-25) mentions the venation of *M. muricata* as being immersed.

In general, *M. muricata* appears wider and thicker than *M. acuta*.

The specimen illustrated on Pl. 5, fig. 4, was loaned to the author by Dr. C. A. Arnold of the University of Michigan. This specimen exhibits pinnules on the upper portion of a secondary pinnae. The pinnules are more elongated with rounder apices than those of the ultimate pinnae figured on Pl. 9, fig. 6. The venation is the same for both specimens.

Mariopteris muricata is considered to be essentially a Westphalian form, rarely extending down into the Namurian; however, Carpentier (1907) reports it from his 1B and 2A zones which are Upper Namurian A. Crookall (1934) reports one specimen from the Lanarkian of Great Britain.

Figured specimen.—USNM 42887.

Genus *NEUROPTERIS* Brongniart 1822

(Memoirs du Museum d'Histoire Naturelle, v. 8, p. 233)

Neuropteris gigantea Sternberg

Pl. 3, fig. 3

1821 *Osmunda gigantea* STERNBERG—Versuch der Flora der Vorwelt, v. I, fasc. II, p. 33, pl. XXXII.

1825 *Neuropteris gigantea* STERNBERG—*ibid.*, v. I, fasc. IV, p. XVI.

1962 *Neuropteris gigantea* STERNBERG, TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 93, pl. 1, fig. 7.

Discussion.—*Neuropteris lunata* White and *N. gigantea* are very similar. *N. lunata*, however, has more narrow pinnules than *N. gigantea* which are proportionately less acute. The curvature, when present in *N. lunata*, is more uniformly distributed, slightly crescentic, through the whole length rather than being expressed as an upward turn near the apex (Crookall, 1959).

The material from the Manning Canyon Shale applicable to the species appears to have broader pinnules and more falcate shape than pinnules of *N. lunata*.

Neuropteris gigantea has been recorded from the Westphalian A through D (Crookall, 1959). Gothan and Remy (1957) show this form to be distributed from Namurian C to Westphalian D definitely, and possibly into Namurian B.

Figured specimen.—USNM 42899.

Neuropteris cf. *pocabontas* White

Pl. 5, figs. 4, 6

1900 *Neuropteris pocabontas* WHITE—U. S. Geol. Surv. 20th Ann. Rept., p. 888, pl. CLXXXIX, figs. 4, 49; pl. CXCI, figs. 5, 5a.

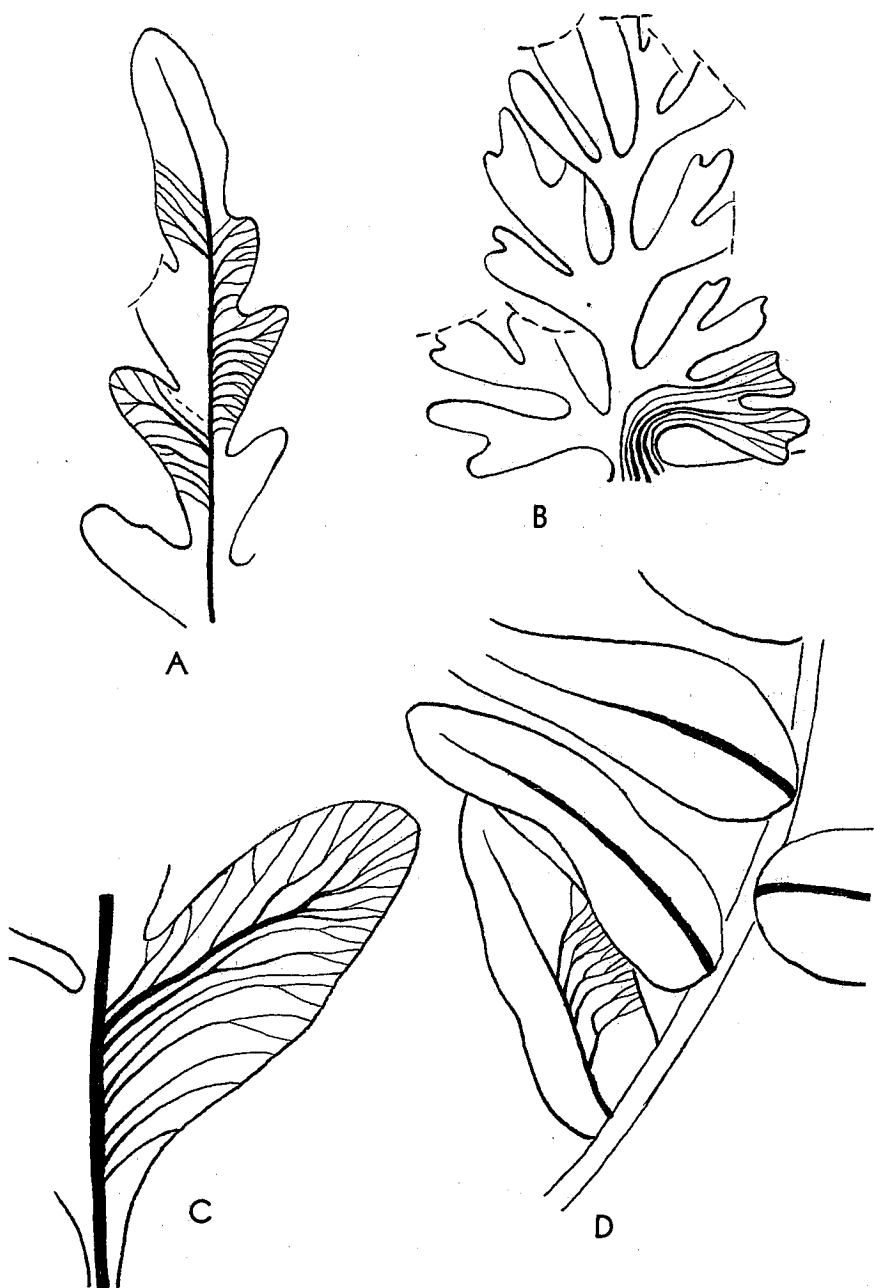
Discussion.—Specimens attributable to this species are small and often incomplete. They have the characteristic attachment and pinnule shape of *N. pocabontas* and the *Neuropteris* manner of lobing. *N. pocabontas* characterizes the lower Pottsville of the Appalachian region.

Figured specimen.—USNM 42900.

Neuropteris ampelina Tidwell, sp. nov.

Pl. 4, fig. 5

Description.—Frond: bi- or tri- (?) pinnate. Pinnae: alternate, right angles to rachis, but curving sharply upward, rachis flexuous, no terminal pinnules present. Pinnules: lanceolate, apex acute to pointed, rarely obtuse, asymmetrical base with single point attachment on the larger (mature) pinnules, pinnules nearer the pinnae apex have one-half basal attachment. Pinnules: 9-15 mm long, 3 mm wide, closely spaced, although gaps occur due to preservation, sometimes contiguous or overlapping, oblique, alternate, no small (young) pinnules present. Venation: midrib strong, raised, continuous from $\frac{3}{4}$ to near apex, decurrent.



TEXT-FIGURE 4.—A.— *Crossopteris utahensis* Tidwell, gen. and sp. nov. (5X). Terminus of a penultimate pinnae. B.— *Sphenopteridium zaitzeffii* Tidwell, sp. nov. (5X); C.— *Odontopteris* sp. (8X); D.— *Neuropteris ampelina* Tidwell, sp. nov.

Laterals: fine, close (54 per cm), arise acutely, strike margins generally at an oblique angle, sometimes right angles, after arching strongly and forking 2-3 times.

Discussion.—*Neuropteris ampelina* differs from *Crossopteris utahensis* in its finer venation, single point attachment and viney, lax habit. *N. ampelina* and *N. pocahontas* White are separated from one another on the finer venation, one-half basal attachment of some of its pinnules, and the more lax habit of *N. ampelina*.

Figured specimen.—Holotype: USNM 42901.

Genus CROSSOPTERIS Tidwell, gen. nov.

Description.—Tri- or quadripinnate forms with large triangular to broadly lanceolate pinnae. Pinnules: irregular, polymorphous. Small pinnules near pinnae apex decurrent with complete basal attachment, upper margins may be constricted forming an asymmetrical base. Upper margins in larger pinnules become constricted, creating a one-half basal attachment which may or may not be slightly decurrent and in some forms having single point attachment, pinnatilobate pinnules have single point attachment. Lobing is pecopteroid-alethopteroid. Venation distinct with midrib in larger pinnules continuous but not extending to apex of pinnule. Midrib lacking or very indistinct in smaller pinnules. Secondary veins arise acutely, arch strongly and strike margins obliquely, after forking 2-3 times, rarely 4. Subsidiary veins arise directly from rachis in pinnule with partial or entire basal attachment.

Type species.—*Crossopteris utahensis* Tidwell.

Discussion.—This genus is similar to *Neuropteris* in venation, general pinnule shape, size, and in nearly reaching single-point attachment in larger pinnules, but differs from it on several points.

(1) The manner of lobing. In *Crossopteris* the first larger ("mature") pinnules have undulating margins (Text-fig. 5b). These marginal indentations become deeper in each succeeding pinnule in the direction of the pinnae-base, until small ("young") pinnules are distinct from the preceding lobes. This pecopteroid manner of lobing is similar to *Pecopteridium armosi* and many *Alethopteris* species such as *A. helenae* Lesq. and *A. gibsoni* Lesq.

In *Neuropteris* the first lobe forms at the base of the larger ("mature") pinnule, and a lobe or small pinnule is added to each succeeding large pinnule in sequence towards the base of the pinnae.

(2) The attachment of the small ("young") pinnules. In *Crossopteris* they are strongly decurrent with contractions of their upper margins near the pinnae apex (text-fig. 5a) whereas in *Neuropteris*, and particularly in *N. pocahontas*, *N. obliqua*, and *N. schlehani*, these features are generally not as pronounced. *N. condrusiana* Stockmans and Williere has small pinnules near pinnae apex which are very similar to *Crossopteris* type; however, its larger pinnules are like *N. obliqua*.

Crossopteris varies from *Alethopteris*, *Pecopteris*, and *Neuraalethopteris* on venation and manner of attachment. The midvein is not continuous to the pinnule

apex as in *Alethopteris* and *Neuralethopteris*, and the secondary veins arch more strongly and are more oblique than in *Alethopteris* (Text-fig. 5c). Although the small pinnules have complete basal attachment (alethopteroid) in *Crossopteris*, the larger pinnules have either a single or nearly a single point attachment rather than a persistent complete basal attachment as in *Alethopteris* and *Pecopteris*.

The lanceolate or oblong, irregular, polymorphous pinnules of *Crossopteris* vary from the relatively uniform *Pecopteris* pinnules which have parallel or weakly convergent, lateral margins and rounded, rarely pointed apices. The venation of *Pecopteris* is also simple or grouped by twos, threes, and rarely fours.

Odontopteris is also close because the majority of the small pinnules in *Crossopteris* have odontopteroid venation, but *Crossopteris* varies from *Odontopteris* by its pecopteroid-alethopteroid lobing, and by having a distinct midvein in larger pinnules.

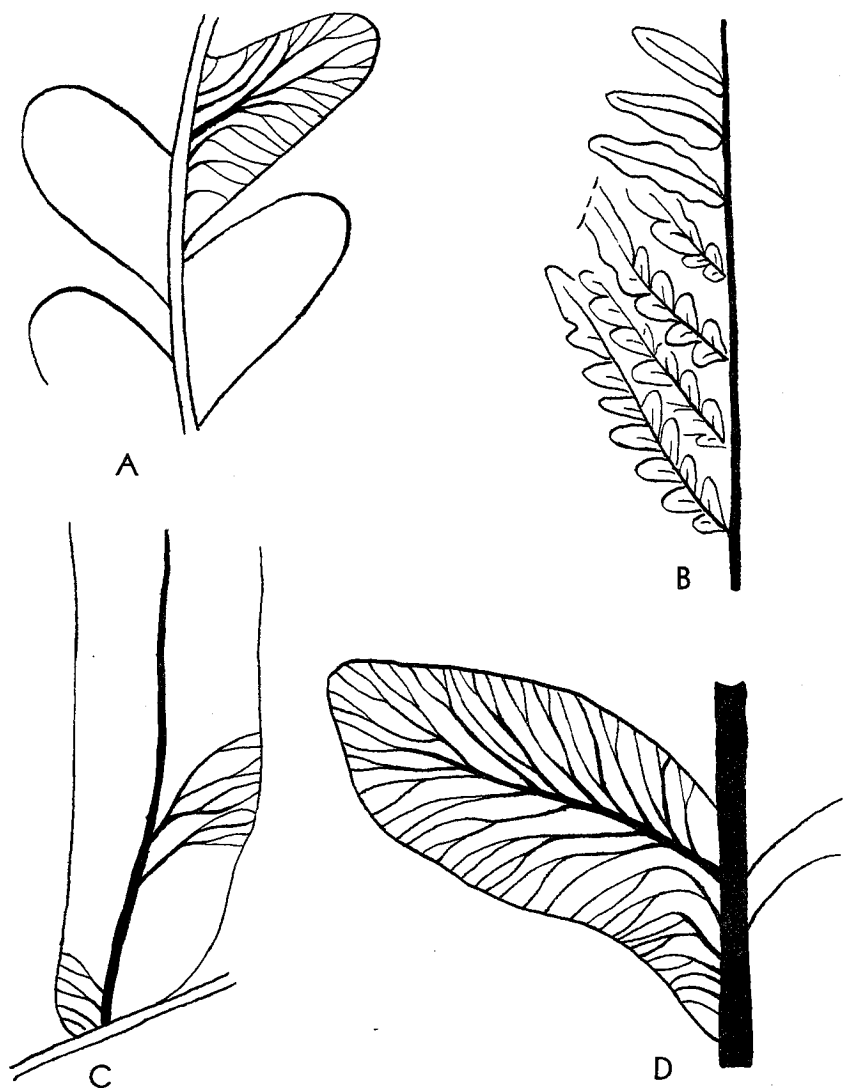
Basically, therefore, *Crossopteris* is characterized by (1) its pecopteroid-alethopteroid manner of lobing; (2) its complete (alethopteroid), one-half basal or single point (neuropteroid) attachment (Text-fig. 5c); and (3) its neuropteroid-odontopteroid venation.

This new genus was named in honor of Dr. Aureal T. Cross of Michigan State University for all of the advice and assistance he so willingly gave to this study.

Crossopteris utahensis Tidwell, sp. nov.
Pl. 3, fig. 7; Pl. 6, fig. 1; Pl. 10, fig. 8

Description.—Frond: tri- perhaps quadripinnate. Antepenultimate pinnae, large, triangular to broadly lanceolate, terminal portion missing. Penultimate pinnae: alternate, linear-lanceolate to triangular; mostly oblique, although on some specimens they appear normal to the rachis; margins taper rapidly to form an acute apex, close, contiguous, overlapping, some slightly distant. Ultimate pinnae: lanceolate, tapering somewhat to base, pinnatifid (undulating margins), attached with single point; base symmetrical, although some are obtuse, alternate, both oblique and normal to the rachis. Pinnules: generally small (5-30 mm long, 3-8 mm wide); irregular, polymorphous, alternate, rarely subalternate; oblique, few at right angles; distant (2 mm) with some close, contiguous or overlapping, laterally unequal. Pinnules nearer apex of pinnae elliptic, rarely ovate, decurrent with complete basal attachment, upper margins constricted forming an asymmetrical base. Pinnules of the upper margin become more constricted in each succeeding pinnule in direction of pinnae-base until margin is constricted to near midrib. Larger pinnules are both oblong and lanceolate with obtuse to acute apices, attachments are one-half basal, eventually acquiring single point attachment in pinnatifid pinnules. Pecopteroid-alethopteroid manner of lobing.

Venation: distinct, thin, regular. Midvein distinct in larger ("mature") pinnules but does not reach pinnule apex or lacking or very indistinct in smaller ("young") forms. Laterals arise acutely, arch, and reach margins obliquely (38 per cm) after forking 2-3 times, rarely 4. Laterals strike the margins of the pinnatifid pinnules at nearly right angles. Subsidiary veins arise directly from the rachis. Terminal pinnule: linear-lanceolate, laterally unequal, sublobate, apex generally acute, rarely rounded.



TEXT-FIGURE 5.—A.—*Crossopteris utahensis* sp. nov. (7X). These are small pinnules from the upper portion of a penultimate pinnae. Note complete basal attachment with lower margin decurrent and the odontopteroid venation. B.—*Crossopteris utahensis* sp. nov. Penultimate pinnae illustrating the $\frac{1}{2}$ basal attachment becoming single point attachment in the pennatilobate pinnules. C.—*Crossopteris utahensis* sp. nov. (5X). Lower portion of pinnule showing the $\frac{1}{2}$ basal attachment and the neuropteroid venation. D.—*Crossopteris utahensis* sp. nov. (7.5X). Small pinnule of an upper portion of a penultimate pinnae or a small ultimate pinnae. This pinnule would be situated below the small pinnules in Text-fig. 5A.

Discussion.—*Crossopteris utahensis* is the most abundant form in the Manning Canyon Shale. This species is comparable in abundance to *Neuropteris pocahontas* in the Lower Pottsville of the Appalachians and *Neuropteris schlehani* which characterizes the Lower Westphalian of Europe.

Neuropteris, *Alethopteris*, *Callipteris*, *Callipteridium*, *Odontopteris*, and perhaps *Pecopteris* are considered to have had a common ancestor (White, 1900). This concept came from the observance of the intermediate forms between these intergradational groups. *Neuropteris schlehani* is an example of one of these intermediate forms. It intergrades with *Alethopteris*, and at times is distinguished from *Alethopteris lonchitica* or *A. decurrens* only with difficulty.

A more primitive form of *Crossopteris*, perhaps the ancestor to *C. utahensis*, may have been the ancestor for *Neuropteris* which may in turn have given rise to *Callipteridium* and *Mixoneura* through the neurocallipterid *Neuropteris pocahontas*. This primitive form may have also given rise to *Alethopteris* through the neuroalethopterid form *Neuropteris uniformis* Lesq. or through a form similar to *Neuropteris schlehani*.

By grouping the veins slightly, evolving more uniform pinnules, and achieving complete basal attachment, the primitive form of *Crossopteris* may have become *Pecopteris*.

Jackson (1917) discussed a form he related to *Alethopteris* sp. from the Lower Pennsylvanian of Indiana. This form has an attachment of its pinnules similar to the attachment of *Crossopteris*, but differs from *C. utahensis* by its wider pinnules. Its venation is neuropteroid, and is represented by only the upper portion of a pinnae.

In the preliminary study of the Manning Canyon Shale flora, several fragmental specimens with decurrent pinnules were placed with *Alethopteris* (Tidwell, 1962). These specimens (*Alethopteris* B, C, and E) are now placed in the polymorphic form *Crossopteris utahensis* Tidwell.

Figured specimens.—Holotype: USNM 42902; paratypes: USNM 42903, 42904.

Crossopteris mcknightii Tidwell, sp. nov.
Pl. 7, fig. 5

1962 *Neuropteris* sp. A cf. *N. falcata*, TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 94, pl. 1, figs. 1, 9.

Description.—Frond: bipinnate, perhaps tripinnate. Penultimate pinnae: large, linear-lanceolate. Ultimate pinnae: incomplete. Pinnules: alternate, linear to linear-lanceolate (ratio 6:1), rather erect, distant, sessile, and decurrent small ("young") pinnules, base asymmetrical, some pinnules normal, others oblique to the rachis. Larger pinnules with one-half basal attachment, becoming attached with single point in the pinnatilobate forms. Apex pointed, tapering to a nearly rounded point in some. Smaller pinnules odontopteroid, triangular in outline.

Venation: distinct, midvein continuous to five-sixth or to near apex and decurrent on the rachis. Laterals: thick, close (30 per cm), arise acutely, arch rather strongly and meet the margins obliquely.

Discussion.—*Crossopteris mcknightii* varies from *Crossopteris utahensis* by the shape and size ratio of its pinnules, the more pointed shape of its apex, and its more strongly arched venation. The author (Tidwell, 1962) had original-

ly thought this variety had affinities with *Neuropteris falcata*, but *Crossopteris mcknightii* lacks the single point attachment except in pinnatilobe pinnules.

The species was named for my good friend and colleague, Dr. Kent McKnight of the National Fungus Herbarium.

Figured specimen.—Holotype: USNM 42906.

Crossopteris undulata Tidwell, sp. nov.

Pl. 4, fig. 3

Description.—Frond: at least bipinnate. Ultimate pinnae not complete. Pinnules: alternate, oblique to normal to the rachis, distant, oblong, acute to rounded apices, some pinnules curved, upper and lower margins parallel, both margins constricted at the base to form an asymmetrical base with single point attachment in the larger pinnules, pinnules are 18-25 mm long, 5-8 mm wide. Smaller pinnules odontopteroid with complete basal attachment. Alethopteroid-pecopteroid lobing.

Venation: midrib broad, distinct, often in relief, continuing to nearly five-sixth the pinnule length. Lateral veins very thin, fine, close, numerous (56-64 per cm), arising at an acute angle, arching strongly, forking 2-3 times, and striking margins at nearly right angles. Subsidiary veins direct from rachis in smaller pinnules.

Discussion.—This form is closely related to *C. utahensis* in its pinnule shape, size, small pinnule attachment and lobing but is distinctive in its finer, more numerous venation and single point attachment of the larger pinnules.

Figured specimen.—Holotype: USNM 42905.

Genus ODONTOPTERIS Brongniart 1828

(Memoirs du Museum d'Histoire Naturelle, v. 8, p. 234)

Odontopteris sp.

Pl. 2, fig. 1

Discussion.—This species is frequently encountered in collections of the Manning Canyon Shale. Although other odontopteroid forms are also encountered, they are not considered here because of the similarity to odontopteroid pinnules attached to *Crossopteris utahensis*.

This species is similar to *Odontopteris peyerimhoffi* Bertrand, but sufficient material is not available to be conclusive.

Figured specimen.—USNM 42907.

Order CORDAITALES

Genus CORDAITES Unger 1850

Paleobotanists have long considered the name *Cordaites* for leaves. Grand'Eury subdivided this genus on the basis of leaf characters. *Eu-cordaites* contained leaves which were broad, with rounded apex and with strong veins alternating with weaker. *Poa-cordaites* had long, linear, grass-like leaves; and *Dorycordaites* included broad-lanceolate leaves with acute apices and rather fine, equal veins.

Stockmans and Williere (1953) states that this system is not useful in practice and that these divisions should therefore be reunited with *Cordaites*, a

concept with which the author agrees. These divisions have been used as subgenera by some authors, but in general have been largely ignored.

Cordaites principalis (Germar) Geinitz
Pl. 10, fig. 1

1855 *Cordaites principalis* (GERMAR) GEINITZ—Vers. d. Steinhg. in Sachsen, p. 41, pl. XXI, figs. 1, 2.

1949 *Cordaites principalis* (GERMAR) GEINITZ, ARNOLD—Univ. Mich. Contr. Mus. Paleont., v. 7, p. 223, pl. XXX, figs. 1-3; pl. XXI, fig. 1.

1962 *Cordaites communis?* LESQUEREUX, TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 97, pl. 4, fig. 1, 2.

Discussion.—The chief distinguishing feature of this species consists of a number of strongly marked parallel veins running down the leaf. Between each pair of these strong veins one to five (usually three to five) finer, parallel veins are found. The venation on the Manning Canyon Shale specimens is irregular with nine veins per centimeter.

Cordaites principalis is a wide-ranging species from Namurian B into Lower Permian.

Figured specimen.—USNM 42908.

Cordaites sp. A
Pl. 9, fig. 8

Discussion.—Incomplete specimens, long, linear leaves without either apex or base. The venation is too indistinct for definite placement of these forms into species, or for determining their relationships to one another.

Figured specimen.—USNM 42909.

Cordaites sp. B
Pl. 9, fig. 9

Discussion.—Incomplete leaves of broad spatulate shape without a definite base or apex. Venation indistinct. Separated from the other *Cordaites* species on shape which is similar to the shape for *Cordaites lingulatus* Grand' Eury. The venation is too incomplete to make a positive identification.

Figured specimen.—USNM 42910.

Genus *CORDAIANTHUS* Grand'Eury 1877
Cordaianthus pseudofluitans Kidston
Pl. 10, fig. 6

1950 *Cordaianthus pseudofluitans* KIDSTON, FLORIN—Acta Horti Berg., bd. 15(6), p. 112.
1951 *Cordaianthus pseudofluitans* KIDSTON, FLORIN—Acta Horti Berg., bd. 15(11), pp. 307-9, figs. 15, 16.

Discussion.—*Cordaianthus pseudofluitans* is considered by Florin (1950) to be geologically older and more primitive than the other forms of *Cordaianthus*. They have widely projecting, elongated, lateral fertile appendages which are repeatedly forked by "cruciate dichotomy" and carry more than one ovule (or seed). Florin (1951) considered *Cordaianthus zeilleri* as the more modern

cordaitean fructification, and it is characterized by very short, unbranched, and uniovulate megasporophylls, concealed among the sterile scales of the flower axis. *C. pitcairniae*, *C. lindleyi*, and *C. longibracteatus* of Westphalian age are intermediate, resembling *C. pseudofluitans* in the appearance of their megasporophylls which are only occasionally bifurcated at their apices and are always uniovulate.

Florin (1951) gives a Westphalian age for *C. pseudofluitans*.

Figured specimen.—USNM 42911.

SEEDS, CUPULES, AND SPORANGIA

Genus *CORDAICARPUS* Geinitz 1862

Cordaicarpus elongatus (Newberry) Tidwell, comb. nov.

Pl. 7, figs. 3, 4; Pl. 9, fig. 4; Table V

1873 *Cardiocarpon elongatum* NEWBERRY—Geol. Surv. Ohio Paleont., v. 1, p. 373, pl. 43, fig. 5.

Description.—Seed: 15 mm long, 10 mm wide, cuneate to cordate with a slightly truncated base; widest portion of seed across center, tapering to an acute apex. Wings: thin around base, thickening toward apex, becoming emarginate near micropylar end, 3 mm wide near micropyle. Micropyle faint. Nucellus cordate, rounded base, acute apex.

Discussion.—This species is similar to *Cordaicarpus cordatus* but differs from it in size and shape. *C. elongatus* is widest near the middle of the seed, whereas *C. obtusum* is widest near the base.

Figured specimens.—USNM 42913, 42914, 42915.

Cordaicarpus globosus Tidwell, sp. nov.

Pl. 10, fig. 4; Table 5

Description.—Seed about 8 mm long, 7 mm wide; cordate in outline. Nucellus cordate with a rounded base and an acuminate apex. Wings somewhat uniformly surrounding base and thickening toward apex, emarginate near micropyle.

Discussion.—This species differs from *Cardiocarpon acuminatum* Jackson by having a more cordate outline and emarginate wings, and from *Cardiocarpon late-alatus* Lesq. by having a smaller wing, a broader nucellus, and a slightly smaller size.

Figured specimen.—Holotype: USNM 42912.

Cordaicarpus cordatus (Jackson) Tidwell, comb. nov.

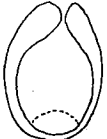


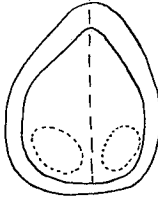
Pl. 8, figs. 4, 5, 7, 10; Table 5

1916 *Cardiocarpon cordatum* JACKSON—Proc. Indiana Acad. of Science, p. 426, pl. X, fig. 10.

1916 *Cardiocarpon obtusum* JACKSON—Proc. Indiana Acad. of Science, p. 426, pl. X, figs. 13-14.

Description.—Small, cordate seeds with rounded base and acute apex. 9-10 mm long and 5-7 mm wide. Nucellus cordate, rounded base and acute apex. Micropyle faint. Wings thin around base and expanding in direction of apex; emarginate near apex, 0.1 mm wide around base, becoming 2 mm wide near apex.

TABLE V

Name	<i>Cordaicarpus cordatus</i> (Jackson) Tidwell, comb. nov.	<i>Cordaicarpus globosus</i> Tidwell, sp. nov.	<i>Cordaicarpus elongatus</i> (Newberry) Tidwell, comb. nov.	<i>Cordaicarpus binotus</i> Tidwell, sp. nov.
Illus.				
	(1X)	(0.5X)	(0.75X)	(1X)
Shape	Ovate to cordate	Cordate	Cuneate-cordate	Ovate to cordate
Base	Rounded	Rounded	Semi-truncate	Cordate
Apex	Acute	Acute	Acute	
Size				
Length	8 mm.	8 mm.	15 mm	10-15 mm
Width	6 mm	7 mm	10 mm	10-11 mm
Nucellar Shape	Cordate	Cordate	Ovate-cordate	Cordate
Base	Rounded	Rounded	Truncated	
Apex	Acuminate	Acuminate	Acute	Pointed
Wings	Expanded toward apex.	Expanded toward apex.	Expanded toward apex.	Expanded toward apex.
Shape	Emarginate at apex. Thin around base.	Emarginate at apex	Emarginate	
Size	Base: 0.5 mm Apex: 1 mm	Base: 0.5 mm Apex: 1 mm	Base: 0 Apex: 2 mm	Base: 0.5-1 mm Apex: 2 mm
Misc.	No line as Jackson described. Small depression near base.	NC	NC	Two reniform depressions near base.
Stalked	NC	NC	NC	NC
Micropyle	Faint	Present	Present	NC

Discussion.—*C. cordatus* is one of the most abundant seeds in the Manning Canyon Shale flora. This form varies from *C. gracile* Jackson, which it closely resembles, by its smaller size, more acute nucellus, and more truncate base.

In examining the Jackson types at the National Museum, Washington, D. C., the author found no difference between his *C. cordatus* and *C. obtusum*. The specimen in Pl. 8, fig. 5, 7, appears to be the nucellus of *C. cordatus* with the wings missing.

Figured specimens.—USNM 42920, 42921.

Cordaicarpus jaysbulerii Tidwell, sp. nov.
Pl. 8, fig. 3; Pl. 9, fig. 7; Pl. 10, fig. 5; Table 6

Description.—Seed nearly round, although some specimens tend toward a cordate shape; broad, rounded base, slightly acute apex, 10-14 mm long, 7-12 mm wide. No wings are present.

Discussion.—This species is similar to *Cardiocarpon circulare* Lesq. and *Cardiocarpon subcirculare* Jackson in shape and size, but varies from both by not having a wing.

This species is named for my friend and colleague, Jay Shuler of Greenville, South Carolina.

Figured specimens.—Holotype: USNM 42916; paratypes: USNM 42917, 42918.

Cordaicarpus manningcanensis Tidwell, sp. nov.
Pl. 3, fig. 4; Table 6

1962 *Cardiocarpon* sp. A. TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 99, pl. 3, fig. 3.

Description.—Seed oval outline, truncate to cordate at base, 8 mm long, 7 mm wide with greater width near center. Nucellus cordate, cordate at base, apex acute. Inner and outer integuments appear to be present. Nucellus divided by a broad, flattened ridge extending from micropyle to base. Wings less than 1 mm at base, and about 2 mm wide at apex, sharply emarginate apex.

Discussion.—This species is similar to *C. moreiranum* White in shape, but is much larger with narrower wings. This species also lacks the acuminate apex which characterizes *C. minus* Newberry.

Figured specimen.—Holotype: USNM 42919.

Cordaicarpus binutus Tidwell, sp. nov.
Pl. 10, fig. 2; Table 5

1962 *Cardiocarpon* sp. B. TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 99, pl. 3, fig. 2.

Description.—Seed ovate to cordate outline. Size varies slightly from 15 mm long, 11 mm wide to 10 mm long, 10 mm wide for smaller specimens. Greatest width occurs slightly below center on some specimens and nearer the base on others. Base is cordate, although one specimen has an obtuse-rounded shape. Two reniform depressions occur near the basal walls of the nucellus. Wings are 0.5 to 1 mm wide near base and expanding to 1 to 2 mm at the apex. Nucellus cordate in outline, pointed above.

Discussion.—These specimens are separated from *C. cordatus* by the larger size and the two depressions near the base.

Figured specimen.—Holotype: USNM 42922.

Genus TRIGONOCARPUS Brongniart 1828
(Prod. d'Hist. Veg. Foss. I, p. 137)

The genus *Trigonocarpus* was established by Brongniart (1828) to include radially symmetrical seeds characterized by three longitudinal ribs. Hoskins and Cross (1946) restricted this genus to seeds known from external characteristics. This revision was necessary to avoid the conflict between seed compressions and impressions and those seeds which are preserved as petrifications.

Stockmans and Williere (1953) mention the difficulty in making specific determinations in *Trigonocarpus*-type seeds. They considered the arbitrary system of measurements as the best way of placing these seeds into species. It would seem, however, that these seed forms would be too intergradational as to size for this system to be of value.

Trigonocarpus noeggerathi (Sternb.) Brongniart
Pl. 10, fig. 10

1880 *Trigonocarpus noeggerathi* (STERNB.) BRONGNIART, LESQUEREUX—Coal Flora, 2nd Geol. Surv. Pennsylvania Rept. P., p. 584; pl. LXXXV, fig. 1.

1949 "*Trigonocarpus*" *noeggerathi* (STERNB.) BRONGNIART, ARNOLD—Univ. Mich. Contr. Mus. Paleont., v. 7, p. 214, pl. XXIX, fig. 3.

Discussion.—This specimen matches exactly a specimen from the Michigan Coal Basin identified as this species by Dr. C. A. Arnold.

Arber (1914) placed this species in a new genus *Schizospermum*. This is based upon the appearance of three valves at one end of a cast and a foramen or opening at the other. Neither of the features are observable in the specimen under consideration.

Stockmans and Williere (1955) found *Trigonocarpus* specimens resembling *T. noeggerathi*, *T. parkinsonii* Brongt., and *T. schultzeanus* Goeppert in the Zone de Bioul in the lowermost Namurian A of Belgium. They did not attribute these specimens to these species because as they stated, this would imply they were known. Their reasoning is that the plants to which the above *Trigonocarpus* species have been associated are not present in the beds from which their seed specimens were collected.

Figured specimen.—USNM 42923.

Trigonocarpus sp.
Pl. 2, fig. 3

Discussion.—The seed consists of a smooth sclerotesta and a portion of the micropyle of *Trigonocarpus* forma B as described by Arber (1914). The sarco-testa can be observed as a thin film partially embedded in the matrix surrounding the sclerotesta. The specimen here described is about twice the size of *Trigonocarpus parkinsonii* as illustrated by Arber (Pl. VI, fig. 2). The micropyle of *Trigonocarpus parkinsonii* is much longer and thinner than for the Manning Canyon Shale specimen.

This form is also similar in size and shape to *Trigonocarpus ampullaeforma* Lesq.

Figured specimen.—USNM 42924.

Genus *HOLCOSPERMUM* Nathorst 1914
(Zur. Foss. Flora der Polarländer, Teil I, Lief 4, p. 28.)

Holcospermum sp.

Pl. 10, fig. 11

1962 (?) *Cardiocarpus* sp. TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 100, pl. 1, fig. 4.

Description.—Seed: elongately elliptical to oblong, 10-20 mm long, 5-7 mm wide, broadest part occurs about middle, base and apex, rounded. Seed bears two prominent longitudinal ribs which gradually approach each other at base and apex. Fine striations or grooves appear between the ridges, traversing the length of the seed.

Figured specimen.—USNM 42925.

Genus *CORNUCARPUS* Arber 1914, emend. Tidwell
(Ann. Bot., v. 28, p. 88)

Arber (1914) originally included in this genus small seeds, not winged, triangular shaped, with a short stalk at one end and two well-marked, projecting "horns" from the other. Halle (1927) redefined the genus for "platyspermous seeds, with or without wings, provided at the apex with two acute projecting horns, which are at least as long as they are broad and more often longer."

The definition should perhaps be amended slightly to include all seeds with prominent horn-like or whip-like projections from their micropylar end, and other modifications of appendages from wing apices.

Cornucarpus longicaudatus Tidwell, sp. nov.
Pl. 10, fig. 9

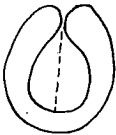
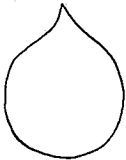
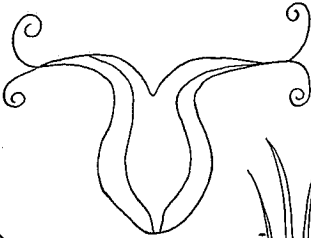
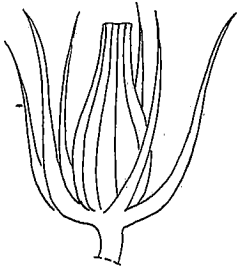
1962 *Cornucarpus* sp. A. TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 100, pl. 3, fig. 4.

Description.—Broad oval outline, base slightly rounded and pointed. 10 mm long, 8 mm wide with greatest width near center. Nucellus oblanceolate, obtuse base tapering to a cut apex. Micropyle extends into upper end of nucellus. Wings are 1 mm wide near base, increased to 1.5 mm near apex, and extending beyond into long, narrow "whip-like" projections. These projections are about 11 mm long and bifurcate near their tip into two dichotomies which curl back on themselves. Stalked base.

Discussion.—This species is unlike any species attributed to this genus. They differ from others by the long "whip-like" projections which often recurve on themselves. The purpose these projections may have served is uncertain.

Figured specimen.—Holotype: USNM 42926.

TABLE VI

Name	<i>Cordaicarpus manningscanensis</i> Tidwell, sp. nov.	<i>Cordaicarpus jaysbulerii</i> Tidwell, sp. nov.	<i>Cordaicarpus longicaudatus</i> Tidwell, sp. nov.	<i>Rigbyocarpus ebracteatus</i> Tidwell, gen. & sp. nov.
Illus.				
	(1X)	(1X)	(1X)	(1.5X)
Shape	Oval	Cordate	Broad oval	Elongate bottle shape
Base	Truncate- cordate	Rounded	Slightly rounded	
Apex	Acute	Acute	Pointed	Acute
Size				
Length	8 mm	12 mm	10 mm	8 mm
Width	7 mm	10 mm	8 mm	2 mm
Nucellus				
Shape	Cordate		Oblanceolate	
Base	Cordate	NC	Obtuse	NC
Apex	Acute		Cut	
Wings	Widening to- ward apex		Expands into narrow whip- like horns.	
Shape	slightly emarginate.	NC		NC
Size	Base: 1 mm Apex: 2 mm		Base: 1 mm Apex: 1.5 mm	
Misc.	Divided by broad, flattened ridge.	NC	Horns: 11 mm long. Bifurcate and recurved.	Seed: ribbed and surrounded by long bracts. Bracts: 10 mm long.
Stalked	NC	NC	Present	Present
Micropyle	Present	Faint	Present	NC

Genus RIGBYOCARPUS Tidwell, gen. nov.

Rigbyocarpus ebracteatus Tidwell, sp. nov.

Pl. 10, figs. 3, 7

Description.—Seed: small, 8 mm long 2 mm wide at the base, somewhat "jug-shaped," elongated, ribbed, apex cut. Bracts beginning near base of seed, reaching up around seed. Bracts are 10 mm long, tapering to a pointed apex. Small stalk at base which may have been point of attachment.

Discussion.—This seed is only found isolated. The bracts (Pl. 10, fig. 3) have been uncovered with the seed portion missing. The bracts are generally complete and attached to one another which would indicate the seed was not lost due to excessive movement. The mature seed may have been shed enclosed within the bracts but later broke away.

This genus is named for Dr. J. Keith Rigby of Brigham Young University, Provo, Utah, in recognition of his friendship, interest, and aid in this study.

Figured specimens.—Holotype: USNM 42927; paratype: 42928.

Genus LAGENOSPERMUM Nathorst 1914
(Zur Foss. Flora Polarländer, Teil I, Lief. 4, p. 29)

Nathorst (1914) introduced *Lagenospermum* for small, fusiform or elongated seeds, characterized by being completely enclosed within a cupule, and having six (?), well-marked longitudinal ribs or ridges.

Two species—*Lagenospermum sinclairi* Arber and *L. arberi* Nathorst are typified by a long stalk terminated with a cupule.

Lagenospermum discissium Tidwell, sp. nov.
Pl. 7, fig. 1

1962 *Pterispermotrobos* sp. A. TIDWELL—Brigham Young University Geol. Studies, v. 9(2), p. 100, pl. 4, fig. 9.

Description.—Seed, ribbed, with oblong or lanceolate outline, rounded base and acute apex. 6 mm long, 3.5 mm wide. The cupule which contained the seed is often present. The seed when missing leaves a depression in the cupule 4 mm long and 2 mm wide. The cupule has 5-6 "teeth" or lobes projecting toward apex. These often converge to form an acute apex. Each cupule terminates an equally dichotomized lateral branch.

Discussion.—This species from the Manning Canyon Shale resembles closely *Pterispermotrobos bifurcatus* Stopes from the Lower Pennsylvanian Fern Ledges of New Brunswick. The specimen described by Stopes (1914) was only a carbonized film in which structural details were indiscernible, and she was unable to determine whether the fructification was a seed or a sporangium. She therefore created the new genus *Pterospermotrobos* for fructifications of this nature.

The Utah specimens are smaller than *Lagenospermum imparirameum*, as described by Arnold (1939) from specimens collected from the Pocono Formation, and their bracts or lobes are not as widely spread. They also differ in the manner in which the stalks bifurcate. The stalks of *L. discissium* generally divide equally, whereas in *L. imparirameum* and *L. sinclairi* Arber, they are un-

equally divided. Lobes on *Lagenospermum kidstoni* are rounder than the Manning Canyon specimens. Its testa is smooth with only slight longitudinal ridges.

Nathorst (1914) established the genus *Lagenospermum* for fructifications resembling *Lagenostoma*, but lacking internal structure. Arnold (1939) suggests that the affinities of this genus are apparently with the lyginopterid pteridosperms. Carpentier (1925) found forms similar to *L. kidstoni* with *Sphenopteris striata*.

Figured specimen.—Holotype: USNM 42929.

Genus GNETOPSIS Renault 1884

(Cours de Bot. Foss., Tome IV, pls. XIX-XXII)

Gnetopsis was originally proposed for small petrified seeds and impressions which Renault believed belonged to some Cretaceous plant. Early paleobotanists used *Gnetopsis* to indicate affinity between these Paleozoic seeds and the Gnetales. Depape and Carpentier (1913) state that if this relationship actually existed, the cup-shaped organ containing several seeds would have been equivalent to two capillary leaves. They suggested the existence of several important characters which *Gnetopsis elliptica* Oliver and Salisbury has in common with the Lagenostomales. No affinities between *Gnetopsis* and the Gnetales have actually been established.

Seward (1917) proposed *Gnetopsis* as a transitional form between the Radiospermae and the Platyspermae. He does not explain the reason for this proposed relationship. *Gnetopsis* is a pteridosperm, but nothing is known of its vegetative parts.

Gnetopsis anglica Kidston

Pl. 2, figs. 4, 5

1917 *Gnetopsis anglica* KIDSTON, SEWARD—Fossil Plants, v. 3, p. 318, figs. 494 E, F, G, H.

Discussion.—The Utah specimens correspond closely to Seward's (1917) description and illustrations. He cites the size of *Gnetopsis anglica* as being 4 mm in length with appendages extending to 3.2 cm. The appendages do not show the hair-like structure which are a prominent feature on the French specimens.

The specimens figured and described by Stockmans and Williere (1953) are similar to the Manning Canyon Shale specimens in size and shape, but vary from them by having the hair-like attachment to the appendages and a longitudinal ridge traversing the seed body. They remark on the form described as *G. hexagona* by Depape and Carpentier (1913) which has six distinctive ridges as having been transferred into *G. anglica* by Seward (1917). They state that *G. anglica* varies according to the preservation of its envelope.

Depape and Carpentier (1913) reported their form (*G. hexagona*) from the Stephanian of Commeny. Stockmans and Williere (1953) report their specimens of *G. anglica* from Namurian B.

Figured specimen.—USNM 42930.

Genus TELANGIUM Benson 1904

Stur (1875), Kidston (1887), and others described under the name *Calymmatotheca* impressions which they considered to be sporangia. These in-

cluded the species *C. affine* and *C. bifida*. Because *Calymmatotheca* had been originally applied to fossil seeds, Benson (1904) concluded that sporangia should not be included in it. Therefore, she proposed the name *Telangium* for certain petrified synangia from the Lower Coal Measures and included *T. affine* and *T. bifidum*. She considered *Telangium* to be applicable to microsporangia of a pteridosperm, possibly *Lyginopteris*.

Seward (1917) noted the similarity of *Telangium* and *Crossotheca*, and recalls Scott's (1908) interpretation that *Telangium* cannot be generically separated from *Crossotheca*. Kidston (1905) regarded *Telangium scotti* Benson as a pteridosperm microsporangiate structure, but not related to *Lyginopteris*. He differentiated *Telangium* from *Crossotheca* on the basis of the presence of a single locule in *Telangium* as compared to the double locule of *Crossotheca*. Later he (1923) also noted that the microsporangia of *Telangium* stand upright on the rachis, whereas in *Crossotheca*, they are attached below.

Walton (1931) deplored the practice of including impressions and structureless compressions as well as petrifications for which the genus has been originally proposed. He expressed the opinion that a new genus should be created for impressions and structureless compressions, especially for the specimen of fructification recorded by Carpentier for *Sphenopteris striata*.

Benson (1936) reported *Telangium affine* and *T. bifidum* as being ovular apparatus belonging to *Sphenopteridium* and transferred them to the genus *Clathriops*. This interpretation has essentially been ignored by subsequent writers. Andrews (1961) mentions collecting a large tulip-shaped fossil (*Megatheca thomasi*) associated with *Telangium* foliage. He indicates the possibility of this form being the same as the petrified seed-bearing organ *Clathropermum scotium* collected by Walton from Lower Carboniferous of Scotland.

Telangium affine (L. & H.) Benson
Pl. 4, fig. 2

1831 *Sphenopteris affinis* LINDLEY AND HUTTON—The Fossil Flora of Great Britain, v. 1, pl. 45.

1887 *Calymmatotheca affinis* (L. & H.) KIDSTON—Trans. Roy. Soc. Edinburgh, v. 32, p. 145, pl. IX, figs. 18-22.

1904 *Telangium affine* (L. & H.) BENSON—Ann. of Bot., v. 18, p. 164, pl. XI, fig. 12, text-fig. 33.

1936 *Clathriops affinis* BENSON—New Phytologist, v. 34, p. 233-237, pls. V, VI, text-figs. 1, 29.

Discussion.—*Telangium affine* is known from the Lower Carboniferous of Europe. Bell (1938) described some sterile foliage from Canso Group which he attributed to this species. *T. affine* may possibly have been borne on stems assigned to *Tetrastichia* (Andrews, 1961).

Figured specimen.—USNM 42931.

Genus AULACOTHECA Halle 1933

This name was proposed for elongated, cylindrical or narrowing club-shaped, seed-like, spore-bearing bodies with marked longitudinal furrows and ridges. The spores from *Aulacotheca* are of the *Whittlesey* type.

Hemingway (1941) reports that these spores are large, smooth, oval bodies with a longitudinal germinal slit and vary in size from 100 to 300 microns, de-

pending upon the species represented. These spores are larger than those previously reported for pteridosperms which rarely exceed 50 microns in diameter. Hemingway therefore proposed that perhaps two distinctive families of pteridosperms are represented.

The type of pteridosperm to which *Aulacotheca* belongs has not been decided. Hemingway (1941) reported that it was invariably found associated with the fronds of *Alethopteris*, usually of the *A. lonchitica* group. Dix (1932a) recorded a similar form, later named *Aulacotheca dixiana* by Hemingway, as being attached to *Neuropteris schlehani*. Hemingway (1941) reported that they were not attached, but rather the foliage and carpons in falling close together simulated organic connection. However, this association supports the concept that *Aulacotheca* is the microsporangiate organ of certain members of the Medullosaceae.

Aulacotheca has not been found closely associated with any particular foliage type in the Manning Canyon Shale. *Alethopteris lonchitica* and definite *Neuropteris schlehani* have not been uncovered as yet. Therefore, *Aulacotheca* may have also occurred on other pteridosperm types.

Aulacotheca campbellii (White) Halle
Pl. 8, fig. 2

1900 *Whittleseya campbellii* WHITE—U. S. Geol. Surv. 20th Ann. Rept., p. 905, pl. CXC, figs. 9-11.

1933 *Aulacotheca campbellii* (WHITE) HALLE—K. Svenska. Vet. Akad. Handl., v. 12(6), p. 20, 39.

1949 *Aulacotheca campbellii* (WHITE) HALLE, ARNOLD—Univ. Mich. Cont. Mus. Paleont., v. 7, p. 207, pl. XXIV, figs. 4-6.

Discussion.—A description of the specimens from the Manning Canyon Shale is as follows: compressions, elongated, companulate male spore-bearing structure, terminal position broad with parallel margins, eventually tapering to a pointed attachment. "Tubes" long and narrow and overlap because of compression. Six lobes or "apices" at the terminal end give the appearance of six locules. No spores observed.

Halle (1933) mentioned that he was certain *Whittleseya campbellii* White from the Pottsville Formation of the Anthracite Coal Basin was attributable to this genus, although he had not seen any specimens. Arnold (1949) makes definite comparisons for material from Michigan. Arnold also discussed the variation in size of this species. Arnold reports White as stating that the smaller sporocarps generally occur in the lower horizons of the Pottsville, whereas the larger forms are found closer to the top.

Jongmans (1937) listed *Aulacotheca* from two localities in the Pocahontas coal series and one from the New River Series.

Figured specimen.—USNM 42932.

Aulacotheca hemingwayi Halle
Pl. 8, fig. 8

1933 *Aulacotheca hemingwayi* HALLE—K. Svenska Vet. Akad. Handl., v. 12(6), p. 36, pl. 8, figs. 1-16.

1941 *Aulacotheca hemingwayi* HALLE, HEMINGWAY—Ann. Bot. N.S., v. 5, p. 198, pl. V, figs. 1-9.

Discussion.—The *Aulacotheca* specimens from Utah referred to *A. hemingwayi* were placed with this species because of their size and shape. The size range of the Utah specimens is close to the range outlined for *A. hemingwayi* by Arnold (1949). He gives the size for this species as 4.5-5.5 mm x 28-30 mm.

A. hemingwayi is separated from *A. elongata* (Kidston) Halle on size and its more prominent ridges. The Utah specimens have a more truncated apex.

Jongmans (1937) reports *A. hemingwayi* from Pocahontas coal seams 1-3 which he places in Namurian B. He states that from White's figures, he supposes *A. campbelli* should be placed with *A. hemingwayi* with White's specific name having priority. Darrah in a subnote in Jongmans' paper thinks they are distinct because *A. hemingwayi* has "a rather broader aspect and a somewhat different ornamentation."

Figured specimen.—USNM 42933.

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