A LOWER PENNSYLVANIAN FLORA FROM UTAH AND ITS STRATIGRAPHIC SIGNIFICANCE

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ABSTRACT

A LOWER PENNSYLVANIAN FLORA FROM UTAH AND ITS STRATIGRAPHIC SIGNIFICANCE

by

William D. Tidwell

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-six genera and sixty-eight species. Thirteen new species and two new genera; *Crossopteris* and *Rigbyocarpus*, are described. The new species are *Neuropteris ampelinos*, *Crossopteris utahensis*, *Crossopteris undulatus*, *Crossopteris mcKnightii*, *Alloiopteris cruciatus*, *Sphenopteridium zaitzeffis*, *Lepidostrobus skemmatos*, *Cordaicarpus globosus*, *Cordaicarpus zjayshuleri*, *Cordaicarpus manningcanensis*, *Cordaicarpus binutus*, *Cornucarpus discissus*, and *Rigbyocarpus ebracteatus*. Five species were recombined.

The occurrence of *Sphenopteridium dissectum*, *Sphenopteris gothanica*, *Diplothmema arnoldi*, *Gnetopsis anglica*, and *Tingia* sp.

are 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 shales with quartzites, sandstones and limestones 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). 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 is known from this vast region. The state of preservation of these floras is generally too poor to allow detailed differentiation. Consequently, the number of species from each is small. In comparison, the flora from the Manning Canyon Shale is well preserved and consists of a relatively diverse assemblage of plants.

(2) The flora occurs in rocks situated stratigraphically between strata containing fossil invertebrate fauna of Lower Pennsylvanian age near the top of the formation and a Mississippian invertebrate assemblage near the middle. The flora is transitional and the time boundary between these two periods is probably 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 are also placed in the repository at Michigan State University, East Lansing, Michigan.

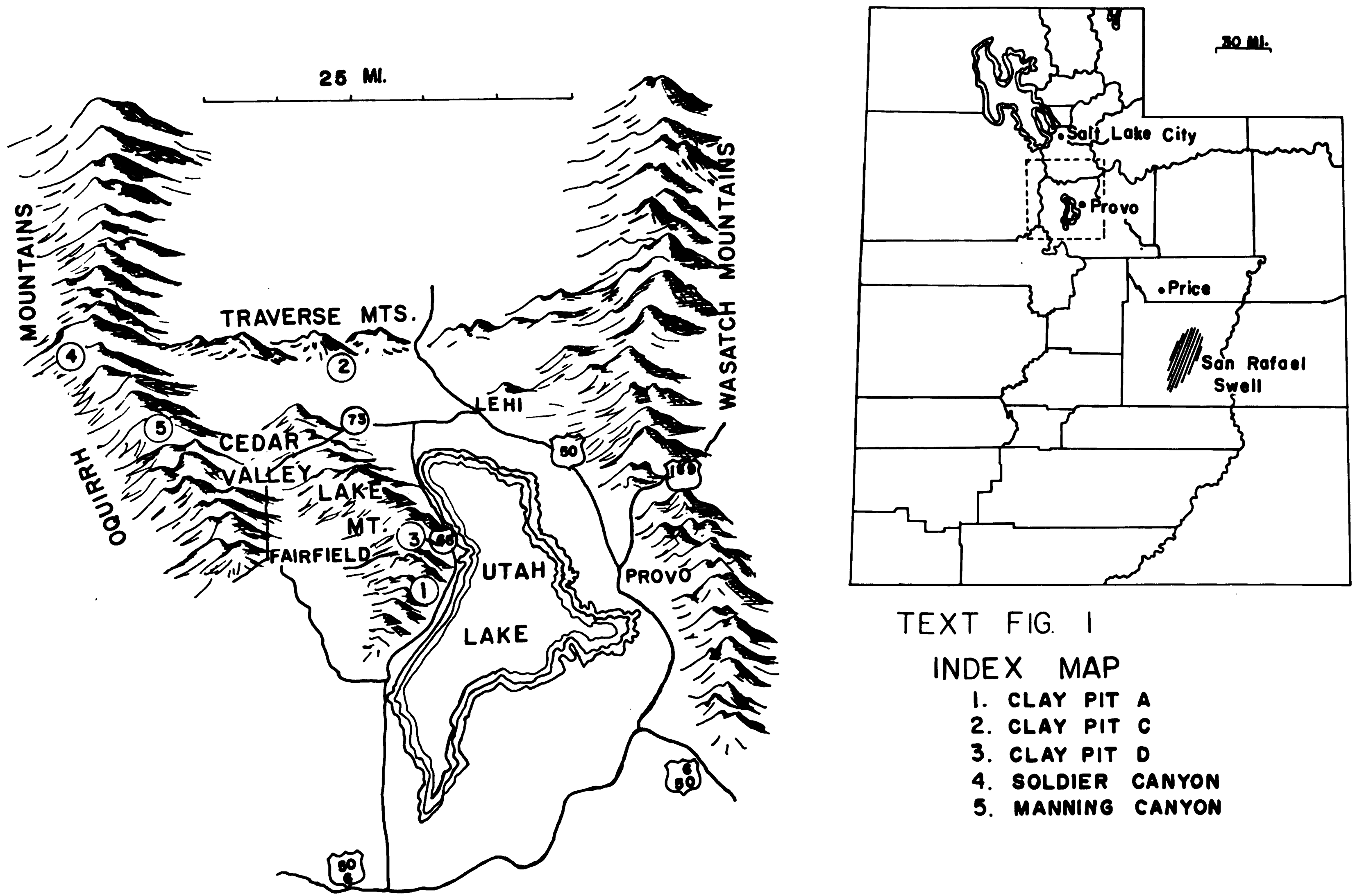
LOCATION AND AREA

The Manning Canyon Shale is exposed in central and northern Utah within the eastern Great Basin and the western Central Rocky Mountain physiographic provinces. Most of the 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 (fig. 1). The Wasatch Mountains mark the western boundary of the Central Rocky Mountain province. They are 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. They are a small, subdued, east-west branch of the Oquirrh Mountains, and separate Utah Valleu 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 clay pits where they are quarried. The clay pits on Lake Mountain (pl. I, fig. 1; pl. II, fig. 2) are

approximately thirteen miles southwest of Lehi, Utah, near state highway 68. The clay pits on Traverse Mountains (pl. II, fig. 2) are about nine miles west of Lehi and about two miles north of state highway 73 (fig. 1).



TEXT FIG. I

INDEX MAP

1. CLAY PIT A
2. CLAY PIT C
3. CLAY PIT D
4. SOLDIER CANYON
5. MANNING CANYON

PREVIOUS WORK

The Manning Canyon Shale is the name given to a certain sequence of rocks exposed in the 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 many others. Studies of the Manning Canyon Shale include a selenium abundance by Robertson (1950, ms) and one by Brimhall (1963); a study of the physical and chemical sedimentary characteristics by Herbertson (1950, ms), a study of the Mississippian-Pennsylvanian time boundary by Sadlick (1955, ms), studies of the clays by Orneales (1953, ms) and Hyatt (1956), a paleoecological and sedimentation study by Moyle (1958), a preliminary study of the flora and its stratigraphic position by Tidwell (1962), and a study of cyclothems in the Manning Canyon Shale by Prince (1963).

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 (1962).

GEOLOGY

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

The formation is a time-transgressive unit, containing the Mississippian-Pennsylvanian boundary within its limits. It is predominately shales with interbedded limestones, orthoquartzite and some siltstone (fig. 3). The shales are black, gray, 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-gray to dark blue-gray, usually weathering light gray and brown to yellow, and contain abundant fossils. The light gray to light tan orthoquartzites show variable characters of grain size, cementation and porosity as well as crossbedding 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 following is a modified stratigraphic section after Calderwood (1951).

Oquirrh Formation.

Conformable contact.

Manning Canyon Shale.

Bed No.	Description	Feet
9.	Limestone, shaly, sandy to silty, also calcareous sandstones. Limestones dark blue-gray on fresh surfaces, weather gray-brown. Sandstones shaly and weather reddish brown to flesh colored	95
8.	Base of a ledge of mudstones, argillaceous calcareous shales, sandy and silty limestones, siltstones, and interbedded orthoquartzites. Numerous leaf impressions, mud cracks, and other indications of shallow water environment. Above are limestones, dark blue-gray to brown, sandy, rough weathering, shaly fragments and limestone, dense black, weather pink and lavender.....	173
7.	Shale at base, to shaly limestone. Shales tan, yellow-brown, buff and tan, some dark gray. Limestones, dark gray, weather pale blue-gray to gray-blue. Banded orthoquartzites, flesh colored to reddish brown (on weathered surface)..	139

6. Medial limestone of the Manning Canyon: limestone, dark gray to medium dark gray, dense, hard, weathers pale somber gray to gray-blue and light to light medium gray; nonfossiliferous lower part, few brachiopods upper part, well bedded in beds, average 18" - 24"............. 93

5. Series of arkosic (?) orthoquartzite, subgraywackes, orthoquartzites and chloritic to micaceous shales........ 128

4. Shale, brown, red brown, purplish brown, containing lingulid brachiopods; soft, argillaceous clay shales. Beds contain seams of calcite and gypsum. Some yellow, ochre, and limonite-stained shales present; most beds in this unit are clay shales....................................... 92

3. Base of ledge is brown-weathering, gray to pink orthoquartzites; seamed with white quartz, well bedded in 6-inch to 2-foot layers. Arkosic in part, locally cross-bedded.. 94

2. Top of black shales, base of dense, hard, very fine-grained orthoquartzite, pink to tannish gray with many white quartz seams; interbedded black shale similar to underlying shales.................................. 140

1. Base: shale, brown and black, fissile, and interbedded 1- to 3-foot beds of dense black siliceous limestone; shale weathers black and very dark brown. Some siliceous ironstone concretions present........................ 176

Total 1,130

Conformable contact.

Great Blue Limestone

A lithologic summary of the Lake Mountain section is as follows: (after Moyle, 1958)

Rock Type	Thickness in feet	%
Shales	1231	64.5
Quartzites, arkose and graywackes	600	31.4
Limestones	79	4.1
	1910	100.0

The formation is underlain by the ridge-forming Chesterian Great Blue Limestone and overlain by the limestones of the Morrowian portion of the Oquirrh Formation. The Great Blue Limestone and Manning Canyon Shale contact on Lake Mountain is taken at the top of a dark gray, light gray-weathering cherty limestone. The contact with the Oquirrh formation is not readily discernible, but a point beneath a dominant, medium gray brown-weathering quartzite was used.

Baker (1947) measured 1,645 feet of Manning Canyon Shale in the Wasatch Mountains. This section includes coarser sediments

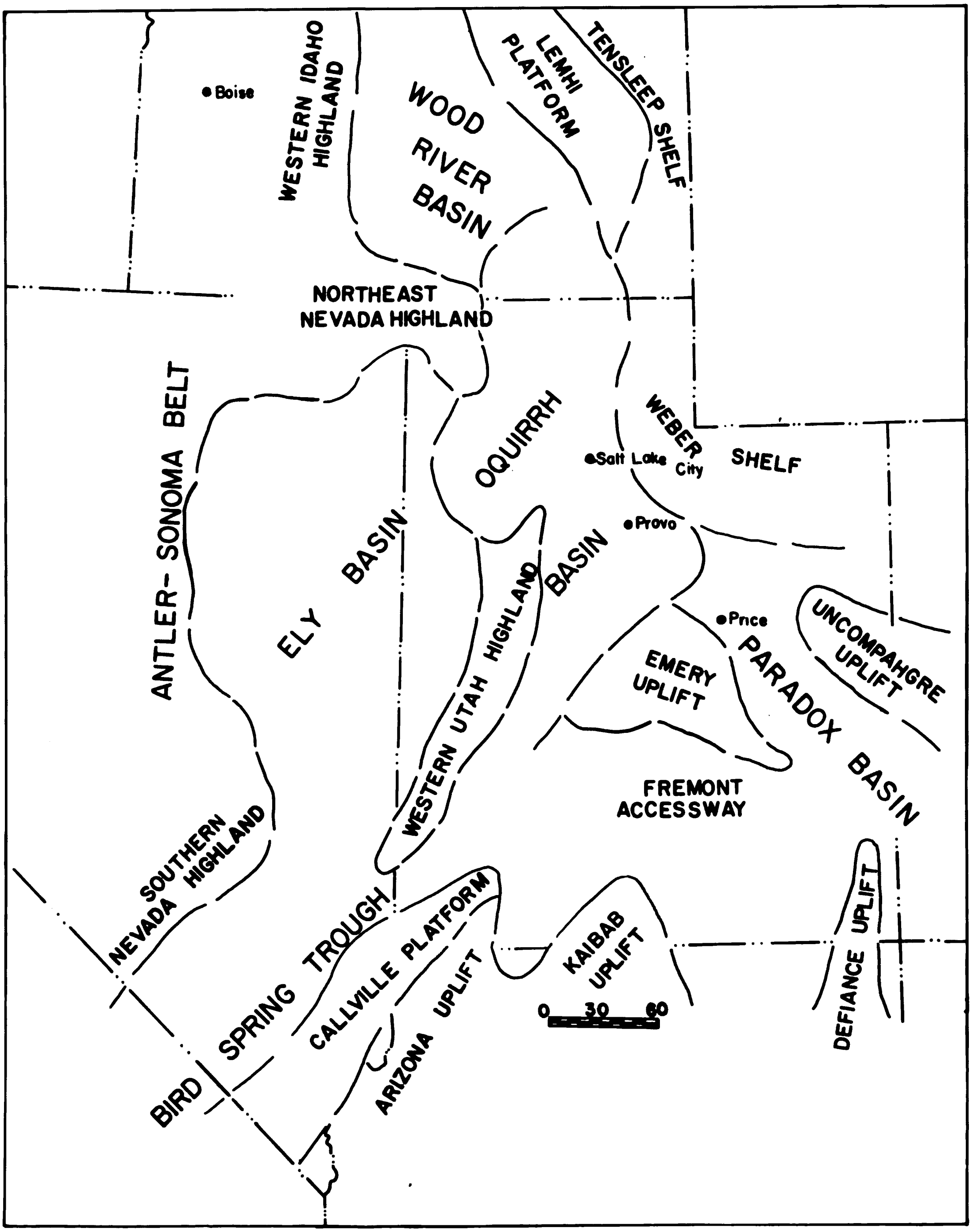


Fig 2 - Paleotectonic map of Cordilleran area during Pennsylvanian and Early Permian time (After Bissell, 1962) than those characterizing the rocks at Lake Mountain which is one indication of an eastward source of much of the material. Stokes and Cohenour (1956)report that possibly as much as 800 feet of the section is Manning Canyon Shale in wells located at the Mounds in southern Carbon County, Utah. They state that the resemblance of the section at the north end of the San Rafael Swell (Fig. 1) to that of the Wasatch Mountains indicates a deeper trough which entered from the southwest and received more sediments than the area on the Swell to the south. Zabrisky (personal communication) stated that only fifteen feet of the Manning Canyon shale occurs in wells drilled north and west of Price, Utah, (fig. 1). This variation appears to be due to a thick accumulation of coarser materials in the Oquirrh Basin along the flanks of the emerging Emery Uplift (fig. 2) with a concurrent thinning of the formation over the uplift and then a thickening again in the direction of the Paradox Basin.

The Manning Canyon Shale was probably deposited in an embayment which was alternating lagoonal and paludal, dominately marine to the west and nonmarine to the east and south. The embayment was bordered by three other late Paleozoic positive areas in addition to the Emery Uplift. These uplifts were also

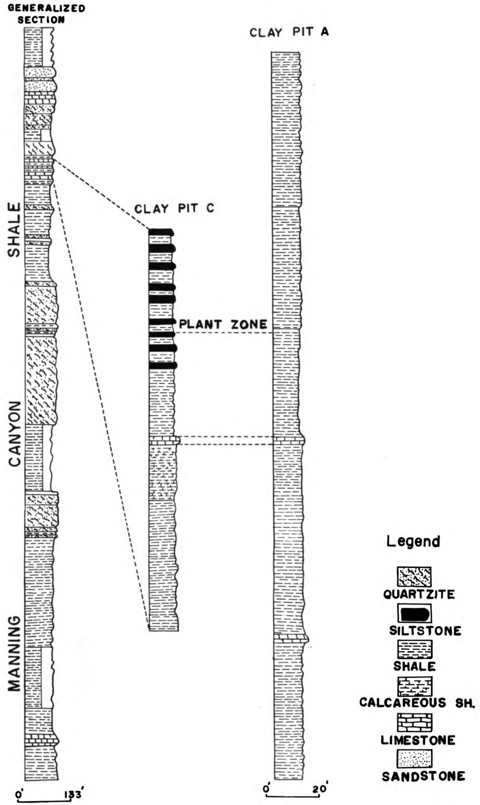


Fig 3. Stratigraphic section of Manning Canyon Shale, Lake Mt. with relationships of clay pit A and clay pit C.

possible sources for the sediments comprising the Manning Canyon Shale. Sediments in the Oquirrh and Lake Mountain areas may have been derived in part from the Western Utah Highland (Bissell, 1962) which was located along the southwestern border of the embayment (fig. 2).

The northern part of the embayment may have received sediments from the northeastern Nevada Highland (Bissell, 1962). The highland, located in northeastern Nevada and northwestern Utah (fig. 2), may have been active during the Antler Orogeny, a late Mississippian-early Pennsylvanian disturbance. Dott (1955) reported that coarse conglomerates and quartzites in the Tonka Formation of eastern Nevada grade laterally eastward into shales.

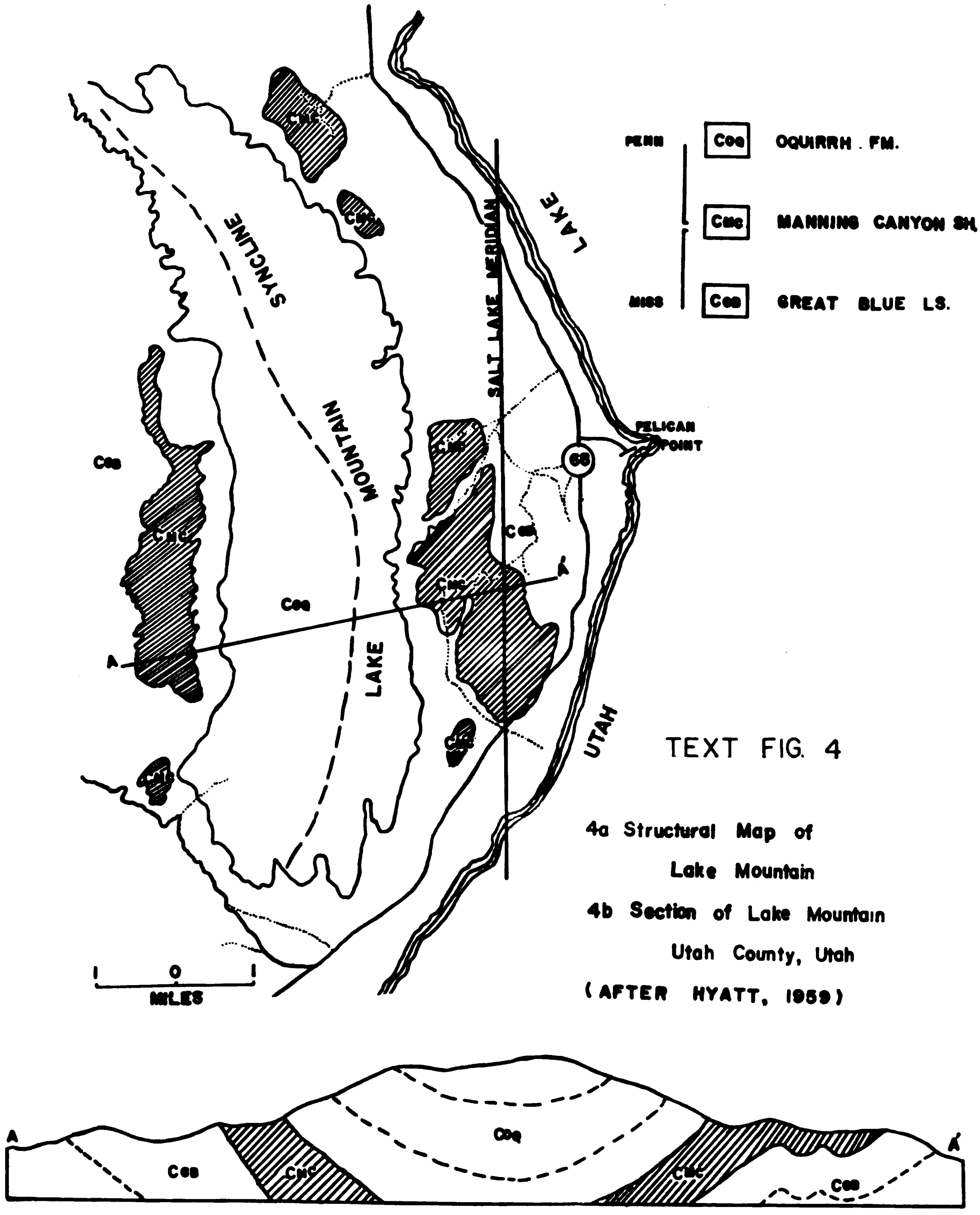
The Uncompahgre uplift to the southeast may also have contributed some sediments to the embayment.

Structure: In the area of Lake Mountain, the strata are deformed into a major syncline and anticline with many minor folds; thrust, tear and normal and reverse faults (fig. 4a). According to Bullock (1951), Lake Mountain is a broad syncline with a large anticline to the north.

The Lake Mountain syncline can be traced approximately eleven miles. It is a northwest-southeast trending, slightly assymmetrical syncline with maximum dips on the steepest limb of nearly 55° (fig. 4b)

and a northwest plunge of about 14^{o} (Bullock, 1951). The north end of the syncline is in structural continuity with the Bingham Syncline in the Oquirrh Mountains, and the two appear to be parts of the same fold.

A broad northwest trending anticline is exposed at the northern end of Lake Mountain and in the southern portion of the Traverse Mountains (Bullock, 1951). Minor folds and faults complicate the main folding.



TEXT FIG. 4

4a Structural Map of Lake Mountain

4b Section of Lake Mountain Utah County, Utah

(AFTER HYATT, 1959)

FLORAL COMPOSITION

The plant fossils of the Manning Canyon Shale consist of impressions of stems, portions of fronds, and detached pinnules, isolated seeds and other dissociated plant remains. Nearly all of these fossils are compressions. Very little of the original carbonaceous material is preserved. The remains have been secondarily replaced with limonite and hematite, resulting in reddish or brownish coloration of the impressions. This replacement shows little cellular structure and cuticle of the original plants.

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

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

The synopsis of Table I reveals the most common groups to be represented are crossopterids, calamitean forms and seed types.

These comprise the majority of the compressions. Crossopteris utahensis, 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 5% 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 species of the more common types, particularly C. utahensis.

The relative abundance of species does not necessarily infer similar relationships of sparseness or profuseness to the actual numbers of the plants. A megaflora generally gives a good record as to the abundance of the lowland flora, but an inadequate record of the "upland" plant types. The usual plant remains encountered as megafossils are of plants which grew along waterways or in low, moist areas and were preserved in situ or near the locality in which they grew. Very few "upland" forms are represented and these were probably transported by wind or water.

The microfossil flora should, by comparison, give a more accurate indication as to the numbers and plant types present. Unfortunately, this is not always true. Spores and pollen may be destroyed by oxidation, abrasion and metamorphism. Samples were collected from the various lithologies in the type section of the Manning Canyon Shale and from different clay pits. These were processed for spore-pollen analysis, but were found to be barren.

TABLE I Cont.

	AB	F	R
Palaeostachya (?) sp.			X
Calamostachys (?) sp.			X
Tingia (?) sp.			X
Mariopteris _muricata_ Schloth			X
Diplothmema _obtusiloba_ (Brgnt.) White		X	
Diplothmema _trifoliata_ (Artis) White			X
Diplothmema _arnoldi_ Stockmans & Williere			X
Sphenopteris (?_Renaultia_) _schatzlarensis_ (Stur) Zeiller			X
Sphenopteris _gothanica_ (?) Dolianiti) comb. nov.		X	
Corynepteris _angustissima_ (Stbg) Nemejc			X
Alloiopteris _cruciatus_ sp. nov.			X
Sphenopteridium _dissectum_ Goppert		X	
Sphenopteridium _Zaitzeffium_ sp. nov.		X	
Rhodea _vespertina_ Read			X
Rhodea sp.			X
Adiantites sp.		X	
Adiantites (_Wardia_) _tenufolius_ var. _defoliolatus_ (White) comb. nov.			X
Zeilleria (?) sp.			X
Neuropteris _gigantea_ Sternberg			X
Neuropteris _heterophylla_ Brongniart			X
Neuropteris cf. _pocahontas_ White			X

TABLE I Cont.

	AB	F	F
Neuropteris ampelinos sp. nov.			X
Crossopteris utahensis sp. nov.	X		
Crossopteris undulatus sp. nov.	X		
Crossopteris mcknightii sp. nov.			X
Cyclopteris dilatata Lindley & Hutton			X
Odontopteris sp.		X	
Cordaites principalis (Germar) Geinitz			X
Cordaites sp. A			X
Cordaites sp. B		X	
Cordaites sp. C		X	
Cordianthus pseudofluitans Kidston			X
Cordaicarpus globosus sp. nov.			X
Cordaicarpus elongatus (Newberry)			X
Cordaicarpus jayshuleri		X	
Cordaicarpus manningcanensis sp. nov.		X	
Cordaicarpus cordatus (Jackson) comb. nov.		X	
Cordaicarpus binutus sp. nov.		X	
Trigonocarpus noeggerathi (Stnbg.) Brongniart			X
Trigonocarpus sp. A			X
Trigonocarpus sp. B		X	
Trigonocarpus sp. C		X	
Holcospermum sp.			X

TABLE I Cont.

	AB	F	R
Cornucarpus discissus sp. nov.		X	
Rigbyocarpus ebracteatus gen. & sp. nov.		X	
Lagenospermum bifurcatus (Stopes) comb. nov.		X	
Gnetopsis anglica Kidston	X		
Telangium affine (L.& H) Benson			X
Aulacotheca campbelli (White) Halle			X
Aulacotheca hemingwayi (?) Halle		X	

COMPARISON WITH OTHER NORTH AMERICAN FLORAS OF MISSISSIPPIAN AND PENNSYLVANIAN AGE

A comparison of the Manning Canyon Shale flora with other Mississippian and Pennsylvanian floras is very difficult because of the inadequate knowledge of these floras in the United States. 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 incomplete. 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), "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."

The comparison of the Manning Canyon Shale flora with the Chesterian plant materials from the Uinta Mountains of Utah (Arnold, 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 distribution. Fossil plant localities in the Manning Canyon Shale are geographically midway between the Spotted Ridge flora (500 miles northwest) and the Mosquito Range flora (600 miles east). The Mississippian Uinta flora lies about 150 miles northeast of Lake Mountain.

Archeocalamites radiatus (=Asterocalamites scrobiculatus) and Rhodea sp. are the only species common to both previously described Utah Carboniferous floras. The genera Cardiopteris (=Fryopsis) and Caulopsis, present in the Uinta flora, are not found in the Manning Canyon Shale collections and with the exception of Archeocalamites, Rhodea and Lepidodendron, none of the 36 genera represented in the Manning Canyon Shale flora have been reported from the Uinta Mountain locality.

If Lacey and Eggert (1964) are correct in referring the Lepidodendron 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.

A flora possibly equivalent to the Uinta Mountain flora is located near the base of the Manning Canyon Shale in the Soldier

Canyon section. This very poorly preserved flora has a stratigraphic position similar to that of the Uinta flora; but it has not been extensively collected or studied.

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 Phyllotheca in the Oregon flora have not been recognized in the Manning Canyon Shale, and conversely , in the Oregon flora, Neuropteris, Alliopteris, clearly identifiable lycopsids, Sphenopteris, Mariopteris and several other forms present in the comparatively well-preserved Manning Canyon Shale flora have not been found. Whether these generic differences are due to differences in preservation, the author is unable to say, but from information available, the floras appear to be distinct.

Mamay and Read (1956) considered the Spotted Ridge flora to be Pennsylvanian; but were uncertain as to whether the flora represented Upper, Middle, or Lower Pennsylvanian. Arnold (1953) thinks its affinities are more closely related to floras of early Pennsylvanian age.

The species common to the Mosquito Range flora and the Manning Canyon Shale flora are Asterophyllites longifolius, Neuropteris

heterophylla (?), Neuropteris gigantea, and Stigmaria ficoides (=S. verrucosa). There are thirteen other species described from the Mosquito Range which Read places in the Lower Pennsylvanian.

These floras are floristically distinctive as well as geographically separated. The distinct difference is probably due to a difference in their time of growth, for the Manning Canyon Shale flora appears to be older. The Oregon and Colorado Carboniferous floras are very poorly preserved. 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-Jacks fork and the Wedington, - have no species correlative with those found in the Manning Canyon Shale. The Stanley-Jack fork flora, thought to be Pennsylvanian by White (1937), is now considered as Mississippian by Mamay (in Miser and Hendricks, 1960).

Similarity between the Manning Canyon Shale flora and the Chesterian flora from Illinois (Lacey and Eggert, 1964) is indicated by the common occurence of the species Archeocalamites radiatus,

Lepidodendron volkmannianum and *Stigmaria ficoides. L. Volkmannianum* from the Manning Canyon Shale is an isolated specimen in quartzitic material which is stratigraphically lower than the horizon from which the remainder of the collection was made.

Rhodea vespertina is the only species common to the Mississippian Pocono and Price floras of eastern United States (Arnold, 1949; Read, 1955) and the Manning Canyon Shale. These Appalachian floras contain the characteristic Mississippian genera *Triphyllopteris, Cardiopteris* and *Lepidodendropsis* which do not occur in the Manning Canyon Shale.

The Michigan Coal Basin flora (Arnold, 1949) has ten forms from a total of forty-five species in common with the Manning Canyon Shale. These are *Lepidodendron aculeatum, Lepidocarpon linearfolium, Stigmaria ficoides, Asterophyllites equisetiformis, N.* cr. *heterophylla, N. gigantea (?) Sphenopteris obtusiloba, Aculacotheca campbelli, Trigonocarpus noeggerathi,* and *Cordaites principalis.* Arnold (1949) considers the Michigan Coal Basin flora to be late Westphalian A to Westphalian 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 (table II). The coal seams 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 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 schatzlarensis are found in the Kanawha (Westphalian B) and Alleghany (Westphalian C). They are indicative of Upper Namurian and Westphalian age in Europe.

Johngmans (1937) states that the Pocahontas seam #3 on the basis of its 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.

Lepidodendron aculeatum, Lepidophyllum sp., Lepidostrobus variabilis, Diplothmema obtusiloba, Neuropteris heterophylla, and Asterophyllites equisetiformis are species common to both the Stanley Cemetery flora of Indiana (Wood, 1963) and the Manning Canyon Shale flora. Wood (1963) considers the Stanley Cemetery flora to be Westphalian B in age.

Bell (1938, 1944) divided the Upper Carboniferous strata of Nova Scotia into three groups based on their distinctive floral components. These are the Canso Group, the Riversdale Group and the Cumberland Group.

The Canso Group has three species, Telangium affine, Archeocalamites radiatus (=Asterocalamites scrobiculatus) and Calamites (Mesocalamites) cistiiformis in common with the Manning Canyon Shale flora. According to Bell (1944) the poorly preserved calamitean stems are fairly abundant in the Canso Group, but other fossil plant remains are scarce. Bell (1944) 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 (Table II).

The Riversdale Group contains five species common with the Manning Canyon Shale flora. They are Sphenopteris obtusiloba, S. schatzlarensis, A. equisetiformis, Lepidostrobus variabilis, and Cordaites principalis. Bell (1944) considers the Riversdale Group to be no older than late Namurian or younger than Westphalian A. He favors Westphalian A, and bases this on Neuropteris schlehani and Mariopteris acuta which are the most characteristic forms present. He also cites the first appearance of Cordaites principalis as evidence for this age assignment.

The Cumberland Group which he studied has the same seven floral components in common with the Manning Canyon as those in the Riversdale Group and in addition, Lepidodendron aculeatum and Alloiopteris (Corynepteris) sternbergi are found in both the Cumberland and Manning Canyon Shale floras. Bell (1944) cites this flora as indicative of late Westphalian A or Early Westphalian B, because - "a number of species reach their acme of development in late Westphalian B or early Westphalian C time." He gives more importance to the presence of Asterophyllites equisetiformis, Neuropteris tenuifolia and Lepidodendron dichotomum than to the "rare survival" of Neuropteris schlehani which is not present in the Westphalian B of Europe. Lonchopteris is the index form for this time interval in Europe, but it is rare in North America. Bell (1944) attributes this "to the non-deposition of sediment throughout most of Westphalian B time."

The Pictou Group of New Brunswick, which Bell (1962) states is Westphalian C in age, has Asterophyllites longifolius, Stigmaria ficoides, and Neuropteris heterophylla in common with the Manning Canyon Shale flora.

COMPARISON WITH EUROPEAN CARBONIFEROUS FLORAS

Crookall (1934) outlined the three following factors to be used in comparing fossil floras: 1) the occurrence of certain assemblages of species; 2) the frequency of individual forms composing the assembalges; and 3) the absence of other assemblages. The problem encountered in using his second criterion 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: The following species are found in both the floras of the Upper Carboniferous of Great Britain and the flora of the Manning Canyon Shale.

	R*	S*	Y*	L*
Asterophyllites equisetiformis	8	5	8	6
A. Longifolius		1	2	1
Cordaites principalis		3	9	6
Corynepteris sternbergi		1	4	
Gnetopsis anglica			3	
Lepidostrobus variabilis		2	2	2
Mariopteris muricata		1	3	1
Neuropteris gigantea		3	10	3
Neuropteris heterophylla	1	2	10	4

Sphenopteris obtusiloba		(?)		
Sphenopteris schatzlatensis			6	1
Sphenopteris trifoliata			7	
Stigmaria ficoides	6	6	10	7
Trigonocarpus noeggerathi	4	2	1	
Lepidodendron aculeatum	4	4	9	5
Lepidodendron obovatum		2	9	4
Lepidostrobophyllum majus	5	2	1	

(*Time intervals: R=Radstockian; S=Staffordian; Y=Yorkian; and L=Lanarkian. Quantitative data: 1-2 = very rare; 3-4 fairly rare; 5-7 = fairly common; 8-10 = very common.)

The six species in common with the Radstockian are from a total of 132 species reported from Great Britain. Twelve from 168 species in Staffordian, sixteen species in the Yorkian out of 392, and nine species of 91 for the Lanarkian are also in common.

Pecopterids as a group are characteristic of the Radstockian Series; an abundance of Linopteris 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.

Species from the Manning Canyon Shale which correspond to the Lower Namurian of Great Britain are:

Eumorphoceras Zone (Namurian A)

Cordaites principalis

Lepidostrobus variabilis

Mesocalamites cistiiformis

(From a total of 51;
after Dix, 1933)

Reticuloceras Zone (Namurian B)

Calamites cf. *cistiiformis*

Neuropteris gigantea

N. cf. *heterophylla*

Cordaites principalis

Stigmaria ficoides

(From a total of 26+
after Dix, 1933;
Lacey, 1951)

Of the species listed for the Lower Carboniferous of Great Britain (Crookall, 1934), the species *C. cistiiformis*, *Asterocalamites scrobiculatus* (*Archeocalamites radiatus*), *Sphenopteris affine* (=*Telangium affine*), *Sphenopteridium dissectum*, and *Lepidodendron volkmannianum* also occur 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 those already given, are composed largely of long ranging species

TABLE II

General Stratigraphic Nomenclature of the Carboniferous in Europe and North America

		Europe	Dix	Kidston - Crookall	Belgium	Goniatites Zone	Nova Scotia	West Virginia	U. S.
Upper Carboniferous	Westphalian	D	"H"	Radstockian			?	Allegheny Series	Pennsylvanian
		C	"G"	Staffordian	Assise de flenu		Pictou Group	Kanawha Group	
			"F"	Yorkian					
		B	"E"		Assise de Charleroi		Cumberland Group		
		A	"D"			Gastrioceras (G)	Riversdale Group	New River Group	
			"C"	Lanarkian	Assise de Chatelet				
	Namurian	C	"B"		Assise d'Andenne		Canso Group	Pottsville (Pocahontas Group)	
		B	"A"	Upper part of Lower Carboniferous (Kidston)		Reticuloceras (R)			
		A			Assise de Chokier	Homoceras (H) Eumorphoceras (E)			
Lower Carb.	Din.	Visean Tournaisian							Miss.

(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 only three species, Stigmaria ficoides, Lepidodendron obovatum and Archeocalamites cf. radiatus in common from a total of 77 species. The Assise d'Andenne (Namurian B) has ten in common from 176 species. These are Lepidodendron obovatum, L. variabilis, Trigonocarpus noeggerathi, Gnetopsis anglica, Lepidostrobophyllum majus, Sphenopteris (=Diplothmema) obtusiloba, Corynepteris angustissima, Neuropteris gigantea, Cantheliophorus aff. linearifolius (= Lepidocarpon linearifolium), and Aulacotheca hemingwayi.

Ancion and Van Leckwijck (1947) described a flora from Zone de Gilly (uppermost Namurian B) which has five species, Asterophyllites equisetiformis, A. angustissima, Neuropteris gigantea, Sphenopteris obtusiloba, and Aulacotheca hemingwayi, corresponding to species collected from the Manning Canyon Shale.

France: Two species are common to the Namurian A of France as reported by Carpentier (1928) from the Basse-loire. They are Asterocalamites scrobiculatus (=Archeocalamites radiatus), and Calamites cistiiformis. Carpentier recorded 34 species in this flora.

Carpentier (1907) listed about 50 species for coals of Valenciennes. The following are species found in both the Valenciennes beds and the Utah flora. These are divided into Carpentier's Zones.

Zone A^2 - Base of B^1

Mariopteris muricata

Sphenopteris trifoliata

S. sternbergi

S. obtusiloba

Neuropteris heterophylla

N. gigantea

Asterophyllites equisetiformis

Trignocarpus noeggerathi

Lepidodendron aculeatum

L. obovatum

L. volkmannianum

L. variabilis

S. ficoides

Zone A^2, which is stratigraphically younger, is characterized by Zeiller (1888). It contains:

Neuropteris heterophylla

Mariopteris muricata

Sphenopteris trifoliata

Sphenopteris trifoliata is also reported from Zone B^1 to B^2.

Again, the species common to this flora and the Manning Canyon Shale flora are only long ranging species with the exception of L. 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 (12 of about 50) in the lower coal beds, becoming less numerous upward, indicating very little relationship between these two floras.

Germany: Gothan (1931) listed six species from 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 longifolius, Alloiopteris sternbergi (-Corynepteris angustissima) 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+ others 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* (=*Archeocalamites radiatus*), *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) synthesized the information on the coal floras from the Anatolie region. Sixteen species of these floras are common with the Manni ng Canyon Shale flora. These are given in chart form with the age where they were found in the Netherlands.

		Namurian			Westphalian			
	Diant	A	B	C	A	B	C	D
Asterocalamites scrobiculatus (=*Archeocalamites radiatus*)	X	?						
Mesocalamites cistiiformis		X						
Asterophyllites charaeformis					X	X	X	
A. equisetiformis					X	X	X	X
A. longifolius					X	X	X	
Lepidodendron aculeatum					X	X	X	
L. obovatum					X	X		X
Lepidostrobophyllum majus						X	X	X
Lepidostrobus variabilis					X	X	X	
Alloiopteris sternbergi (-*C. angustissima*)					X	X	X	
Neuropteris gigantea				X	X	X	X	
N. heterophylla					X	X	X	

	Namurian Diant	A	B	C	Westphalian A	B	C	D
Renaultia schatzlarensis					X	X	X	X
Sphenopteris obtusiloba				X	X	X	X	X
Sphenopteris trifoliolata					X			
Cordaites principalis					X	X	X	?
Jongmans total species		25	19	30	132	147	124	123

Bulgaria: Hartung (1935) reported on the Carboniferous floras from Bulgaria which share the following species with the Utah flora.

	Namurian	Westphalian A	B	C
Lepidodendron obovatum	Rare	X	X	X
Lepidostrobus variabilis		X	X	X
Stigmaria ficoides	X	X	X	X
Asterophyllites longifolius		X	X	X
Sphenopteris schatzlarensis		X	X	
Neuropteris gigantea		X	X	X
Cordaites principalis		X	X	X

Russia: The mutual species between the floras of the Russian "Coal Measures" and the Manning Canyon Shale are listed as to the levels used by the Russian stratigraphers for the Namurian.

Level C_1^2
- Lepidodendron aculeatum
- L. obovatum
- Lepidostrobophyllum majus
- Stigmaria ficoides
- Asterocalamites scrobiculatus (=Asterocalamites Radiatus)

Level C_1^3
- Stigmaria ficoides
- Asterocalamites scrobiculatus

Level C_1^4
- Stigmaria ficoides
- Asterocalamites scrobiculatus
- Asterophyllites charaeformis
- Sphenopteris (Renaultia) schatzlarensis
- Lepidostrobophyllum majus

Level C_1^5 Stigmaria ficoides
Asterophyllites charaeformis
A. equisetiformis
Neuropteris gigantea

Stockman and Willière (1953) place C_1^2 to C_1^4 of D. Zalessky as comprising all of Namurian A and a part of Namurian B. Jongmans (1939) gave his equivalents as C_1^5 equalling Namurian B and into Namurian C, C_2^1 as part of Namurian C and C_2^2 as entering into the Westphalian.

AGE OF THE MANNING CANYON SHALE FLORA

It might be possible to determine the Mississippian-Pennsylvanian boundary, which has not been accurately determined in the type section of the Manning Canyon Shale, by using fossil invertebrates or fossil plants.

Fossil fish in the Manning Canyon Shale are not well enough known to be of any value for stratigraphic differentiation of this formation.

Sadlick (1955) identified as Springerian an assemblage of fragments of the fossil invertebrates *Schizophoria* cf. *S. texans* 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 (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 III. In compiling the stratigraphic ranges, floral lists were studied as well as ranges recorded by Gothan and Remy (1957) and Dix (1932). The chart shows the probable ranges for all but new species, although a number of gaps may be noted for species not frequently reported.

Eighteen of the thirty-five species listed on table III 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 III, Namurian A and Namurian B, contai n the majority of first appearances.

Index species are also important. Sphenopteris (?Renaultia) schatzlarensis and Corynepteris angustissima are indicative of uppermost Carboniferous of Europe. Bell (1944) reported both from Canada. He reports Sphenopteris schatzlarensis from the Riversdale 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 are equivalent 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 Stigmaria ficoides, there are six species in this flora which are known to characterize the Mississippian. Three of these, Sphenopteridium dissectum, Sphenopteris gothanica and Telangium affine are fairly common,

TABLE III

STRATIGRAPHIC RANGES OF 34 PLANT SPECIES OF THE MANNING CANYON SHALE

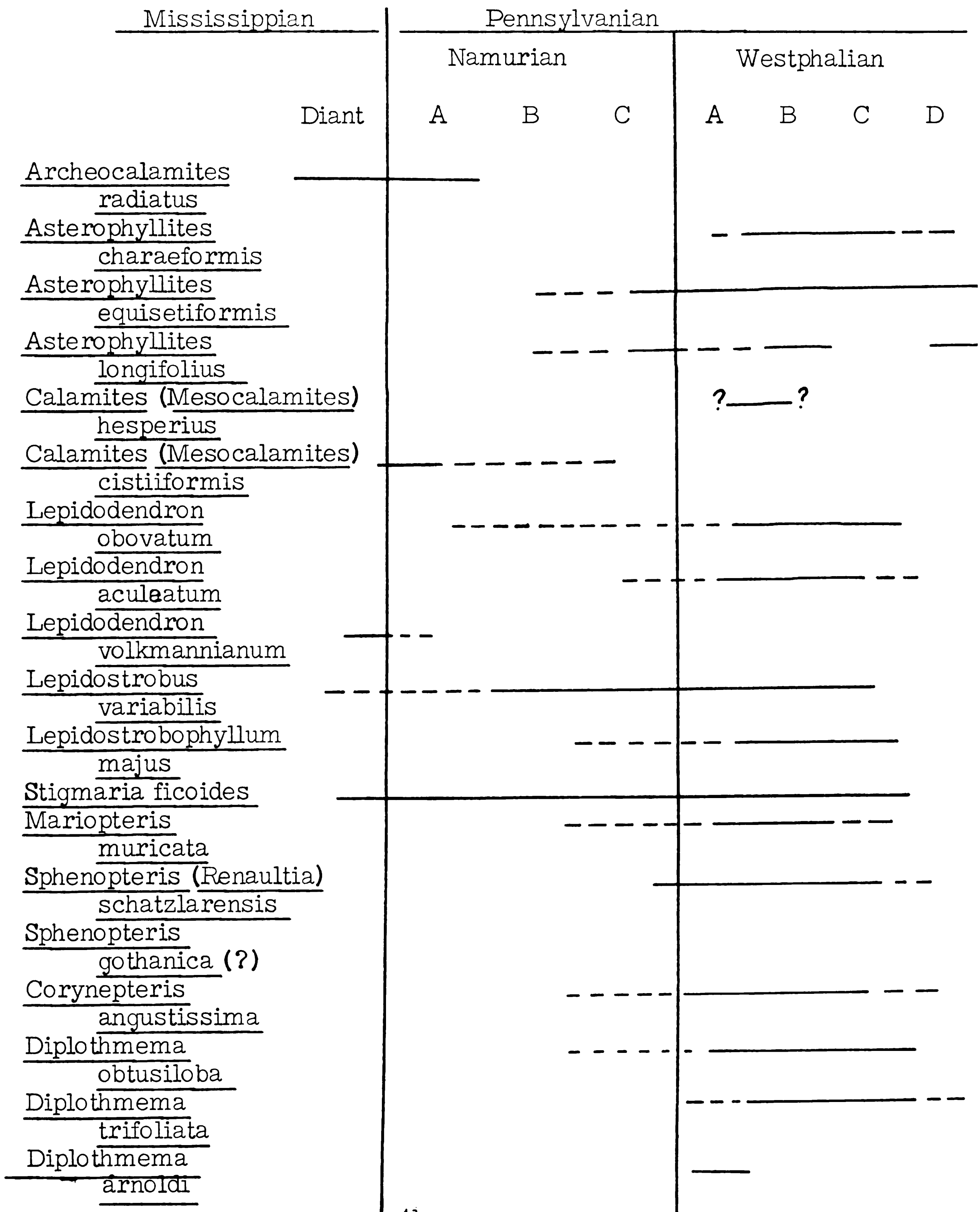
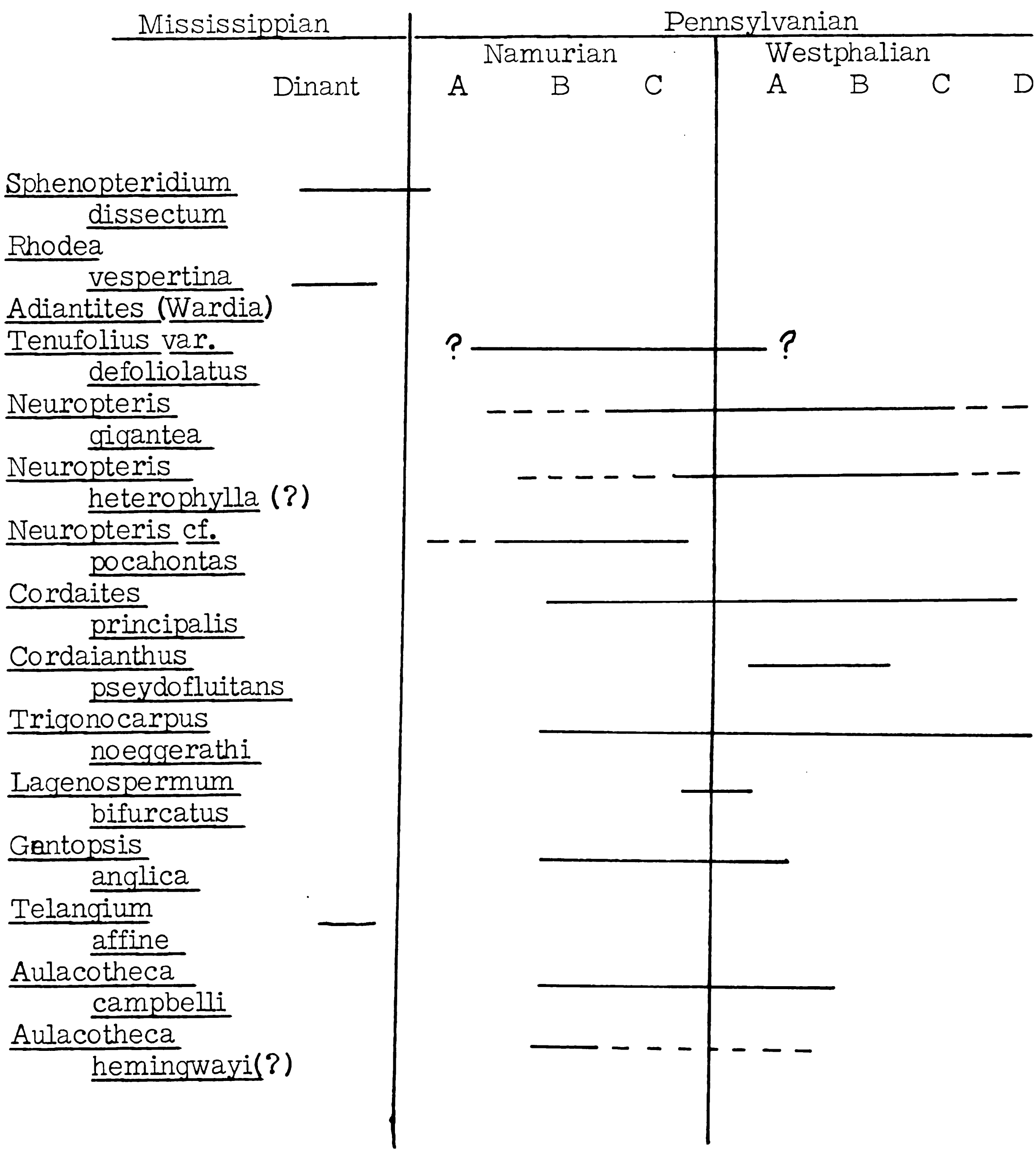


TABLE III Cont.



whereas three; Rhodea vespertina, Lepidodendron volkmannianum, and Archeocalamites radiatus are rare. Twenty-two Pennsylvanian species are present.

In this transitional flora, other typical Mississippian genera such as Cardiopteris (Fryopsis), Triphyllopteris, Rhacopteris, and Lepidodendropsis are lacking; but also conspicuously missing are Pecopteris, true Alethopteris, Sphenophyllum, Lepidophloios, 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; tansitional 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 L. 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) consistly thought 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 forms 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 reported, its range has not been established.

The Mississippian form Archeocalamites radiatus is known to extend into Westphalian A. Telangium affine has been previously reported only from the Lower Carboniferous of Europe and from the Lower Namurian of Canada (Bell, 1944). 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 the 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 A or possibly as young as Namurian B.

PALEOECOLOGY

The study of the structure, development and affinities of the Manning Canyon Shale plant types, especially lycopods and calamitens, found in association with the Pennsylvanian coals of eastern North America, indicates a paludal environment. Potonie' (1910) has pointed out that the enlarged bases of many of the older Sigillarians or other lycopods are analogous to the basal enlargements of the black gum, bald cypress and other extant forms growing in tropical and warm temperate swamps. The Lepidodendron leaf scars were, in effect, lenticels, or gaseous exchange surfaces augmenting plant aeration at least when water covered the root systems (stigmarian rhizomes and rootlets). These shallow root systems extended horizontally for some distance, thus functioning effectively as absorptive organs above the toxic air-exhausted deeper layers (White, 1913). The hollow interior of stigmarian appendages and the absence of root hairs also indicate an aqueous habitat.

White (1913) cites the air chambers in calamitean roots, the air chambers for seed flotation, the production of two kinds of spores in lycopods and Calamiteans, requiring water to insure fertilization as evidences for humid, swamp environment.

The vegetation at the time of deposition of the Manning Canyon Shale consisted of pteridosperms, ferns, lycopods and calamitens growing in or near the water, depending upon the needs of each individual plant. Forms such as Cordaites probably grew in areas at the edges of the swamps, possibly even in upland areas. This vegetation was established in a region with a uniform climate characterized by generally mild temperatures. The temperatures were possibly subtropical.

The presence of marine invertebrates and the cyclic nature of the sediments indicates the swamps were close to the sea. The repeated vertical change in the sediments from silty, sandy and clayey shales to calcareous shales and limestones suggests two overall shifts in the sedimentary environments from shallow to deeper marine.

The plant remains which are not in situ have not been transported far from their place of growth. This is inferred by (1) their random orientation and; (2) the occurrence of many complete plant organs, particularly leaves. Specimens of Stigmaria ficoides with rootlets attached have been uncovered. The radially extended positions of the interlacing rootlets, passing outward from the parent root in all directions and oblique to the bedding planes indicates the roots are in situ. Several intact Lepidostrobules, calamitean cones, calamitean and fern-like foliage have been collected. If these plant organs had been transported far, they would have been degraded or broken, or perhaps destroyed.

Most of the fossil plant remains are found in the laminated silty and clayey shales which were probably deposited in a lagoonal environment from silt-laden waters. These plant materials were incorporated into the mud and silt layers. At some later time, iron-rich ground waters percolating through the sediments and seeping along joints, fault planes and bedding surfaces replaced the original plant remains with iron oxides.

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 68 species of Mississippian and Pennsylvanian age, indicating that these strata are transitional between these two periods. Six species have a Mississippian range, twenty two are known Pennsylvanian species, twenty one have no definite range, five are longer ranging species. This flora contains two new genera, thirteen new species and one species (Tingia sp.) 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 A or possibly as late as Namurian B in European terminology. The flora is compared here with other Carboniferous floras described from Europe and North America, but none of these floras appear to be similar to the Manning Canyon Shale flora. There is some similarity in long-ranging species present in those floras but none has the overall aspect of the Utah flora. The flora of 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 Western United States. One small Mississippian flora is reported by Arnold (1962) from the Uinta Mountains of Utah.

The flora appears to have been deposited under swampy conditions with a rather humid environment in an embayment which was progressively silting in.

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

Lepidodendron obovatum Sternberg

pl. III fig. 5; text fig. 5B
pl. XI fig. 4

1820 Lepidodendron obovatum Sternberg. -Flora der Vorwelt, v. 1, fasc. 1, p. 20, 23, pl. VI, fig. 1, pl. VII, fig. 1A.

1875-77 Lepidodendron rhodeanum Stnbg. -Stur, Culm-flora der Ostrauer und Waldenburger Schichten, p. 283, pl. XXIV, figs. 1,2,3.

1951 Lepidodendron obovatum Stockmans and Willière. - Quelques Végétaux Namuriens et Westphaliens du Charbonnage d'Aiseau-Presle, pl. 2, fig. 11.

1962 Lepidodendron sp. A. Tidwell. -Brigham Young University Geol. Studies. Vol. 9(2), p. 99, pl. 5, fig. 2.

Description: Scars transversely diamond-shaped, bolsters prominent, 10 mm. long, 5 mm. wide. Elliptical leaf scar located in the upper one-half of bolster; wider than high; lateral angles acutely pointed and lower angles obtusely rounded. Lingule scar at upper edge of leaf scar. Vascular strand and parichnos occur in lower portion of leaf scar. Large aerencyhma areas on each side of upper portion of keel. Keel is raised near lower edge of leaf scar and near base of bolster, but is obscure between.

Transverse markings on the keel are absent on some bolsters and not well preserved on others.

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

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

One specimen (Pl. XI, fig. 4) is a branched portion of a stem with what appears to be a strobilus or a cluster of sterile leaves attached. No spores have been obtained from this specimen.

Lepidodendron aculeatum Sternberg

pl. III fig. 7; text fig. 5A

1820 *Lepidodendron aculeatum* Sternberg 1820. - Flora der Vorwelt, pl. 1, p. 20, 23, pl. VI, fig. 2, pl. VIII, figs. 1Ba, b.

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

Description: Bolsters prominent, contiguous, rhomboidal with rounded sides and pointed at top and bottom; 14 mm. wide and 30 mm. long, acute ends asymmetrical; median line straight or slightly curved. Leaf scar cuneate with lateral angles and basal angles acute; top obtusely rounded. Leaf scar situated toward right side of

bolster. Right lateral angle of scar nearly touches right margin of bolster and occupies one-half of the distance to the left margin. Vascular scar appears to be in lower portion of leaf scar; parichnos areas are not preserved; aerenchyma tissue present; keels obscure, but present. One form has faint transverse irregular lines.

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

The preservation of Lepidodendron aculeatum (pl. III fig. 7) is relatively poor. The leaf scars, ligule scars and the keels are present. A composite figure (Text fig. 5A) 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 may at times be very difficult to distinguish from one another.

Lepidodendron volkmannianum Sternberg

pl. III fig. 1; text fig. 5C

1957 Lepidodendron volkmannianum Stnbg.-Gothan & Remy, Steinkohlenpflanzen, p. 36; pl. 25.

1964 _Lepidodendron volkmannianum_ Stnbg. -Lacey & Eggert, Am. Jour. Bot. 51, p. 979, figs. 5-13.

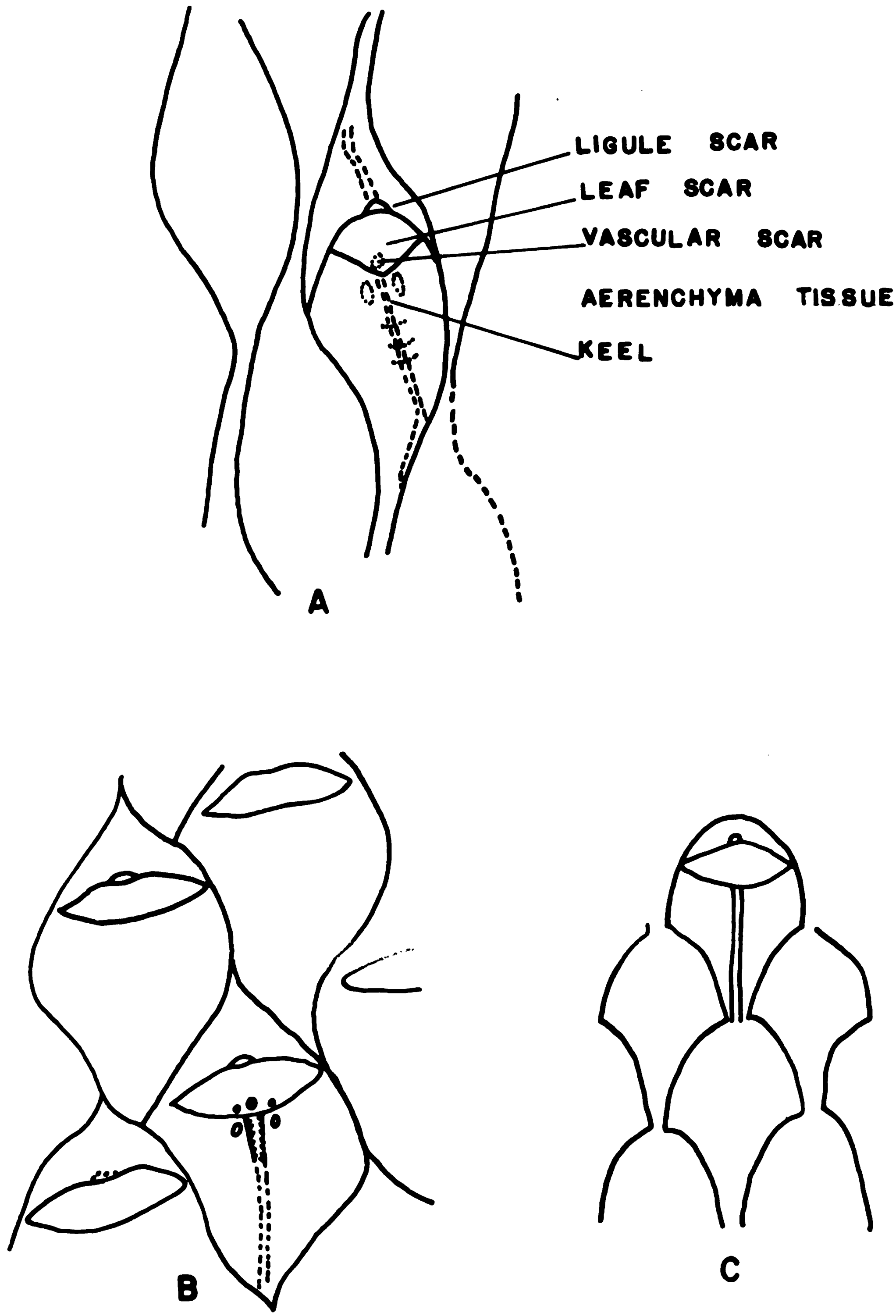
Description: Bolsters somewhat inverted pear-shape; upper portion ovate, lower somewhat blunt, inserted contiguously above the bolster below. Leaf scar elliptical to rhomboidal situated in upper portion of bolster. Bolsters are aligned horizontally and vertically.

Discussion: The specimens of this species were collected from a quartzite bed about 200 feet below the plant horizon where the remainder of the specimens were obtained.

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

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

EXPLANATION OF TEXT FIG. 5


LIGULE SCAR
LEAF SCAR
VASCULAR SCAR
AERENCHYMA TISSUE
KEEL
A
B
C

TEXT FIG. 5

Genus LEPIDOSTROBUS Brongniart 1828

Although the majority of the species of _Lepidostrobus_ are heterosporous, a few have been described as homosporous. Abbott (1963) has proposed the generic name _Lepidostrobopsis_ for such "unisexual" strobili. This genus would contain "unisexual" strobili, either microsporangiate or megasporangiate, whose overall characteristics are otherwise similar to _Lepidostrobus._ Although this taxon appears to be useful, the problem arises into what genus should a specimen be placed that (1) has no spores, or (2) is incomplete with only the apex, containing microspores, or a strobilus base with only megaspores present. These should perhaps be placed with _Lepidostrobus_ until more refined criteria are delineated.

Lepidostrobus variabilis Lindley & Hutton

pl. III fig. 3

1831 _Lepidostrobus variabilis,_ Lindley & Hutton.-The Fossil Flora of Great Britain, v. 1, pls. 10 & 11.

1963 _Lepidostrobus variabilis,_ L. & H.-Wood, Ind. Geol. Surv. Bull. 29, p. 37, pl. 2, figs. 4, 5, and 6.

Description: Strobili linear-oblong, at least 100 mm. long and 18 mm. wide in specimens studied. Margins are essentially parallel; base and apex rounded or truncated. Axis 4 mm. wide. Sporophylls

wide, fusiform in cross-section, 3 mm. wide, 2 mm. high. Sporophylls crushed together, spirally arranged, inserted obliquely to the axis near base, becoming more oblique near apex. Bracts about 6 mm. long, 1 mm. wide; acuminate-lanceolate to linear, overlapping distal laminae of 3 to 4 sporophylls above. Pedicel 3-7 mm. long with sporangium on upper surface; crestline of sporophyll slightly curved upward above keel.

Discussion: No spores are present. Specimen preserved as limonite replacement with minute, quartz, box-like structures transcending the sporophylls obliquely across the surface of the cone.

Lepidostrobus variabilis L. & H. is an extremely variable form. Into this group are placed Lepidostrobus cones which have sporophylls resembling sterile leaves and are often difficult to separate.

In 1880, Lesquereaux 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, Indiand, housed at the University of Missouri (Wood, 1963) and the Geological Survey of Canada compare favorably with the Utah material. Bell (1944) thought that his specimens of L. variabilis from the Cumberland Group, the Riverside Group and the Stellarton Group may have included more than one species. But, examination of the types does not indicate great variations.

Gothan and Weyland (1959) discuss L. variabilis and mention that its axis corresponds to the structure of Lepidodendron oldhamius Williamson. Its axis also shows a central stele with pith similar to Lepidodendron vasculare Binn. Hirmer (1927) also notes L. variabilis may be the strobilus of 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.

Lepidostrobus skemmatos sp. nov.

pl. III fig. 2; text fig. 7E

Description: Atrobilus oblong with parallel margins tapering to form a pointed apex. Strobilus incomplete, basal portion is missing. Axis 2 mm. wide. Sporophylls crowded and crushed; spirally arranged, normal to the axis. Bracts linear-elongate

to linear-lanceolate, at least 11 mm. long, 2 mm. wide at base, and overlapping 3-6 sporophylls distally. Pedicels 6-7 mm. long with sporangia on upper surface, crestline about horizontal with slight rise toward bract.

Discussion: No spores are present. This type varies from *Lepidostrobus variabilis* in shape of the bract, more compact structure, sporophylls more nearly perpendicular to the axis, pointed apex and larger size.

Lepidostrobus skemmatos is similar to *Lepidostrobus butleri* Lx., but *L. butleri* is smaller, of more oblong-oval shape, and apex is not as pointed.

Genus LEPIDOCARPON Scott 1900

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* all 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 has 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 is used for fructifications with strobilar habit which shed their entire sporophylls by disintegration of the strobilus at maturity. An integument completely envelopes the megasporangium which provides the large "seed-like" megaspore with a distinct integumentary organ. A slit between the two membranes at the crest corresponds morphologically to a micropyle. Only one megaspore matures per sporophyll. The remainder of the tetrad aborts (Schopf, 1941).

Lepidocarpon linearifolium (Lesq) Schopf

pl. V fig. 3 text fig. 7F

1880 Lepidophyllum linearifolium Lesquereux, Coal Atlas, 2nd Geol. Surv. Penn., Rept. of Prog., pp. 452-454, pl. 69, fig. 39.

1919 Cantheliophorus linearifolius (Lesq.) Bassler - Botanical Gaz. Vol. 67, p. 97, pl. IX, figs., 1, 8-10.

1940 Lepidocarpon linearifolium (Lesq.) Schopf - Schopf, J., in

Janssen, 1940, Illinois State Museum Sci. Pub. Vol. I, p. 43.

1949 Lepidocarpon linearifolium (Lesq.) Schopf.-Arnold, Univ. Michigan Contr. Mus. Paleont., v. VII, p. 174, pl. IX, figs. 2-3.

Description: No strobilus. Single megasporophyll with sporangium showing ligule. The pedicel is perpendicular to the axis and extends 11 mm. to the upturned distal lamina. Distal lamina is 30-35 mm. long, extending from base of heel to apex of sporophyll (distal lamina). Vascular bundle enters directly from the axis, and can be seen nearly to heel where it disappears. Lateral lamina extends above and around the sporangium, and forms an investing structure. Ligule obscure. Megasporangium small, 10 mm. long, 4 mm. wide, sporangial cavity about 2.5 mm. high. Sporangial wall extends vertically above the megaspore for 1.5 mm. to formthe megasporangial ridge. Sporangium appears to be attached for nearly its entire length along the upper surface of the pedicel.

Discussion: Isolated sporophylls of Lepidocarpon linearifolium are very abundant in the Manning Canyon Shale. These sporophylls are nearly exact duplicates of L. linearifolium specimens described by Arnold from the Lower Pennsylvanian of Grand Ledge, 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^{o} angle to the pedicel. The latter form is the general type encountered in the Manning Canyon Shale.

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

The stratigraphi range of L. linearifolium is at present undefined.

Genus LEPIDOSTROBOPHYLLUM Hirmer 1927)

Lepidostrobophyllum majus (Brognt.) Hirmer
Pl. III, fig. 6

1928 Lepidophyllum majus Brongnt Prodrome

1880 Lepidophyllum majus Brognt.-Lesquereux, Coal Flora, 2nd Geol. Surv. Pennsylvania, Rpt. of Prog., p. 499.

1927 Lepidostrobophyllum majus (Brognt.) Hirmer - Handbuch der Palaobotanik, Bd. 1, p. 193, fig. 213.

Description: Lamina of sporophyll large, rather oblong, parallel margins tapering near tip to a lanceolate shape with an acute apex. Single midrib; sporangiophores obovate, obtusely rounded at the base.

Discussion: 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 rare in the Manning Canyon Shale.

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

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

Genus LEPIDOPHYLLUM Brongniart 1828

Lepidophyllum longifolium Brongniart
pl. IV, fig. 5

1939 Lepidophyllum longifolium Brongniart; Janssen, Leaves and Stems from Fossil Forests, p. 62, fig. 44.

A large number of the sterile leaves of the ancient lycopods are found isolated and in a fragmental condition. Some of these from the Manning Canyon Shale are referable to this species. Although incomplete, some measure 4 mm. wide and over 20 mm.

long; complete length indeterminable. A single midrib traverses the length of this linear, grass-like leaf.

<u>Lepidophyllum</u> sp.

pl. III fig. 4

These sterile leaves are smaller than <u>Lepidophyllum</u> <u>longifolium</u>, 5-6 cm. long, 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 found attached to L. 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 usfficient to determine if spores are present.

Genus STIGMARIA Brongniart 1822

<u>Stigmaria</u> <u>ficoides</u> (Sternberg) Brongniart

pl. IX, fig. 5

1820 <u>Variolaria</u> <u>ficoides</u> Sternberg.-Flora der Vorwelt, vol. 1, fasc. 1, pp. 23-26, pl. 12, figs. 1-3.

1822 <u>Stigmaria</u> <u>ficoides</u> (Stnbg.) Brongniart.-Class. distr. veget. foss. Mem. Mus. Hist. Nat. V. 8, pl. I, p. 219, fig. 7.

1877 <u>Stigmaria</u> <u>verrucosa</u> Miller.- Amer. Paleozoic Fossils, p. 40

1899 <u>Stigmaria</u> <u>verrucosa</u> White.-U.S. Geol. Surv. Prof. Paper 185-D, p. 82.

1962 Stigmaria verrucosa Tidwell. -Brigham Young University Geol. Studies, v. 9 (2), p. 99, pl. 5, fig. 1.

Description: A few, rather large-sized specimens were collected. Rhizome with spirally disposed circular scars of rootlets, each with a raised upper rim and a central cicatrix. Appendages (rootlets) still attached.

Discussion: Our knowledge of Stigmaria, the rhizome of certain Lepidodendreae, is still very imperfect, although fossils of Stigmaria are among the most common Carboniferous specimens. The idfficulty lies in the inability to place specimens of Stigmaria into natural species or to relate them to the genus of lycopods to which they were attached. They have been found in connection with the stems of both Sigillaria and Lepidodendron.

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.

Order EQUISETALES

Genus ARCHEOCALAMITES Stur. 1875

Archeocalamites radiatus (Brgnt.) Stur.

pl. V, fig. 7, text fig. 6C

1828 Calamites radiatus Brongniart, -Prod. Hist. Veg. Foss. I, p. 122, pl. 26, figs. 1, 2.

1875 Archeocalamites radiatus (Brongnt.) Stur. -Culmflora Abh. K. Geol. Reinchsanst. v. 8, pl. I, figs. 3-8; pl. 2, 3, 4, pl. 5, figs 1 & 2.

1964 Archeocalamites radiatus (Brongnt.) Stur. -Boureau, Sphenophyta, Noeggerathiophyta. Traite de Paleobotanique III, p. 209, figs. 186, 187, 188.

Description: Compression. Ribs straight, narrow, passing directly through the nodes. The foliage consists of long, narrow, linear leaves which bifurcate several times. The leaves arise from nodes.

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. V, fig. 7) 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.

Archeocalamites has a particularly primitive appearance with its bifurcated leaves and opposite ribs (text fig. 6C). This primitive group was possibly derived from the Hyeniales of the Middle Devonian. Its foliage has changed during this transition from the leaves of Hyeniales which were thickened to Archeocalamites which are disposed in a plane (Boureau, 1965).

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 has been reported from the Lower Carboniferous up into Namurian A which approximates the Miss issippian and the very lowest Pennsylvanian.

Genus CALAMITES Suckow, 1784

(Hist. Comm. Acad. Elect. Sci., Litt. Theod.-Palat. V: 355, Mannheim)

EXPLANATION OF TEXT FIG. 6

Fig. 6A Illustrates the dichotomies of a Mariopteris frond.

Fig. 6B Illustrates the dichotomy of a Diplothmema frond.

Fig. 6C Schematic diagram of the ribs of Archeocalamites passing directly through the nodes.

Fig. 6D Schematic diagram of Mesocalamites showing the alternation of some ribs passing directly through the node and other ribs alternating.

Fig. 6E Schematic diagram of the alternating ribs of true Calamites.

Calamites (Mesocalamites) hesperius Arnold

pl. V, figs. 2, 5

1953 Calamites hesperius Arnold. - Palaeontographica, V 93B, pp. 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 Traite de Paleobotanique III, Sphenophyta, Noeggerathiophyta. p. 247, fig. 217.

Description: Pith cast compression. Ribs nearly straight with rounded or flattened surfaces; ribs 1.5 mm. wide, some terminating in acute or rounded points and alternating; others truncated and pass directly across the node. Tubercles oval-elongate near rib apex; smaller oval tubercles near rib base. Internodes 2.4 - 3.0 cm. in length. No branch scars are present.

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

The mesocalamitian group, because of its series of alternating ribs and ribs crossing directly through the node, occupies a morphological and stratigraphic position between Archeocalamites and the other subgenera of Calamites.

Archeocalamites with its ribs extending straight through the nodes, 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.

Mesocalamites resembles a mixture of these two types, with the opposing ribs more or less predominant over the alternating ribs (text fig. 6D). 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 transitionally from Namurian A. into Westphalian A.

Calamites (Mesocalamites) cistiiformis Stur

pl. IV fig. 3, pl. V fig. 1

1877 Calamites cistiiformis Stur. -Culm Flora II, K. Geol. Reichsanst. Sbh. Wien, VIII, p. 200, pl. 4, figs. 5,6.

1917 Calamites cistiiformis Stur. - Kidston and Jongmans, Monograph of Calamites of Western Europe, Rijpsop van Delfst. Meded., v. 1 pp. 192-195

1964 Calamites(Mesocalamites) cistiiformis Stur.-Boureau, Sphenophyta, Noeggerathiophyta. Traite de Paleobotanique III, p. 245.

Description: Internodes longer than broad, straight, narrow, alternating or passing straight over the node. The alternating ribs end in acute apices. Tubercles appear to be oval; furrows straight, ribs 1 mm. wide.

Discussion: The width of the specimen illustrated in pl. IV fig. 3 is 24 mm. and its internodes are 42 mm. long.

There is a strong similarity between C. cistiiformis and C. cisti Brongnt. 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.

C. cistiiformis is a typical Namurian form, especially for Namurian A. However, Gothan, Leggewie and Schonefeld (1959) found it frequently in Namurian B and C. They state that C. cistiformis

is not found in the lower Westphalian. Leggewie and Schonefeld (1961) report its occurrence in the Homoceras zone (H_1 & H_2) (Table II).

Calamites (Stylocalamites) sp.

pl. IV, fig. 7

Description: Compression of a pith cast. Ribs narrow, relatively straight, alternating; constricted at the nodes to form two small branch scars.

Discussion: None of the available literature describes or illustrates any species comparable to this form. Not enough material is available to make a new type. The internodes are considerably longer (74 mm.) than broad (15 mm.) and the ribs are approximately the same size as the intervening furrows. Of the number of specimens attributable to thisspecies, very few show evidence of branch scars.

This species is somewhat similar to the form illustrated by Lesquereux (1880) as the stem of Asterophyllites graciles.

Calamites (Calamatina?) sp.

pl. V fig. 4, text fig. 7D

Description: Incomplete specimen of pith cast showing large branch scars and leaf scars. Internodes between nodes with branch

scars are 30 mm in length, whereas the internodes between nodes bearing leaf scars are about two-thirds as long. Ribs poorly preserved. Branch scars roughly rhombohedral in outline with the umbilicus small, oval, approximately 6 mm. wide. Two nodes bearing branch scars occurring together are followed by at least two nodes bearing leaf scars. The specimen is incomplete and it is not known whether the cycle repeats itself. Branch scars appear to alternate around the stem with those on the node below not being aligned with the scars above.

Discussion: The specimen is too incomplete to make a comparison with specimens previously figured. The manner of the cycle of branch scars and leaf scars appears to be unique. No similar illustration or description was found in the literature. This speciman may, however, constitute an abnormality of some species already known.

The branch scars are actually too widely spaced to be placed with the subgenus *Calamitina* and too close, large and numerous to coincide with *Diplocalamites*.

The shape of the branch scar of this species is similar to those described and figured by Jongmans (1956) for *Calamites pyriformis* although somewhat reverse to it in outline. The shape of the branch

EXPLANATION OF TEXT FIG. 7

Fig. 7A <u>Cordaianthus pseudofluitans</u> (?) Kidston 134

A strobulis in axil of a bract. Note bifurcated sporophylls.

Fig. 7B <u>Rigbyocarpus ebracteatus</u> sp. nov. 148

Fig. 7C <u>Zeilleria</u> (?) sp. (2.5X) 100

Dotted lines indicate fructifications. Note the thickened terminus of the veins

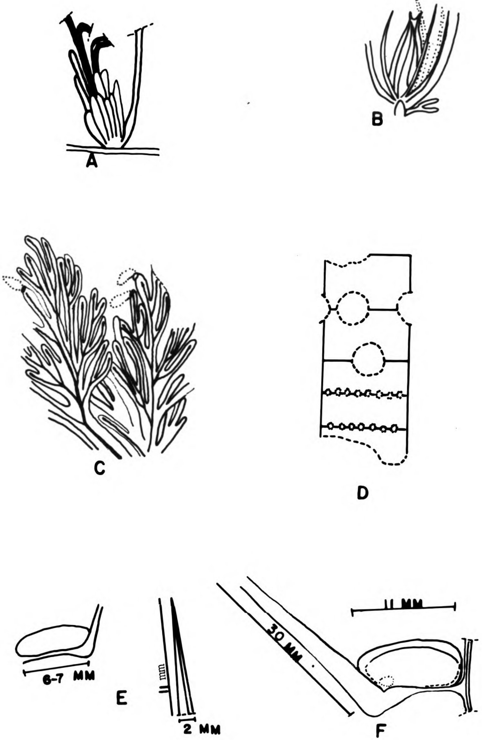
Fig. 7D <u>Calamites</u> (<u>Calamitina</u>) sp. (nearly 1/2X) 74

Two nodes with branch scars with two lower nodes showing leaf scars.

Fig. 7E <u>Lepidostrobus skemmatos</u> sp. nov. 59

Megasporangium and sporophyll with a distal lamina figured apartto illustrate its shape and size

Fig. 7F <u>Lepidocarpon linearifolium</u> (1X) Schopf 61



TEXT FIG. 7

scars is also similar to those of *Calamites discifer* Weiss, but the specimen differs in other ways. He separated *C. pyriformis* from *C. semicircularis* and *C. wedekindi* on the form of the branch scars.

This species differs from *C. wedekindi* on the shape of the leaf scars which are elongate-oval in that species and transversely oval on the Manning Canyon specimen. These two have a similar distance between scars.

Genus ASTEROPHYLLITES Brongniart 1822

(Class., Mem. Mus. Hist. Nat. 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. V fig. 8, pl. IV fig. 1

1828 *Asterophyllites equisetiformis* (Schloth.) Brongniart. - Prodrome d' hist. veg. foss., p. 159, 176.

1958 *Asterophyllites equisetiformis* (Schloth.) Brongniart. - Abbott, Bull. Amer. Paleo. No. 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.

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

Description: Leaves linear-lanceolate with nearly parallel margins. They are 5-6 mm. in length with a length-width ratio of 20 to 1. The single vein occupies nearly 1/2 the width of each leaf. They occur in whorls with the average 12 per whorl. The nodes from which the whorls originate appear to shorten toward the end of the branch causing the leaves from each preceeding whorl to overlap the succeeding whorl, giving the tip a "paint brush" effect which is characteristic of this species.

Discussion: 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.

Asterophyllites charaeformis (Sternberg) Goeppert

pl. IV, fig. 2

1825 Bechera charaeformis Sternberg. -Flora der Vorwelt I, v. 4, p. 30, pl. 55, figs. 3, 5.

1844 Asterophyllites charaeformis (Sternberg) Goeppert, in Wimmer, Flora von Schlesian Preuss, und Oster, Anth., Breslau, p. 198.

Description: Leaves 3 mm. long with 4-10 leaves per whorl. Their width-length ratio is 1:4. Leaves are falcate, wide at base. Their basal attachment is nearly perpendicular to the stem but cups somewhat distally about the axis. The vein is nearly one-half the width of the leaf.

Discussion: This form is rare in the Manning Canyon Shale. Its distribution as given by Abbott (1958) is Pottsville to lower Allegheny. According to Leggewie 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.*

Asterophyllites longifolius (Stnbg.) Brongniart

pl. IV, fig. 4

1825 *Bruckmannia longifolia* Sternberg. -Flora der Vorwelt, V. 1, no. 4, p. 45, pl. 58, fig. 1.

1828 *Asterophyllites longifolius* (Sternberg) Brongniart. - Prodrome d'Hist. Veget. Foss., p. 159-176.

1880 *Asterophyllites longifolius* (Stnbg.) Brongnt. -Lesquereux, Coal Flora, Sec. Geol. Surv. Pennsylvania, Rept. P, p. 36, v. 1.

1958 *Asterophyllites longifolius* (Stnbg.) Brgnt. -Abbott, Bull Am. Paleont., 38 (174), p. 303, pl. 40, fig. 53, pl. 42, fig. 60, chart I.

1962 *Asterophyllites longifolius* (Stnbg.) Brongniart. -Tidwell, Brigham Young University Geol. Studies, v. 9 (2), p. 98, pl. 4 fig. 7.

Description: Leaves approximately 33 mm. long and covering one internode and most of another (20 mm. between internodes).

Leaves curve upward on some and parallel the rachis on others. Some may be distorted due to preservation and others are lost; venation obscure.

Discussion: Asterophyllites longifolius is very rare in the flora from the Manning Canyon Shale. The specimen illustrated on Pl. IV fig. 4 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. Miklausen (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).

Genus PALAEOSTACHYA Weiss 1879

(Steinkohl. Calamar. I. Abh. 2. geol. Spezial K. v. 2 (1):103-105)

Palaeostachya (?) sp.

pl. IV fig. 6

Description: The main stem from which the branches arise appears to be a mesocalamitean form with some ribs alternating

and some extending through the nodes. Ribs taper into the node forming round cicatrices from which the branches are attached. The branches are also ribbed and give rise to a whorl of strobili at each node. Each strobilus consists of alternating sterile bracts and sporangiophores in its lower portion, but is comprised of sterile bracts only in its upper portion. Sporangiophores are peltate and located in the axils of the sterile bracts. Axis of the strobilus is ribbed, but not too well preserved. The sterile bracts are generally oblique to the axis, occasionally saucer-shaped and rarely at right angles, turning upward abruptly near the tip of the bract. No spores were preserved.

Discussion: Although the species is of the Palaeostachya type, it is placed with this genus provisionally. The lack of sporangiophores with the sterile bracts near the cone apex is not clearly understood. This form is similar to Palaeostachya elongata (Presl) Weiss, but the latter species does not have the feature of only sterile bracts in the upper portion of its strobili.

Genus CALAMOSTACHYS Schimper 1869

(Traite, V. 1, p. 328)

Calamostachys (?) sp.

pl. V, fig. 6

Description: 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.

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

Genus TINGIA Halle 1925

(Geol. Surv. China, Bull. 7, pp. 4-6)

Tingia sp.

pl. VI, fig. 3

Description: Frondlike. Leaves obcuneate 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: _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 obcuneate-obovate to oblong or linear, deeply lobed. Those on the lower side similar, but narrower and often more deeply dissected. The venation of this genus is nearly parallel to the margins.

These characters fit _Tingia_ sp. 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 sp. is extremely close to _Tingia carbonice_ Halle, the type species for the genus, and differs only on the size and the s lender axis of _Tingia_ sp. In fact, they are so close that _Tingia_ sp. looks like a small replica of the specimen figured by Halle (1927) on plate 62, fig. 6. _Tingia_ sp. appears to 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._

Orders FILICALES AND CYCADOFILICALES

Genus Sphenopteris Brongniart 1822

The genus Sphenopteris constitutes a heterogenous group and assignment here does not imply systemic 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 organs of species with general similarity of 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 fructification 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 (Renaultia) schatzlarensis (Stur) Zeiller

pl. VII, fig. 4a, text-fig. 8C

1885 Hapalopteris schatzlarensis Stur. Pars. - Die Farne: Carb. - Flora d. Schatzlarer Schichten I Farne: K. K. Geol. Reichsanst, Wien, XI, p. 58, text-fig. 2, pl. XXXIX, figs 7, 7a; pl. XL, figs. 2-6.

1899 Sphenopteris (Renaultia) Schatzlarensis (Stur) Zeiller. -Flore Foss. bassin houil. d'Heraclee, p. 15, pl. 1, fig. 2.

1923 Sphenopteris (?Renaultia) schatzlarensis Stur. -Kidston, Fossil plants of the Carboniferous rocks of Great Britain: Mem. of Geol. Surv. Breat Brit., Paleont. v. II, pt. 2, p. 123, pl. XXIX, fig. 4; pl. XXX figs. 1, 1a.

Descriptions: Antepenultimate pinnae incomplete, rachis somewhat flexuous. Penultimate pinnae: alternate, normal to the primary rachis, lanceolate, rachis flexuous. Ultimate pinnae: alternate, oblique, lanceolate with rounded apices. An ultimate pinna arises at each flexuous curve of the secondary rachis. Pinnules: alternate oblique, deltoid, 2-3 lobes which spread in more mature forms; complete basal attachment, decurrent, contracted slightly above; apices rounded, obtuse, sometimes acute. Venation: midrib arising acutely from rachis, dividing to supply each lobe with one veinlet.

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 generally entire as compared with S. schatzlarensis. According to Bell (1944), 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 B to Westphalian D. Bell (1944) records occurrences of Sphenopteris schatzlarensis in Cumberland and Riversdale groups in Canada.

Sphenopteris gothanica (?) Dolianiti) comb. nov.

pl. VI, fig. 6; text fig. 8D

1954 Adiantites gothanica Dolianiti.-Bol. Div. Geol. Mineral. 148, p. 41, pl. I, II.

Description: Frond at least bipinnate. Penultimate pinnae not complete; rachis felxuous. Ultimate pinnae; somehwat oblong with constricted base, alternate, 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 on outer segments tapering toward base, attached with a short, broad footstalk, 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: Gothan (1928) stated that Berry's (1922) Palmatopteris furcata from Peru was incorrectly identified and that it resembles a narrow-leaf Adiantites and renamed it Sphenopteris paracasica Gothan. Colianiti (1954) reported Gothan believes 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 than the Manning Canyon specimen and 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.

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 gothanica. This species is fairly abundant in the Manning Canyon Shale flora and is placed provisionally with Sphenopteris gothanica although it lacks the "nervils" which are so important in Dolianiti's description. This may be due to lack of preservation or they may have never been present. These "nervils", as defined by Dolianiti 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.

Dolianiti (1954) gives the age for this species as Lower Carboniferous.

Genus CORYNEPTERIS Baily 1860

Corynepteris was founded for unique fertile foliage placed with the leptosporangiate ferns. Their sporangia are united in sori, with 6-8 situated along the axis. The axis is represented by the f 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. Dober (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) these two genera 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 without fructifications should be placed with Alloiopteris until their fructifications become known. Those with fructification known may be properly assigned to Corynepteris.

Corynepteris angustissima (Sternberg) Nemejc

pl. VII, fig. 5, text-fig. 8a

1823 Aspidium angustissimum Sternberg. -Versuch einer geognotischen botanischen Darstellung d. Flora d. Vorwelt, v. 1, fasc. 2, p. 29, pl. 23, fig. 1a & b.

1825 Pecopteris angustissima sternberg. Versuch. v. I, fasc. 4, pl. XVIII.

1854 Aspenites sternbergi Ettingshausen. -Die Steinkohlenflora von Radnitz, K.-k. Geol. Reichsanst., Abh. Wien. V. 2, p. 42, pl. XX figs. 2, 3.

1899 Alloiopteris sternbergi Potonie, N. -Lehrbuch der Pflanzen palaontologie, p. 139.

1899 Sphenopteris (Corynepteris) sternbergi Zeiller. - Mem. Soc. Geol. France No. 21, p. 24, pl. II figs. 8, 9.

1923 Corynepteris Zygopteris sternbergi Kidston. -Mem. Geol. Surv. Great Britain, Paleont. III, p. 301, pl. LXXIV, figs. 1, 5; pl. LXXVII, figs. 1, 2.

1938 Corynepteris angustissima Nemejc. - Rev. Karvon. a. Perm. Pal. Bohemiae, part 2: no. 16, pp. 15 (Czech) 41, (Engl), pl. I figs 3, 4; pl. III figs 8-10, text-fig. 4, 5, 9b.

1955 Saccopteris sternbergi Daber. - Pflanzengeograph. Besond Karbonflora Zwickau-Lagauer. Geologie Berlin, Beih, No. 13 (1955), p. 22, pl. IV, fig. 2.

1956 Corynepteris angustissima Danze. -Contribution a L'etudes des Sphenopteris, fougeres sphenopteridiennes; Etudes Geologiques, 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

Description: Small, assymmetrical, pecopteroid leaflets with complete basal attachment, united, sloping forward, 4-6 teeth, alternate perpendicular to the rachis. Venation: midvein decurrent, arising acutely, branching into two equal dichotomies, which subdivide again to supply a veinlet to each tooth.

Discussion: The French authors use Corynepteris angustissima which Sternberg figured as Pecopteris, but, as Danze (1956) points out, which has pinnules similar to those for which Ettinghausen created Asplenites sternbergi. The Germans use Alloiopteris sternbergi designated by Potonie (1899) for the form. White (1899) created Alloiopteris winslovii for similar forms. Thus we have three names with the specific differences being whether you speak French, German or English. However, Alloiopteris winslovii may be a valid species, based on fairly consistent larger size.

Corynepteris antuqtissima 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.

Genus ALLOIOPTERIS Potonie 1899

Alloiopteris cruciatus sp. nov.

pl. VII, figs. 3,7

Description: Pinnules: small (3 mm long), essentially the same size, assymmetrical, slightly inclined forward, sphenopteroid with complete basal attachment, decurrent, alternate, united, normal to the rachis. Venation: assymmetrical; midvein decurrent along rachis, essentially paralleling the lower pinule margin, dividing four to five times. Two branches of midvein to lower side of pinnule, three branches to the upper side. These secondary veins may again divide supplying each lobe or tooth with a veinlet.

Discussion: The uniform, assymmetrical pinnule attributed to this species compose long, linear pinnae which are characteristic

of the genus Alloiopteris. They are larger than pinnules of most species assigned to this genus. They are larger, more erect with more branching of the veins than Corynepteris angustissima Stnbg. They are more erect and not so broad as C. coralloides Gutb. and are not as deeply dissected as Corynepteris essinglii Andra. The venation also differs from these three forms. The midvein branches more than in C. angustissima and C. coralloides. The venation pattern in A. cruciatus differs from C. essinglii in being more distant between branches of the midrib and broader, more dichotomising secondary branching.

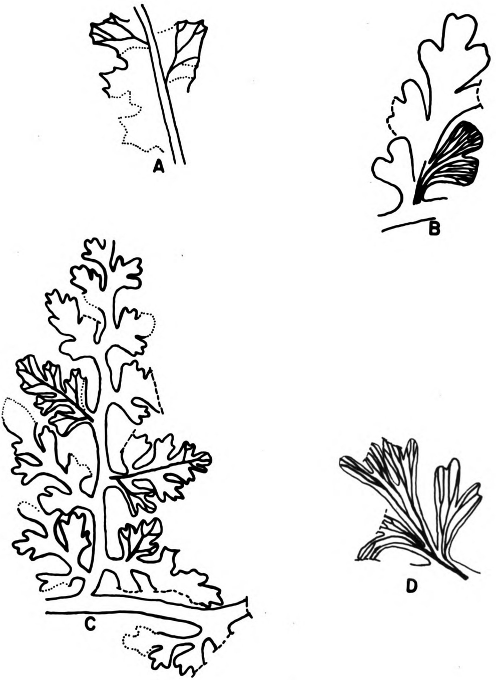
A. cruciatus is very close to A. quercifolia (Goepp) Pot. in pinnule shape, but A. quercifolia has more elongated pinnules with a number of secondary veins arising from the midrib.

Alloiopteris cruciatus cannot be assigned to Corynepteris because its fructifications are presently unknown.

Genus RHODEA Presl 1838

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 laminae. Kidston (1923) arbitrarily

EXPLANATION OF TEXT FIG. 8



TEXT FIG. 8

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 *Hemenophyllaceites*, and subsequently, had placed it in synonymy with *Hymenophyllites*. Stur (1879) re-established it as a separate genus.

Kidston (1923) assigned the fertile forms to *Zeilleria*, *Urnatopteris* and some species of *Telangium*.

A. Carpentier (1929) reported a fructification for *Rhodea gutheri* 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 would complicate the genus 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. VII, fig. 8

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

Description: Frond incomplete. Tertiary pinnae: alternate to subopposite, oblique, linear-lanceolate, slender axis. Pinnules: slender, delicate, finely divided, lobed, linear, rounded apex; alternate, oblique, single vein.

Discussion: Read (1955) reports this species as the most widely distributed and most abundant plant species in Lower Mississippian of the Appalachian trough. Arnold (1962) reports a Rhodea sp. which he suggests may be conspecific. His figured specimen issimilar to those from the Manning Canyon Shale.

Rhodea sp.

Description: Tertiary pinnae: linear-lanceolate, incomplete. Pinnules: small, erect, alternate, oblique, open, elongate, distant, forking at 45^{o} two or four times to form elongated segments or lobes with but a slight change in width of the lamina. Apices of these segments are rounded. Lamina rather thick, of nearly equal width in all parts of the pinnule. The lower-most pinnule shows a zig-zag (flexuous) pattern of branching. This appears to be present in varying degrees in the other pinnules, but not as conspicuous. Venation arises from rachis, decurrent, forks to fill each lobe with a vein.

Discussion: This form is similar to White's *Rhodea goepperti* (Ettingshausen) Stur reported from the Stanley Shale of Arkansas. White (1937) has originally thought his form was *Sphenopteris gersdorfii* based on the "zig-zag" pattern of its branching and on the general shape and size of its pinnules; but he has decided in favor of *R. goepperti*. *Rhodea* sp. differs from both on its more slender, delicate pinnules. This *Rhodea* form approaches closely the illustrations Kidston (1923) gives for the sterile foliage of *Telangium bifida*. Assignment of this species, however, must await more complete specimens.

This species is also similar to *Rhodea lemayi* Broussier and Bertrand. However, *R. lemayi* is larger with more variable pinnules as compared to *Rhodea* sp.

Genus ZEILLERIA Kidston 1884

Zeilleria (?) sp.

pl. VI, figs. 1, 4; text-fig. 7C

Description: Frond rather delicate; rachis slender, rigid. Ultimate pinnae alternate, oblique, linear-lanceolate, close, overlapping. Pinnules alternate, oblique, finely divided, deeply incised into 2 to 4 lobes or segments. Lobes slender, forming only a slight wing of lamina on each side of the single vein in each lobe; apices of the lobes are rounded. Fruiting structures of some nature terminate the vein in each lobe, some hanging pendant or nearly pendant.

Discussion: Rhodea-like forms, but Rhodea is for sterile foliage. Therefore, this species is provisionally placed with Zeilleria because that genus was proposed for fertile fern foliage with the sporangia terminating the pinnule or each veinlet.

Genus SPHENOPTERIDIUM Schimper 1874

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 pinnate. Ultimate pinnae of these fronds are sessile orslightly petioled. They are largely oval near frond base, becoming more elongate and lanceolate near frond center. Pinnules shorter and subtrilobed to trilobed. Pinnules are wedge-shaped with truncate or rounded apex. Veins parallel the margins of the pinnule and dichotomize.

The foliage attributed to this genus was initially described by Goeppert (1852) under Cyclopteris and attached to the neuropterids. Schimper (1874) redescribed them under Sphenopteridium and placed them with sphenopterids. Pontine (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 it.

Sphenopteridium differs from Sphenopteris by its veins radiating from the pinnule base and by its lacking a distinct midrib.

Sphenopteridium dissectum (Gopp) Schimper

pl. VII, fig. 2, text fig. 8b

1852 Cyclopteris dissecta Goeppert.-Foss. Fl. des Uberganesgeb. Nova Acta Acad. Caes. Lep. Car. Nat. Cur. Suppl., p. 161, taf. XIV, fig. 3.

1874 Sphneopteridium dissectum (Goepp.) Schimper.- Traite Pal. Veg. v. 3, p. 488, pl. CVII, fig. 12.

1875 Archeopteris dissecta (Goepp.) Stur.-Culm Flora, Pt. 1 K. Geol. Reichsanst. Abh. v. 8, p. 61.

1899 Sphenopteridium dissectum (Goepp.) Schimper.-Potonie, Lehrbuch der Pflanzenpalaeontologie, p. 130, text-fig. 119.

1962 Diplothmema subdecipiens, White. - Tidwell, Brigham Young University Geol. Studies, v. 9 (2), p. 97, pl. 3, fig. 6.

Description: Frond at least tripinnate. Penultimate pinnae lanceolate, normal to rachis, alternate, closely spaced. Ultimate pinnae triangular or broadly lanceolate, alternate at nearly right angles to the rachis. Pinnules cuneate, bisublobate to trilobate with lobes having truncated, obtuse or rounded apices. Small pinnules are decurrent and broadly attached, constricted above. Venation: no central midvein, several veins arise from rachis and curve upward and outward, divinding and furnishing many veinlets per lobe.

Discussion: Sphenopteridium dissectum differs from Sphenopteridium pachyrrachis (Goepp.) Schimper by having narrower ultimate pinnae and from Sphenopteridium collombianum (Schimper) Potonie' by having more triangular pinnules.

Sphenopteridium dissectum is similar to the polymorphous Diplothmema subdecipiens which has elongated, lobed, truncated to rounded pinnules; but differs 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.

Sphenopteridium zaitzeffium sp. nov.

pl. VII, fig. 12, text fig. 9B

1962 Sphenopteris (Diplothmema) spinosa Goeppert. -Tidwell, Brigham Young University Geol. Stud., v. 9 (2), p. 97, pl. 3, fig. 5.

Description: Tripinnate (?). Pinnae flabelliform, deltoid to lanceolate, alternate, attached by broad, although rather constricted stalked-base. Pinnules constricted above, decurrent below on the pinna 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 Diplothmema 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 Zaitzeffium varies from the other Sphenopteridium species by its more flabellate shape of both pinnules and pinnae, and its somewhat broader footstalk. This species was named for the author's colleague, James B. Zaitzeff.

Genus ADIANTITES Boeppert 1836

This genus has had 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_. Geinitz (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._ _Adiantites_ was subsequently placed in synonymy with _Adiantites_ by Kidston (1887) who had 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 generic level. The usage of _Aneimites_ as a genus persists in North America. White (1904) rejected _Aneimites_ 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 (1964) mentions "_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_.

Read (1955) defines _Adiantites_ as rather lax, angular fronds which are several times pinnate, owing to a climbing habit. "Pinnae alternate. Pinnules: alternate, usually cuneate, apically truncate, attached at the base by a footstalk or sessile, the base constricted. Venation derived from a single strand or plexus of strands at the base and radiating to supply the lamina by repeated dichotomy. Texture usually coriaceous."

Adiantites sp.

pl. VI, fig. 5

Description: Generally detatched pinnules cut into two lobes.

Oblong-cuneate to deltoid with rounded apex, stalked, venation consists of several veins of equal size radiating from the base and bifurcating as they extend to the margins.

Discussion: Adiantites sp. is close to Adiantites ungeri Read and A. antiquus (Ettingshausen) Stur, but is much smaller. This species may be new but the specimens are not complete enough to establish specific differentiation.

Adiantites (Wardia) tenufolius Goeppert var. difoliolatus (White) comb. nov.

pl. VII, fig. 11

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

1962 Aneimites (Wardia) tenuifolius (Goeppert) var difoliolatus White. -Tidwell, Brigham Young University Geol. Studies. v. 9 (2), p. 98, pl. 2, fig. 4.

Description: Specimen small. Pinnules oblong in larger and cuneate in smaller forms, 5 to 10 mm. long, 2 to 5 mm. wide. Contracted to a narrow base; divided into two or three unequal cuneate lobes which are obliquely truncated or rounded. Obscurely striated with nervation indistinct.

Discussion: Specimen very small and delicate, having both difoliate and trifoliate lobation. They are lower Pennsylvanian in age.

Genus DIPLOTHMEMA Stur 1877

Stur (1877-79) proposed Diplothmema to include many unrelated species which he regarded as an absolutely natural genus. White (1943) in the 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 non 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 fron structure of Diplothmema and Mariopteris and that they were intergradiational.

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 lacks a quadripartite aspect (text-fig. 6B). She considered the primary rachis to be in general naked, but occasionally partially covered with pinnae. The pinnae of this genus have sphenopteroid pinnules.

White (1943) in his synopsis states that Diplothmema, Mariopteris and Palmatopteris 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.

Diplothmema trifoliolata (Artis) Stur

pl. VII, fig. 1

1825 Filicites trifoliolatus Artis.-Antediluvian Phytology, p. 11, pl. XI.

1828 Sphenopteris trifoliolata (Artis) Brongniart.-Prodrome d'une histoire des Végéteaux Fossiles, p. 50.

1880 Pseudopecopteris trifoliolata (Artis) Lesquereux.-Coal Flora, Penn. 2nd Geol. Survey, Report P, Vol. 1, p. 217.

1885 Diplothmema trifoliolata (Artis) Stur.-K. Geol. Reichsanstalt Abh. Vol. II, p. 346, pl. 19, figs. 1-4.

1943 Diplothmema trifoliata (Artis) Stur.-White, U.S. Geol. Surv. Prof. Paper 197-C, p. 98, pl. 32.

1962 Diplothmema trifoliolata (Artis) Stur.-Tidwell, Brigham Young University Geol. Studies, v. 9 (2), p. 96, pl. 3, fig. 7.

Description: Ultimate pinnae alternate; open at nearly right angles, ovate lanceolate, narrow flexuous rachis, Pinnules alternate, small, oblique, uppermost ovate-cuneate, remainder ovate, constricted near base. Largest are lobed, forming three to five ovate lobes, becoming pediculate with the terminal lobe larger and unequally deltoid. Venation indistinct, although primary nerve is strongly decurrent.

Discussion: The pinnules of D. trifoliolata are smaller and more distant than those of D. obtusiloba Brgnt. 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 probably lead to some erroneous conclusions, (Kidston, 1903). Kidston (1923-25) doubted that Sphenopteris trifoliolata existed on continental Europe but that the various authors using this taxon were actually identifying S. obtusiloba.

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

Diplothmema obtusiloba (Brongniart) Stur

pl. VII, fig. 10

1829 Sphenopteris obtusiloba, Histoire des vegetaux fossiles, p. 204, pl. LIII, fig. 2.

1877 Diplothmema obtusilobum (Brongniart) Stur. -Die Culmflora K. k. Geol. Reichsanstalt Abh., B. 8, Heft, 2, p. 230.

1943 _Diplothmema obtusiloba_ (Brgnt.) Stur.-White, U.S. Geol. Surv. Prof. Paper 197-C, p. 97, pl. 30, fig. 4; pl. 35, fig. 7, 9.

1962 _Diplothmema spectabilis_ White.-Tidwell, Brigham Young University Geol. Studies, v. 9(2) p. 96, pl. 3, fig. 8.

1962 _Diplothmema obtusiloba_ (Brgnt.) Stur.-Tidwell, Brigham Young University Geol. Studies, v. 9 (2), p. 97, pl. 3, fig. 9.

Description: Quadripinnate. Penultimate pinnae ovate to oblong-lanceolate, alternate, at nearly right angles to primary rachis. Ultimate pinnae oblique to nearly right angles to the rachis, alternate oblong to broadly lanceolate. Pinnules stalked, alternate sometimes contiguous, decurrent; pinnules near center of pinna are oblong to oval with less prominent lobes, and those near pinna apex are more or less rounded and entire. Venation indistinct. Midrib originates low on rachis and branches outward towards margins. In the more or less orbicular pinnules the veinlets radiate from the base without any clearly defined midvein.

Discussion: The similarity between this form and _D. trifoliolata_ (Artis) Stur was discussed under the later species.

Diplothmema arnoldi Stockmans and Williere

1956 _Diplothmema arnoldi_, Stockmans and Williere.-Vegetaux de la Zone d'Oupeye d"Argenteau-Sarolay. Publ. Assoc. Etude. Paleont. no. 25, pl. A.

Description: 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: mid-vein distinct, divides twice supplying each digitate segment and lobe with one lateral vein.

Discussion: 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 & Williere (1956) report this form from the "Zone d'Oupeye" which is equivalent to lowermost Westphalian A.

Genus MARIOPTERIS Zeiller

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 are borne the tertiary pinnae, which in turn support the pinnules.

The pinnules of Mariopteris are pecopteroid to sphenopteroid, generally sub-triangular, with complete basal attachment or constricted at the 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 mid-vein 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 Mariopteris belongs to the pterido-sperms. 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 may also not be of sufficient magnitude on which to base a specific distinction.

Mariopteris muricata (Schlotheim) Zeiller

pl. VI, figs. 2,8; pl. VII, fig. 6

1804 Schlotheim, "Flora d. vorwelt" pp. 54,55, pl. XII, figs. 21, 23.

1836 Pecopteris muricata Brongniart "Hist. des Veget. Foss." Vol. I, p. 352, pl. XCV, figs. 3,4.

1880 Pseudopecopteris muricata Brngn. -Lesquereux, Coal Flora, Vol. I, p. 203, pl. XXXVII, fig. 2.

1886-88 Mariopteris muricata (Schl.) Zeiller. -Flore fossile du basin houillier de Valenciennes, Etude Gites Mineraux de France, pl. XX, fig. 2,3; pl. XXI, fig. 1.

1953 Mariopteris muricata (Schl.) Zeiller. -Danze-Corsin; Les Mariopteris du Nord de La France; Etudes Geol. Houill. du Bassin du Nord et du Pas-de-calais; pp. 122-135, pl. XXII to XXXVIII.

Description: Fragmental. Ultimate pinnae: alternate, oblique, lanceolate or triangular. Terminal pinnule: broadly triangular, acute apex, sublobate base. Pinnules: ovate-lanceolate to sub-triangular, acute apex, lower margin of young pinnae strongly decurrent, upper margin constricted, complete basal attachment with an assymmetrical base, margins entire, crenulate becoming toothed, alternate, close, oblique, larger pinnules near base becoming lobed with five lobes with acute apices forming, spreading out somewhat fan-shaped. 11 mm. long, 4 mm. wide. Venation: obscure, one strong midvein arising obliquely from the rachis near lower margin of the pinnule, decurrent, swinging through center and terminating before reaching apex. Lateral veins arise from midvein alternately, forking 3-4 times, some arching strongly, others cruising to the margins rather obliquely.

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. VI, fig. 2, are clearly assymmetrical 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* is 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; by 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 it and M. muricata as basically M. nervosa having entire margins and the margins of M. muricata being 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; (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 is wider and thicker than M. acuta.

The specimen illustrated on plate VII, fig. 6, was loaned to the author by Dr. C. A. Arnold of the University of Michigan. This specimen exhibits pinnules of the upper portion of a secondary pinnae. The pinnules are more elongated with rounder apices than those of the ultimate pinnae figured on plate VI, fig. 2 and 8. The venation is the same for both specimens.

EXPLANATION FOR TEXT FIG. 9

Page

Fig. 9A <u>Crossopteris</u> <u>utahensis</u> sp. nov. (5X)----------- 125

Terminus of a penultimate pinnae.

Fig. 9B <u>Sphenopteridium</u> <u>zaitzeffium</u> sp. nov. (5X)----- 104

This species has no midvein. All veins arise from the rachis and bifurcate several times before reaching the margin.

Fig. 9C <u>Odontopteris</u> sp. (8X)------------------------ 131

Fig. 9D <u>Neuropteris</u> <u>ampelinos</u> sp. nov. -------------- 121

(4.5X)

TEXT FIG. 9

Mariopteris muricata is essentially a Westphalian form, rarely extending down into the Namurian.

Carpentier (1907) reports it from his 1B and 2A zones which are Upper Numerian A. Crookall (1933) reports one specimen from the Lanarkian of Great Britain.

Genus NEUROPTERIS Brongniart 1822

Neuropteris gigantea Sternberg

pl. IX, fig. 4

1821 *Osmunda gigantea* Sternberg. - Versuch, v. i, fasc. ii, p. 33, pl. xxxii

18 *Neuropteris gigantea* Sternberg. - ibid, v. i, fasc. iv, p. xvi.

1962 *Neuropteris gigantea* Sternberg. - Tidwell, Brigham Young Univ. Geol. Studies, v. 9 (2), p. 93, pl. 1, fig. 7.

Description: Specimen at hand fragmentary. Pinnules flat, falcate, alternate, nearly right angles to the rachis, contiguous, sessile, slightly cordate at base, rounded apex; 25 mm. long, 8 mm wide. Strong mid-vein continuous to nearly two thirds pinnule length. Lateral veins arise from midrib at a sharp angle and subdivide several times to form very fine, very close veinlets.

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 appear 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) shows this form to be distributed from Namurian C. to Westphalian D definitely, and possibly into Namurian B.

Neuropteris heterophylla Brongniart

pl. VIII, fig. 2; pl. IX, fig. 3

1709 Lithosmunda minor Scheuchzer. - Herbarium Diluvianum, p. 15, pl. iv. fig. 3.

1833 Neuropteris heterophylla Sternberg. - Versuch, v. i, fasc. v-vi, p. 73.

1962 Neuropteris heterophylla. - Tidwell, Brigham Young Univ. Geol. Studies, v. 9 (2), p. 93, pl. 1, figs. 3, 8.

Description: Bi- to tripinnate. Pinnules alternate, oblique, ovate to oblong, attached by single point, those on upper pinnae odontopteroid, 15 mm. long, 7 mm. wide. Pinnules have a distinct midrib with lateral vein distinct, close (35 to 40 per cm.), arising at an acute angle, oblique, strongly arched on some, divides two or three times, contacts margins obliquely. Unipinnate near apex with the terminal pinnule lanceolate or rhomboidal, 30 mm. long, 6 mm. wide, sharply to bluntly pointed, slightly lobed on margins.

Discussion: N. heterophylla and N. tenuifolia are similar. N. heterophylla differs from N. tenufolia in having stronger and fewer lateral veins and in having pinnules shorter in relation to width.

N. heterophylla's stratigraphic range is from Westphalian A through Westphalian D.

Neuropteris cf. pocahontas White

pl. VIII, figs. 4, 6

1900 Neuropteris pocahontas, White. - U. S. Geol. Surv. 20th Ann. Rept., p. 888, pl. CLXXXIX, figs. 4, 49; pl. CXCI, figs. 5, 5a.

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

Neuropteris ampelinos sp. nov.

pl. IX, fig. 2, text-fig. 9D

Description: Frond: bi-or tri (?) pinnate. Pinnae: alternate, right angles to rachis, but curving sharply upward, rachis flexuous, no terminal pinnules present. Pinules: lanceolate, apex acute to pointed, rarely obtuse, asymmetrical base with single point attachment on the larger (mature) pinnules, pinnules nearer the pinnae apex have 1/2 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 3/4 to near apex, decurrent. 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 ampelinos* differs from *Crossopteris utahensis* in its finer venation, single point attachment and viney, lax habit. *N. ampelinos* and *N. pocahontas* 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. ampelinos*.

Genus CROSSOPTERIS 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 four. Subsidiary veins arise directly from rachis in pinnule with partial or entire basal attachment.

Discussion: This genus is similar to Neuropteris in venation, general pinnule shape, size and in nearly reaching single point attachment; but differs from it on several points:

(1) The manner of lobing. In Crossopteris, the first larger (mature) pinnules have undulating margins (text-fig. 10B). 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 LX and A. gibsoni LX.

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. 10A, 10D) whereas in *Neuropteris*, particularly *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 *Neuralethopteris* on venation and manner of attachment. The mid-vein 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. 10C). 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 with rounded, rarely pointed apices. The venation of *Pecopteris* is also simple or grouped by twos, threes, 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.

Basically, therefore, Crossopteris is characterized by (1) its pecopteroid-alethopteroid manner of lobing; (2) its complete (alethopteroid) 1/2 basal or single point (neuropteroid) attachment (text fig. 10C); 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.

Crossopteris utahensis sp. nov.

pl. IX, figs. 1, 6; pl. X: text figs. 9a, 10.

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, pinnitilobate (undulating margins), attached with single point, base assymmetrical, 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 (2mm.) 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. The upper margin becomes more constricted in each succeeding pinnule in direction of pinnae-base until margin is constricted to near mid-rib. Larger pinnules both oblong and lanceolate with obtuse to acute apices, attachment one-half base, eventually acquiring single point attachment in pinnatilobate pinnules.

Pecopteroid-alethopteroid manner of lobing. Venation: distinct, thin, regular. Midvein distinct in larger (mature) pinnules but does not reach apex of pinnule, 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 four. Laterals strike the margins of the pinnatilobate forms at nearly right angles. Subsidiary veins arise directly from the rachis. Terminal pinnule: linear-lanceolate, laterally unequal, sublobate, apex generally acute, rarely rounded.

Discussion: Crossopteris utahensis is the most abundant form in the Manning Canyon Shale. This species is comparable in abundance to Neuropteris pocohantas which characterize 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. This concept came from the observance of the intermediate forms between these intergradational groups. *Neuropteris schlehani* is an example 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 neuralethopterid form *Neuropteris biformis* LX 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) described 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*. Its variation from *C. utahensis* is by its wider pinnules. It is repre-

EXPLANATION OF TEXT FIG. 10

		Page
Fig. 10A	Crossopteris utahensis sp. nov. (7X)----------	125
	This is a small pinnule from the upper portion of a penultimate pinnae. Note complete basal attachment with lower margin decurrent and the odontopteroid venation.	
Fig. 10B	Crossopteris utahensis sp. nov. (1X)----------	125
	Penultimate pinnae illustrating the 1/2 basal attachment becoming single point attachment in the pennatilobate pinnules.	
Fig. 10C	Crossopteris utahensis sp. nov. (5X)----------	125
	Lower portion of pinnule showing the 1/2 basal attachment and the neuropteroid venation.	
Fig. 10D	Crossopteris utahensis sp. nov. (7.5X)--------	125
	Small pinnule of an upper portion of a penultimate pinnae or a small ultimate pinnae. This pinnule would be situated below the small pinnule in text fig. 10A.	

TEXT FIG. 10

sented by only the upper portion of a pinnae. Its venation is neuropteroid.

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 sp.'s B, C, and E) are now placed in the polymorphic form: Crossopteris utahensis.

Crossopteris mcKnightii sp. nov.

pl. VIII, fig. 5

1962 Neuropteris sp. A cf N. falcata, Tidwell, Brigham Young Univ. Geol. Studies. v. 9 (2), 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 1/2 basal attachment, becoming attached with single point in the pinnatilobate forms. Apex pointed, although roundly pointed on some. Smaller pinnules odontopteroid, triangular in outline. Venation: distinct, midvein continuous to 5/6th 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 originally thought this variety had affinities with *Neuropteris foilcata*, 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 Botany Dept. at Brigham Young University who has contributed significantly to this study.

Crossopteris undulatus sp. nov.

pl. VIII, 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 constricted at the base to form an asymmetrical base with single point attachment in the larger pinnules, 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 5/6th the pinnule length. Lateral veins very thin, fine, close, numerous (56-64 per cm.), arising at an

acute angle, arching strongly, forming 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.

Genus ODONTOPTERIS Brongniart 1828

Odontopteris sp.

pl. VII, fig. 1; text fig. 9C

Description: Bi - or tri - (?) pinnate. Ultimate pinnae linear, tapering to a rounded apex, alternate, normal to the secondary rachis, decurrent, rachis striated. Pinnules: broadly elliptic, thickened in middle, with acute to obtuse apices, laterally unequal, complete basal attachment, decurrent, upper margin slightly contracted, distant, oblique, alternate, 6 mm. long, 3 mm. wide. Venation: veins arising direct from rachis generally, midrib, if present, obscure, veins arch and subdivide one to two times before striking margins obliquely.

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 their similarity to odontopteroid pinnules attached to *Crossopteris utahensis*.

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

Order: CORDAITALES

Genus CORDAITES Unger 1850

Paleobatanists 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 *Dory-cordaites* 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 re-united 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. XI, fig. 5

1855 *Cordaites principalis* (Germar) Geinitz. Vers. d. Steinhf. 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. XXXI, fig. 1.

1962 Cordaites communis? lx. -Tidwell, Brigham Young Univ. Geol. Studies, v. 9 (2) p. 97, pl. 4, fig. 1, 2.

Description: Leaves spatulate in outline, tapering to a thickened apex, long, attaining a length of 22 mm., and sometimes 20 mm. wide, narrowed towards base. Apex rounded or obtuse (?). Venation: irregular, nine veins per centimeter. Strong vein alternating with from 3 to 5 weaker veins.

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 strong veins one to five (usually three to five) finer, parallel veins are found.

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

Cordaites sp. A

pl. XI, figs. 1, 6

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.

Cordaites sp. B

pl. XI, fig. 3

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 too incomplete to make a positive identification.

Cordaites (?) sp. C

pl. XI, fig. 2

Description: Long, tapering to thin base, apex rounded, veins of about the same strength, dichotomizing as they proceed toward the apex.

Discussion: Cordaites (?) sp. C. rare in the Utah flora. This species is placed provisionally with Cordaites, but may belong to the genus Ginkophyton.

Genus CORDAIANTHUS Grand 'Eury 1877

Cordaianthus pseudofluitans (?) Kidston

pl. XIII, fig. 7, text fig. 7A

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.

Description: Cordaitean inflorescences with maximum width of 35 mm. Bracts alternate or subopposite, 45 to 90 degrees to axis, 20 mm. long, although not complete. Sterile scale leaves spirally arranged, oppressed, imbricated, linear-lanceolate to lanceolate, 10 mm. long, 1-1.5 mm. wide. Megasporophylls three to four per strobilus, stalk-like, unbranched, 16 mm. long, bifurcated at the distal end.

Discussion: *Cordaianthus pseudofluitans* is considered by Florin (1950) to be geologically older and more primitive than the older 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). *Cordaianthus zeilleri*, Florin (1951) considers as the more modern cordaitean fructification. 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. pseudofluitons* in their megasporophyll appearance which are only occasionally bifurcated at their apices and are always uni-ovulate.

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

SEEDS, CUPULES AND SPORANGIA

Genus CORDAICARPUS Geinitz 1862

The identification and classification of flattened, bilaterally symmetrical seeds using as criteria the external shape of the nucellus and the integuments surrounding it are subject to a high degree of uncertainty. The integuments may be partially destroyed or flattened or separated from each other or the nucellus during the process of deposition and preservation. The surface of the seed or its integuments may also acquire different textures, and the resulting seed may assume an appearance quite different from other members of its species or genus, making identification difficult.

Another difficulty arises from the lack of a uniform classification system. In many of the older works, seeds are vaguely described and inadequately figured, causing frequent misapplication of names. Generic descriptions were often interpreted differently, and the precarious application of names originally used to designate structuraly preserved types for seed impressions has added to the confusion.

Brongniart (1828) made the first attempt at classification by giving the generic name _Cordaicarpon_ to "Fruits comprimes, lenticulaires, cordiformes ou reniformes termines par une pointe peu aigue". This name was later changed to _Cordaicarpus_ by Geinitz (1862).

Goeppert (1864) used the term _Cardiocarpon_ to include seeds of _Cardiocarpus_ and _Samaropsis_ types. White (1899) used _Cardiocarpon_

and Samaropsis as synonyms or at least placed Samaropsis as a subgenus of Cardiocarpon. He described seeds under Cardiocarpon and Cordaicarpon using Brongniart's Cardiocarpon in the synonymies of both.

Kidston (1909) included Cardiocarpon and Cordaispermum under Cordaicarpus, and distinguished it from Samaropsis by the absence of lateral wings and from Cardiocarpus by its more cordate outline.

Lesquereux (1880, 1884) Arber (1914) and Seward (1917) made attempts at correcting this situation.

Lesquereux (1880) used four generic divisions for seeds. These were Cardiocarpus, Rhabdocarpus, Trigonocarpus and Carpolithes. In 1884, he defined Cardiocarpus as "seeds of various shapes, composed of a compressed, gen erally cordiform or oval acute or acuminate nucelus surrounded by a flattened, fibrous border or a membraneous wing and often narrowed at the base into a short pedicel or acute appendage." To Cordaicarpus he referred seeds of various shapes and sizes which were "hypothecially considered until now by their association to Cordaites as the fructifications of these plants."

Lesquereux (1880) recognized a difference between Samaropsis whose nucelus was superposed to or enclosed into a kind of samara

or thin membraneous scale; and Cardiocarpus with a "generally narrower margin." He noted transitional forms between these two groups but included both under Cardiocarpus.

Arber (1914) defined Cardiocarpus as not-winged, and referred all platysperms with a "triangular or heart-shaped nucellus, surrounded by a more or less circular wing" to Samaropsis. She restricted Samaropsis to seeds which were "not longer than broad or broader than long," and created a new genus Samarospermum for those forms having a very long and narrow wing.

Although Arber's classification simplifies generic identification, the relationship between the broad, membraneous wing and a small fiberous coating should be more distinct. Seward (1917) attempted to classify seeds by (1) restricting Cardiocarpus to petrified seeds exhibiting characters described by Brongniart (1881) and Bertrand (1908) (2) including those seeds with broader and more clearly defined border under Samaropsis, (he also restricted the designation of Samaropsis to Paleozoic seeds) and (3) placing platyspermic seeds, preserved as casts or impressions with a comparatively narrow border enclosing an ovate or cordate-ovate nucellus and having a rounded or cordate base, with _Cordaicarpus_. In his classification, the choice between Cordaicarpus and Samaropsis is much the same as Lesquereux (1880) proposed. Seward also mentions that seeds preserved with a narrow border could be assigned only to _Cordaicarpus_, although many are undoubtedly incomplete or immature. He also comments that _Cordaicarpus_, thought more suggestive of a cordaitean alliance, may in some cases be a pteridosperm.

The problems encountered with Sewards classification are (1) identification of the transitional forms between Samaropsis and Cordaicarpus, and (2) the lack of constant characters by which to distinguish Cardiocarpus from Cordaicarpus - i.e., distinguish a petrification from a cast or impression.

Seward's system has the advantages of (1) being more universal, (2) separating petrifaction genera from impression genera, (3) eliminating unnecessary generic names and (4) having more definite descriptions.

The generic names used in the study follow Seward's classification system.

Cordaicarpus elongatus (Newberry) comb. nov.

pl. XII figs 6, 11, Table IV

1873 _Cardiocarpon elongatum_ Newberry, Geol. Surv. Ohio Paleontology, 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. Wings emarginate near micropylar end, 3 mm. wide near micropyle. Micropyle faint. Nucellus cordate, rounded base, acute apex.

Discussion: This species is similar to *C. 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.

Cordaicarpus sp. *globosus* sp. nov.

pl. XII fig. 2, table IV

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 *Cardiocarpus late-alatus* Lx by having a smaller wing, a broader nucellus, and a slightly smaller size.

Cordaicarpus cordatus (Jackson) nov. comb.

pl. XII figs. 8, 9, 12, 13, 14; Table IV

1916 Cardiocarpon cordatum Jackson, Proc. Indiana Acad. Sci. pl. X, fig. 10.

1916 Cardiocarpon obtusum Jackson, Proceedings of the Indiana Acad. Sci., pl. X, figs. 13-14, p. 426.

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.

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, the author found no difference between his C. cordatus and C. obtusium. The specimen in plate XII, fig. 9, 13, appears to be the nucellus of C. cordatus with the wings missing.

Cordaicarpus jayshuleri sp. nov.

pl. XII figs. 3, 4, 5 Table V

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* Lx 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, James B. Shuler of Greenville, South Carolina.

Cordaicarpus manningcanensis sp. nov.

pl. XIII fig. 2, Table V

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 greatest 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 microphyle 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.

Cordaicarpus binutus sp. nov.

pl. XII fig. 3; table IV

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

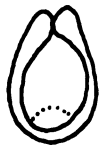
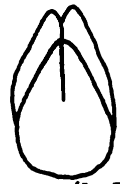
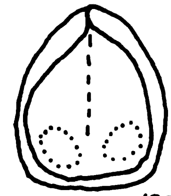
Description: Seed ovate to cordate outline. Size varies slightly from 15 mm. long, 11 mm. wide to 10 mm. long, 10 mm. wide for smaller specimens. Greatest width occurs slightly below center on some specimens and nearer the base on others. Base is cordate, although one specimen has an obtuse-rounded shape. Two reniform depressions occur near the basal walls of the nucellus. Wings are o. 5 to 1 mm. wide near base and expanding to 1 to 2 mm. at the apex. Nucellus cordate in outline, pointed down.

Discussion: These specimens are separated from C. cordatum by the larger size and the two depressions near the base.

Genus TRIGONOCARPUS Brongniart 1828

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

TABLE IV

Name	Cordaicarpus cordatus (Jackson) comb. nov.	Cordaicarpus globosus sp. nov.	Cordaicarpus elongatus (Newberry) comb. nov.	Cordaicarpus binutus sp. nov.
Illus.	 (2X)	 (1X)	 (1. 5X)	 (2X)
Shape Base Apex	Ovate to cordate Rounded Acute	Cordate Rounded Acute	Cuneate-cordate Semi-truncated Acute	Ovate to cordate Cordate
Size: Length Width	 8 mm 6 mm	 8 mm 7 mm	 15 mm 10 mm	 10-15 mm. 10-11 mm
Nucellar Shape Base Apex	Cordate Rounded Acuminate	Cordate Rounded Acuminate	Ovate-Cordate Truncated Acute	Cordate Pointed
Wings Shape Size	Expanded toward apex Emarginate at apex. Thin around base Base:0. 5 mm Apex:1 mm	Expanded toward apex Emarginate at apex Base: 0. 5 mm Apex: 1 mm	Expanded toward apex Emarginate Base: 0 Apex: 2 mm	Expanded toward apex 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
Micropule	Faint	Present	Present	NC

impressions and those seeds which are preserved as petrifactions.

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.

Triginocarpus noeggerathi (Stnbg.) Brongniart

pl. XIII fig. 14

1880 Trigonocarpus noeggerathi Brgnt.-Lesquereux, Coal Flora, 2nd Geol. Surv. Penn. Rept. P, p. 584; pl. LXXXV fig. 1.

1949 "Trigonocarpus" noeggerathi (Stnbg.) Brgnt.-Arnold, Univ. Mich. Contr. Mus. Vol. VII, p. 214, pl. XXIX, fig. 3.

Description: Seed elliptical with one longitudinal ridge visible. Micropylar portion of the specimen is missing. The specimen measures 1.4 cm. wide, and at least 2.5 cm. long. The remainder of its exposed surface is smooth.

Discussion: This specimen matches exactly a specimen from the Michigan Coal Basin identified to 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 these features are observable in the specimen under consideration.

Stockmans and Williere (1955) found _Trigonocarpus_ specimens resembling _T. noeggerathi_, _T. parkinsoni_ Brgnt; and _T. schultzianus_ Goepp, in the Zone de Bioul in the lowermost Namurian A of Belgium. They state it would be dangerous for them to attribute them to these species, because this would imply they were known. The reason they hesitate to place them with these species is that the plants which the seeds have been associated with are not present in the beds from which the seeds were collected.

Trigonocarpus sp. A.

pl. XIII fig. 11

Only one specimen of this type has been found. The seed is compressed and the surface shows three longitudinal ridges, although its probable number is six. These ridges are 1 mm wide and divide the visible surface into four equal parts and converge toward the micropylar end. The surface between the ridges is smooth. The specimen is 1.5 cm. wide and 3 cm. long. It appears to be surrounded by a marginal band. The micropylar type is missing.

Trigonocarpus sp. B

pl. XIII fig. 10

Smooth scleratesta and a portion of the micropyle of *Trigonocarpus* forma B described by Arber (1914). The sarcotesta can be observed as a thin film partially imbedded in the matrix surrounding the sclerotesta. The specimen here described is about twice the size of *Trigonocarpus parkinsoni* as illustrated by Arber (pl. VI, FIG. 2). The micropyle of *Trionocarpus parkinsoni* is much langer and thinner than for the Manning Canyon Shale specimen.

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

Trigonocarpus sp. C

pl. XIII figs. 9, 13

Seed, 3.4 cm long, 1.5 - 2.5 cm. wide, flask shape, micropyle short, apex truncated. One specimen with 4 longitudinal ridges visible. Preservation is poor as to internal features. This species is similar to *Trigonocarpus clavatus* (Sternberg), but appears to be wider and generally larger than the latter species.

Genus HOLCOSPERMUM Nathorst

Holcospermum sp.

pl. XIII, fig. 8

1962 (?) *Cardiocarpus* sp., Tidwell - Brigham Young University Geol. Studies, v. 9 (2), p. 102, 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.

Genus CORNUCARPUS Arber 1914

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 emended slightly to include all seeds with prominent horn-like or whip-like projections from their micropylar end.

Cornucarpus discissus sp. nov.

pl. XIII, fig. 1; table V

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 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.

Genus RIGBYOCARPUS Gen. nov.

Rigbyocarpus ebracteatus sp. nov.

pl. XIII, figs. 5,6; text fig. 7B tableV

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. XIII fig. 6) 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 was named for Dr. J. Keith Rigby of Brigham Young University, Provo, Utah; in recognition of his friendship, interest and aid in this study.

Genus LAGENOSPERMUM Nathorst 1914

Nathorst (1914) introduced *Lagenospermum* for small, fusiform or elongated seeds, characterized by being completely enclosed within a cupule, and having six (?) conspicuous, longitudinal ribs or ridges. Two species, *Lagenospermum sinclairi* Arber and *L. arberi* Nathorst, are typified by a long stalk terminated with a cupule.

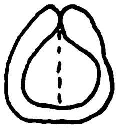
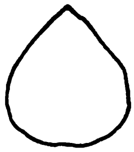
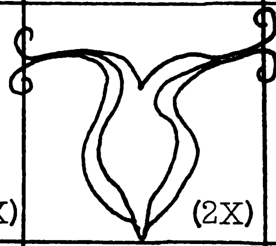
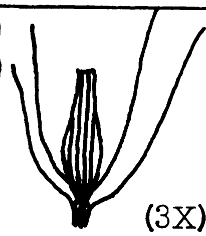
Lagenospermum bifurcatus (Stopes) comb. nov.

1914 *Pterispermostrobus bifurcatus* Stopes, -Geological Survey of Canada Memoir 41, p.p. 74-77, pl. XVII, fig. 45; pl. XXV, fig. 69 and text-fig. 15.

1962 *Pterispermostrobus* sp. A-Tidwell-Brigham Young University Geol. Studies v. 9 (2), p. 100, pl. 4, fig. 9.

Description: Seeds 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 preserved. The seed

TABLE V

Name	<u>Cordaicarpus Manningcane-sis</u> (A)	<u>Cordaicarpus jayshuleri</u> sp. nov.	<u>Cornucarpus discissus</u> sp. nov.	<u>Rigbyocarpus ebracteatus</u> gen & sp. nov.
Illus.	 (2X)	 (2X)	 (2X)	 (3X)
Shape Base Apex	Oval Truncate-cordate Acute	Cordate rounded Acute	Broad oval slightly rounded pointed	Elongate bottle shape Acute
Size: Length Width	 8 mm 7 mm	 12 mm 10 mm	 10 mm 8 mm	 8 mm 2 mm
Nucellus Shape Base Apex	Cordate Cordate Acute	NC	Oblanceolate Obtuse Cut	NC
Wings Size	Widening toward apex slightly Emarginate Base: 1 mm Apex: 2 mm	NC	Expands into narrow whip-like horns Base: 1 mm Apex: 1.5. mm	NC
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

forms a depression or mold 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 branch.

Discussion: This species from the Manning Canyon Shale resembles closely Pterispermostrobus bifurcatus from the Fern Ledges of New Brunswick. The specimen described by Stopes (1914) was only a carbonized film in which structural details are indiscernible. It could not be determined whether the film was a fructification or a seed or a sporangium. Therefore, she created the new genus Pterispermostrobus for fructifications of this nature.

The specimens here described appear to be closely comparable to Stope's specimen. The Manning Canyon Shale forms contain "ribbed" seeds and therefore should be placed with the genus Lagenospermum.

The Utah specimens are smaller than Lagenospermum imparirameum, described by Arnold (1939) for fossils from the Pocono Formation, and their bracts or lobes are not as spread out. They also differ in the manner in which the stalks bifurcate. The stalks of L. bifurcatus generally divide equally, whereas in L. imparirameum and L. sinclairi Aber, they are unequally divided.

Nathorst 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. Lobes on L. kidstoni are rounder. Its tests is smooth with only slight longitudinal ridges.

Genus GNETOPSIS Renault and Zeiller 1884

Gentopsis was originally proposed for small petrified seeds and impressions which Renault and Zeiller believed belonged to some Cretaceous plant. The early paleobotanists used Gnetopsis to indicate an 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 suggest the existence of several important characters which Gnetopsis eliptica Oliver and Salisbury has in common with Lagenostomales. No affinities between Gnetopsis and the gentaleans have actually been established.

Seward (1917) proposed that Gnetopsis is a transition 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. XIII, fig. 4

1917 Gnetopsis anglica Kidston, Seward, Fossil Plants, p. 318, figs. 494 E, F, G, H.

Description: Seed oval, elongate, with terminal "appendages" attached to the micropylar end. These terminal appendages appear to be partially united on some species or divided into four components in others. No nucellus or other internal structure is discernible. The length of these small seeds is 4 mm. Their maximum width through the median area is 2 mm. Their "appendages" are 25 mm. or more in length.

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 prominent 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 & Carpentier (1913) which had six distinctive ridges as having been transferred into _G. anglica_ by Seward (1917). They stated that _G. anglica_ must vary according to the preservation of its envelope.

Depape and Carpentier (1913) reported their form (_G. hexagona_) from the Stephanian of Commentry. Stockman and Willere (1953) report their specimens of _G. anglica_ from Namurian B.

Genus TELANGIUM Benson 1904

Stur (1875-77), Kidston (1887) and others described under the name _Calymmathotheca_, impressions which they considered to be sporangia. Because _Calymmathotheca_ 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. She considered _Telangium_ to be applicable to microsporangia of a pteridoseprm, 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 (1906) 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 also noted (1923) 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 as well as petrified structureless compressions in the genus Telangium as well and the petrifactions showing internal structure only, for which the genus had been originally proposed. He expressed the opinion that a new genus should be created for impressions and structureless compressions, especially for the specimen of a fructification recorded by Carpentier for Sphenopteris striata.

Telangium affine (L. & H.) Benson

pl. XII, figs. 1, 10, 16

1832 Sphenopteris affinis Lindley and Hutton, "Fossil Flora" Vol. 1; pl. XLV.

1887 Calymmatbtheca affinis (L. &H.) Kidston, Trans. Roy. Soc. Edinburgh, Vol. XXXII: p. 145, pl. IX, figs. 18-22.

1904 Telangium affine (L. &H.) Benson, Ann. of Bot. Vol. XVIII: p. 164; pl. XI, fig. 12, text-fig. 33.

Description: Rachis dichotomizes several times, terminating in two short dichotomies and the resulting branches are terminated with small upright synangium. The synangia are 3 mm. long and

about 4 mm. wide. The synangia are united to one another at their bases and form a cup-shaped synangium. The lower portion of this synangium appears to be solid and merges into the supporting rachis. Six sporangia seem to form a synangium. Each sporangia is 3 mm. long and 0.5 mm. wide.

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.

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 Whittleseya type

Hemingway (1941) reports that these spores are large, smooth, oval bodies with a longitudinal germinal slit which vary in size from 100 to 300 U, depending upon the species represented. These spores are larger than those previously reported for pteridosperms which rarely exceed 50 U 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 (1932) recorded a form of this type, later named *Aulacotheca dixiana* by Hemingway, as being attached to *Neuropteris schlehani.* Hemingway (1941) thinks that it is not attached, but rather the foliage and carpons in closely falling together, have 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 pteridosperms.

On the stratigraphic range of this genus, Arnold states that "Since *Aulacotheca* extends throughout the entire vertical extent of the Pottsville group in the Appalachian region, its use as a horizon marker within the Pottsville is limited, although White's comment that the sporocarps in the higher beds usually are larger than those found at lower levels may be based upon genuine difference."

Aulacotheca campbelli (White) Halle

pl. XIII fig. 12

1900 *Whittleseya Campbelli* White 20th Ann. Report U.S.G.S., p. 905, pl. CXC, figs. 9-11

1933 Aulacotheca Campbelli (White) Halle K. Svenska Vet. Akad. Hand. p. 20, 39.

1949 Aulacotheca Campbelli (White) Halle, Arnold. Cont. Mus. Paleo, Univ. of Mich. p. 207, pl. XXIV, figs. 4-6.

Description: Compression, 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.

Discussion: Halle (1933) mentioned that he was certain Whittleseya campbelli 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 and also discusses the variation in size of this species. He states that the smaller sporocarp generally occur in the lower horizons of the Pottsville, whereas the larger forms are found nearer the top.

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

Aulacotheca Hemingwayi Halle

pl. XII, fig. 7

1933 Aulacotheca hemingwayi Halle, K. Svenka Vet. Akad. Handl. Vol. XII (6), p. 36, pl. 8, figs. 1-16.

1941 Aulacotheca hemingwayi Halle, Hemingway, Ann. of Bot. N.S., vol. V, p. 198, pl. V, figs. 1-9.

Description: Small (18-25 mm. long, 4-4.5 mm. wide near apex), microsporangiate structure with 9(?) locules. Surface longitudinally striated. General shape oblong, broad at the apex, tapering toward a narrow base. Apex dentate. No spores observed.

Discussion: The Aulacotheca specimens from Utah referred provisionally 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 (1941). He gives its size 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 supposed A. campbellis should be placed with A. hemingwayi with White's specific name having priority. Darrah in a sub-note to Jongman's paper thinks they are distinct because A. hemingwayi has "rather broader aspect and a somewhat different ornamentation."

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EXPLANATION OF PLATE I

Fig. 1 North view of Clay pit A on Lake Mountain. Plant horizon occurs in the shales along the eastern face of the pit. (right side).

Fig. 2 Clay pit C looking northwest. Plants were collected from southwestern face of the pit. (left side).

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PLATE I

EXPLANATION OF PLATE II

Fig. 1 View looking east at the type section of the Manning Canyon Shale in Soldier Canyon. The median limestone appears to the right in the figure beneath the lone tree on the lower skyline.

Fig. 2 A view of the northern end of Clay Pit A. The plant horizon is situated in the ledges to the right in the illustration.

1

2

PLATE II

EXPLANATION OF PLATE III

Page

Lepidodendron volkmannianum Sternberg 53

fig. 1 Specimen showing the characteristic horizontal and vertical alignment of the leaf bolsters (lX)

Lepidostrobus skemmatos sp. nov. 59

fig. 2 Strobilus showing its compacted sporophylls and its general shape (pointed apex) incomplete (IX)

Lepidostrobus variabilis L. & H. 57

fig. 3 Strobilus demonstrating its oblong shape, its axis and crowded sporophylls. Note the quartz box-work near its apex. (lX)

Lepidophyllum sp. 65

fig. 4 Sterile leaf; midvein and stomatal grooves are visible. The base of the leaf is at the base of the illustration, tapering to a pointed apex (2X)

Lepidodendron obovatum Sternberg 51

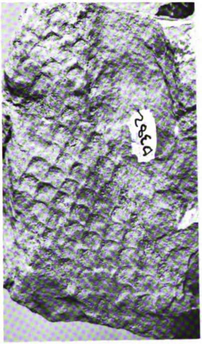
fig. 5 Leaf bolsters on a stem. Note broad-as-long size of bolsters with elliptical leaf scar in upper one-half of bolster. A bolster near base shows the bascular and parichnos scars (lX)

Lepidostrobophyllum majus 63

Fig. 6 Broad, lanceolate lamina of sporophyll with fertile portion missing (lX)

Lepidodendron aculteatum Sternberg 52

fig. 7 Bolsters with leaf scar visible. Ligule scar is



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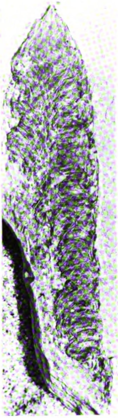

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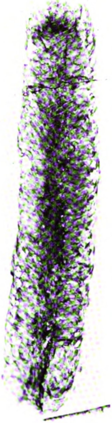

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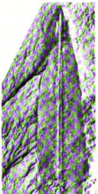

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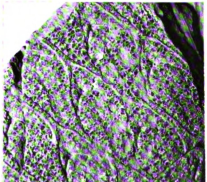

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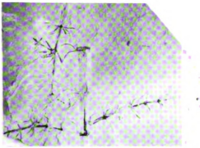
PLATE III

EXPLANATION OF PLATE IV

	Page
<u>Asterophyllites equisetiformis</u> (Schloth.) Brongniart	79
fig. 1 Branches with whorls of leaves attached.	
<u>Asterophyllites charaeformis</u> (Stnbg.) Goeppert	80
fig. 2 Branch with whorled leaves (1X)	
<u>Calamites</u> (<u>Mesocalamites</u>) <u>cistiiformis</u> Stur	72
fig. 3 Stem with two nodes and part of another showing straightness of ribs and how some ribs alternate at the node while others pass through the nodes, particularly at the middle node (1X)	
<u>Asterophyllites longifolius</u> (Stnbg.) Brongniart	81
fig. 4 Small stem with leaves attached at nodes. Note how leaves overlap the node above (1X)	
<u>Lepidophyllum longifolium</u> Brongniart	64
fig. 5 Basal portion of leav illustrating the central midvein and the two stomatal grooves on each side (1X)	
<u>Palaeostachya</u> sp.	82
fig. 6 Portion of stem, branching at each node. The nodes of the branches support the calamitean cones. The dark areas near the cone bases are the fertile part, whereas the lighter areas near the apex are the sterile portions (1X)	
<u>Calamites</u> (<u>Stylocalamites</u>) sp.	74
fig. 8 Stem with two nodes (1X)	



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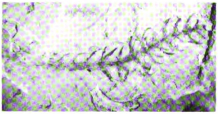

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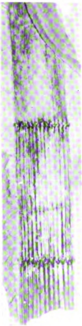

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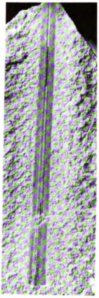

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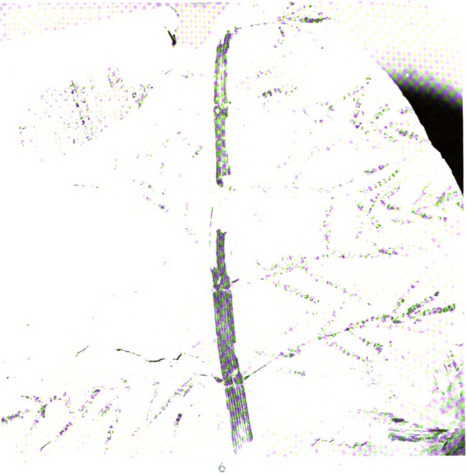

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PLATE IV

EXPLANATION OF PLATE V

	Page
Calamites(Mesocalamites) cistiiformis Stur	72
fig. 1 (1X)	
Calamites(Mesocalamites) hesperius Arnold	71
fig. 5 Two nodes of a stem showing the broad, straight ribs, some of which alternate at nodes while others go directly across (1X)	
fig. 2 An enlargement of fig. 5 showing the alternation between some ribs continuing straight through the nodes and others which alternate at the nodes (1.5X)	
Lepidocarpon linearifolium (Lx) Schopf	61
fig. 3 Specimen of the megasporangium with the sporophyll still attached (1X)	
Calamites(Calamitina?) sp.	74
fig. 4 Specimen with the branch scars distinct at two nodes. The leaf scars which occur on the nodes below the branch scars are not readily observable.	
Calamostachys (?) sp.	83
fig. 6 The strobilus is associated with Asterophyllites equisetiformis. (1X)	
Archeocalamites radiatus (Brgnt.) Stur	66
fig. 7 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 at the nodes be seen here. (1X)	

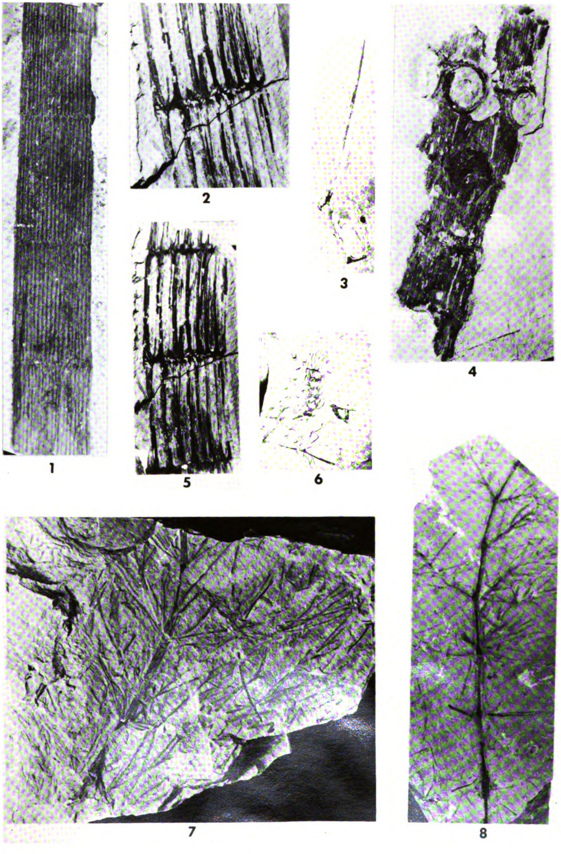

PLATE V

EXPLANATION OF PLATE V Cont.

Asterophyllites equisetiformis (Schloth.) Brongniart 79

fig. 8 Stem with branches arising from each node. The leaves are whorled at each node with internodal area becoming shorter distally eventually achieving the "bottle brush" affect near the tips of the branches. (1X)

EXPLANATION OF PLATE VI

	Page
<u>Zeilleria</u> sp.	100
fig. 4 Upper penultimate pinnae showing fructification (1X)	
fig. 1 Enlargement of fig. 4 (2X)	
<u>Mariopteris</u> <u>muricata</u> Schloth.	114
fig. 2 Fragment of ultimate pinnae (1X)	
fig. 8 Enlargement of fig. 2 (s.5X)	
<u>Tingia</u> sp.	84
fig. 3 Upper pinnules from an antepenultimate or a penultimate segment. The deeply dissected lobing can be observed in pinnules on right side of rachis (1X)	
<u>Adiantites</u> sp.	106
fig. 5 Isolated pinnule illustrating typical Adiantites venation (1X)	
<u>Sphenopteris</u> <u>gothanica</u> (?) (<u>Dolianitii</u>) comb. nov.	88
fig. 6 Antepenultimate segment. Note that two veinlets per lobe are distinctly visible.	
<u>Diplothmema</u> <u>arnoldi</u> Stockmans & Williere	111
fig. 7 Pinnules and ultimate pinnae (1X)	

PLATE VI

EXPLANATION OF PLATE VII

	Page
Diplothmema trifoliata (Artis) White	109
fig. 1 Specimen showing several ultimate pinnae (1X)	
Sphenopteridium dissectum Goeppert	102
fig. 2 Specimen illustrating general pinnule shape and venation. Note veins arise direct from rachis. No central midvein is present. (1X)	
Alloiopteris cruciatus sp. nov.	94
fig. 3 General pinnule outline and venation are observable on this specimen. Note the uniform size of the pinnules and their assymmetrical shape (1X)	
fig. 7 Specimen with only the venation visible. The outline of the pinnules on specimen are generally lacking (2X)	
Sphenopteris (?Renaultia) schatzlarensis (Stur) Zeiller	87
fig. 4 This species is illustrated in the lower right portion of this figure. Asterophyllites equisetiformis occupies the remainder of the figure (1X)	
Corynepteris angustissima (Stbg.) Nemejc	92
fig. 5 Specimen showing the toothed aspect of the species (2X)	
Mariopteris muricata Scloth	114
fig. 6 Pinnules from near apex of penultimate pinnae (1X)	

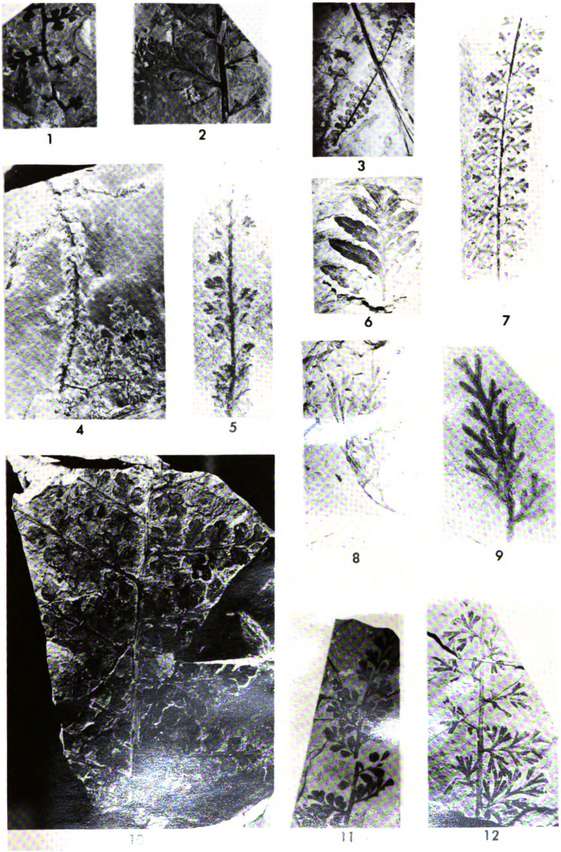

PLATE VII

EXPLANATION OF PLATE VII Cont.

Rhodea vespertina Read 99

fig. 8 (1X)

Rhodea sp. 99

fig. 9 Elongated segments and pinnules distinctly showing venation (3X)

Diplothmema obtusiloba (Brgnt.) White 110

Fig. 10 Portion of an antepenultimate pinnae (1X)

Adiantites Wardia tenuifolius var. *Difoliolatus* (White comb. nov. 107

fig. 11. Penultimate segment of a frond. (1X)

Sphenopteridium Zaitzeffium sp. nov. 104

fig. 12 Antepenultimate segment. Notice the flabelliform lax pinnules. (1X)

EXPLANATION OF PLATE VIII

	Page
Odontopteris sp.	131
fig. 1 Ultimate pinnae (2X)	
Neuropteris heterophylla Brongniart	120
fig. 2 Terminal pinnule (1X)	
Crossopteris undulatus sp. nov.	130
fig. 3 Penultimate segment (1X)	
Neuropteris cf. *pocahontas* White	121
fig. 6 Penultimate pinnae (1X)	
fig. 4 Enlargement of fig. 6 showing the single point attachment (1.5X)	
Crossopteris mcknightii gen. & sp. nov.	129
fig. 5 Antepenultimate of penultimate pinnae One-half basal attachment, alethopteroid-pecopteroid lobing and neuropteroid venation can be seen. (1X)	

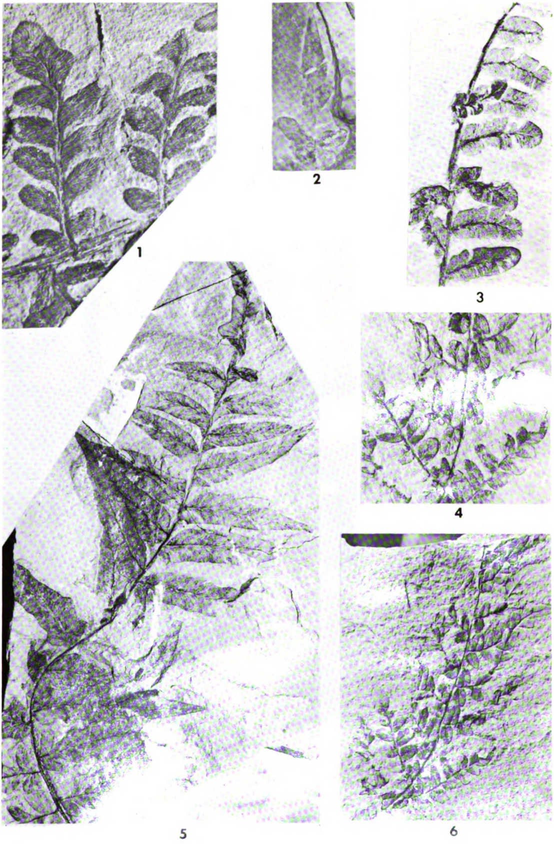

PLATE VIII

EXPLANATION OF PLATE IX

Crossopteris utahensis gen. & sp. nov. 125

fig. 1,6 Penultimate segments illustrating one-half basal attachment, alethopteroid-pecopteroid lobing and odontopteroid-neuropteroid venation (1X)

Neuropteris ameplinos sp. nov. 121

fig. 2 Penultimate segment. (1X)

Neuropteris heterophylla Brongniart 120

fig. 3 Fragment of penultimate or ultimate pinnae (1X)

Neuropteris gigantea Sternberg 119

fig. 4 Fragment showing four falcate pinnules (1X)

Stigmaria ficoides (Stnbg.) Brongniart 65

fig. 5 Portion of rhizome with rootlets attached (1X)

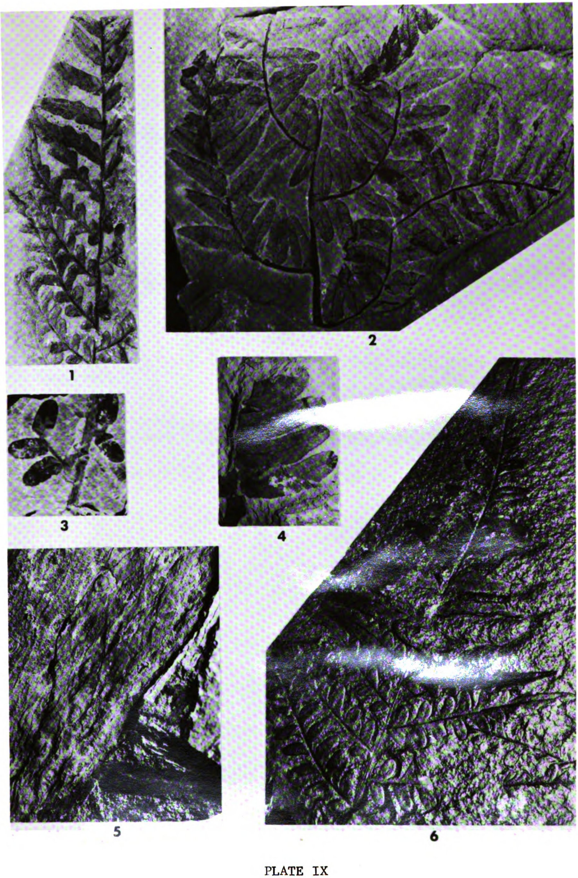

PLATE IX

EXPLANATION OF PLATE X

Crossopteris utahensis gen. sp. nov. 125

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 terminous of this frond is missing. (X 1/2)

PLATE X

EXPLANATION OF PLATE XI

Cordaites sp. A 133

figs. 1, 6 Portion of leaves illustrating the poor preservation. (1X)

Cordaites (?) sp. C 134

fig. 2 Long, linear leaf with rounded apex (1X)

Cordaites sp. B 134

fig. 3 Leaf, illustrating the broad, spatulate shape (1X)

Lepidodendron obovatum Sternberg 51

fig. 4 Branched stem, showing leaf scars on left branch and cluster of leaves on tip of right branch. These leaves are possibly the lower portion of a cone, or sterile leaves still attached. (1X)

Cordaites principalis (germar) Geinitz 132

fig. 5 Spatulate leaf (X 1/2)

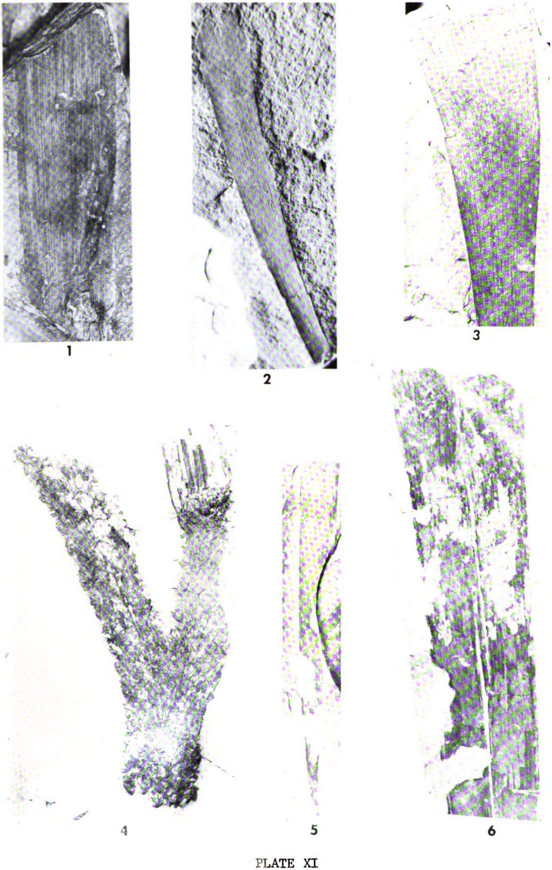

PLATE XI

EXPLANATION OF PLATE XII

Telangium affine (L. & H.) Benson 154

figs. 1, 10 Specimens showing branching (1X) of fertile frond and sporangia

fig. 16 Enlargement of fig. 10 (2X)

Cordaicarpus globosus sp. nov. 140

fig. 2 Figure illustrating shape and relationship of nucellus to the wings. (2X)

Cordaicarpus jayshuleri sp. nov. 141

figs. 3, 4, 5 Illustration showing striated surfaces of seeds and lack of wings. (2X)

Cordaicarpus elongatus (Newberry) comb. nov. 139

fig. 6, 11, 14 These specimens illustrate general shape and size of wings. (2X)

Aulacotheca hemingwayi (?) Halle 157

fig. 7 Specimen of the sporocarp.

Cordaicarpus cordatus (Jackson) comb. nov. 141

fig. 12 Seed illustrating shape with wings attached (1X)

fig. 8 Enlargement of fig. 12

fig. 13 Nucellus with wings missing

fig. 9 Enlargement of fig. 13

Lagenospermum bifurcatus (Stopes) comb. nov. 149

fig. 15 Seed cupules, some with seed still present (1.5X)

fig. 17 Enlargement of fig. 15. (3X)

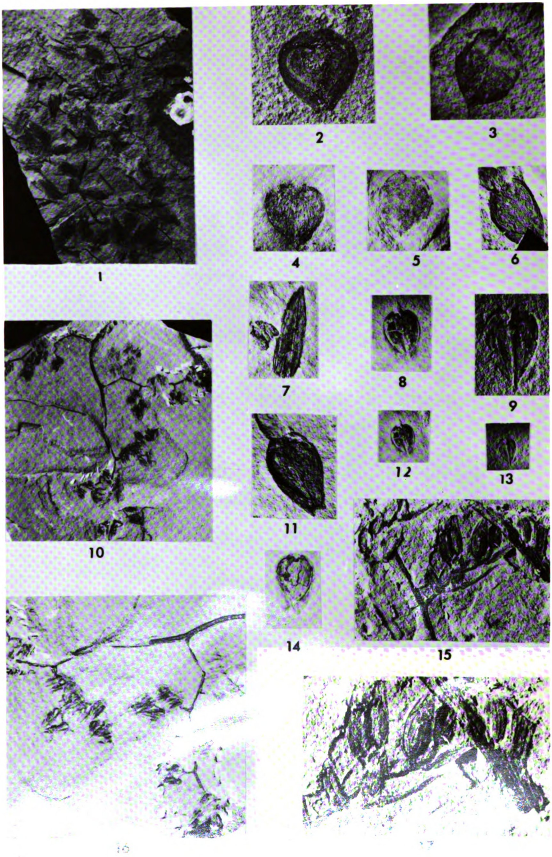

PLATE XII

EXPLANATION OF PLATE XIII

	Page
Cornucarpus discissus sp. nov.	147
fig. 1 Seed with bifurcating appendages. Note recurving of the bifurcations. (1X)	
Cordaicarpus manningcanensis sp. nov.	142
fig. 2 Seed showing rounded shape, distinct micropule. (1X)	
Cordaicarpus binutus sp. nov.	143
fig. 3 Seed with a depression showing where the reniform bodies were harbored. (X1)	
Gnetopsis anglica Kidston	152
fig. 4 Seed, with appendages. Note longitudinal folding of seed coat along right edge of seed. (4X)	
Rigbyocarpus ebracteatus sp. nov.	148
fig. 5 Seed surrounded by bracts (2X)	
fig. 6 Bracts with the seed missing (2X)	
Cordaianthus pseudofluitans (?) Kidston	134
fig. 7 Cordaitean strobilis without seeds attached (1X)	
Holcospermum sp.	146
fig. 8 (1X)	
Trignocarpus sp. C	146
figs. 9, 13 Specimen illustrating size and general shape (fig. 9 shows ribs) (1X)	
Trignocarpus sp. B	145
fig. 10 Sarcotesta with a portion of the micropyle present.	

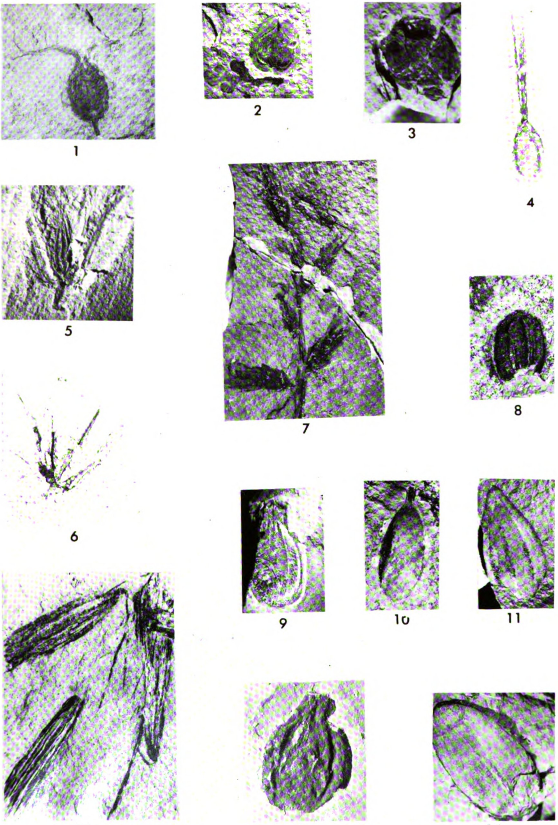

PLATE XIII

EXPLANATION OF PLATE XIII Cont.

Trignocarpus sp. A 145

fig. 11 (1X)

Aulacotheca campbelli (White) Halle 156

fig. 12 Three micro-sporangiate structures on the specimen illustrating the ribbing (2X0

Trignocarpus noeggerathi (Stnbg.) Brongniart 144

fig. 14 Specimen showing a single longitudinal ridge (1X)