Upper Paleozoic Floral Zones and Floral Provinces of the United States

By CHARLES B. READ *and* SERGIUS H. MAMAY

With a GLOSSARY OF STRATIGRAPHIC TERMS

By GRACE C. KEROHER

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An analysis of the succession of floras in the Mississippian, Pennsylvanian, and Permian Systems

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UPPER PALEOZOIC FLORAL ZONES AND FLORAL PROVINCES OF THE UNITED STATES

By CHARLES B. READ and SERGIUS H. MAMAY

ABSTRACT [1]

Fifteen more or less well-defined floral zones occur in Mississipian, Pennsylvanian, and Permian rocks of the United States. The Mississippian contains three zones in eastern North America, where its continental facies is best formed. In ascending order they are the zones of *Adiantites* spp., *Triphyllopteris* spp., and *Fryopsis* spp. This sequence is probably incomplete, because the American Mississippian is dominantly marine.

By contrast, the Pennsylvanian contains uninterrupted floral sequences that provide bases for subdivisions and correlation of strata over broad areas. In ascending order, Pennsylvanian floral zones are characterized by: *Neuropteris pocahontas* and *Mariopteris eremopteroides*, *Mariopteris pottsvillea* and *Aneimites* spp., *Mariopteris pygmaea* and *Neuropteris tennesseeana*, *Megalopteris* spp., *Neuropteris tenuifolia*, *Neuropteris rarinervis*, *Neuropteris flexuosa* and *Pecopteris* spp., *Lescuropteris* spp., and *Danaeites* spp.

The Permian of the Southwestern United States contains three floral zones, the lowermost characterized by *Callipteris* spp. This underlies a zone containing three contemporaneous but geographically restricted floras whose provinciality may be due to paleophysiographic or paleoedaphic features of that region These are the *Supaia* flora of Arizona and New Mexico, the *Glenopteris* flora of Kansas and the *Gigantopteris* flora of Texas, Oklahoma, and New Mexico. The third and youngest zone, containing a modified *Gigantopteris* flora, is known only in a restricted area in northwest Texas.

INTRODUCTION

Much information has been accumulated during the past 75 years in regard to the distribution in both time and space of upper Paleozoic floras in the conterminous United States,[2] and it now seems appropriate to summarize briefly the acquired knowledge. This report is to be regarded as an account of progress based on data that are admittedly incomplete and will likely continue to be so for some decades.

Serious attempts to use Palezoic plants in the solution of stratigraphic problems in the United States were first made by Lesquereux during the period 1852–93. This pioneer paleobotanist wrote and published a large series of articles on Paleozoic paleobotany. His greatest work, generally referred to as the "Coal Flora," carefully lists locality data for all species described and also includes lists of plants from various parts of the upper Paleozoic sequences in the eastern United States (Lesquereux, 1880, 1884).

Contemporaneous with the work of Lesquereux were the investigations of Fontaine and White (1880) on the Permian floras of the Appalachians. Their work, which was similar in pattern to that of Lesquereux, described the floras of the Dunkard Group with special emphasis on the large and varied flora of the Cassville Shale Member of the Washington Formation.

David White (1862–1935) joined the U.S. Geological Survey in 1886 and began his long and brilliant paleobotanical career, which was terminated by his death in 1935. His published works are many, and most of them are attempts to use fossil plants in problems that involve the dating and correlation of the containing strata. His reports form a substantial framework for the application of paleobotany to stratigraphic problems in the upper Paleozoic systems.

Excluding investigators of the present generation, the list of others who made contributions to Paleozoic paleobotany is small. A. C. Noé contributed to our knowledge of the flora of the famous Mazon Creek locality in the Pennsylvanian of northern Illinois. Ward and Berry casually described a few species of Paleozoic plants from time to time, as have some others.

The present generation of Paleozoic paleobotanists in the United States includes students of morphology and anatomy of fossil plants and a few stratigraphic paleobotanists working with megafossils. A large number of palynologists are investigating the abundant spores and pollens that occur in the upper Paleozoic systems and the applications of these to stratigraphic paleobotany. Their publications are not referred to in this report, as they deal entirely with microfossils rather than megafossils.

[1] This abstract was first published in Congreso Geológico Internacional, 20th, Mexico 1956, Resumenes de los Trabajos Presentados, p. 123–124.

[2] Inasmuch as there are no Paleozoic rocks in Hawaii and the Paleozoic floras of Alaska are too scantily understood for inclusion in this report, the term "conterminous" should be understood as applicable throughout this report.

Upper Paleozoic floras, as used in this report, are defined as those occurring in the Mississippian, Pennsylvanian, and Permian Systems. The Dovonian floras, although related, are not discussed in detail, because they present special problems involving the origin and development of subaerial assemblages that can best be discussed elsewhere. Any discussion of the sequence of upper Paleozoic land plants, however, should also take into account in a general way the kinds of plants that existed immediately before the beginning of upper Paleozoic time. An understanding of these forerunners is necessary, in fact, to visualize the setting for the floral evolution that took place later. A prefatory discussion of these antecedent floras is therefore included here.

The fossil record indicates that the plants that lived during upper Paleozoic times were different from their modern descendants. Undoubtedly there were representatives of the lower groups of plants, such as the algae, fungi, mosses, and liverworts. The remains of most of these, with the exception of the algae, are rarely incorporated into the fossil record. The remains ordinarily found are of various groups of higher plants that are characterized by the presence of woody tissue in stems and leaves and hence are more apt to be preserved as fossils.

The floras of the upper Paleozoic systems have often been referred to as being dominated by ferns. Although many of these plants were similar to ferns in many respects, this belief is incorrect. The dominant types, both in species and in genera, and probably in masses of vegetation, were fernlike gymnosperms that are commonly referred to as seedferns; however, some true ferns lived. Many of the ferns appear to have been rather small, but others were large and resembled modern treeferns. Also common in the fossil record were ancestors of the modern clubmosses, scouring-rushes, and conifers.

The remainer of the upper Paleozoic floral assemblages consisted of two important groups, the sphenophylls and psilophytes, for which modern counterparts are lacking.

ACKNOWLEDGMENTS

The writers wish to acknowledge the technical counsel and aid received during the preparation of this report. First they express their gratitude to the late John B. Reeside, Jr., who some 20 years ago urged the senior author to prepare one or more summaries of the type here presented. Early drafts discussing parts of the upper Paleozoic floral sequence were prepared; but during and after the war years, technical activities were diverted into other fields. In 1956, while on a visit to New Mexico, Dr. Reeside again urged that a report summarizing the status of knowledge of upper Paleozoic floral sequences be prepared.

The writers are indebted to Thomas A. Hendricks and Richard A. Scott of the U.S. Geological Survey and to Robert M. Kosanke of the Illinois Geological Survey for critically reading drafts of the manuscript and offering many valuable suggestions.

They also thank Hannah A. Kath, Sidney R. Ash, and Arthur D. Watt of the U.S. Geological Survey. Miss Kath and Mr. Ash, in Albuquerque, N. Mex., took special care in the final preparation of the manuscript and the illustrations. In Washington, D.C., Mr. Watt worked with the authors in the selection of specimens for use in illustrating the report.

THE ANTECEDENT FLORAS

Striking similarities and surprising differences exist betwen the known Devonian floras and those of the succeeding Mississippian. It is evident that most of the major groups of plants characteristic of the upper Paleozoic systems existed during Devonian time. There are representatives of the Sphenopsida—types ancestral to the common sphenophylls and calamites that characterize upper Paleozoic floras. The Lycopsida are represented by several types that apparently were the precursors of the Lepidodendrons and Sigillarias, which are common in the Mississippian and Pennsylvanian Systems. Among the Pteropsida in the Devonian are representatives of the ferns, the seedferns, and the primitive conifers.

In addition, a surprisingly large number of unusual types of plants apparently became extinct near the end of the Devonian. These plants have been assigned to several major groups. They appear to represent evolutionary trends or lineages that for one reason or another could not compete with the plants that dominated the landscapes in later times.

Although the beginnings of plant life were certainly in Precambrian time, as evinced by the fairly common occurrence of the problematical calcareous algae called stromatolites, a reasonably clear and continuous record of land plants does not begin until Devonian time. It is well known that there are plantlike remains in the Silurian that could have been terrestrial. Halle (1920) described Psilophyton-like material from the Silurian of Gotland. Somewhat similar material has been described from the Silurian of England (Seward, 1933). The upper Silurian of Australia has yielded both stemlike organs that bear small crowded scalelike leaves and branched leafless specimens (Lang and Cookston, 1927). These compare with *Thursophyton* Nathorst and *Hostimella* Barrande, both fairly well known in Devonian rocks (Seward, 1933). Although fragmentary, these records reasonably establish the fact that pre-Devonian land floras existed.

The earlier Devonian floras are dominated by plants belonging to groups that became extinct in later Devonian time. Among the more abundant are the Psilophytales. Representatives of this major group of plants are known in the Devonian of Canada (Dawson, 1859), the eastern and central United States (Arnold, 1935; Read, 1939), the Rocky Mountains (Dorf, 1933), and the Basin and Range province (Teichert and Schopf, 1958). These were small simple land plants, some of which were mosslike in general aspect. This general resemblance has, in fact, led to some speculation that the Psilophytales represent a link between the true mosses and the vascular plants (Bower, 1935).

Contemporaneous with the earlier Psilophytales are the rare remains of highly specialized types such as *Cladoxylon scoparium* Kräusel and Weyland. Such material appears to be in the fern lineage but is known only from petrifications.

The Sphenopsida or articulated types related to the late Paleozoic *Calamites* Schlotheim and *Sphenophyllum* Koenig are known in the Early Devonian at several localities. Some of the best preserved of these are *Hyenia* Nathorst and *Calamophyton* Kräusel and Weyland from the Devonian of Germany and Norway.

One of the more advanced groups of plants in the Early Devonian was that of the coniferlike gymnosperms. In the United States the best known of these is the genus *Callixylon* Zalessky, first thoroughly investigated by Arnold (1930). The specimens known from the Early Devonian are only a few inches in diameter, but by Late Devonian time representatives of the genus *Callixylon* were sufficiently large that the main trunks were several feet in diameter (Arnold, 1930); the trees may well have been similar to modern conifers in height and general appearance.

Beck (1960) reported organic connection between *Archaeopteris* cf. *A. macilenta* Lesquereux and pyritized fragments of wood showing the characteristic structure of *Callixylon* in a specimen from the Katsberg Redbeds of Chadwick (1933) of Late Devonian age near Sidney, N.Y. This connection suggests that *Callixylon* may have had fernlike foliage and possibly occupied a position intermediate between the Paleozoic gymnosperms and fern or fernlike ancestors (Beck, 1960). Additional material is necessary in order to confirm this possibility.

One of the more enigmatic groups of Early Devonian plants is represented by the genus *Nematophyton* Dawson. Material referred to this genus is widespread in the Devonian of eastern Canada and the United States. Originally regarded as the remains of a conifer in a rather primitive stage of development, such remains are now believed to be algal, although unlike any of the modern forms of this group. Possibly the group represented by *Nematophyton* was an unsuccessful evolutionary lineage among the aquatic algae.

As might be expected, the Upper Devonian floras are not only more diverse but also have more similarities to the Mississippian floras that follow than do the Lower Devonian floras. One of the most characteristic Upper Devonian plants is the fernlike *Archaeopteris*. The remains of this fossil are in the form of highly dissected fronds, some of which are large. Fertile bodies borne on the fronds are ascribed by some investigators to sporangia, but they may be seeds. Both possibilities have been considered by Arnold (1935; 1947). Another fernlike plant that is well known at one locality in the United States is *Eospermatopteris textilis* Goldring from the Catskill Formation at Gilboa, N.Y. (Goldring, 1924). This material is known mainly from molds and casts of large plants probably similar in habit to the modern treeferns. Strata of Late Devonian age have also yielded the remains of small zygopterid ferns, the forerunners of types that are well known in upper Paleozoic strata (Dawson, 1881; Read, 1939).

The Lepidodendrales are represented in Upper Devonian rocks, possibly by *Protolepidodendron* Krejči and by several other types that are unquestioned. Most of these early forms were smaller than the Lepidodendrons and Sigillarias of the Mississippian and Pennsylvanian Systems.

The Sphenopsida, or jointed stemmed plants, are represented in Late Devonian strata by several genera, the best known of which is probably *Protocalamites* Goebel. Except for anatomical details, such plants are similar to the *Calamites* of upper Paleozoic times. Other representatives of this group are *Pseudobornia* Nathorst and *Prosseria* Read.

The earlier mentioned *Callixylon* continued into strata of Late Devonian age where it is abundant. It is the best-known representative of several coniferlike gymnosperms that occur in Upper Devonian strata in North America.

The Late Devonian seedferns are best known from the remains of structurally preserved stems and petioles from localities in the eastern and central parts of the United States; they include such genera as *Calamopitys* Unger, *Diichnia* Read, *Stenomyelon* Kidston, and *Kalymma* Unger (Scott and Jeffrey, 1914; Read, 1936, 1937).

As previously mentioned, the Psilophytales were one of the more common groups in earlier Devonian time. Similar plants are known from strata of Late Devonian age, but they appear to have become nearly, if not quite, extinct prior to Misissippian times. Another group of vascular plants that also became extinct near the close of Devonian time is best known from the genus *Cladoxylon* Unger (Bertrand, 1935). Appearing in Early Devonian time and probably representing an offshoot from the ferns, this highly specialized group is another example of plants that were unable to fit into the plant associations characteristic of the upper Paleozoic systems. The genus *Nematophyton*, previously mentioned, is abundant in rocks of Late Devonian age. It, too, appears to have become extinct near the end of Devonian time and like some of the land plants, it was probably unable to find a niche in the changing associations of aquatic plants.

From the foregoing discussion it is apparent that all the major groups of plants that occur in the rocks of late Paleozoic ages existed during the Devonian. Some of these were obviously primitive, but most were surprisingly specialized in many of their characteristics. A comparison of these Devonian floras with those of the Mississippian and Pennsylvanian Systems reveals major differences, however; and both the extinction of older types and the development of new ones proceeded seemingly at a rapid rate.

UPPER PALEOZOIC FLORAL ZONES

Investigations of upper Paleozoic floras have been largely studies of the plants that occur in coal measures—nonmarine strata sufficiently rich in plant debris for coal beds to be common. Throughout the Mississippian, Pennsylvania, and Permian strata in parts of North America, however, several floras have been reported that do not appear to have grown or accumulated in coal swamps. Several facies problems therefore, exist in interpreting the sequences of floras with respect to time.

At present, 15 more or less well-defined floral zones are recognized in the Mississipian, Pennsylvanian, and Permian Systems in parts of the United States. Three of these are in the Mississippian; nine are in the Pennsylvanian; and three are in the pre-Guadalupe Permian. These floral zones are named either for common or for characteristic genera or species. Acquaintance only with the so-called index fossils, however, is not sufficient to identify the zones with assurance. Definite zone identification requires careful study of assemblages that have been carefully and thoroughly collected.

Although the Mississippian and Pennsylvanian floral zones are reasonably consistent in their botanical makeup throughout, the floristic situation in the North American Permian is more complex. The floras of lowermost, or Wolfcamp, Permian maintain much similarity wherever found, but the succeeding floras display striking provincialities that invite speculation as to the causes in terms of evolving paleogeography, paleoedaphology, and other ecologic factors.

MISSISSIPPIAN FLORAL ZONES

ZONE 1. ZONE OF ADIANTITES SPP.

(Table 1; pl. 1, figs. 1, 2)

The oldest Mississippian floral zone that can be consistently recognized in the United States is referred to here as the zone of *Adiantites* spp. (Read, 1955). It characterizes the basal strata of the Pocono and Price Formations in parts of the Appalachian trough, and fragmentary material tentatively assigned to the same zone has been reported at various localities elsewhere on the continent. Collectively, this flora is rather small and includes species of *Adiantites* Göeppert, emend., *Rhodea* Presl, *Rhacopteris* Schimper, *Alcicornopteris* Kidston, *Lagenospermum* Nathorst, *Calathiops* Göeppert, *Girtya* Read, and *Lepidodendropsis* Lutz (Read, 1955).

Similar floras characterized by *Adiantites* and *Rhacopteris* are also known in the lower part of Lower Carboniferous sequences of nonmarine facies in South America (Read, 1938, 1941a, 1942), Australia (David and Sussmilch, 1936), and Europe (Jongmans, 1939). Jongmans (1954) pointed out the worldwide uniformity of basal Mississippian floras; he referred to them as the "*Lepidodendropsis* floras," and regarded them as the chief element of distinction between Upper Devonian and Lower Mississippian strata.

Jongman's (1954) reference to the Pocono floras as the "*Lepidodendropsis* floras" is, of course, correct. The genus *Lepidodendropsis* occurs in both the zone of *Adiantites* spp. and the overlying zone of *Triphyllopteris* spp. *Lepidodendropsis*, however, is not common in the zone of *Adiantites* spp. but is one of the more abundant types of plants in the zone of *Triphyllopteris* spp.

Although distinct from the floras of the Upper Devonian in the United States, the zone of *Adiantites* spp. contains elements that show some affinities with the antecedent floras. Forms similar to, if not congeneric with, the genus *Rhacopteris* are known to occur in the Upper Devonian (Smith and White, 1905). The genus *Adiantites* also resembles in many general aspects some of the late Devonian fern or fernlike types in pinnule architecture. The genus has not, to the writers' knowledge, been reported in the Upper Devonian. Although *Rhodea* is also unreported from the Upper Devonian, there are many examples of imperfectly preserved, finely divided pinnules in the Devo-

TABLE 1.—*Mississippian floral zones*

Floral zone	Name	Appalachian region except for Southern anthracite field	Southern anthracite field	Midcontinent region
3	*Fryopsis* spp. and *Sphenopteridium* spp.	Mauch Chunk Formation	Mauch Chunk Formation	Chester Series. Similar flora occurs in Stanley Shale.
		No floras known	No floras known	Meramec Series. No floras known.
2	*Triphyllopteris* spp	Upper part of Pocono and Price Formations.	Upper part of Pocono Formation.	Osage Series. No floras known.
1	*Adiantites* spp	Lower part of Pocono and Price Formations.	Lower part of Pocono Formation.	Kinderhook Series. Only spores and fossil wood known.

nian strata that can be compared with the dominantly Mississippian genus *Rhodea*.

Lepidodendropsis is known only from incrustations and impressions. It can be reasonably interpreted as a forerunner of the later *Lepidodendrons* and as a distinct structural advance over the Devonian lycopods.

Alcicornopteris is a rather poorly understood genus of plants that is known only from the Mississippian and correlative lower Carboniferous strata of other continents. In its flabellate appearance it, too, is reminiscent of some of the Devonian plants. The most striking contrasts with Upper Devonian floras are shown in the fertile organs of genera such as *Lagenospermum*, *Calathiops*, and *Girtya*. All these genera are advanced and specialized in their morphology and suggest rapid evolution of the seedferns in the Lower Mississippian after their appearance and early development in the Devonian.

ZONE 2. ZONE OF TRIPHYLLOPTERIS SPP.

(Table 1; pl. 1, fig. 3; pl. 2, figs. 1–3)

The upper part of the Pocono and equivalent formations in the Appalachian trough are characterized by a flora that shares certain elements with the older *Adiantites* flora but which is dominated by several species of *Tryphyllopteris* Schimper. In addition, the *Triphyllopteris* flora is characterized by some early forms of *Fryopsis* Wolfe (=*Cardiopteris* Schimper; see Wolfe, 1962) and by species of *Rhodea*, *Lagenospermum*, and *Lepidodendropsis* (Read, 1955).

The flora of the zone of *Triphyllopteris* spp. is very distinct from the zone of *Adiantites* spp. Several species of *Triphyllopteris* and of *Lepidodendropsis* characterize the zone. *Lepidodendropsis* is sparingly known in the *Adiantites* assemblage and appears in abundance for the first time in the zone of *Triphyllopteris* spp. As the name of the zone indicates, most collections from the interval are dominated by *Triphyllopteris*, and this genus is known only from the upper part of the Pocono and its correlatives in the United States. Present also are species of *Rhodea* that are in general similar to those in the zone of *Adiantites* spp. *Lagenospermum* is also present in both zones.

Plant material from the medial part of the Mississippian above the zone of *Triphyllopteris* spp. has not been found in sufficient abundance to permit characterization of floral sequences. Because facies of the middle Mississippian strata are dominantly marine, it is unlikely that material will be found in the United States that will increase knowledge of the middle Mississippian floras. In consequence, the strata cannot be expected to yield plant material other than scattered specimens that have been rafted or otherwise transported considerable distances.

ZONE 3. ZONE OF FRYOPSIS SPP. AND SPHENOPTERIDIUM SPP.

(Table 1; pl. 2, fig. 4; pl. 3, fig. 1)

The uppermost Mississippian strata in the Appalachian trough, represented by the Mauch Chunk Formation and correlative strata, are characterized by a small flora with abundant *Fryopsis* and specimens of *Sphenopteridium* Schimper and *Aneimites*-like *Adiantites* (Read, 1955). Although *Fryopsis* makes its appearance in the zone of *Tryphyllopteris* spp., it is rare in the collections. The genus, in general, is probably most characteristic of Late Mississippian strata.

The fragmentary and little-known floras from the Bluestone Formation of West Virginia and adjacent parts of Virginia and the Parkwood Formation of Alabama are also tentatively assigned to zone 3. These formations contain many examples of a small alethopteroid species of *Neuropteris* (Brongniart) Sternberg that is similar to *Neuropteris pocahontas*. Observations by one of the authors (Read, unpublished data), both in the field and in the laboratory, suggest, however, that the form is new. Associated with *Neuropteris* is fragmentary material of *Sphenopteris* (Brongniart) Sternberg. Neither *Fryopsis* nor *Sphenopteridium* are known to occur in these formations at the present time.

In consequence, a fourth floral zone may be recognized eventually in the uppermost Mississippian. As previously stated, however, so little is known about this flora that it is included in zone 3.

Fryopsis, in association with one or more species of *Lepidodendron* Sternberg, is found at some localities in the Chester Series in parts of southern Illinois and western Kentucky. Strata containing these meager floras are almost certainly correlative with the strata that contain the floras here called the zone of *Fryopsis* spp. and *Sphenopteridium* spp. in the Appalachian trough.

White (1937) described a fragmentary flora from the Wedington sandstone in northern Arkansas. The types critical for dating include representatives of *Adiantites*, *Fryopsis*, *Neuropteris*, *Rhodea*, *Sphenopteris*, *Lepidodendron*, and *Archaeocalamites* Stur. This flora is probably characteristic of a late subzone in zone 3.

White (1936) described a flora from the Stanley Shale and Jackfork Sandstone in west-central and southeastern Oklahoma, and expressed the opinion that these rocks are Lower Pennsylvanian in age. White listed the genera *Adiantites*, *Alloiopteris*, *Archaeocalamites*, *Calamites* Schlotheim, *Lepidodendron*, *Neuropteris*, *Rhodea*, *Sigillaria* Brongniart, *Sphenophyllum* Koenig, and *Wardia* White as the more critical forms. Recent reexamination of White's collections (Mamay *in* Miser and Hendricks, 1960) indicates that the genera have closer affinities with the flora of the Wedington Sandstone Member of the Fayetteville Shale than White had suspected. Other geologic data (Miser and Hendricks, 1960) also support the conclusions that the upper or plant-bearing part of the Stanley Shale, as well as the overlying Jackfork Sandstone, is Mississippian in age. It is suggested that this flora is most likely the equivalent of the Wedington flora but may find its counterpart in the floras of the Bluestone and Parkwood Formations in the Appalachian trough, which are possibly slightly younger than those contained in the Wedington Sandstone Member of the Fayetteville Shale.

PENNSYLVANIAN FLORAL ZONES

ZONE 4. ZONE OF NEUROPTERIS POCAHONTAS AND MARIOPTERIS EREMOPTEROIDES

(Table 2; pl. 4, figs. 1, 2)

The oldest Pennsylvanian strata of continental facies known to contain abundant fossil plants in North America comprise the Pocahontas Formation [3] and correlative beds in the Appalachian trough. The older Pennsylvanian rocks in the anthracite fields of Pennsylvania and in the deeper parts of the trough to the south (table 2) are characterized by an abundance of *Neuropteris pocahontas* White and *Mariopteris eremopteroides* White (White, 1900a; Read, 1947).

TABLE 2.—*Lower Pennsylvanian floral zones*

Floral zone	Name	Appalachian region except for Southern anthracite field	Southern anthracite field	Midcontinent region
6	*Neuropteris Tennesseeana* and *Mariopteris pygmaea*.	Upper part New River Formation and upper part Lee Formation.	Schuylkill Member, Pottsville Formation.	Bloyd Shale, Morrow Series.
5	*Mariopteris pottsvillea* and *Aneimites* spp.	Lower part New River Formation.	Lykens Valley No. 4 coal bed and adjacent strata of Tumbling Run Member, Pottsville Formation.	Locally, basal strata of Pennsylvanian System in midcontinent region.
4	*Neuropteris pocahontas* and *Mariopteris eremopteroides*.	Pocahontas Formation.	Lykens Valley No. 5 and No. 6 coal beds and ajdacent strata of Tumbling Run Member, Pottsville Formation.	No floras known.

Although the zone is best characterized by these two species, it also contains several species of *Sphenopteris* of the diminutive and round-lobed types. Prevalent in most collections are species of *Eremopteris* and various species of *Lepidodendron* and *Calamites*. Most localities that contain floras assigned to this zone are relatively poor in species. Thus, Lykens No. 5 coal in the southern anthracite field has yielded *Mariopteris eremopteroides*, *Sphenopteris asplenioides* Sternberg, *S. patentissima* (Ettinghausen) Schimper, *Neuropteris pocahontas*, *Calamites roemeri* Göeppert, *Asterophyllites parvulus*, *Lepidophyllum quinnimontanum* White, *L. lanceolatum* Lindley and Hutton, and *Sigillaria kalmiana* White (White, 1900a). Because this small flora was obtained from several localities in the western part of the coal field, it is a composite flora.

[3] Pocahontas Formation is here redefined and stratigraphically expanded upward to include strata up to the top of the Flattop Mountain Sandstone, which is here reduced in rank to member status in the Pocahontas. As redefined, the Pocahontas overlies the Mauch Chunk Formation or the Bluestone Formation and underlies the New River Formation (redefined).

One of the writers (Read) spent some time collecting and studying floras from the lower part of the Pocahontas Formation in southern West Virginia and adjacent parts of Virginia. The flora in this lower part is also small, and almost every collection contains specimens of *Neuropteris pocahontas* and *Mariopteris eremopteroides*.

Strata of nonmarine facies equivalent to the oldest Pennsylvanian of the Appalachian trough have not been definitely recognized elsewhere in the United States. Floras assigned to zone 4 thus appear to be restricted to the eastern part of the country.

ZONE 5. ZONE OF MARIOPTERIS POTTSVILLEA AND OF COMMON OCCURRENCE OF ANEIMITES SPP.

(Table 2; pl. 4, figs. 3, 4; pl. 5, fig. 1)

Floras of the zone of *Mariopteris pottsvillea* and *Aneimites* spp. occur in much of the Appalachian trough and are found locally at the very base of the system in the midcontinent region (White, 1900a; Read, 1947).

These floras are typically represented in the Lykens Valley No. 4 coal and adjacent strata and are also characteristic of the Quinnimont Shale Member in the lower part of the New River Formation [4] of southern West Virginia. They are presumed to occur farther south in the deeper parts of the Appalachian basin in Tennessee, Alabama, and Georgia. The species *Mariopteris pottsvillea* White and one or more species of *Aneimites* (Dawson) Ettinghausen are present in almost all collections. Associated with these species are early alethopteroid forms of *Neuropteris*, such as *Neuropteris smithsii* Lesquereux. *Sphenophyllum tenue* White is a fairly common in this zone. Several species of *Sphenopteris*, early species of *Alethopteris* Sternberg, and representatives of *Lepidodendron* Sternberg and *Calamites* Schlotheim are present. Although most characteristic of zone 5, it must be recognized that *Mariopteris pottsvillea* makes a first appearance somewhat lower than Lykens Valley No. 4 coal and its correlatives and is commonly found in the strata transitional between zone 4 and zone 5. Such florules are known not only in the Appalachian region but also in the Eastern Interior coal field. The Hindostan Whetstone of Cox (1876) in Orange County, southern Indiana, appears to represent the transition between these two zones. There, *Mariopteris pottsvillea* is associated with *Neuropteris pocahontas*. It is perhaps noteworthy that *Mariopteris eremopteroides* and *Aneimites* spp. are unknown at this locality, just as they are absent in transitional sequences in the Appalachians. As is true of the flora of zone 4, the interval may be represented elsewhere in North America, but the facies are unfavorable for the preservation of fossil plants.

ZONE 6. ZONE OF NEUROPTERIS TENNESSEEANA AND MARIOPTERIS PYGMAEA, AND TO SOME EXTENT OF OVOPTERIS COMMUNIS, ALLOIOPTERIS INAEQUILATERALIS, AND ALETHOPTERIS DECURRENS

(Table 2; pl. 5, figs. 2–5; pl. 6, figs. 1–3; pl. 7, fig. 1)

The zone of *Neuropteris tennesseeana* (Lesquereux mss.) White and *Mariopteris pygmaea* White is widespread in the Appalachian area and is recognized at several places in the Ancestral Rocky Mountain province (White, 1900a; Read, 1947).

In the Appalachian area, the flora of zone 6 occurs in the roof of Lykens Valley No. 2 and No. 3 coals in the Southern Anthracite region and in the Sewell Member of the New River Formation of West Virginia. Equivalents also occur in Tennessee and Alabama. In western Pennsylvania and adjacent parts of Ohio, the roof of the Sharon coal contains this flora.

In the Eastern Interior coal field, the Caseyville Formation of the McCormick Group [5] occupies zone 6. In northern Arkansas in the Ozark region, the Bloyd Shale of the Morrow Series is partly in this floral zone.

Knowledge of the appearance of this floral zone in the Rocky Mountain area is derived from far fewer localities than in the eastern part of the United States. In central Colorado a section of the Weber(?) Formation in the Leadville mining district yielded a florule referable to this zone (Read, 1934). Present are specimens of *Neuropteris* of the alethopteroid type, as well as *Sphenopteris cheathami* Lesquereux and *Trichopitys whitei* Read, a somewhat problematical coniferous type. It has been suggested that these plants indicate less swampy, possibly mesophytic conditions. Similar floras, which have not yet been described, are found in the lower part of the Sandia Formation in parts of New Mexico. This zone is probably represented by marine strata in the Cordilleran province.

ZONE 7. ZONE OF COMMON OCCURRENCE OF MEGALOPTERIS SPP.

(Table 3; pl. 7, figs. 2, 3)

The zone of *Megalopteris* spp. can be recognized in the Appalachian region at or near the base of the Kanawha Formation and its equivalents and in the midcontinent in the lower part of sequences that are

[4] The New River Formation is here redefined to include the Quinnimont Shale Member (near the base), the Raleigh Sandstone Member, and the Sewell Member whose Nuttall Sandstone Bed is at the top. The formation overlies the Pocahontas Formation (redefined) and underlies the Kanawha Formation.

[5] As used in Illinois, the McCormick Group consists of the Caseyville Formation overlain by the Abbott Formation. The name Tradewater Group has been abandoned in Illinois by the Illinois Geological Survey (Kosanke and others, 1960). It included strata now belonging to the Abbott Formation.

believed to be equivalent to the Atoka Series (Read, 1947). In New Brunswick it is represented in the Little River group (Stopes, 1914). In Illinois it is prominently represented in the Tarter Member of the Abbott Formation of the McCormick Group and occurs in equivalent units in eastern Iowa. In Texas the zone can be recognized in the base of the Lampasas Series of Cheney (1940). This zone has not been identified in the Ancestral Rocky Mountain and Cordilleran provinces but is probably represented by marine strata.

Although species of *Megalopteris* Schenk are especially characteristic of zone 7, they are by no means present in all collections from this zone. The zone is also characterized by *Neuriopteris lanceolata* Newberry and by large cardiocarpons of the *Cardiocarpon phillipsi* Read type. Species that occur in this zone in Illinois are as follows:

Pecopteris serrulata Hartt
Alethopteris Sternberg n. sp.
Neuropteris missouriensis Lesquereux?
  tenuifolia (Schlotheim) Brongniart?
Eremopteris sp.
Sphenopteris palmatiloba White
  communis Lesquereux
Megalopteris dawsoni Hartt
  hartii Andrews
  southwellii Lesquereux
  abbreviata Lesquereux
  fasciculata Lesquereux
  marginata Lesquereux
Psygmophyllum Schimper sp.
Cordaites principalis (Germar)
Cordaianthus Grand 'Eury sp.
Cardiocarpon Brongniart spp.
Trigonocarpon Brongniart spp.
Sigillaria rugosa Brongniart
Lepidodendron crenatum Sternberg
  volkmannianum Sternberg
Annularia cuspidata Lesquereux

The various species of *Megalopteris* seem to be most abundant where Pennsylvanian strata of early Atoka age occur immediately above pre-Pennsylvanian karst surfaces. This occurrence suggests the possibility that *Megalopteris* spp. found habitats most favorable for growth in and adjacent to sinkholes and in calcareous soil.

One of the best-known floras of this zone is from the "Fern Ledges" of Little River Group (Lancaster Formation: see Bell, in Moore and others, 1944) near St. John, New Brunswick (Stopes, 1914). The known species that characterize the flora at this locality are given by Stopes (1914) as follows:

Calamites suckowi Brongniart
Annularia sphenophylloides (Zenker) Stopes
  stellata (Schlotheim) Wood
  latifolia (Dawson) Kidston
Stigmaria ficoides Brongniart
Adiantites obtusus (Dawson) Stopes
Rhacopteris busseana Stur
Sphenopteris marginata Dawson
Oligocarpia splendens (Dawson) Stopes
Sphenopteris valida (Dawson) Stopes
Pecopteris plumosa (Artis) Stopes
Diplothmema subfurcatum (Dawson) Stopes
Alethopteris lonchitica (Schlotheim) Stopes
Megalopteris dawsoni (Hartt) Stopes
Neuropteris heterophylla Brongniart
  gigantea Sternberg
Sporangites acuminata Dawson
Pterispermostrobus bifurcatus Stopes
Dicranophyllum glabrum (Dawson) Stopes
Whittleseya dawsoniana D. White
  concinna Matthew
Cordaites robbii Dawson
  principalis (Germar) Stopes
Dadoxylon ouangondianum Dawson
Cordaianthus devonicus (Dawson) Stopes
Cardiocarpon obliquum Dawson
  baileyi Dawson
  cornutum Dawson
  crampii Hartt
Sphenophyllum? cuneifolium (Sternberg) Zeiller
Lepidodendron sp. (foliage)
Lepidodendron sp. (in "*Bergeria*" condition)
Sigillaria sp.
Neuropteris selwyni Dawson
  eriana (Dawson) Stopes
Poacordaites sp.
Sternbergia sp.

An especially interesting situation exists in the Morien Series, which is apparently slightly younger

TABLE 3.—*Middle Pennsylvanian floral zones*

Floral zone	Name	Appalachian region except for Southern anthracite field	Southern anthracite field	Midcontinent region
9	*Neuropteris rarinervis*	Lower part Allegheny Formation.	Upper part Sharp Mountain Member, Pottsville Formation.	Lower part of Des Moines Series.
8	*Neuropteris tenuifolia*	Major part Kanawha Formation.	Not known.	Major part of Atoka Series.
7	*Megalopteris spp.*	Base of Kanawha Formation.	Not known.	Base of Atoka Series.

than the Little River Group in the Sydney coal field of Nova Scotia. The lower part of this coal-bearing sequence of rocks is characterized by a flora that is marked by the only known occurrences of the genus *Lonchopteris* Brongniart (Bell, 1938) in North America. Although widely found in Europe, *Lonchopteris* has not been reported elsewhere on the North American continent. The *Lonchopteris* flora of the lower part of the Morien Series may eventually be found somewhere in the middle of the Kanawha Formation and equivalent coal-bearing strata in the central part of the United States; in this event a floral zone intermediate between zones 7 and 8 of this report may be established.

Because of its possible significance, the known species in this flora are listed from Bell (1938) as follows:

Sphenopteris missouriensis? (Lesquereux) White
Hymenotheca dathei Potonié
Hymenotheca? sp.
Hymenophyllites bronni Gutbier
Zeilleria avoldensis (Stur) Kidston
Dipplotmema furcatum (Brongniart) Stur
Neuropteris tenuifolia (Schlotheim) Sternberg
  aculeata Bell
  scheuchzeri forma *angustifolia*
Linopteris müensteri (Eichwald) Potonié
Alethopteris lonchitica (Schlotheim) Brongniart
  serli (Brongniart) Goeppert
Lonchopteris eschweileriana Andrae
Eupecopteris (*Dactylotheca*) *dentata* (Brongniart) Zeiller
Asterotheca miltoni (Artis) Zeiller
Calamites suckowi Brongniart
  waldenburgensis Kidston
Annularia radiata Brongniart
  sphenophylloides (Zenker) Gutbier
Asterophyllites equisetiformis (Schlotheim) Brongniart
Calamostachys germanica Weiss
Sphenophyllum cuneifolium (Sternberg) Zeiller
Cordaites principalis (Germar) Geinitz
Samaropsis cornuta (Dawson) Grand 'Eury

ZONE 8. ZONE OF NEUROPTERIS TENUIFOLIA

(Table 3; pl. 7, fig. 4)

The zone of *Neuropteris tenuifolia* is widespread in the Appalachian area where it appears to include the Mercer Shale, the major part of the Kanawha Formation, and other equivalents farther south (Read, 1947). It is present in the Morien Series in Nova Scotia (Bell, 1938). In the midcontinent region it includes most of the Atoka Series. In the Ancestral Rocky Mountains this zone is recognized in the upper part of the Sandia Formation in New Mexico and in the Kerber Formation in Colorado. Elsewhere the zone is unknown, but it is almost certainly represented by marine rocks.

This zone is characterized by the first appearance of *Neuropteris* Brongniart of the *N. ovata* Hoffman type. Both *Neuropteris rarinervis* Bunbury and *N. flexuosa* Brongniart also make their appearances in this zone, although they are scarce and are most characteristic of higher zones. *Pecopteris vestita* Lesquereux may occur sparingly in this zone.

A flora from the Eagle coal bed of the Kanawha Formation is characteristic of the zone (White, 1900a) and is listed from White (1900b) as follows:

Eremopteris sp.
  sp. cf. *E. lincolniana* White
Pseudopecopteris trifoliolata (Artis) Lesquereux
Mariopteris muricata (Schlotheim) Zeiller
  nervosa (Brongniart) Zeiller
  acuta (Brongniart) Zeiller
  inflata (Newberry) White
Sphenopteris spinosa Göeppert
  furcata Brongniart
  linkii Göeppert
  cf. *S. dubuissonis* Brongniart
  tracyana Lesquereux
  schatzlarensis Stur
  cf. *S. microcarpa* Lesquereux
Pecopteris sp. cf. *P. integra* Andrä
Alethopteris decurrens Artis
  serlii (Brongniart) Göeppert
Neuropteris sp. cf. *N. zeilleri* Potonié
  tenuifolia
Calamites ramosus Artis
Asterophyllites minutus Andrews
  rigidus Sternberg
Annularia ramosa Weiss
  acicularis (Dawson) Renault
Calamostachys ramosus Weiss
Sphenophyllum furcatum Lesquereux
  cuneifolium (Sternberg) Zeiller
Lepidodendron sp. cf. *L. dichotomum* Sternberg
  obovatum Sternberg
Bothrodendron sp.
Lepidostrobus variabilis Lindley and Hutton
Lepidophyllum campbellianum Lesquereux
Rhabdocarpos sulcatus Göeppert and Bein

ZONE 9. ZONE OF NEUROPTERIS RARINERVIS

(Table 3; pl. 8, figs. 1–3)

Zone 9 marks the appearance of the cyatheoid pecopterids, although they occur sporadically and rarely in abundance. *Neuropteris ovata* occurs abundantly in this zone, but it is not especially characteristic, inasmuch as it also occurs in higher strata.

A flora characterized by *Neuropteris rarinervis* in association with *Pecopteris vestita*, *Mariopteris occidentalis* White, and *Linopteris rubella* (Lesquereux) White occurs in the lower part of the Allegheny Formation in the Appalachian region and in the lower part of the Des Moines Series in the midcontinent region (Read, 1947).

A typical assemblage from the Hartshorne Sandstone of Oklahoma and Arkansas is given by Read (in Hendricks and Read, 1934) as follows:

Sphenopteris mixta cf. *S. stipulata* Gupta
cristata (Brongniart) Presl
Pseudopecopteris obtusiloba (Sternberg) Lesquereux
neuropteroides Bouley (not Kutorga)
macilenta (Lindley and Hutton) Lesquereux
Mariopteris occidentalis
muricata
nervosa
Neuroptersis scheuchzeri Hoffmann
rarinervis Bunbury
harrisi White
ovata
missouriensis Lesquereux
griffithii Lesquereux
capitata Lesquereux
Linopteris gilkersonensis White
Pecopteris vestita cf. *P. candolliana* Brongniart
oreopteridia (Schlotheim) Brongniart
clintoni cf. *P. arborescens* Brongniart
dentata Brongniart
Callipteridium sullivantii (Lesquereux) Weiss
Alethopteris serlii (Brongniart) Göeppert
Taeniopteris? *missouriensis* White
Odontopteris wortheni Lesquereux
Annularia stellata
sphenophylloides (Zenker) Gutbier
Calamites suckowi
Calamodendron approximatum Cotta
Asterophyllites equisetiformis (Schlotheim) Brongniart
Sphenophyllum emarginatum Brongniart
cuneifolium
suspectum White
lescurianum White
Lepidophyllum truncatum Lesquereux
Lepidocystis vesicularis Lesquereux
Rhabdocarpus multistriatus (Sternberg) Lesquereux

In the Ancestral Rocky Mountain region, the zone of *Neuropteris rarinervis* occurs in the lower part of the Madera Formation in New Mexico and in the lower part of the Hermosa Formation in Colorado but is unknown elsewhere in that area. This occurrence is probably due to the dominantly marine character of rocks of Middle Pennsylvanian age throughout this province. In Canada the zone is identified in the Morien Series in Nova Scotia (Bell, 1938).

ZONE 10. ZONE OF NEUROPTERIS FLEXUOSA AND APPEARANCE OF ABUNDANT PECOPTERIS SPP.

(Table 4; pl. 9, figs. 1–3; pl. 10, fig. 1)

The zone of *Neuropteris rarinervis* (zone 9) is succeeded by an interval characterized by abundant *Neuropteris flexuosa* and by abundant representatives of the cyatheoid species of *Pecopteris* (Brongniart) Sternberg.

Although *Neuropteris flexuosa* rarely occurs in strata younger than zone 10, the cyatheoid pecopterids occur abundantly in much younger strata and, in fact, are present in the youngest Permian strata that carry fossil plants in the United States. (See zones 14 and 15.) Zone 10, therefore, is best referred to as the zone of appearance of abundant species of *Pecopteris* and can be determined on the basis of this genus only by noting the floral succession in older strata in any sequence of rocks under investigation.

Zone 10 occurs in the upper part of the Allegheny Formation and the lower part of the overlying Conemaugh Formation in the Appalachians. It is also characteristic of the upper part of the Des Moines Series and its equivalents in the midcontinent region. In the Rocky Mountains a few collections indicate its presence in the medial parts of the Madera and Hermosa Formations of New Mexico and Colorado. In the Rocky Mountain area conifers of types usually considered to be characteristic of the Permian occur locally in strata that on other floristic bases are assigned to this zone. Thus, in the McCoy Formation of Roth (1930) in north-central Colorado there occurs a florule characterized by *Odontopteris mccoyensis* Arnold, *Samaropsis hesperius* Arnold, *Walchia stricta* Florin, *Walchia* sp., and *Walchiostrobus* sp. (Arnold, 1941; Read, 1947). Similar floras have been noted by one of the authors (Read) at several stations in northern and central New Mexico.

TABLE 4.—*Upper Pennsylvanian floral zones*

Floral zone	Name	Appalachian region except for Southern anthracite field	Southern anthracite field	Midcontinent region
12	*Danaeites* spp.	Upper part Monongahela Formation.	Not known.	Missouri and Virgil Series.
11	*Lescuropteris* spp.	Lower part Monongahela Formation and upper part Conemaugh Formation.	Not known.	In midcontinent region, zones 11 and 12 are not separable and are together designated the zone of *Odontopteris* spp.
10	*Neuropteris flexuosa* and *Pecopteris* spp.	Lower part Conemaugh Formation and upper part Allegheny Formation.	Post-Pottsville rocks undifferentiated.	Upper part of Des Moines Series.

The presence of coniferous material in the Rocky Mountains in zone 10 suggests that the plant associations represented in collections are from sediments of more nearly piedmont than coal-swamp facies. Independent geologic data provide supporting evidence for this suggestion, inasmuch as this was a time of widespread orogeny during which the Ancestral Rocky Mountains were in the process of being formed. In consequence, it is believed that swamp habitats were restricted and piedmont and upland habitats were expanded (Read, 1947; Read and Wood, 1947).

A typical flora from zone 10 is the flora of the Buck Mountain or Twin coal bed in the southern anthracite region of Pennsylvania which is listed from White (1900a) as follows:

Mariopteris sphenopteroides (Lesquereux) Zeiller
muricata var. *nervosa* (Brongniart) Kidston
cf. *sillimanni* (Brongniart) White
Pseudopecopteris squamosa (Lesquereux) White
obtusiloba (Brongniart) Lesquereux
Sphenopteris pseudomurrayana Lesquereux?
nummularia Gutbier
Sphenopteris n. sp.?
mixta Schimper
suspecta White
Oliogocarpia cf. *Brongniarti* Stur
Pecopteris dentata Brongniart
arguta Sternberg
unita Brongniart
villosa Brongniart?
oreopteridia
pennaeformis Brongniart
Alethopteris aquilina (Schlotheim) Göeppert
serlii
Callipteridium grandini (Brongniart) Lesquereux
Neuropteris flexuosa
ovata
plicata Sternberg
capitata
vermicularis Lesquereux
fimbriata Lesquereux
scheuchzeri
Calamites cistii Brongniart
Cyclocladia sp.
Asterophyllites equisetiformis
Annularia stellata
Sphenophyllum emarginatum
cuneifolium
fasciculatum (Lesquereux) White
Lepidodendron brittsii Lesquereux?
modulatum Lesquereux?
vestitum Lesquereux?
sp. indet.
Lepidostrobus cf. *L. variabilis* Lindley and Hutton
cf. *L. geinitzii* Schimper
Lepidophyllum cultriforme Lesquereux
oblongifolium Lesquereux
cf. *L. mansfieldi* Lesquereux
affine Lesquereux?
Lepidocystis vesicularis
(*Sigillariostrobus*?) *quadrangularis* Lesquereux
Sigillaria cf. *S. brardii* Brongniart
tessellata (Steinhauer) Brongniart
Trigonocarpum olivaeforme Lindley and Hutton?
Rhabdocarpos sp.
multistriatus
mamillatus Lesquereux
Cordaicarpon cinctum Lesquereux
Carpolithes transsectus Lesquereux
cf. *C. ellipticus* Sternberg

ZONE 11. ZONE OF LESCUROPTERIS SPP.

(Table 4; pl. 11, figs. 1, 2)

The zone of *Lescuropteris* spp. has been clearly recognized only in the Appalachian region, where it is characteristic of the upper part of the Conemaugh and the lower part of the Monongahela Formations. Unfortunately, the collections of fossil plants from the Conemaugh Formation in the possession of the U.S. Geological Survey and the U.S. National Museum are relatively poor compared with those from both underlying and overlying stratigraphic units, because the rocks containing the plants are of types that are poorly suited for plant preservation. The *Lescuropteris* flora is best known from shales a short distance below the Pittsburgh coal bed and from overlying strata in the lower part of the Monongahela Formation.

A typical flora from this interval is listed below; knowledge of the flora in this zone is limited virtually to these species. The flora is based on collections made by White (1913) in the vicinity of Wheeling, W. Va., from the roof of the Pittsburgh coal bed and is as follows: *Mariopteris*? *spinulosa* (Lesquereux) White, *Alethopteris aquilina*, *Pecopteris unita*, *P. villosa*?, *Pecopteris* sp. cf. *P. jenneyi* White, *Neuropteris grangeri* Brongniart, *N. scheuchzeri*, *Lescuropteris moorei* (Lesquereux) Schimper, and *Aphlebia filiciformis* (Gutbier) Schimper.

In the midcontinent region this zone has been reported only from the Elmdale Shale of former usage near Onaga, Kans. As identified by White (1903) the flora is as follows: *Pecopteris newberriana* Fontaine and White, *P. hemitelioides* Brongniart, *P. oreopteridia*?, *Pecopteris* cf. *P. polymorpha* Brongniart, *Odontopteris brardii* Brongniart, *O. moorii* (Lesquereux) White (=*Lescuropteris moorii* Lesquereux), *Neuropteris plicata* Sternberg, *N. auriculata* Brongniart?, *N. scheuchzeri*, *Daubreeia* sp., *Asterophyllites equisetiformis*, *Annularia stellata*, *Radicites capillaceous* (Lindley and Hutton) Potonié.

White preferred to consider *Lescuropteris moorii* a species of *Odontopteris*. Clearly the genus *Lescuropteris* is an odontopterid type. The generic distinction, however, seems to be valid. The species of *Lescuroptersis* possibly remain unreported in many collections, and their stratigraphic significance is therefore not recognized because of their identification by some investigators as *Odontopteris* spp.

Strata in about the same position in the Rocky Mountains are characterized by primitive conifers, such as *Walchia piniformis* and typical odontopterids. Such an assemblage is characteristic of the upper member of the Madera Formation in parts of central New Mexico.

ZONE 12. ZONE OF DANAEITES SPP.

(Table 4; pl. 11, fig. 3; pl. 12, fig. 1)

Danaeites is especially characteristic of the uppermost Pennsylvanian strata in the Appalachian trough, and, although not present everywhere, it is sufficiently common to be regarded as most useful in the identification of these strata.

The presence of this zone was first pointed out in 1944 (Read *in* Moore and others, 1944) on the basis of examination of available collections in the possession of the U.S. Geological Survey and the U.S. National Museum. In 1954 examination of Upper Pennsylvanian and Lower Permian strata in the Georges Creek coal basin, Allegany County, Md., resulted in additional collections which further confirm the presence of the zone of *Danaeites* Göeppert and its position in the sequence of rocks (Berryhill and de Witt, 1955). The flora found in the roof shales of the Koontz coal bed, which is probably the equivalent of the Uniontown coal bed, is characterized by abundant *Danaeites emersoni* Lesquereux. Several species of cyatheoid pecopterids are also present, as are some of the later variations of *Neuropteris scheuchzeri*. The Uniontown coal and the apparently correlative Koontz coal are about 100 feet below the Cassville Shale Member of the Washington Formation. The member is regarded by some as the base of the Permian System; others question that the member is the base of the Permian System.

ZONES 11 AND 12 (LOCALLY COMBINED). ZONE OF ODONTOPTERIS SPP.

(Pl. 12, figs. 2–5)

As previously indicated, the zones of *Lescuropteris* spp. and *Danaeites* spp. are readily recognizable in the Appalachian region but are clearly formed only locally in the midcontinent and Ancestral Rocky Mountain regions. Consequently, it seems desirable to group the two zones together and classify them as the zone of *Odontopteris* spp. in the latter areas (Read, 1947). The general equivalence of the *Lescuropteris* and *Danaeites* zones with the *Odontopteris* zone is attested by the abundance of *Odontopteris* in the two zones in the Appalachian region.

This floral zone is usually characterized by the absence of *Lepidodendron*, by numerous species of cyatheoid pecopterids, by the larger varieties of *Neuropteris ovata*, and by the presence, at least in some areas, of *Neuropteris lindahli*. *N. lindahli* is relatively abundant in the southwest and is of considerable use as an index fossil in some areas. It seems to be restricted to strata that on the bases of other evidence are probably of Virgil age.

In the Ancestral Rocky Mountain area, associations of plants that are characterized by mixtures of ferns and fernlike types with conifers are common. Similar associations are also known to occur at a few localities in the Virgil of Kansas.

PERMIAN FLORAL ZONES

ZONE 13. ZONE OF CALLIPTERIS SPP.

(Table 5; pl. 13, figs. 1–5)

Permian time represents a significant chapter in the geological history of vascular plants, inasmuch as it was a period of marked floristic transition. The long-stabilized luxuriant cosmopolitan coal-forming plant assemblages of the Pennsylvanian were gradually subjected to more variable and, in some areas, more rigorous ecological conditions. More demanding physiological requirements were imposed on plant populations and new forms appeared. The subtlety of the changes is suggested by the fact that many remnants of the cosmopolitan Pennsylvanian floras persisted as conspicuous elements into the Permian. Indeed, the differences between the uppermost Pennsylvanian floras and those of Early Permian age are commonly so slight that only the presence of the index genus *Callipteris* Brongniart may serve to distinguish a lowermost Permian flora.

The *Callipteris* flora is characteristic of the lowest Permian strata over a large area. The upper part of the Dunkard Group in parts of Pennsylvania and West Virginia contains such a flora (Fontaine and White, 1880). In parts of Kansas, Oklahoma, and west Texas the Wolfcamp Series contains a well developed *Callipteris* flora (Read, 1941b). Finally, the flora is well developed at several localities in New Mexico in the lower part of the Abo Formation, in strata that are adjudged for other reasons to be Lower Permian (Read, 1941b; Mamay and Read, 1954).

Although *Callipteris* is the one reliable index fossil in these assemblages, it is not necessarily dominant either with respect to number of species or to individuals in a given collection. The North American *Callipteris* floras are in general dominated by several species of *Pecopteris* and are further characterized by strong representations of *Sphenopteris*, *Sphenophyllum* Koenig, *Odontopteris* Brongniart, *Neuropteris*, *Annularia* Sternberg, and other typically Pennsylvanian genera. *Taeniopteris* Brongniart appears in

TABLE 5.—*Permian floral zones*

Floral zone	Name	Kansas	Oklahoma	North Texas	Arizona and New Mexico
15	Younger *Gigantopteris* flora.			Lueders Limestone and Clear Fork Group.	
14	Zone of older *Gigantopteris* flora; *Glenopteris* flora; *Supaia* flora.	Sumner Group (*Glenopteris* flora).	Garber Sandstone (older *Gigantopteris* flora).	Belle Plains, Clyde Formations (older *Gigantopteris* flora).	Upper part Abo Formation; Hermit Shale (*Supaia* flora).
13	*Callipteris* spp.	Wolfcamp equivalents; highest occurrences in Chase Group.	Wolfcamp equivalents; highest occurrences in Stratford Formation.	Wolfcamp equivalents; highest occurrences in Moran Formation.	Lower part of Abo Formation.

moderate numbers and the *Walchia* complex is dominant locally. On the other hand, the cordaiteans and arborescent lycopods, which were among the principal "coal-makers" during the Pennsylvanian, are only sparingly represented in the zone of *Callipteris*.

ZONE 14. ZONE OF THE OLDER GIGANTOPTERIS FLORA IN PARTS OF TEXAS, OKLAHOMA, AND NEW MEXICO, EQUIVALENT ZONE OF GLENOPTERIS SPP. IN KANSAS, AND EQUIVALENT ZONE OF THE SUPAIA FLORA IN NEW MEXICO AND ARIZONA

(Table 5; pls. 14–18)

As Permian time advanced, floral assemblages gradually assumed more individuality and lost much of the cosmopolitan aspect of their Pennsylvanian forerunners. The lowermost Permian *Callipteris* floras, which apparently occupied a circumpolar distribution in the northern hemisphere, became modified by the appearance of strikingly new, geographically restricted dominant forms. Relatively limited areas of the southwestern and midcontinental United States became capable of producing a variety of distinct assemblages. There, strata that probably represent approximately synchronous deposits of early Leonard age contain the remains of at least three distinct floras.

Although they approach each other closely, horizontal ranges of these floras are not known to overlap. Thus, a flora referable to as the older *Gigantopteris* flora [6] succeeds the *Callipteris* flora in the Garber Sandstone of early Leonard age in parts of north and west Texas and in Oklahoma (White, 1912; Mamay and Read, 1954) and New Mexico. The Wellington Formation of the Sumner Group in southern and central Kansas, which is the equivalent of the *Gigantopteris*-bearing strata in Oklahoma, contains a distinct flora, which is referred to as the *Glenopteris* flora (Sellards, 1908). Similarly, in the Ancestral Rocky Mountain province the upper parts of the Abo Formation and the Hermit Shale contain the *Supaia* flora (White, 1929) and are also known to be early Leonard in age (Read *in* King, 1942).

The floras of zone 14 collectively are the most diversified Permian assemblages known in the world. They share four common genera (*Taeniopteris*, *Callipteris*, *Walchia*, and *Sphenophyllum*), but, on the other hand, each flora is characterized by at least one distinctive genus; the distinguishing genera—*Supaia* White, *Glenopteris* Sellards, and *Gigantopteris* Schenk—are nowhere known to have coexisted. The fact that the *Gigantopteris*, *Supaia*, and *Glenopteris* floras share several common elements is not surprising, in view of their probable derivation from a common ancestral complex—the Wolfcamp *Callipteris* flora. The dissimilar morphologic aspects of their dominant genera and their failure to intermingle, however, are of considerable interest, inasmuch as they imply evolution under dissimilar environmental conditions and provide a basis for speculation on the ecological factors responsible for such floristic differentiation and segregation.

THE SUPAIA FLORA

(Pl. 14, figs. 1–3; pl. 15, figs. 1–2)

The *Supaia* flora, known only from a few localities on the western flank of the Ancestral Rocky Mountains, is the least diversified flora of zone 14. Although about 20 plant genera have been attributed to the flora, several of these are doubtful because of generally poor preservation, and a more realistic appraisal of the flora would likely yield no more than half as many generic designations. The flora is a conifer-pteridophyll association; it lacks lycopods and the true ferns that occur abundantly in other Permian floras; the arthrophytes are represented by only one species, *Sphenophyllum gilmorei* White. The conifers, predominantly of the

[6] Detailed descriptions of the American gigantopterids and associated plant assemblages are being studied by Mamay. In this connection, a revision of the Gigantopteridaceae by Asama (1959) suggests the necessity for revision of nomenclatural treatment of the American gigantopterids; however, for the purpose of the present paper, the old generic designation will be adhered to, pending formal revision by Mamay.

Walchia type, contribute nothing unusual to the aspect of a flora of this age. The pteridophylls include *Taeniopteris*, *Callipteris*, and several callipteroid species, of which the majority are referable to *Supaia*, the dominant genus. *Supaia* is distinguished by the dichotomous forking of its frond, its simple pinnation and large linear pinnae, and the unequal development of pinnae, of which the longest are on the outside of the frond.

Physical features of the enclosing sediments indicate that the *Supaia* flora lived under drier conditions than those of the coal floras, which would, in part, explain the generally impoverished aspect of the assemblage.

THE GLENOPTERIS FLORA

(Pl. 16, figs. 1–4)

The *Glenopteris* flora is apparently restricted stratigraphically to rocks of the Sumner Group and has been found only at a few localities in central Kansas. This flora shows more diversification that the *Supaia* flora, both in total numbers of genera and in supergeneric groups represented. Associated with *Glenopteris* are several pecopterid ferns, cordaiteans, sparse lycopods, calamarians, neuropterids, odentopterids, and a few other elements not found in association with *Supaia*.

Glenopteris is represented by five species (Sellards, 1908, p. 467). This genus, presumably a pteridosperm, is the most abundant element in the flora. It is characterized by simple pinnation, large pinnae with decurrent or auriculate bases, an extremely stout and striated rachis, and an originally thick fleshy texture. The textural feature is implied by the fact that the fronds are invariably preserved as a thick carbonaceous residue, which often obscures the laminar venation.

THE GIGANTOPTERIS FLORA

(Pl. 17, figs. 1–4; pl. 18, figs. 1–4)

The *Gigantopteris* flora is the most diversified assemblage characteristic of zone 14. It is known from several occurrences in the Garber Sandstone of north-central Oklahoma and from several others in the Belle Plains and Clyde Formations of north-central Texas; there is also one known occurrence in the upper part of the Abo Formation near Orogrande, N. Mex., but the material consists of only one small fragment of *Gigantopteris* and a few small unidentifiable fragments of other plant types. The Oklahoma material is generally sparse at any given locality and is commonly very poorly preserved; consequently, the Oklahoma flora is not well understood. In Baylor County, Tex., however, the red beds of the Belle Plains Formation locally contain lenses and channel deposits of fine-grained gray shales and mudstones, which at various localities have produced an extremely rich and well-preserved flora. The same flora is found in the Clyde Formation but is generally not as abundantly or as excellently preserved as in the Belle Plains occurrences.

The *Gigantopteris* flora of zone 14, particularly the assemblages found in the Belle Plains sediments, is remarkable in its diversity and luxuriance. The abundance and variety of plant remains at certain localities suggest that locally this flora rivaled the Pennsylvanian coal-swamp floras in specific differentiation and population density but grew under conditions not amenable to coal formation. Several species of *Pecopteris* form a strong link with the pre-Permian stock ancestral to this flora; locally, the pecopterids assume such dominance as to constitute more than half the total of plant material. *Callipteris* is a prominent constituent of the flora; here it reaches the greatest degree of specific differentiation known in the American Permian, including representatives of the *flabellifera-strigosa* types, as well as the more common *conferta-lyratifolia* types. *Odontopteris* is moderately abundant and is represented in part by extremely large-pinnuled species that suggest a relationship between this flora and the Permian Angara flora of Siberia, which has been described in a long series of papers by Zalessky (1918). The pteridophyllous element in the flora is completed by a great abundance of *Gigantopteris americana* White, relatively abundant *Taeniopteris* and *Aphlebia* Presl, and rare specimens of *Neuropteris*.

In zone 14 the primitive conifers are generally conspicuous and locally dominant, particularly at a lowermost Clyde locality near Fulda in Baylor County, Tex. There they are abundantly represented by species of *Walchia*, *Ernestiodendron* Florin, *Gomphostrobus* Marion, and several types of winged seeds of *Samaropsis* Göeppert. Cordiatean conifers are almost totally absent from this zone.

Only a few lepidodendralean and sigillarian fragments have been found in zone 14, and their scarcity foreshadows the extinction of the arborescent lycopods. The arthrophytes are fairly conspicuous and include several species of *Annularia* and *Sphenophyllum*, as well as *Lobatannularia* Kawasaki, which provides an interesting link with the Permian floras of East Asia. The noeggerathialean genus *Discinites* K. Feistmantel is also present in this flora; this discovery marks the first known Permian occurrence of *Discinites* (Mamay, 1954).

Other interesting elements in this flora are several types of unidentified and undescribed fructifications, some of which resemble the megasporophylls of Recent cycads. Unfortunately, the specimens are among those collected by White in 1910, and efforts to rediscover White's original locality have been unsuccessful; probably the outcrop was very small and has been completely destroyed by erosion.

The characteristic genus of this flora is, of course, *Gigantopteris*, which appears abundantly in lower Leonard rocks and has no obvious precursors in the underlying *Callipteris* flora. It is the most easily recognized of Permian plant genera and is distinguished by the following features: The frond is very large, as much as 20 cm in width and an unknown maximum length; the lamina is undissected but usually dichotomously forked and has entire or slightly undulate margins; the ultimate veins assume the general pattern of a "herringbone weave," variably forking and anastomosing, and join a "sutural vein" to create a series of irregularly shaped meshes, to some extent reminiscent of the reticulate venation of dicotyledonous angiosperms. The venation is so characteristic that, unlike many of its contemporary genera, only a small fragment of a *Gigantopteris* frond is necessary for positive identification, even on the specific level.

Although *Gigantopteris* is not always dominant at zone-14 localities in the *Gigantopteris* province, it is almost invariably present, at least as a minor element where plant remains are found in significant amounts. Peculiarly enough, although this is the richest flora known in the American Permian, its characteristic genus, *Gigantopteris*, is known only from one species, *Gigantopteris americana*. This occurrence of *Gigantopteris* contrasts with the occurrence of the characteristic genera of the two contemporary floras in zone 14. These contemporary floras are poorer in total species than the *Gigantopteris* flora, but instead of just one species each, the distinguishing genera *Supaia* and *Glenopteris* are each represented by several species.

One other important element first appears in the *Gigantopteris* flora of zone 14. This is a genus of pinnate fronds, whose large entire-margined parallel-veined pinnae are strongly reminiscent of cycadean foliage but which were identified by Darrah (1938) as *Tingia* Halle; the genus is otherwise known only from eastern Asia. Because a large suite of specimens has now been collected and neither anisophylly nor the digitate pinna apices characteristic of *Tingia* are evident, there is reason to believe that Darrah's identification of his limited material as *Tingia* was erroneous. This plant seems thus far to be restricted to the Belle Plains Formation and occurs in abundance at only one locality.

ZONE 15. ZONE OF THE YOUNGER GIGANTOPTERIS FLORA

(Table 5; pl. 19, figs. 1–7)

In a restricted area of north Texas a few scattered localities in the Lueders Limestone and the Clear Fork Group have yielded sparse plant collections. These assemblages are generally less well preserved and biologically less diversified than the older *Gigantopteris* flora of zone 14. Sufficient differences, however, are apparent in their composition to warrant recognition of another floral zone, zone 15.

Aside from a relatively impoverished aspect—which, of course, may actually be a function of the generally poorer conditions for preservation of plants that prevail higher in the Permian section—the flora of zone 15 differs from the older *Gigantopteris* flora by the absence of *Gigantopteris americana* and by its apparent replacement by at least two new, yet undescribed, species of *Gigantopteris*, whose evolutionary relationship to *Gigantopteris americana* is at present difficult to assess. However, features of their ultimate venation clearly indicate that they are distinct from the older species and, at the same time, can be used to make easy identifications of the species from small fragments.

A small florule from about the middle of the Lueders Limestone is one of the best known assemblages in zone 15 and is characterized by *Gigantopteris* new species A. This species is distinct from *G. americana* in having four orders of venation, whereas *G. americana* has only three. Associated with this species is a sparse conifer-*Callipteris* assemblage. *Gigantopteris* new species A apparently persists as far as the bottom of the Vale Formation of the Clear Fork Group.

Gigantopteris new species B first appears at about the same horizon as that of the earliest known appearance of *G.* new species A. This species, like *G. americana*, has only three orders of venation but is distinguished by the simplicity of its venation; whereas the tertiary veins of *G. americana* frequently dichotomize and anastomose, those of *Gigantopteris* new species B rarely dichotomize and never anastomose.

Gigantopteris new species B has been found at several localities, and its associated flora is best known from two outcrops in the lower part of the Vale in Taylor County, Tex., where it is associated with a fairly diverse assemblage of callipterids, sphenopsids, pecopterids, odontopterids, neuropterids, abundant *Taeniopteris*, and several conifers. Several of the callipterids and odontopterids are extremely large pinnuled types that occur elsewhere only in the Permian Angara flora of Siberia; however, in certain features the two species of *Gigantopteris* (*Gigantopteris* new species A occurs sparingly in the Taylor County flora) are remarkably similar to gigantopterid species that occur together in the flora of the Shihhotse Series in Shansi province, China (Halle, 1927).

A small collection of plants, including fragments of *Gigantopteris* new species B, was made by Mamay from the uppermost part of the Vale Formation in Knox County, Tex. This is the youngest Paleozoic megafossil flora presently known in North America.[7] The plants are poorly preserved and, with the exception of *Gigantopteris* new species B, reliable specific or even generic identification are not possible; however, the flora was clearly dominated by coniferous elements. This assemblage also contains some unidentifiable leaf fragments, which show, in general, odontopterid venation but which are of a laminar size not approached by any other Paleozoic nongigantopterid pteridophylls except some of the Siberian Angara plants. This flora contains fragmentary fronds related to, if not identifiable with, *Pterophyllum* Brongniart. This is the only known occurrence in the American Permian of this type of foliage, which lends the flora a Mesozoic aspect.

UPPER PALEOZOIC FLORAL PROVINCES

Mississippian and Pennsylvanian floral provinces contrast sharply with Permian floral provinces in the United States. The following notes, although obviously incomplete, substantially summarize our knowledge regarding the geographic distribution of the successive Paleozoic floras.

MISSISSIPPIAN FLORAL PROVINCES

As previously indicated, three floral zones have been recognized in the Mississippian strata in parts of the United States and Canada. These are the zones of *Adiantites* spp., *Triphyllopteris* spp., and *Fryopsis* spp. The paleogeography of North America during Mississippian time was such that the areas of continental sedimentation were largely restricted to the eastern part of the United States and to eastern Canada. In consequence, our knowledge of the distribution of floras is similarly restricted.

Floras that can be assigned to the zone of *Adiantites* spp. with confidence are found primarily in basal Mississippian strata only in the eastern part of the United States and the martime provinces of Canada (Dawson, 1858, 1873). However, this flora, when carefully analyzed, seems to be similar to lower Carboniferous floras elsewhere in the world that are dominated by species of *Adiantites*. In consequence, the *Adiantites* flora is strongly suspected to be cosmopolitan, occurring not only over much if not all of North America but also in parts of Europe. The flora perhaps occurs even in the Southern Hemisphere, as suggested by floras described from South America (Read, 1938) and Australia (David and Sussmilch, 1936).

The succeeding *Triphyllopteris* flora is also known chiefly from the Appalachian trough and the adjacent Maritime Provinces. Again one may assume on the basis of rather meager evidence that the *Triphyllopteris* flora was widespread in suitable environmental realms during Osage time.

The *Fryopsis*-dominated floras occur in beds of latest Mississippian age both in the Appalachian belt and in the midcontinent of the United States. These floras also were probably cosmopolitan over the continent.

PENNSYLVANIAN FLORAL PROVINCES

The study of Pennsylvanian plants has been largely a study of floras of the coal measures; that is, associations of plants in strata that are largely continental in origin and that probably accumulated in extensive flood plains and in deltas under mild and humid climatic conditions. As previously indicated, nine Pennsylvanian floral zones are recognized in the eastern and midcontinent regions of North America. These zones provide a practical basis for general correlation of the fossil-containing rocks in these areas.

When one compares the floras of the Pennsylvanian coal measures with the floras from the Rocky Mountain and Pacific Coast regions, certain differences may be noted (Read, 1947). The plant associations in the older parts of the Pennsylvanian requences in the western areas are similar to those of the coal measures, but the relative rarity of Lycopodiales suggests drier habitats than those indicated by the approximately contemporaneous floras in the eastern coal basins. The younger Pennsylvanian floras in the western United States, however, are striking departures from the plant associations of the same general ages in the eastern part of the country, as inferred from index forms and independent stratigraphic data. The plants in the western area occur in suites of sediments that were deposited during a period of widespread orogeny in parts of the Rocky Mountain region. Many geological data indicate that the lowlands were restricted and the upland habitats or areas were expanded during this period of mountain building. The floral modifications include the presence of abundant conifers and appear to be in the direction of mesophytic associations. The term "Cordilleran flora" has been used for the modifications that occur in the Rocky Mountains (Read, 1947).

PERMIAN FLORAL PROVINCES

Although Permian plant fossils in the United States are much more sporadic in occurrence than those of the Pennsylvanian, it is evident that the geographic distribution and botanical makeup of the post-Wolfcamp

[7] Scattered fragments of unidentifiable wood are known to occur higher in the American Permian, and Wilson (1959) has reported a small assemblage of gymnospermlike pollen from the Flowerpot Shale (El Reno Group) of Oklahoma. Affinities of these fossils are not sufficiently well understood, however, to warrant recognition of another floral zone.

assemblages constitute a more complex problem than those of the Mississippian and Pennsylvanian floral provinces. This floral differentiation and segregation did not develop until early Leonard time, for American floras of the Wolfcamp and correlative units are characteristically similar to the *Callipteris* floras of the European Lower Permian. The American *Callipteris* flora is known to occur in the Appalachian basin and at various points in the midcontinent and southwestern regions; its botanical similarity at all places indicates a broad, virtually uninterrupted geographic distribution.

Overlying the Wolfcamp, the Leonard Series contains a floral complex that is of much interest from the standpoints of characteristic genera and provincial geographic distribution which climaxes a long Paleozoic history of cosmopolitan floral successions. Thus, the *Glenopteris* flora characterizes the Wellington Formation of the Sumner Group in central and Southern Kansas, whereas farther south in central and northern Oklahoma the *Glenopteris* flora is unknown. Instead, the older *Gigantopteris* flora occurs there in the Wellington Formation and the Garber Sandstone, which are regarded as equivalents of the strata containing the *Glenopteris* flora to the north. Still farther south, the older *Gigantopteris* flora again appears in the Belle Plains Formation, which independent evidence indicates to be equivalent to the Wellington rocks of northern Oklahoma. The westernmost known occurrence of this flora is in southeastern New Mexico at approximately the southern tip of the Ancestral Rocky Mountains where fragments of the flora have been found in the upper part of the Abo Formation.

To the west of the Ancestral Rockies in central and northern New Mexico, strata that are probably basal Leonard and therefore the lateral equivalents of the Sumner Group, the Garber Sandstone, the Wellington Formation and the Belle Plains Formation contain plant fossils that are indistinguishable from certain elements of the *Supaia* flora and that were originally described by White (1929) from the Hermit Shale in the Grand Canyon of Arizona. The Grand Canyon occurrence marks the westernmost limit of the known range of the *Supaia* flora; to the east, the lower part of the Supai Formation in areas along the Mogollon rim in Arizona has also yielded traces of the *Supaia* flora.

Even though these three floras have geographic ranges that closely approach each other, they are not known to have overlapped. Some explanation of the provinciality of these contemporary assemblages is desirable, and although this attempt will be largely speculative, we feel that the correct answers possibly are to be found in the paleophysiography and paleoedaphology of the region involved. It is almost certain that environmental differentiation was largely responsible for the floristic differentiation, because the presence in the floras of several common elements suggests derivation of the specialized floras from a common ancestry.

The Ancestral Rocky Mountain system appears to have been the chief physical factor affecting floral distribution during Leonard time. They separated the *Supaia* flora on the west from the *Gigantopteris* flora to the east. The fact that the concentration of known occurrences of the *Supaia* flora is greatest at points nearest the mountain system may indicate that eastward dispersal of the flora was blocked by the mountain barrier, even though the western flank of the mountains was well populated by members of the *Supaia* flora.

Conditions under which the *Supaia* flora existed may be inferred from certain features of the flora itself and features of the enclosing sediments. The sediments contain mud cracks and molds of salt crystals, which suggest a relatively rigorous climate; and rapid deposition of sediments is indicated by plant stems and leaves that are preserved in nearly erect positions that cut across bedding planes (White, 1929). The flora itself lacks true ferns, arborescent lycopods, calamiteans, and other elements that normally grew under swampy or nearly swampy conditions. The evidence thus suggests that the *Supaia* flora represents the remnants of a lush flora that became impoverished by an unfavorable environment and was barred from eastward dissemination by the Ancestral Rocky Mountains.

The older *Gigantopteris* flora, on the other hand, presents a more "normal" aspect, as it includes a variety of ferns, scattered lycopods, calamarians, and other mesophytic elements. Its province is limited to the east of the Ancestral Rocky Mountains, and it occurs in greatest abundance in the deltaic and fluviatile facies that characterize the north and south flanks of the Wichita and Amarillo uplifts; the plant fossils are frequently found closely associated with terrestrial tetrapod bones. This flora appears to have been a vigorous association that grew under much milder ecologic conditions than did the *Supaia* flora. It persisted within the same provincial limits until at least late Vale time, by which time specific differentiation of *Gigantopteris* had been accomplished and the introduction of new types had lent the younger *Gigantopteris* flora a more Mesozoic aspect. As mentioned previously, traces of the *Gigantopteris* flora have been found in southern New Mexico at approximately the southern tip of the Ancestral Rocky Mountain uplift but not to the northwest in the *Supaia* province. If our conjectures regarding the climatic conditions under which the two floras grew are correct, the *Gigantopteris* flora, although vigorous in its own province, was possibly not capable of surviving in the presumably more adverse climate of the province to the west. Thus, a combination of climatic contrasts and physical barriers was seemingly responsible for the failure of the two floras to intermingle.

The narrow geographic limits of the Kansas *Glenopteris* province seem to be a manifestation of edaphic conditions, for the floral remains there occur in, and in association with, highly saline sediments. This occurrence suggests a physiological aridity that was incompatible with the ecological tolerances of the *Gigantopteris* flora and that prevented this flora from migrating the short distance to the north necessary to permit it to intermingle with the *Glenopteris* flora. The fossil remains of the *Glenopteris* flora support such a supposition, for the leaf compressions, in particular those of *Glenopteris*, are invariably preserved as thick carbonaceous crusts, which suggest that in life the leaves were thick and fleshy, as in typically halophytic plants. The fact that the two floras share a few elements in common, not only with each other but with the *Supaia* flora as well, indicates that some genera were more tolerant of varying ecological conditions than others and were able to survive under conditions of either aridity or salinity, whereas their associates were physiologically less versatile.

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GLOSSARY OF STRATIGRAPHIC TERMS

By Grace C. Keroher

Names printed in boldface type have been adopted for use by the U.S. Geological Survey. Names preceded by a dagger (†) have been abandoned for use by the Survey. Names in roman type without a dagger are those that the Survey has had no occasion to consider for use. Reports are indicated in glossary by reference number. Parentheses enclose numbers of cited publications.

Abbott Formation (in McCormick Group)
Middle Pennsylvanian: Illinois
Consists of strata that were included in lower part of sequence formerly called Tradewater Group. Characterized by dominance of sandstone, sandy shale, and siltstone; some coal beds. Maximum thickness, 300 to 350 ft in southern Illinois; thins westward and northward.

Overlies Caseyville Formation; underlies Spoon Formation.
Type locality: Along Illinois Central Railroad, sec. 5–7, T. 11 S., R. 5 E., Pope County. Named for Abbott Station.
Reference: 75.

Abo Formation, Sandstone or **Redbeds**
Lower Permian (Wolfcamp and Leonard Series): Central New Mexico.
Red shale, mudstone, sandstone, arkose, and conglomerate. Thickness, 910 feet at type locality; as much as 1,400 ft in Sacramento Mountains. Intertongues with Hueco Limestone. Underlies Yeso Formation. Rests on beds ranging in age from early Wolfcamp in area of type locality to Precambrian in Zuni Mountains. Overlies Bursum Formation at type locality; overlies Laborcita Formation (103) in Sacramento Mountains.
Type locality: In Abo Canyon, Valencia and Torrance Counties: Base of formation lies about 1 mile northwest of village of Scholle, and top, 2 miles west-northwest of village of Abo.
References: 11, 77, 96, 103.

Allegheny Formation
Middle Pennsylvania: Western Maryland, eastern Ohio, Pennsylvania, Virginia, and West Virginia.
Cyclic sequence of sandstone, shale, limestone, and coal. Overlies Pottsville Formation or Group; underlies Conemaugh Formation. Classified as group by Pennsylvania Geological Survey and as series by Ohio and West Virginia Geological Surveys.
Named for exposures in valley of Allegheny River, Pa.
References: 57, 93, 99, 115, 117.

Atoka Series or **Formation**
Middle Pennsylvanian: Arkansas, Iowa, Kansas, Missouri, Nebraska, and Oklahoma.
Atoka Series is time-rock term defined to include beds from top of Morrow Series to base of Des Moines Series. Comprises zones of *Profusulinella* and *Fusulinella*. As originally defined included the Marble Falls Limestone, Smithwick Shale, and overlying *Fusulinella* (restricted)-bearing beds of central and north Texas and Derry Series (134) in New Mexico and Texas. Term Atoka Formation is used in Oklahoma and Arkansas. Formation, in type area, consists of about 7,000 ft of alternating sandstone and shale beds that underlie Hartshorne Sandstone and overlie Wapanucka Limestone. In Oklahoma six sandstone members have been named; an overlying shale unit is associated with each member. Overlies Bloyd, Hale, or Fayetteville Formations, or Johns Valley Shale.
Named for Atoka, Atoka County, Okla.
References: 18, 63, 67, 91, 123, 126, 132, 134.

Belle Plains Formation (in Wichita Group)
Lower Permian (Leonard Series): Central and central northern Texas.
Chiefly gray limestone beds, 1 to 5 ft thick, separated by shale or marl in beds of comparable thickness. Thickness near Colorado River 400 ft. Underlies Clyde Formation: overlies Admiral Formation.
Named for town of Belle Plains, Callahan County.
References: 92, 107.

Bethany Falls Limestone Member (of Swope Limestone)
Pennsylvanian (Missouri Series): Southwestern Iowa, eastern Kansas, northwestern Missouri, and southeastern Nebraska.
Light-gray dense thin-bedded limestone overlain by gray massive algal limestone or white oolitic limestone. Thickness, as much as 30 ft. Uppermost member of Swope; overlies Hushpuckney Shale Member (94); underlies Galesburg Shale.
Named for exposures at falls of Big Creek, near Bethany, Harrison County, Mo.
References: 22, 90, 94.

Bloyd Shale or **Formation**
Lower Pennsylvanian (Morrow Series): Northwestern Arkansas and eastern Oklahoma.
First defined and named as a division in the Morrow Group. A sequence of alternating limestones and shales and terrestrial sediments including coals. Thickness, as much as 350 ft. In Arkansas subdivided into three named members and an upper unnamed shale; only lowermost member typically developed in Oklahoma. Overlies Hale Formation; underlies Atoka Formation.
Named for Bloyd Mountain, 9 miles southwest of Fayetteville, Washington County, Ark.
References: 63, 67, 110.

Bluefield Shale or **Formation**
Upper Mississippian: Eastern Kentucky, southwestern Virginia, and southern West Virginia.
Principally calcareous shale with some limestone, siltstone, sandstone, and coal beds. Thickness, about 1,250 ft at type locality. Overlies Greenbrier Limestone; underlies Hinton Formation. Reger (114) classified the Bluefield as a group and subdivided it into 31 named units.
Named for exposures at Bluefield, Mercer County, W. Va.
References: 30, 41, 114, 148.

Bluestone Formation (in Pennington Group)
Upper Mississippian: Eastern Kentucky, southwestern Virginia, and southern West Virginia.
Interbedded shale, mudstone, siltstone, sandstone, limestone, and impure coal beds. Overlies Princeton Sandstone; underlies Pocahontas Formation and, in some areas, Lee Formation. Reger (114) referred to unit as group and subdivided it into several formations. Cooper (41) referred to unit as formation and redefined Reger's subdivisions as members.
Well exposed along Bluestone River, Mercer County, W. Va.
References: 30, 41, 114, 148.

Boggy Shale or **Formation** (in Krebs Group)
Pennsylvanian (Des Moines Series): Western Arkansas and central-southern and eastern Oklahoma.
Predominantly dark shale with conspicuous sandstone zones. Thickness ranges from thin edge to maximum of more than 4,000 ft in Cavanal Mountain, Le Flore County, Okla., where top is eroded. Underlies Thurman Sandstone; overlies Savanna Formation; on east flank of Arbuckle Mountains rests on beds as old as Ordovician.
Named for exposures along North Boggy Creek, Pittsburg and Atoka Counties, Okla.
References: 100, 101, 130.

Buck Mountain Coal
Pennsylvanian: Eastern Pennsylvania.
Occurs in post-Pottsville strata which overlie Sharp Mountain Member of Pottsville Formation at type section and reference section of Pottsville.
Reference: 151.

Caseyville Formation or **Sandstone** (in McCormick Group)
Lower Pennsylvanian: Southeastern Illinois and western Kentucky.

Lowermost formation of Pennsylvanian in area. Characterized by dominance of sandstone and prominent development of sandy shale and siltstone. Thickness, commonly 350 ft. Underlies Abbott Formation. In Illinois subdivided into several members.

Type section: Outcrops on Illinois shore of Ohio River between mouth of Saline River and Gentry Landing, below Battery Rock, T. 11 S., R. 10 E., Shawneetown quadrangle, Hardin County. Named for Caseyville, Union County, Ky.

References: 75, 104.

Cassville Shale Member (of Washington Formation)

Pennsylvanian: Southwestern Pennsylvania and northern West Virginia.

Dark gray shale, 5 to 15 ft thick. Commonly separates Waynesburg Sandstone Member of the Washington Formation from Waynesburg coal at top of underlying Monongahela Formation.

Named from exposures in vicinity of Cassville, Monongalia County, W. Va.

References: 16, 144.

Catskill Formation or **Redbeds** (in Susquehanna Group)

Middle and Upper Devonian and Lower Mississippian: Maryland, New York, and Pennsylvania.

Predominantly red-bed sequence with gray conglomerate, sandstone, siltstone, and shale, interbedded. Upper part continental; lower part continental and marine. Maximum thickness, about 9,000 ft. Type Catskill is Middle and Upper Devonian. As facies is followed southwestward from New York into Pennsylvania and Maryland, the red beds become younger, so that Catskill of central and most of eastern Pennsylvania is all Late Devonian. In areas where a "Pocono-Catskill transition group" is recognized, a part of the Catskill may be early Mississippian. In eastern Pennsylvania the Catskill underlies Pocono Formation and overlies Trimmers Rock Sandstone; in central Pennsylvania, it underlies Oswayo Formation and overlies Chemung. The Pennsylvania Geological Survey and the U.S. Geological Survey classify the Catskill as a formation in the Susquehanna Group. From the time the term Catskill was introduced by Mather (83) in 1840, there has been, and continues to be, a discussion as to the precise definition of the Catskill in its type area. Hence, the Virginia and West Virginia Geological Surveys and the U.S. Geological Survey currently apply term Hampshire Formation to Devonian red beds south of Maryland. Terms Catskill and Hampshire are used interchangeably in Maryland Survey reports.

Named for exposures in Catskill Mountains, Greene County, N.Y.

References: 5, 6, 27, 34, 38, 42, 57, 83.

Chase Group

Permian: Eastern Kansas, southeastern Nebraska, and central-northern Oklahoma.

Limestones and shales; chert or flint-bearing limestones. Thickness, about 335 ft. Comprises seven formations. Underlies Wellington Formation of Sumner Group; overlies Council Grove Group.

Named for Chase County, Kans.

References: 51, 94, 109.

Cherokee Group or **Shale**

Pennsylvanian (Des Moines Series): Iowa, Kansas, Missouri, and Nebraska.

Lower major rock unit of Des Moines Series north of Kansas-Oklahoma line. Composed largely of shale, sandstone, carbonaceous shales, thin coals, and thin limestones. As defined in Iowa, Nebraska, Missouri, and Kansas includes about 400 ft of section between post-Mississippian unconformity and Marmaton Group. In Kansas, subdivided into Krebs and Cabaniss Formations; includes same interval as is contained by Krebs and Cabaniss Groups in Oklahoma. In Missouri, comprises all strata in Krebs and Cabaniss Subgroups and is subdivided into several formations.

Named for prominent exposures in Cherokee County, Kans.

References: 60, 65, 69, 91.

Chester Series

Upper Mississippian: Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Missouri, Oklahoma, and Tennessee.

Uppermost of four time-rock divisions of Mississippian in type area. Preceded by Meramec Series. Composed of alternating limestones, sandstones, and shales. In standard reference section includes New Design, Homberg, and Elvira Groups (139) which comprise 16 formations.

Named for Chester, Randolph County, Ill.

References: 139, 152.

Clear Fork Group

Lower Permian (Leonard Series): Central and central northern Texas.

Comprises (ascending) Arroyo, Vale, and Choza Formations. Overlies Wichita Group; underlies Pease River Group.

Probably named for Clear Fork of Brazos River, Jones and Shackelford Counties, Tex.

References: 49, 51.

Clyde Formation (in Wichita Group)

Lower Permian (Leonard Series): Central and central-northern Texas.

Regular beds of moderately hard, medium- to fine-grained gray limestone alternating with shale and marl beds. Thickness, 500 ft near Colorado River. Overlies Belle Plains Formation; underlies Lueders Limestone.

Named for town of Clyde, 8 miles west of Baird, Callahan County.

References: 92, 107.

Conemaugh Formation

Upper Pennsylvanian: Western Maryland, eastern Ohio, Pennsylvania, and northern West Virginia.

Cyclic sequences of red and gray shales and siltstones alternating with thin limestones and coals. Overlies Allegheny Formation; underlies Monongahela Formation. Classified as series by Ohio and West Virginia Geol. Surveys.

Named for exposures along Conemaugh River, Pa.

References: 57, 93, 99, 105, 115.

Des Moines Series

Middle Pennsylvanian: Arkansas, Iowa, Kansas, Missouri, Nebraska, and Oklahoma.

Major time-stratigraphic division of the Pennsylvanian in midcontinent. Spans interval between Atoka Series, below, and Missouri Series, above. Designated paleontologically as zone of *Fusulina*. Upper boundary defined by a disconformity that is inconspicuous in most places but that, on basis of paleontological changes, is judged to be division of first-rank intrasystemic magnitude.

Named for Des Moines River, Iowa.

References: 72, 90, 93.

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Dunkard Group

Pennsylvanian and Permian: Western Maryland, eastern Ohio, southwestern Pennsylvania, and northern West Virginia.

Cyclic sequences of sandstone, limestone, coal, and red shale. Overlies Monongahela Formation; base at top of Waynesburg coal. Comprises Washington Formation, below, and Greene Formation, above.

Named for occurrence on Dunkard Creek, Greene County, Pa.

References: 16, 144.

Eagle coal

Pennsylvanian: Southern West Virginia.

According to I. C. White (143) this name was applied to the lowest workable bed in the Lower Coal Measures (No. XIII) on the Kanawha River. Correlates with Clarion coal of Pennsylvania. Occurs in Kanawha Formation (or Group) as now defined.

Extensively developed at Eagle mines, near Cannelton, Fayette County.

References: 115, 143.

†Elmdale Shale or Formation

Pennsylvanian: Eastern Kansas, southeastern Nebraska, and central-northern and central Oklahoma.

Elmdale Shale, as originally defined and as used for several years, included beds of shale and limestone above Americus Limestone (13) and below Neva Limestone. When Permian boundary was lowered to include Americus Limestone Member of Foraker Limestone, term Elmdale was discarded and formation names applied to the various shales and limestones.

Named for exposures east of Elmdale, Chase County, Kans.

References: 13, 89.

El Reno Group

Permian: Oklahoma.

Name applied to strata above Hennessey Shale and below Whitehorse Group. Includes Flowerpot Shale in lower part. Permian correlation chart (51) uses term Pease River Group in preference to El Reno Group in Texas.

Named for El Reno, Canadian County.

References: 12, 51, 122.

Fayetteville Shale

Upper Mississippian (Chester Series): Northern Arkansas, southern Missouri, and northeastern, central, and eastern Oklahoma.

Chiefly brown to black shales. Contains Wedington Sandstone Member in upper part. In Arkansas underlies Pitkin Limestone and overlies Batesville Sandstone or Boone Limestone. In Oklahoma overlies Hindsville Limestone or, where Hindsville is absent, rests on "Boone" chert knobs; where Pitkin Limestone is missing, the Fayetteville underlies Hale Formation.

Named for Fayetteville, in valley of West Fork of White River, Washington County, Ark.

References: 20, 53, 67, 124.

Flattop Mountain Sandstone Member (of Pocahontas Formation)

Lower Pennsylvanian: Southern West Virginia.

Bluish-gray to brown massive to current-bedded medium-grained micaceous sandstone, 20 to 50 ft. thick. Occurs at top of formation above unit termed Rift Shale by West Virginia Geological Survey; underlies fireclay and shale below Pocahontas No. 8 coal at base of New River Formation. West Virginia Geological Survey treats the Flattop Mountain Sandstone as a formation in Pocahontas Group.

Named for Flattop Mountain, 2 miles northwest of Pocahontas, Va.

References: 115, 146.

Flowerpot Shale (in El Reno, Nippewalla, or Pease River Group)

Permian: Central-southern Kansas, western Oklahoma, and Texas.

Predominantly red, brown, and maroon shales interstratified with green and light-gray shale, thin impure gypsum beds, and thin dolomites. In Oklahoma and Texas, contains named gypsum members. Average thickness in Kansas, 180 ft.; 165 ft. in Carter area, Oklahoma; 274 ft. at type locality of Pease River Group, Texas. Underlies Blaine Formation; underlying units vary according to locality.

Named for Flowerpot Mound, Barber County, Kans.

References: 45, 69, 94, 121, 122.

Garber Sandstone

Permian: Northwestern, central-northern, and south-central Oklahoma.

Thick series of red sandstones and intervening red shales. Underlies Hennessey Shale; overlies Wellington Formation.

Named for exposures at Garber, Garfield County.

References: 7, 51.

Greenbrier Limestone or Formation

Upper Mississippian: Eastern Kentucky, western Maryland, southern Pennsylvania, Virginia, and northern West Virginia.

A sequence of dense crystalline highly fossiliferous locally cherty limestone; commonly grades from gray to brownish gray to black; beds normally thick bedded but relatively thin bedded near top of formation; mottled red and green beds of limestone, calcareous mudstone, and small amounts of gray shale present; crossbedded oolitic and clastic limestones abundant; dolomitic zone near base in many sections. Thickness, 250 to 848 ft. Hillsdale Member and Taggard Red Member differentiated in many areas. Overlies Maccrady Shale or Pocono Formation; underlies Bluefield Formation or Mauch Chunk Formation. In some areas of western Maryland, includes Loyalhanna Member at base. In some areas of Pennsylvania considered a member in Mauch Chunk Formation. West Virginia Geological Survey reports use term Greenbrier Series to include several formations; term Greenbrier Series is used on Mississippian correlation chart (139).

Named for exposures on Greenbrier River, Pocahontas County, W. Va.

References: 5, 57, 114, 119, 139, 148.

Guadalupe Series

Lower and Upper Permian: Southeastern New Mexico and western Texas.

Time-stratigraphic division of the Permian. The series, as defined by Adams and others (2), is 4,100 ft thick at type locality and consists of 2,300 ft. at northern margin of Delaware basin, referred to as type section by Dunbar and others (51). Lower and middle parts characterized by advanced species of *Parafusulina;* upper part by genus *Polydiexodina.* Overlies Leonard Series; underlies Ochoa Series. The U.S. Geological Survey recognizes a twofold division of the Permian. In Permian outcrops of northwestern Trans-Pecos (Delaware Mountains, Guadalupe

Mountains, and Sierra Diablo Mountains) approximate faunal boundary is taken as that between Cherry Canyon and Bell Canyon Formations; this boundary falls between Word and Capitan Formations as recognized in Glass Mountain area.
Type locality: South end of Guadalupe Mountains, Tex.
References: 2, 39, 51, 55.

Hartshorne Sandstone (in Krebs Group)
Pennsylvanian (Des Moines Series): Western Arkansas and eastern Oklahoma.
Basal formation in Krebs Group. Includes beds between top of Atoka Formation and base of McAlester Formation. Thickness, about 200 ft in area of type locality.
Named for exposures near Hartshorne, Pittsburg County, Okla.
References: 93, 100, 116, 130.

Hermit Shale (in Aubrey Group)
Permian: Northern Arizona, southeastern Nevada, and southern Utah.
Brick-red sandstones and shales. Thickness, 300 to 900 ft. Overlies Supai Formation; unconformably underlies Coconino Sandstone. In Grand Wash and Hurricane Cliffs areas overlies Queantoweap Sandstone (82).
Type locality: Hermit basin, Arizona.
References: 51, 82, 98.

Hermosa Formation
Middle Pennsylvanian; Northeastern Arizona, southwestern Colorado, northwestern New Mexico, and southeastern Utah.
Commonly described as comprising: lower member consisting of limestones and dolomites interbedded with dark-gray silty shales; Paradox Member consisting mostly of evaporites; upper carbonate member which consistently recognized only where it overlies Paradox Member. Thickness, about 2,000 ft in type area where it overlies Molas Formation and underlies Cutler Formation. Wengerd and Matheny (140) raised the Hermosa to group rank and subdivided it into (ascending) Pinkerton Trail, Paradox, and Honaker Trail Formations.
Type section: Secs. 26 and 35, T. 37 N., R. 9 W., La Plata County, Colo. Named for Hermosa Creek which flows into Animas River north of Durango. This is composite section measured across strata that dip gently southward into San Juan basin.
References: 10, 46, 140.

Hindostan Whetstone or Beds
Pennsylvanian: Southwestern Indiana.
Series of thin fine-grained laminated beds in lower part of Mansfield Formation. Thickness, about 20 ft.
Named for village which was formerly county seat of Martin County. Village abandoned since 1870.
References: 43, 93, 125.

Jackfork Sandstone
Mississippian: Southwestern Arkansas and southeastern and central-southern Oklahoma.
Where typically developed consists of 5,600 to 5,800 ft of alternating sandstones and dark-gray shales and minor amounts of black siliceous shales that include some thin chert beds. Overlies Stanley Shale; underlies Johns Valley Shale. Oklahoma Geological Survey classifies the Jackfork as a group and subdivides it into five formations.
Named for Jackfork Mountain in frontal Quachitas, Pittsburg, and Pushmataha Counties, Okla.
References: 37, 86, 131.

Kanawha Formation (in Pottsville Group)
Middle Pennsylvanian: Kentucky, Virginia, and West Virginia.
Shales, sandstones, and coals. Thickness, 2,100 ft in West Virginia. Overlies New River Formation; underlies Allegheny Formation. Classified as group by West Virginia Geological Survey.
Well exposed in hills north of Kanawha Falls, W. Va.
References: 32, 115.

Katsberg Red Beds
Upper Devonian: Eastern New York.
Name applied to upper or Enfield part of Catskill Formation. Overlies Onteora Red Beds, underlies Slide Mountain Conglomerate. Thickness, about 3,000 ft where complete.
Type section: Slopes of highest peak, Slide Mountain (in Catskill Mountains). Katsberg is Dutch name for the mountains miscalled "Catskills" by the English.
Reference: 33.

Kerber Formation
Pennsylvanian: Southern Colorado.
In type area consists of about 200 ft of white to gray coarse-grained sandstone and carbonaceous shale, which overlie Leadville Limestone and extend up to base of lowest red micaceous sediments or sandy facies of Maroon Formation. In some areas underlies Minturn Formation or Hermosa Formation. On basis of stratigraphic position may be Morrow or Atoka.
Named for exposures along Kerber Creek, Bonanza district, Saguache County.
References: 19, 21, 24, 81.

Kinderhook Series
Lower Mississippian: Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Missouri, Oklahoma, and Tennessee.
Lowermost time-rock division of the Mississippian in type area. Succeeded by Osage Series. Varies lithologically from place to place. In standard reference section includes Fabius and Easley Groups (139), which comprise seven formations.
Named for exposures at Kinderhook, Pike County, Ill.
References: 85, 139.

Koontz coal
Pennsylvanian: Western Maryland.
Coal bed in Monongahela Formation. Considered correlative of Uniontown coal.
Reference: 17.

Lampasas Series
Pennsylvanian: Texas.
Time-stratigraphic term proposed for beds younger than Morrow and older than type Strawn of Brazos River valley section, Texas. Later redefined to include all beds up to top of Dennis Bridge Limestone (36). By this definition the series included equivalents of Atoka Formation of Oklahoma, Derry Series (134) of New Mexico, and about half of Cherokee Group of Oklahoma, Kansas, and Iowa. Spivey and Roberts (126) considered Lampasas unsatisfactory as series name and proposed that term Atoka Formation be raised to series rank and defined to include all beds from top of Morrow Series to base of Des Moines Series.

Type section: Around Llano uplift of central Texas and in area to north. Well exposed in western Lampasas and eastern San Saba Counties near village of Bend.
References: 35, 36, 93, 126, 134.

Lancaster Formation (in Little River Group or Series)
Pennsylvanian: New Brunswick, Canada.
Thick deposits of clastic sediments that locally carry plant remains. Includes "Fern Ledge Beds."
St. John region, New Brunswick.
References: 3, 4.

Lee Formation or Group
Lower Pennsylvanian: Eastern Kentucky, eastern Tennessee, and southwestern Virginia.
Sandstones, conglomerates, shales, and coals. Overlies Pennington Formation or Group and in some areas Bluestone Formation. Overlying units: Briceville Formation, Tennessee; Norton Formation, Virginia; Hance Formation, Cumberland Gap, Tenn., area; Breathitt Formation, eastern Kentucky. The U.S. Geological Survey classifies the Lee as a group in east-central Tennessee. The Tennessee Geological Survey has discontinued term Lee Group and uses terms Gizzard, Crab Orchard Mountains, and Crooked Fork Groups.
Named for Lee County, Va.
References: 28, 93, 150.

Leonard Series
Lower Permian: New Mexico and Texas.
Time-stratigraphic division of the Permian. At type section is about 2,000 ft thick and consists chiefly of limestone and siliceous shales. Common fusulinids are primitive types of *Parafusulina; Perrinites* is representative of the ammonoids. Disconformably overlies Wolfcamp Series; underlies Word Formation of Guadalupe Series.
Type section: On south face of Glass Mountains, western Texas.
References: 2, 51, 136.

Little River Group or Series
Pennsylvanian: New Brunswick, Canada.
Sandstones, shales, grits, and conglomerates. Includes Lancaster Formation and "Fern Ledge Beds."
Crops out along Little River and shore of Courtney Bay, St. John district.
References: 3, 84, 128.

Lookout Sandstone (in Pottsville Group)
Lower Pennsylvanian: Northeastern Alabama, northwestern Georgia, and southern Tennessee.
Includes two conglomeratic sandstones. Thickness, 50 to 600 ft. In Lookout Mountains, Ga., underlies Whitwell Shale; overlies Pennington Shale.
Named for exposures on Lookout Mountain, northeastern Alabama and northwestern Georgia.
References: 62, 70.

Lueders Limestone (in Wichita Group)
Lower Permian (Leonard Series): Northern and central Texas.
Consists mainly of limestone beds, 1 ft or less to about 3 ft thick, separated by shale beds 1 or 2 in. thick; locally, shale is as much as 5 ft. Thickness, about 225 ft. Limestone characterized by fine algal pellets. Overlies Clyde Formation; underlies Arroyo Formation. Has been referred to as group and subdivided into several formations.
Named for town on Clear Fork of Brazos River, eastern Jones County.
References: 35, 92, 153.

Lykens Valley coals
Pennsylvanian: Eastern Pennsylvania.
A series of seven coals (numbered in descending order) in Pottsville Formation in the anthracite field. Sometimes referred to as Lykens coals.
References: 93, 151.

McCormick Group
Lower and Middle Pennsylvanian: Western and southern Illinois.
Comprises Caseyville and Abbott Formations. Includes strata formerly included in Caseyville Group and lower part of Tradewater Group. Maximum thickness, 850 ft. Lowest group in Pennsylvanian of Illinois. Underlies Kewanee Group.
Named for village of McCormick in northwestern Pope County, which is located in area where strata of the two formations are prominently exposed.
Reference: 75.

McCoy Formation
Pennsylvanian: Northwestern Colorado.
Redefined by Donner (48) to include over 3,500 ft of coarse arkosic sandstones and grits and interbedded shales and limestones. Contains *Walchia*-bearing beds. Uncomformably overlies Mississippian Leadville Limestone; underlies Permian(?) State Bridge Siltstone (48).
Named for exposures at McCoy, Eagle County.
References: 48, 120.

Madera Limestone or Formation (in Magdalena Group)
Pennsylvanian: Southern Colorado and central and northern New Mexico.
In New Mexico commonly consists of a lower gray limestone member and an upper arkosic limestone member. Thickness, as much as 3,000 ft. Locally subdivided into named formations. Overlies Sandia Formation; underlies Abo, Sangre de Cristo, or Bursum Formations. In La Veta Pass area, Colorado, overlies Deer Creek Formation (19) and underlies Pass Creek Sandstone (19); grades laterally into Minturn Formation.
Named for village of La Madera on eastern slope of Sandia Mountains, N. Mex.
References: 8, 19, 71, 73, 149.

Massillon coal
Pennsylvanian: Northeastern Ohio.
Name applied in early reports to Sharon No. 1 coal in the Massillon coal field, which was mapped in parts of Summit, Medina, Wayne, and Stark Counties; also referred to as "Coal No. 1," "Brier Hill," and "Jackson" coal.
References: 97, 102.

Mauch Chunk Shale or Formation
Upper Mississippian: Western Maryland, Pennsylvania, and northern West Virginia.
Commonly red shales with brown to greenish-gray flaggy sandstones. Thickness may be as much as 3,500 ft locally. Underlies Pottsville Formation at type section and reference section of Pottsville. In West Virginia, underlies Pocahontas Formation (or Group). Underlying units vary according to area: Pocono Formation or Group, Greenbrier Limestone, or Loyalhanna Limestone. Geologic map of Pennsylvania (57) shows the Mauch Chunk includes Greenbrier and Loyalhanna Limestones and overlies Pocono Group. West Virginia Geol. Survey classifies

the Mauch Chunk as a series comprising Bluefield, Hinton, Princeton, and Bluestone Groups. Mississippian correlation chart (139) uses term Mauch Chunk in virtually this same sense.

Type locality not stated but commonly assumed to be at Jim Thorpe, formerly Mauch Chunk, Carbon County, Pa.

References: 57, 79, 139, 151.

Meramec Series

Upper Mississippian: Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Missouri, Oklahoma, and Tennessee.

Third (ascending) of four time-rock divisions of the Mississippian in type area. Spans interval between Osage Series, below, and Chester Series, above. In standard reference section, includes (ascending) Warsaw, Salem, and Ste. Genevieve Limestones.

Named for Meramec Highlands and Meramec River, west of St. Louis, Mo.

References: 137, 139.

Mercer Shale Member (of Pottsville Formation)

Pennsylvanian: Maryland, eastern Ohio, western Pennsylvania, and northwestern Virginia.

Shale, fire clay, and coal. Thickness about 40 ft. Underlies Homewood Sandstone Member; overlies Connoquenessing Sandstone Member. Also referred to as Mercer Shale in Pottsville Series (93).

Type locality: Mercer, Mercer County, Pa.

References: 25, 80, 93.

Merrimac coal

Mississippian: Virginia and West Virginia.

Minable coal in upper part of Price Formation in Virginia. In Greenbrier County, W. Va., coal in upper part of Pocono Series is correlated with Merrimac coal of Montgomery County, Va.

References: 23, 108.

Missouri Series

Upper Pennsylvanian: Arkansas, Iowa, Kansas, Missouri, Nebraska, and Oklahoma.

Major time-stratigraphic division of the Pennsylvanian in the midcontinent. Separated by regional disconformities from overlying Virgil Series and underlying Des Moines Series. Composes lower part of zone of *Triticites*.

Named for exposures in northwestern Missouri and along Missouri River, Iowa.

References: 72, 90, 93, 94.

Monongahela Formation

Upper Pennsylvanian: Western Maryland, eastern Ohio, western Pennsylvania, Virginia, and West Virginia.

Cyclic sequences of sandstone, shale, limestone, and coal: limestone prominent in northern outcrop areas; shale and sandstone increase in prominence southward. Includes beds from base of Pittsburgh coal to top of Waynesburg coal. Overlies Conemaugh Formation; underlies Dunkard Group. Also referred to as Monongahela Series.

Named for exposures along Monongahela River, Pa.

References: 57, 93, 117.

Moran Formation (in Wichita Group)

Lower Permian (Wolfcamp Series): Central and central northern Texas.

Consists of alternating limestone and shale but includes some sandstone. Comprises two limestone members and two shale members. Thickness, about 100 ft near Colorado River. Overlies Pueblo Formation; underlies Putnam Formation.

Named for Moran, Shackelford County.

References: 92, 106.

Morien Series or Group

Pennsylvanian: Nova Scotia, Canada.

Laterally changing alternation of sandstones and shales. Subdivided into three zones on basis of fossil plant and animal remains. Thickness, 2,900 to 6,500 ft. Includes many coal-bearing beds.

Occurs in southern part of Sydney coal field.

References: 15, 61.

Morrow Series

Lower Pennsylvanian: Arkansas, Iowa, Kansas, Missouri, Nebraska, and Oklahoma.

Time-rock term applied to major subdivision of Lower Pennsylvanian in midcontinent. Underlies Atoka Series. In terms of fusuline zonation, deposits belong to zone of *Millerella*. Probably throughout most of northern midcontinent area, lower boundary of Morrow Series coincides with a major unconformity that separates Pennsylvanian from older systems.

Named for Morrow, Washington County, Ark.

References: 1, 91.

New River Formation (in Pottsville Group)

Lower Pennsylvanian: Southwestern Virginia and southern West Virginia.

Sandstones, shales, and coals. Thickness 1,030 ft in West Virginia. Includes Pocahontas coals 8 and 9. Comprises (ascending) Quinnimont Shale, Raleigh Sandstone, Sewell, and Nuttall Sandstone Members. Overlies Pocahontas Formation; underlies Kanawha Formation. Classified as group by West Virginia Geological Survey.

Well exposed along New River, Raleigh and Fayette Counties, W. Va.

References: 54, 115, 142.

Nuttall coal seam

Pennsylvanian: Southern West Virginia.

Name applied by I. C. White (143) to first workable coal bed at top of Pottsville or No. XII Conglomerate (about 400 ft below top of Nuttall Sandstone Member of New River Formation). First commercial mining was made by John Nuttall, who established the mining town of Nuttallburg, Fayette County, soon after the C & O Railroad was constructed. The coal had previously been mined for local use near top of Sewell Mountain; hence the name Sewell became attached to the coal, and it is now commonly known by that name.

References: 143, 145.

Nuttall Sandstone Member (of New River Formation)

Lower Pennsylvanian: Southwestern Virginia and southern West Virginia.

Massive sandstone, conglomeratic in many localities. Thickness, 180 to 220 feet. Commonly forms two ledges, each as much as 100 ft thick. Overlies Sewell Member; underlies Kanawha Formation. West Virginia Geological Survey does not use term Sewell and refers to the units as Lower Nuttall and Upper Nuttall Sandstones in New River Group.

Forms cliffs from Gauley Bridge to Nuttallburg, Fayette County, W. Va.

References: 31, 115.

Osage Series

Lower Mississippian: Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Missouri, Oklahoma, and Tennessee.

Second of four time-rock divisions of the Mississippian in type area. Spans interval between Kinderhook Series, below, and Meramec Series, above. In standard reference section includes (ascending) Fern Glen, Burlington, and Keokuk Limestones.

Named for Osage River in Missouri.

References: 139, 147.

Parkwood Formation

Upper Mississippian: Northern Alabama.

Predominantly gray or greenish-gray sandy shale and sandstone. Thickness, 0 to 2,000 ft. Underlies Pottsville Formation; overlies Floyd Shale.

Named for exposures at Parkwood, Jefferson County.

References: 26, 93.

Pittsburgh coal

Pennsylvanian: Maryland, Ohio, Pennsylvania, and West Virginia.

Coal at base of Monongahela Formation (Series).

Reference: 93.

Pocahontas coal beds

Pennsylvanian: Virginia and West Virginia.

Pocahontas coals consist of nine coal beds numbered in ascending order. Coals 1 through 7 are present in Pocahontas Formation (Group) and coals 8 and 9 are in New River Formation (Group) in West Virginia. These coals also occur in lower part of Lee Formation in Virginia.

References: 23, 93.

Pocahontas Formation (in Pottsville Group)

Lower Pennsylvanian: Southwestern Virginia and southern West Virginia.

Sandstones, shales, and coals. Thickness, 720 ft in West Virginia. Includes Flattop Mountain Sandstone Member at top. Underlies New River Formation; overlies Mauch Chunk Shale or Bluestone Formation. Includes Pocahontas coals 1–7. This definition corresponds to I. C. White's (146) Pocahontas Group and to Pocahontas Group as used by West Virginia Geological Survey.

Named for Pocahontas, Tazewell County, Va.

References: 30, 115, 146.

Pocono Formation, Sandstone, or **Group**

Mississippian: Western Maryland, eastern Ohio, Pennsylvania, Virginia, and West Virginia.

Predominantly gray hard massive crossbedded conglomerate and sandstone. Thickness as much as 1,600 ft. Overlies Upper Devonian: Chemung, Catskill, or Hampshire Formations or Mount Pleasant Sandstone (139). Underlies Mauch Chunk, Maccrady, Greenbrier, or Loyalhanna Formations. In Virginia, names Pocono and Price are practically synonymous; name Pocono is applied as far south as western Alleghany County, and name Price, throughout region from southern Alleghany and western Botetourt Counties to Tennessee. West Virginia Geological Survey classifies the Pocono as a series comprising several formations. Mississippian correlation chart uses term Pocono Series in virtually the same sense.

No type locality designated by Lesley (79). Later workers have assumed type area to be in the Pocono Mountains of northeastern Pennsylvania.

References: 27, 79, 112, 139.

Pottsville Formation or **Group**

Lower and Middle Pennsylvanian: Alabama, Georgia, Indiana, Kentucky, Maryland, Mississippi, New York, Pennsylvania, Tennessee, Virginia, and West Virginia.

Formation, at type section and reference section, consists of about 1,200 ft of strata composed predominantly of cobble and pebble conglomerate, conglomeratic sandstone, sandstone, and lesser amounts of siltstone, shale, and coal; comprises (ascending) Tumbling Run, Schuylkill, and Sharp Mountain Members. At type section and reference section overlies Mauch Chunk Formation and underlies later Pennsylvanian Buck Mountain or Twin coal bed. Elsewhere underlies Allegheny Formation. In some areas overlies Bluestone Formation; in Alabama overlies Parkwood Formation. Pennsylvania Geological Survey classifies the Pottsville as a group. Indiana, Ohio, and West Virginia Geological Surveys classify the Pottsville as a series.

Type section: South of city of Pottsville, along Pennsylvania Railroad cut on east side of water gap through Sharp Mountain, Schuylkill County, Pa. Reference section: About 150 ft east of type section is along east side of roadcut for U.S. Highway 122.

References: 57, 58, 79, 93, 115, 129, 151.

Price Sandstone, Siltstone, or **Formation**

Mississippian: Southwestern Virginia.

Lithology varies; in some areas, predominantly siltstone and some interbedded shale; elsewhere, coarse grained and referred to as sandstone. Thickness, as much as 1,700 ft. Underlies Maccrady Shale; overlies Big Stone Gap Shale. Names Price and Pocono are practically synonymous; name Price is applied throughout region from southern Alleghany and western Botetourt Counties to Tennessee; name Pocono applied in northern Virginia.

Named for Price Mountain, Montgomery County.

References: 27, 29, 139.

Quinnimont Shale Member (of New River Formation)

Lower Pennsylvanian: Southwestern Virginia and southern West Virginia.

Shale containing thin beds of sandstone and a few coal seams. Thickness, as much as 300 ft. Underlies Raleigh Sandstone Member; overlies unnamed interval of coal, shale, and clay in lower part of formation.

Named for exposures at Quinnimont, Fayette County, W. Va.

References: 30, 115.

Raleigh Sandstone Member (of New River Formation)

Lower Pennsylvanian: Southwestern Virginia and southern West Virginia.

Commonly consists of two sandstone ledges separated by several feet of shale, coal, and fire clay. Sometimes referred to as Lower Raleigh and Upper Raleigh Sandstones (146). Thickness, as much as 150 ft. Overlies Quinnimont Shale Member; underlies Sewell Member.

Named for occurrence in Raleigh County, W. Va.

References: 32, 115, 146.

Sandia Formation (in Magdalena Group)

Lower Pennsylvanian: Central-northern New Mexico.

Series of sandstones, shales, and conglomerates. Thickness, 0 to over 2,000 ft. Basal formation in group. Underlies Madera Formation. Underlying units: Kelly Limestone, Lake Valley Limestone, Arroyo Penasco Formation, Tererro Formation, or Precambrian rocks.

First described in Sandia, Manzano, and San Andres Mountains.

References: 9, 64, 113.

Schuylkill Member (of Pottsville Formation)
Lower Pennsylvanian: Eastern Pennsylvania.
Several beds of fine to coarse pebble conglomerate and quartzose sandstone intercalated with thinner beds of shale and coal. About 300 ft thick at type section. Includes coal beds that may be correlative with Lykens Valley No. 1, 2, and 3 coals. Middle member of Pottsville is present at reference section of Pottsville; overlies Tumbling Run Member; underlies Sharp Mountain Member. Pennsylvania Geological Survey classifies the Schuylkill as a formation in Pottsville Group.
Type section: East side U.S. Highway 122 about half a mile south of Pottsville. Mapped in Pine Grove, Pottsville, Mahoney, Catawissa, and Lykens quadrangles.
References: 57, 151.

Sewell Member (of New River Formation)
Lower Pennsylvanian: Southwestern Virginia and southern West Virginia.
Overlies Raleigh Sandstone Member; underlies Nuttall Sandstone Member. West Virginia Geological Survey does not use term Sewell but applies names to the several sandstone and shale units that make up the interval.
Named for Sewell, Fayette County, W. Va.
Reference: 32.

Sharon coal
Pennsylvanian: Maryland, Ohio, Pennsylvania, and West Virginia.
Coal in lower part of Pottsville and New River Formations. Lies above Sharon Shale.
Reference: 93.

Sharon Shale Member (of Pottsville Formation)
Lower Pennsylvanian: Western Maryland, New York, eastern Ohio, western Pennsylvania, and northern West Virginia.
Overlies Sharon Conglomerate Member; underlies Connoquenessing Sandstone Member; overlies Olean Conglomerate Member in New York. Ohio Geological Survey refers to the unit as Sharon Shale in Pottsville Series.
Named for Sharon, Mercer County, Pa.
References: 76, 93, 118.

Sharp Mountain Member (of Pottsville Formation)
Lower and Middle Pennsylvanian: Eastern Pennsylvania.
Chiefly cobble and coarse pebble conglomerate and fine to coarse sandstone, siltstone, shale, and coal. About 280 ft thick at type section. Uppermost member of Pottsville is present at reference section of Pottsville; overlies Schuylkill Member; contact with post-Pottsville rocks is at base of carbonaceous shale beneath Buck Mountain coal bed. At type section basal beds are about 70 ft above Lykens Valley No. 1 coal; in many areas in southern anthracite field, basal beds are about 30 ft above the coal. Pennsylvania Geological Survey classifies the Sharp Mountain as a formation in Pottsville Group.
Type section: East side U.S. Highway 122 about half a mile south of Pottsville. Mapped in Pine Grove, Pottsville, Mahoney, Catawissa, and Lykens quadrangles.
References: 57, 151.

Shihhotsi Series
Permian: Northern China.
Light-colored fresh-water and delta deposits without marine intercalations and almost without coal seams. Thickness, about 450 m. Divided into upper and lower parts on basis of lithology.
Occurs in central Shansi Province.
Reference: 59.

Stanley Shale
Mississippian: Western Arkansas and central-southern and southeastern Oklahoma.
Predominantly shale; sandstone common; siltstone in subordinate amounts. Maximum thickness, 11,000 ft in central Ouachitas. Underlies Jackfork Sandstone; overlies Arkansas Novaculite or Woodford Chert. Oklahoma Geological Survey classifies the Stanley as a group and subdivides it into three formations. Mississippian; evidence indicates Meramec. Unit has been assigned to Ordovician. Mississippian, and Pennsylvanian by various workers.
Named for outcrops in valley of Kiamichi River near Stanley, Pushmataha County, Okla.
References: 37, 86, 131.

Stratford Formation (in Pontotoc Group)
Permian: Central-southern Oklahoma.
Consists of series of limestones at base (Hart Limestone Member) and undetermined thickness of dark shales above. About 400 ft of formation exposed in Stonewall quadrangle. Also classified as a facies of Konawa Formation (133).
Named for exposures at and around Stratford, Garvin County.
References: 87, 95, 133.

Sumner Group
Permian: Eastern Kansas.
About 1,000 ft of strata at outcrop. Predominantly gray shale but includes beds of red and green shale, deposits of dolomite, limestone, gypsum, and anhydrite. Thickness, about 1,000 ft. Comprises Wellington Formation, Ninnescah Shale, and Stone Corral Formation. Overlies Chase Group; underlies Nippewalla Group.
Named for Sumner County.
References: 45, 69, 94.

Supai Formation (in Aubrey Group)
Pennsylvanian and Permian: Northern Arizona, western New Mexico, and southern Utah.
Red beds of sandstones, shales, siltstones. Average thickness, about 1,400 ft. In Grand Canyon sections the Supai overlies Mississippian Redwall Limestone and underlies Hermit Shale. In central Arizona, where it is subdivided into several members, it underlies Coconino Sandstone and overlies Naco Limestone. Over Grand Canyon dome, entire Supai is probably Permian. Southeastward the Supai facies descends in the section and has yielded Pennsylvanian fusulinids. Formation transgresses time lines and probably varies in age from Des Moines through Leonard.
Named for exposures at Supai village in Havasu (Cataract) Canyon, northern Arizona. Havasu Canyon drains northward into the Grand Canyon and joins it about 85 miles north of Black Mesa. Supai is contraction of word Havasupai.
References: 47, 51, 66, 68, 78, 82.

Swope Limestone (in Kansas City Group)
Pennsylvanian (Missouri Series): Southwestern Iowa, eastern Kansas, northwestern Missouri, and southeastern Nebraska.
Comprises (ascending) Middle Creek Limestone (94), Hushpuckney Shale (94), and Bethany Falls Limestone Members. Thickness, about 27 ft in Iowa, 21 ft in Nebraska,

28 to 30 ft in Missouri, 20 to 30 ft in Bourbon County, Kans. Overlies Ladore Shale; underlies Galesburg Shale.
Named for Swope Park, Kansas City, Mo.
References: 40, 50, 94.

Tarter Member (of Abbott Formation)
Lower Pennsylvanian: Western Illinois.
Light-gray or bluish-gray argillaceous sandstone; locally discolored by carbonaceous matter. Thickness, a few inches to 3 ft. Present locally below Tarter Coal Member (75) of Abbott Formation. Illinois Geological Survey has discontinued name Tarter Sandstone in order to retain name Tarter for a coal member.
Type section: SE¼ sec. 2, T. 5 N., R. 1 E., Fulton County. Named for Tarter Bridge over Spoon River.
References: 75, 111, 138.

Tradewater Formation
Middle Pennsylvanian: Western Kentucky.
Chiefly shale and a few sandstone beds. Thickness, 175 to 700 ft in Webster County, Ky. Name Tradewater has been used as a group term in Illinois for strata overlying Caseyville Group and underlying Carbondale Group. Recently the Illinois Geological Survey abandoned term Tradewater. Strata formerly included in unit are now included in the Abbott Formation of McCormick Group and Spoon Formation of Kewanee Group.
Named for exposures along Tradewater River, east of Battery Rock, Ky.
References: 56, 75.

Tumbling Run Member (of Pottsville Formation)
Lower Pennsylvanian: Eastern Pennsylvania.
Predominantly conglomerate and sandstone; lesser amounts of conglomeratic sandstone, siltsone, shale, and coal. About 535 ft thick at type section. Basal member of Pottsville is present at reference section of Pottsville; underlies Schuylkill Member; conformably overlies Mauch Chunk Formation. Pennsylvania Geological Survey classifies the Tumbling Run as a formation in Pottsville Group.
Type section: East side U.S. Highway 122 about half a mile south of Pottsville. Mapped in Pine Grove, Pottsville, Mahoney, Catawissa, and Lykens quadrangles.
References: 57, 151.

Twin coal
Pennsylvanian: Eastern Pennsylvania.
An equivalent of the Buck Mountain coal.
References: 141, 151.

Uniontown coal
Pennsylvanian: Ohio, Pennsylvania, and West Virginia.
Coal in Monongahela Formation above Pittsburgh coal and below Waynesburg coal. Considered correlative of Koontz coal.
References: 17, 93.

Vale Formation (in Clear Fork Group)
Permian (Leonard Series): Central and central northern Texas.
Middle formation in Clear Fork Group. Underlies Choza Formation; overlies Arroyo Formation.
Named for old post office at Ballinger-Maverick road on east side of Valley Creek, Runnels County.
References: 14, 51.

Virgil Series
Upper Pennsylvanian: Arkansas, Iowa, Missouri Nebraska, and Oklahoma.
Time-stratigraphic term for youngest Pennsylvanian rocks of midcontinent region. Separated by disconformities from Missouri Series, below, and Permian strata above. Considered as composing upper part of zone of *Triticites*. Brownville zone in northern midcontinent area is recognized as defining the Pennsylvanian-Permian boundary.
Named for town in eastern part of Greenwood County, Kans.
References: 88, 90, 94.

Washington Formation (in Dunkard Group)
Pennsylvanian and Permian: Western Maryland, eastern Ohio, southwestern Pennsylvania, and northern West Virginia.
Lower formation in Dunkard Group. Includes Cassville Shale Member at base. Underlies Greene Formation; overlies Waynesburg coal bed at top of Monongahela Formation.
Named for exposures in highlands of Washington County, Pa.
References: 51, 127.

Waynesburg coal
Pennsylvanian: Maryland, Ohio, Pennsylvania, Virginia, and West Virginia.
Coal at top of Monongahela Formation (Series). Generally accepted as marking top of Pennsylvanian in Appalachian region. In many areas overlain by Cassville Shale Member of Washington Formation.
References: 17, 93.

Weber Quartzite, Formation, Sandstone, or **Shale**
Pennsylvanian: Western Colorado and northeastern Utah.
At type section consists chiefly of gray to white but buff-weathering quartzites and sandstones. Some gray and light-gray limestones containing chert nodules. Thickness, about 3,000 ft. Overlies Morgan Formation; underlies Park City Formation.
Type section: Upper Weber Canyon east of Morgan, Morgan County, Utah.
References: 52, 74.

Wedington Sandstone Member (of Fayetteville Shale)
Upper Mississippian (Chester Series): Northern Arkansas and northeastern Oklahoma.
Fine-grained hard buff to brown sandstone at type locality, becoming flaggy to the east and west. Lies near middle of formation. Thickness, commonly 50 ft; 150 ft at type locality.
Named for Wedington Mountain, Washington County, Ark.
References: 1, 53, 139.

Wellington Formation (in Sumner Group)
Permian: Central and southern Kansas and northern Oklahoma.
Chiefly gray silty shale containing several more or less lenticular beds of gypsum and fine-grained limestone; contains salt in middle part in subsurface. Total thickness, about 700 ft. Basal formation of Sumner Group in Kansas; underlies Ninnescah Shale; overlies Nolans Limestone of Chase Group. In Oklahoma underlies Garber Sandstone; overlies Asher Sandstone in west-central part of the State and Herington Limestone of Chase Group in north-central part; in southwestern part of the State the Garber and Wellington are undifferentiated.
Named for exposures at Wellington, Sumner County, Kans.
References: 44, 51, 94.

Wolfcamp Series
Lower Permian: New Mexico and Texas.
A time-stratigraphic division of the Permian. At type locality consists of about 600 ft of limestones, limestone con-

glomerate, and shales. Varied fauna of fusulines, of which zone fossil is *Pseudoschwagerina*. In West Texas rests with angular unconformity on rocks ranging in age from Precambrian to Late Pennsylvanian and is unconformably overlain by Leonard Series.

Type locality: Along face of Glass Mountains, central Texas. Name derived from old site of Wolf Camp. Wolf Camp Hills, a range of hills 2 miles long having summits of 4,952 and 5,060 ft, are at base of south face of Glass Mountains, 12 to 14 miles northeast of Marathon, Brewster County.

References: 2, 48, 135.

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[Italic page numbers indicate major references]

PLATES 1–19

The numbering of illustrations and positioning of the successively younger floral zones in plates 1–19 presents to the reader a series of illustrations of fossils as they might occur in an idealized stratigraphic section if the plates were removed from the report and attached one above the other with plate 1 at the base.

PLATE 1

[All figures natural size]

ZONE 1. ZONE OF *ADIANTITES* SPP.

FIGURE 1. *Adiantites spectabilis* Read

Part of a rachis showing several pinnules. Note that the pinnules are broadly ovate or obcuneate ovate and are commonly incised into several divisions. The nervation is palmate from a single basal nerve. The rachis appears to have been lax and angularly sinuose; this evidence suggests that the fronds may have had a climbing or clambering habit. Locality: Shale in the lower part of the Pocono Formation at east end of railroad tunnel near Caledona, Clearfield County, Pa. USNM 40688.

2. *Rhacopteris latifolia* (Arnold) Read

Specimen showing the possibly bipinnate nature of the frond. Note the crowded and overlapping pinnules which are subopposite, obovate, and apparently sessile on the rachis. The distal margins of the pinnules are either dentate or crenate. The venation apparently originates from a plexus of strands at the base and commonly dichotomizes as the veinlets pass to the margins. Locality: Shale in lower part of Pocono on Horseshoe Curve just above Kittanning Point on main line of Pennsylvania Railroad near Altoona, Blair County, Pa. USNM 40666.

ZONE 2. ZONE OF *TRIPHYLLOPTERIS* SPP.

FIGURE 3. *Triphyllopteris lescuriana* (Meek) Lesquereux

Specimen of a pinna showing the rigid aspect and the slightly overlapping pinnules of the ultimate pinnae. The pinnules are obcuneate or oblanceolate, slightly decurrent, and rigid in general aspect. Locality: 1½ miles north of Vicker, Montgomery County, Va., on road to Price Forks in an outcrop of upper part of Price Sandstone above Merrimac coal. USNM 19929.

3

ZONE 2, ZONE OF *TRIPHYLLOPTERIS* SPP.

2

1

ZONE 1, ZONE OF *ADIANTITES* SPP.

PLATE 2

[All figures natural size]

ZONE 2. ZONE OF *TRIPHYLLOPTERIS* SPP.

FIGURE 1. *Triphyllopteris rarinervis* Read

Specimen showing the general aspect of a part of the frond that is probably bipinnate. The lateral pinnae alternate and are set at nearly right angles to the rachis, although they become slightly more acute apically. The pinnae slightly overlap and are rigid in general aspect. The bases are slightly decurrent. The pinnules are obcuneate or oblanceolate and asymmetrical; some are bidenticulate or tridenticulate at the apices. The nervation is coarse. Locality: 1½ miles north of Vicker, Montgomery County, Va., on road to Price Forks, in an outcrop of upper part of Price Sandstone above Merrimac coal. USNM 40641.

2. *Lepidodendropsis scobiniformis* (Meek) Read

A specimen showing the elongate bolsters, arranged in a very close spiral so that they appear to be in nearly horizontal as well as vertical rows. The lower parts of the bolsters are almost devoid of any markings. The indistinct leaf scars are situated in the upper part of the bolsters and are somewhat quadrangular with the angles rounded. The vascular strands, which are centrally located, are not known in detail. There is no evidence of a parichnos scar in specimens of this species that have been examined. Locality: Coaly and shaly beds in upper part of Pocono Formation along Pennsylvania Railroad right-of-way south of Pottsville, Schuylkill County, Pa. USNM 40671.

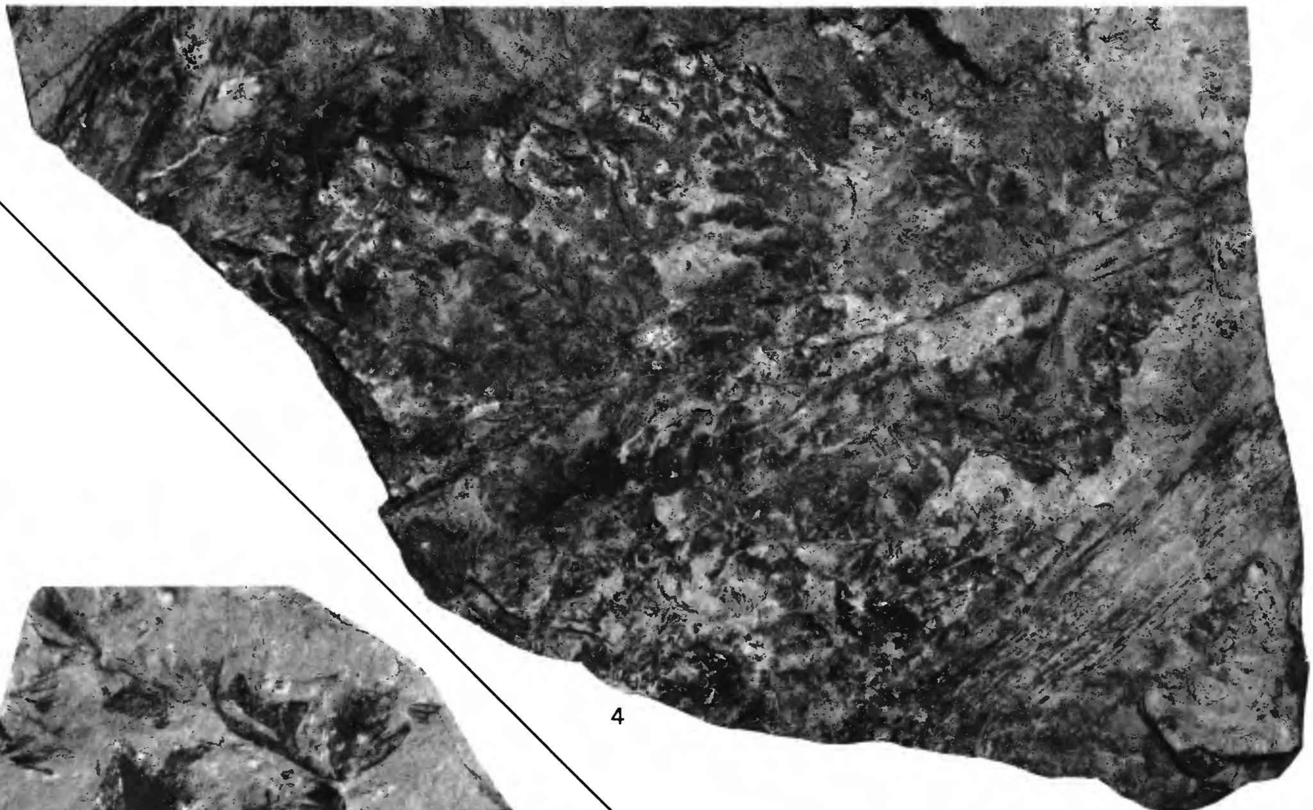
3. *Rhodea vespertina* Read

A specimen showing the delicate nature of the frond with the rigid and rather flexuose pinna axes. The ultimate pinnae are alternate to subopposite, distinct, and set at angles of approximately 45°. The pinnules are finely divided, each lobe having only one nerve. The apices are rounded. Locality: 1½ miles north of Vicker, Montgomery County, Va., on road to Price Forks, in an outcrop of upper part of Price Sandstone above Merrimac coal. USNM 40639.

ZONE 3. ZONE OF *FRYOPSIS* SPP.

4. *Sphenopteridium brooksi* Read

A specimen that indistinctly shows the major part of a dichotomous frond in which the branches both above and below the dichotomy are disposed in a pinnate or bipinnate fashion. The pinnules are ovate-cuneate and are modified by lobation. Locality: Mauch Chunk Formation, on Beech Fork about half a mile southeast of Left Fork of Beech Fork at the level of the abandoned Alexander Lumber Co. railroad grade, Upshur County, W. Va. USNM 40655.



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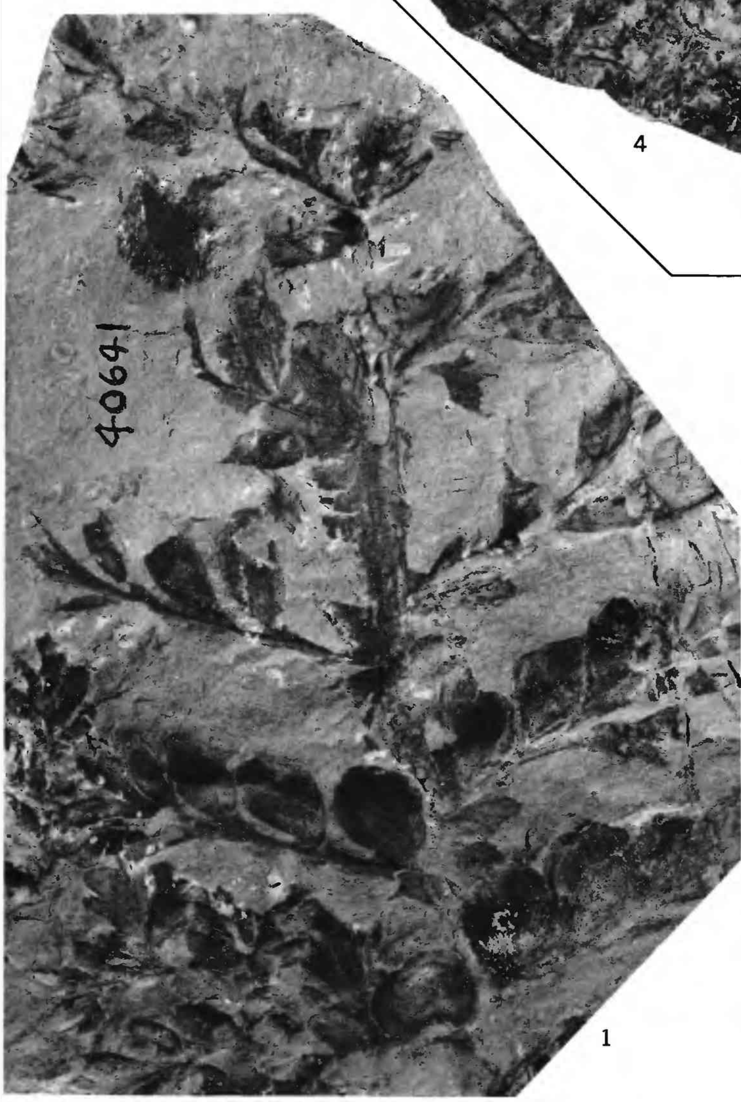
ZONE 3, ZONE OF *FRYOPSIS* SPP.



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ZONE 2, ZONE OF *TRIPHYLLOPTERIS* SPP.

PLATE 3

[Figure natural size]

ZONE 3. ZONE OF *FRYOPSIS* SPP.

FIGURE 1. *Fryopsis abbensis* (Read) Wolfe

Shale slab showing many pinnules. The pinnules are round-cordate and symmetrical; the apices are gently rounded or slightly elongate and more sharply rounded. The venation radiates from the point of attachment to the rachis, and no midrib is apparent. Locality: Lower part of Bluefield Shale, overlying Greenbrier Limestone in Abbs Valley, Tazewell County, Va. USNM 40680.

1

ZONE 3. ZONE OF *FRYOPSIS* SPP.

PLATE 4

[All figures natural size]

ZONE 4. ZONE OF *NEUROPTERIS POCAHONTAS* AND *MARIOPTERIS EREMOPTEROIDES*

FIGURE 1. *Mariopteris eremopteroides* White

A specimen showing the slightly flexuose pinna axis of the crowded ultimate pinnae and pinnules. The pinnules are alternate to subopposite, oval-triangular, narrowly ovate to ovate or rhomboidal. The pinnules show a tendency to lobation. The nervation is coarse, distant, and usually clear. Locality: Brookside Colliery, Southern Anthracite coal field, Pennsylvania, from the lower Lykens coal group of the Pottsville Formation. USNM 40958.

2. *Neuropteris pocahontas* White

A specimen showing the general characteristics of the species. Note the abundance of relatively small crowded pinnules and the long terminals, as well as the many pinnatifid pinnules. The nervation, which is coarse and distinct, is alethopteroid in its general characteristics, as the nerves are crowded, regularly spaced, and very uniform. Locality: Below the Angle mine, West Virginia, at fork of stream from Pocahontas coal group near no. 1 or no. 2 coal. USNM 41213.

ZONE 5. ZONE OF *MARIOPTERIS POTTSVILLEA* AND OF COMMON OCCURRENCE OF *ANEIMITES* SPP.

3. *Aneimites tenuifolius* (Göeppert) White

A part of a sterile segment of the frond showing the slender pinnae and the distant uncrowded pinnules. The pinnules are subpetiolate and obovate to obovate-cuneate, and some are asymmetrical. The nerves originate from a bundle in the subpetiolate base and fork two or three times in passing to the distal margin in a manner similar to that of *Adiantites*. Locality: Shale beneath thick sandstone about 300 feet below Nuttall coal seam, Quinnimont Shale Member of New River Formation, Nuttalburg, W. Va. USNM 40113d.

4. *Aneimites fertilis* White

A specimen showing the small relatively crowded pinnules disposed on several pinnae. Note the slender pinnae axes. The pinnules are narrowly cuneate to spatulate; most are bilobate or multilobate. The nervation is, in general, similar to that of the *Aneimites tenuifolius*. Locality: Below the second sandstone beneath the Raleigh Sandstone Member of the New River Formation (360 feet below Raleigh Sandstone Member), lower railroad cut, Nuttall, W. Va. USNM 40124a.


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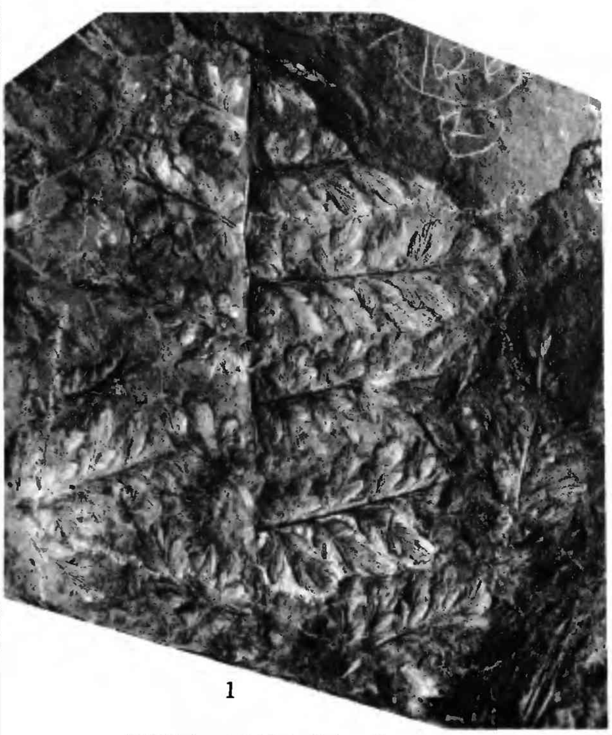
ZONE 5, ZONE OF *MARIOPTERIS POTTSVILLEA*.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ZONE 4, ZONE OF *NEUROPTERIS POCAHONTAS* AND *MARIOPTERIS EREMOPTEROIDES*.

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PLATE 5

[Figures natural size unless otherwise indicated]

ZONE 5. ZONE OF *MARIOPTERIS POTTSVILLEA* AND OF COMMON OCCURRENCE OF *ANEIMITES* SPP.

FIGURE 1. *Mariopteris pottsvillea* White

A specimen showing a part of a polypinnate frond, characterized by distinct and relatively uncrowded pinnae and pinnules. The pinnules are obliquely set on the pinnae axes, are ovate to ovate-pyriform, are asymmetrical, and have broad bases. Locality: Lookout Sandstone, Cole City, Dade County, Ga. USNM 13658.

ZONE 6. ZONE OF *NEUROPTERIS TENNESSEEANA* AND *MARIOPTERIS PYGMAEA*, AND TO SOME EXTENT OF *OVOPTERIS COMMUNIS*, *ALLOIOPTERIS INAEQUILATERALIS*, AND *ALETHOPTERIS DECURRENS*

2, 3. *Mariopteris pygmaea* White

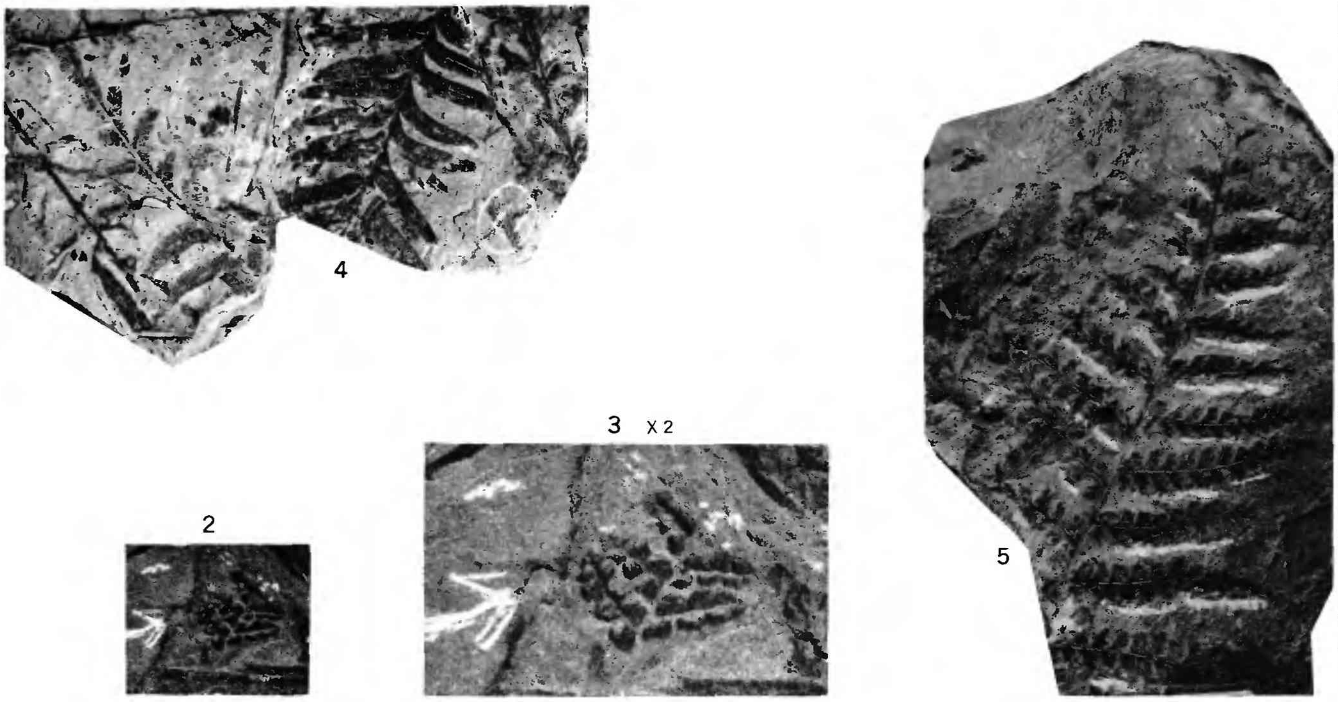
A specimen of this diminutive species showing the small crowded pinnae and pinnules. The pinnules are generally ovate, the laminae appearing to be very thick. The nervation is coarse and generally not very distinct. Locality: Massillon coal near Massillon, Ohio. USNM 41760. Figure 3 × 2.

4. *Alethopteris decurrens* (Artis) Sternberg

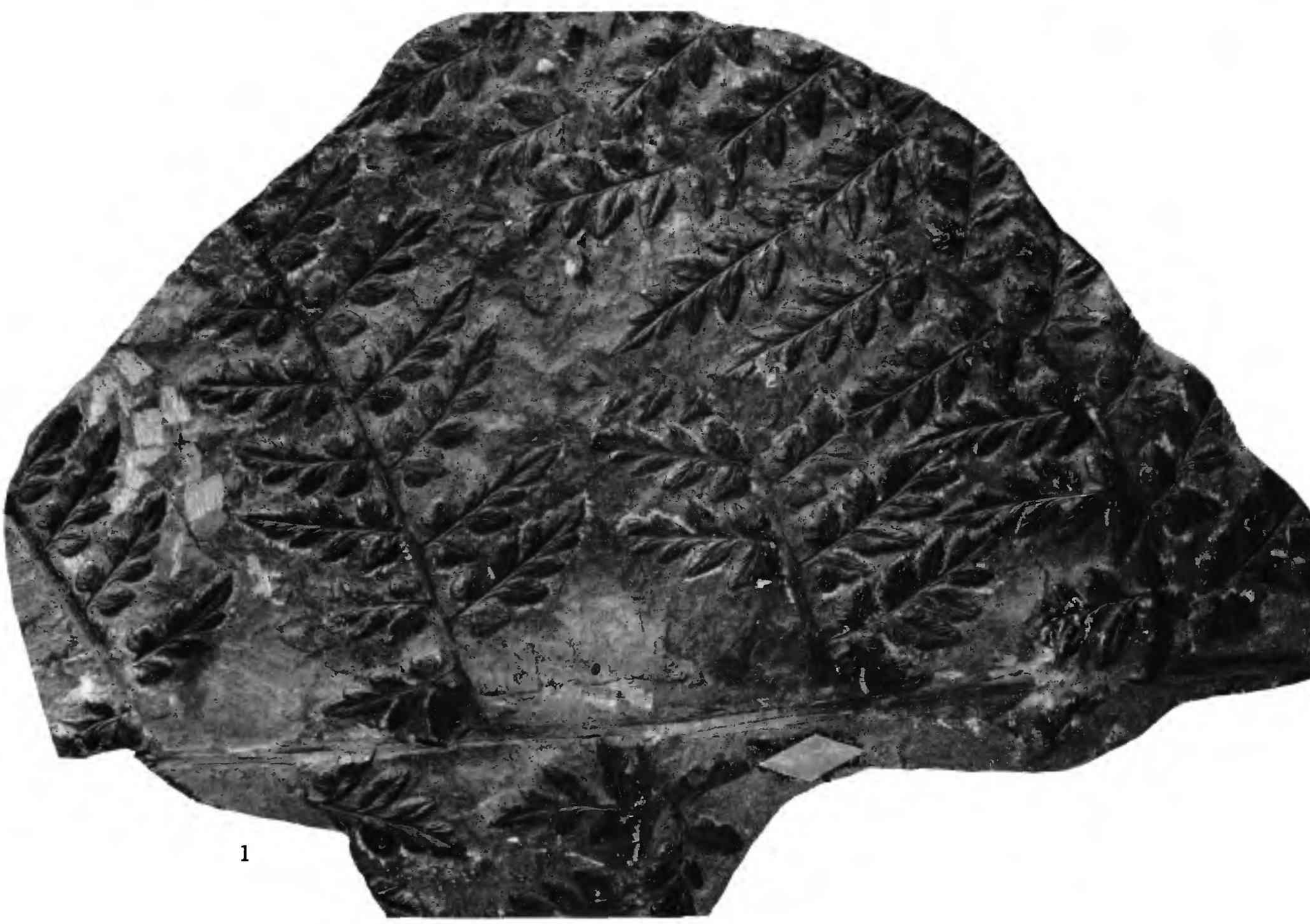
A specimen showing parts of three pinnae. The fronds of this species, as well as most other species of *Alethopteris*, are large and tripinnate to quadripinnate. The pinnae and the pinnules are crowded and may overlap. The pinnules are elongated and narrowly obtuse, seated at nearly right angles on the pinnae, and decurrent in the area of attachment. The nerves are coarse, distinct, and rather open for a member of this genus. Locality: Shale below massive sandstone, a quarter of a mile south of abandoned quarry in the north end of cut of Illinois Central Railroad, about 7½ miles north of Cobden, Carbondale quadrangle, Illinois. USNM 41761.

5. *Alloiopteris inaequilateralis* (Lesquereux), White mss.

A part of a pinna showing the delicate and plumose nature of segments of the frond. The pinnules are commonly alternate, decurrent, close, and some are overlapping; they are broadly deltoid when small and are rhomboidal when larger. They are more or less deeply dissected into two or three lobes, which are all short and bluntly denticulate. The nervation is distinct and of the sphenopteroid type. Locality: Lemon's coal bank, Morrow group, Washington County, Ark. USNM 14223.



ZONE 6, ZONE OF *NEUROPTERIS TENNESSEEANA*



ZONE 5, ZONE OF *MARIOPTERIS POTTSVILLEA*

PLATE 6

[All figures natural size]

ZONE 6. ZONE OF *NEUROPTERIS TENNESSEEANA* AND *MARIOPTERIS PYGMAEA*, AND TO SOME EXTENT OF *OVOPTERIS COMMUNIS*, *ALLOIOPTERIS INAEQUILATERALIS*, AND *ALETHOPTERIS DECURRENS*

FIGURE 1. *Ovopteris communis* (Lesquereux) Potonié

A portion of a large frond showing the crowded, overlapping pinnae. The pinnules vary considerably in size, are alternate and oblique on the rachis, and are ovate to oval when small and elongate and sublobate when large. They are lax in general aspect and have typical sphenopteroid venation. Locality: Morrow Formation, Washington County, Ark. USNM 41218.

2. *Neuropteris tennesseeana* Lesquereux

The specimen designated in Lesquereux's manuscript as the type of the species. This form belongs to the *Neuropteris heterophylla* group and contrasts sharply with the alethopteroid species of *Neuropteris*, which are common in zones 4 and 5. The pinnules are crowded, and some overlap. They vary in form from ovate to oval to narrowly ovate-oblong and are very asymmetrical. The terminals are relatively large and lanceolate-triangular. The venation is less crowded than in most of the alethopteroid species of *Neuropteris*. Locality: Tracy, Tenn. USNM 11790.

3. *Mariopteris pygmaea* White

A specimen showing additional characteristics of this diminutive species, which has been discussed in more detail in the description of plate 5, figs. 2 and 3. Locality: New Lincoln Colliery, 3 miles west of Tremont, Pa., Lykens no. 2(?) coal. USNM 40086.

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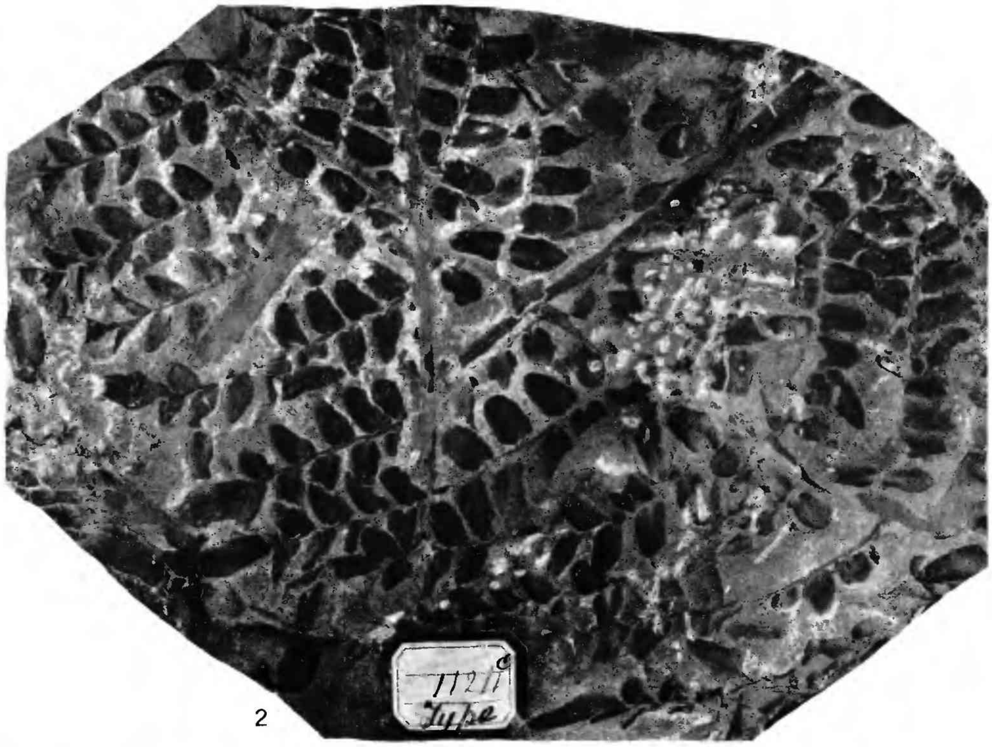

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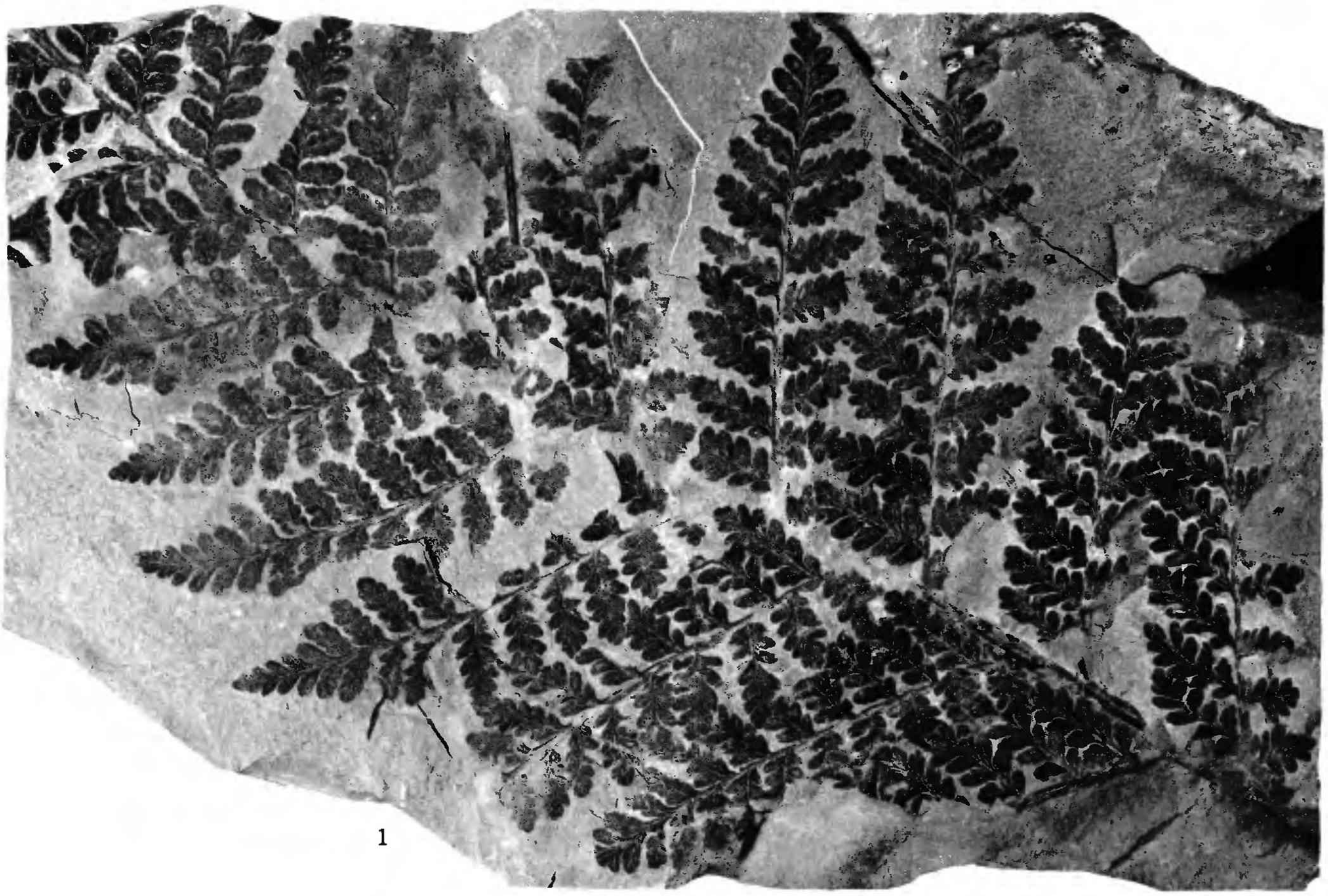

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ZONE 6, ZONE OF *NEUROPTERIS TENNESSEEANA* AND *MARIOPTERIS PYGMAEA*.

PLATE 7

[Figures natural size unless otherwise indicated]

ZONE 6. ZONE OF *NEUROPTERIS TENNESSEEANA* AND *MARIOPTERIS PYGMAEA*, AND TO SOME EXTENT OF *OVOPTERIS COMMUNIS*, *ALLOIOPTERIS INAEQUILATERALIS* AND *ALETHOPTERIS DECURRENS*

FIGURE 1. *Mariopteris pygmaea* White

An enlarged photograph, × 2, of the specimen shown on plate 6, figure 3, showing more distinctly the form of the pinnules. Locality: New Lincoln Colliery, 3 miles west of Tremont, Pa., Lykens no. 2(?) coal. USNM 40086.

ZONE 7. ZONE OF COMMON OCCURRENCE OF *MEGALOPTERIS* SPP.

2. *Cardiocarpon akroni* Read

The type specimen of this species is shown. The large strikingly winged species of *Cardiocarpon*, such as *Cardiocarpon akroni* and *Cardiocarpon phillipsi*, are very common in zone 7. At localities where plants occur in abundance, this group of cardiocarpons also appears to be characteristic of the zone. Locality: Uppermost part of the Sharon Shale Member of Pottsville Formation, near Akron, Ohio. USNM 25382.

3. *Megalopteris southwellii* Lesquereux

The American species of *Megalopteris* are characteristic of zone 7, especially in areas where the pre-Pennsylvanian strata are calcareous. The large generally lanceolate pinnules with the distinct midribs and the regular close venation which is nearly at right angles to the midveins and the margins are similar to those of *Taeniopteris*. The details of the frond architecture are incompletely known, but at least in *Megalopteris southwellii*, the frond was possibly palmate. Locality: A few feet above the base of the Pennsylvanian System at Port Byron, Ill. USNM 41171.

ZONE 8. ZONE OF *NEUROPTERIS TENUIFOLIA*

4. *Neuropteris tenuifolia* (Schlotheim) Sternberg

The general characteristics of two pinnae of this well-known species are shown. Note the relatively large pinnules, which are crowded and set at acute angles on the pinnae axes. The terminals are lanceolate to rhomboidal in outline and are rather large. The venation is more open than in the Early Pennsylvanian alethopteroid species of *Neuropteris*. Locality: Sandy Ridge, Center County, Pa., probably from the Mercer Shale Member, Pottsville Formation. USNM 21219.

4

ZONE 8, ZONE OF *NEUROPTERIS TENUIFOLIA*

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ZONE 6, ZONE OF *NEUROPTERIS TENNESSEEANA* AND *MARIOPTERIS PYGMAEA*

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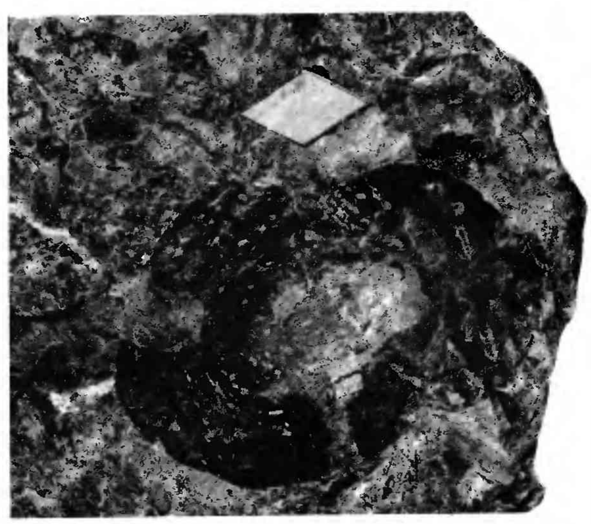

ZONE 7, ZONE OF COMMON OCCURRENCE OF *MEGALOPTERIS* SPP.

PLATE 8

[All figures natural size]

ZONE 9. ZONE OF *NEUROPTERIS RARINERVIS*

FIGURE 1. *Pecopteris vestita* Lesquereux

Parts of several pinnae of *Pecopteris vestita* are shown. The pinnae on the left and upper right show the closely spaced simple pinnule phase of the species; the two in the upper center and lower right show the pinnatifid phase. The pinnules are covered by a moderately dense coating of villi or hairlike processes, which obscure the pecopteroid venation. This species, which is one of the earliest representatives of the genus *Pecopteris,* seems to be fairly important in a general way in separating the younger Pennsylvanian from the older Pennsylvanian strata, although it has only a moderate range in time. Locality: Lower part of the Cherokee shale, Owen's mine, Henry County, Mo. USNM 5745.

2. *Mariopteris occidentalis* White

The rigid aspect of a pinna is shown. The pinnules are simple in outline as compared with the older Pennsylvanian species of *Mariopteris;* except for the inferior basal pinnule on each pinna, they rarely show location. In life, the pinnules may have been thick, inasmuch as the venation is generally obscure. In the right center part of the photograph are two fragmentary specimens of *Sphenophyllum emarginatum* (Brongniart) Koenig, and immediately adjacent is a well preserved specimen of *Lepidophyllum lanceolatum* Lindley and Hutton. Locality: Lower part of the Boggy Formation, on the south flank of Burning Springs dome in tributary to Gaines Creek on the McAlester-Blocker road, about 750 yards northeast of the Gaines Creek bridge, McAlester quadrangle, Oklahoma. USNM 41220.

3. *Neuropteris rarinervis* Bunbury

A compound pinna of the species is shown. Although similar in many respects to *Neuropteris tenuifolia* and *Neuropteris flexuosa,* this species is distinct and is readily recognized by the relatively widely spaced veins, examples of which may be seen in the upper part of the photograph. Locality: Cherokee shale, Penitentiary shaft, Lansing, Kans. USNM 10873.

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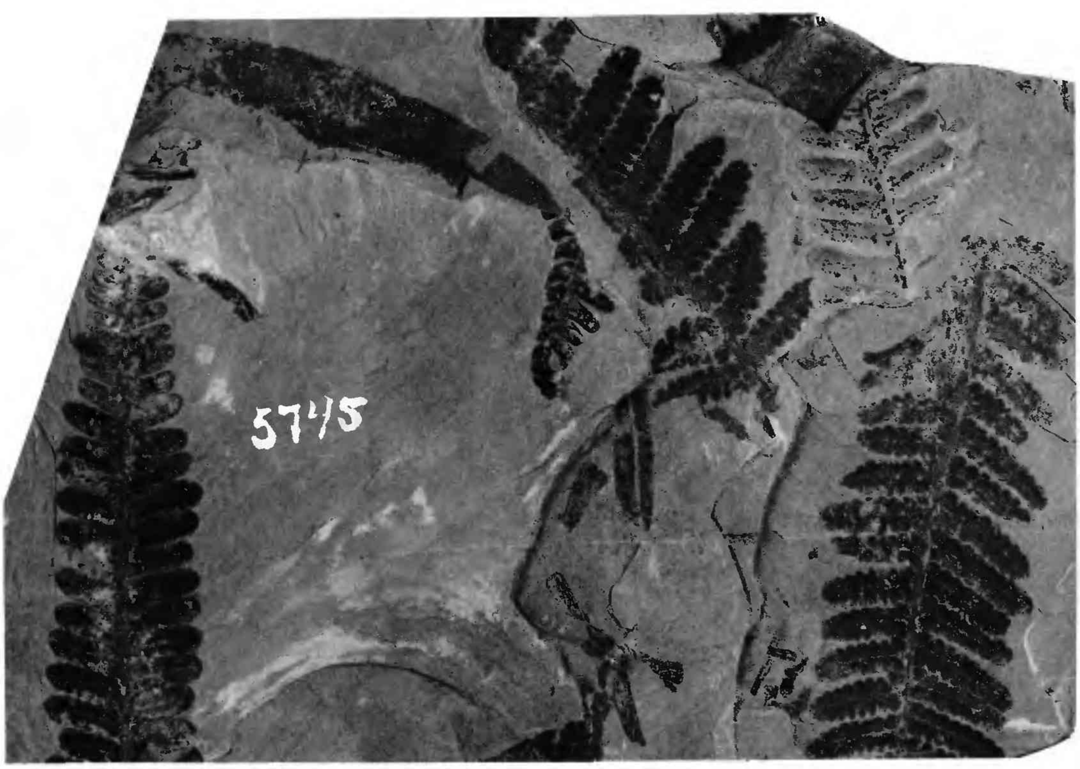

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ZONE 9, ZONE OF *NEUROPTERIS RARINERVIS*

PLATE 9

[All figures natural size]

ZONE 10. ZONE OF *NEUROPTERIS FLEXUOSA* AND APPEARANCE OF ABUNDANT *PECOPTERIS* SPP.

FIGURE 1. *Pecopteris arborescens* (Schlotheim) Brongniart

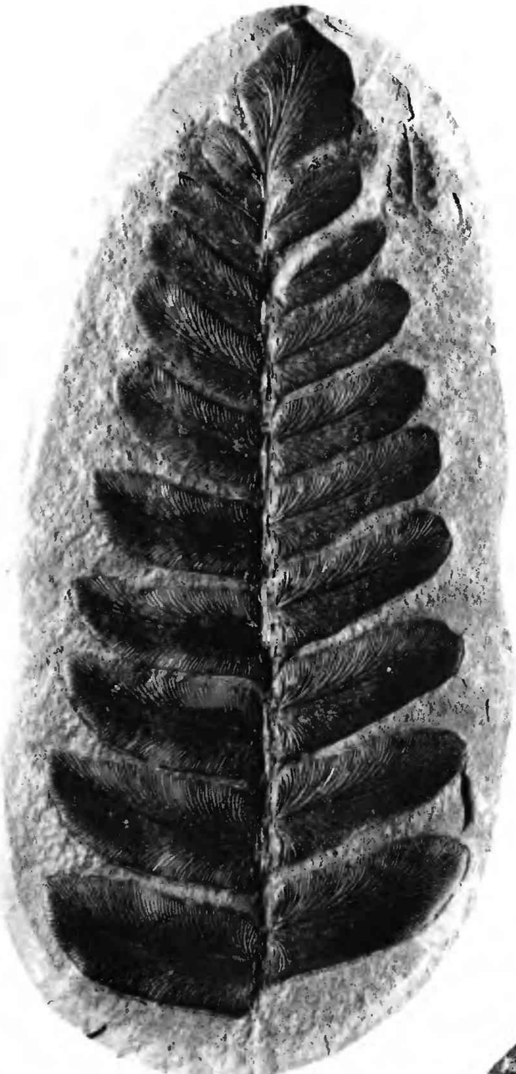
A part of a pinnatifid pinna showing the distant ultimate pinnae and the crowded pinnules, which are small, narrow, and characterized by a venation in which the laterals from the midvein fork only once or twice as they approach the margins. This species is one of a group that is sometimes referred to as the cyatheaoid species of *Pecopteris* because of the similarity of the pinnules to those of the modern fern genus *Cyathea*. Although the species is found sporadically in zone 9, it and other related species of *Pecopteris* become abundant in zone 10 and the succeeding zones. These forms, in fact, range as high as the middle Permian. Locality: Rocks of middle Allegheny age near Olymphant, Pa. USNM 12637.

2. *Neuropteris ovata* Hoffmann

A specimen showing parts of two pinnae and several isolated pinnules. This species is characterized by crowded auriculate pinnules that are modified rhombs in outline. The crowded venation is also characteristic. The species in one or the other of its variations is present in strata as low as zone 8 and extends at least as high as zone 12. However, it first becomes a common element in zone 9 and abundant in zone 10 and the succeeding zones. The early variations of this species are usually small. In the later zones, however, the pinnules become very large. Locality: Cherokee shale, Coon Creek mine, Henry County, Mo. USNM 8901.

3. *Neuropteris flexuosa* Sternberg

Specimen of a pinna showing the moderately crowded to overlapping pinnules. The pinnule form in this species is slightly to distinctly falcate. In comparison with *Neuropteris tenuifolia* and *Neuropteris rarinervis*, the venation is also crowded. As typically formed in the United States, the average of pinnules in *N. flexuosa* is larger than in the two previously mentioned forms, but the terminal is relatively smaller. Locality: Mazon Creek, Will County, Ill. USNM 40311.



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ZONE 10, ZONE OF *NEUROPTERIS FLEXUOSA* AND APPEARANCE OF ABUNDANT *PECOPTERIS* SPP.

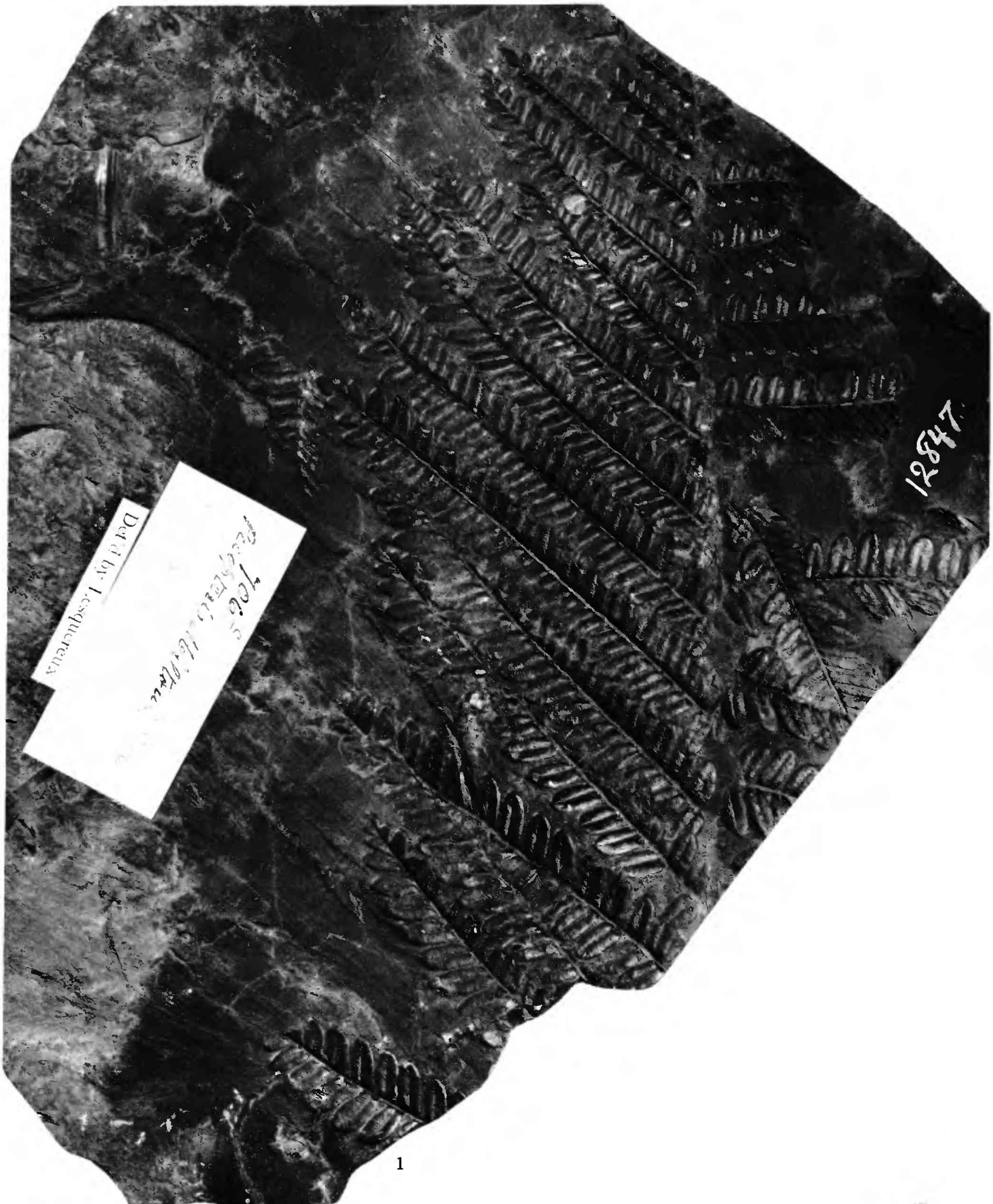
PLATE 10

[Figure natural size]

ZONE 10. ZONE OF *NEUROPTERIS FLEXUOSA* AND APPEARANCE OF ABUNDANT *PECOPTERIS* SPP.

FIGURE 1. *Pecopteris miltoni* Brongniart

A large slab of shale showing a part of the frond representing a group of the genus *Pecopteris* that is characteristic of the Upper Pennsylvanian and that is abundant in zone 10. As contrasted with *Pecopteris arborescens*, the pinnules are distinctly larger; the tips are acutely rather than bluntly rounded; and the pecopteroid venation is more crowded. Although the relationship is not demonstrated conclusively, this species may be related to *Pecopteris vestita* rather than to the cyatheaoid species of *Pecoteris*. Locality: Middle or upper part of the Allegheny Formation, Shamokin, Pa. USNM 12847.



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ZONE 10, ZONE OF *NEUROPTERIS FLEXUOSA* AND APPEARANCE OF ABUNDANT *PECOPTERIS* SPP.

PLATE 11

[All figures natural size]

ZONE 11. ZONE OF *LESCUROPTERIS* SPP.

FIGURES 1, 2. *Lescuropteris moorii* Lesquereux

Two specimens illustrating the characteristics of the genus and species. The fronds are at least bipinnate, as indicated in figure 2. The pinnae are closely spaced and often either touch or overlap. Rachial pinnules are present between pinnae. The pinnules are odontopteroid in their general appearance, are broadly attached and are distinctly falcate or sickle shaped. The venation is odontopteroid. At the present time this genus is known to be represented in North America by two species, *Lescuropteris moorii* and *Lescuropteris adiantites,* according to the literature, although it is possible that the forms may be conspecific. The genus has been reported from strata of probable Conemaugh age in the Southern Anthracite coal field and from several localities in the Conemaugh and lowest part of the Monongahela Formation in western Pennsylvania and adjacent parts of the Allegheny Plateau. It is also found in the Elmdale shale of former usage in Kansas. Locality: Elmdale Shale near Onaga, Kans. USNM 41762 and USNM 41763.

ZONE 12. ZONE OF *DANAEITES* SPP.

3. *Danaeites emersoni* Lesquereux

The type specimen is shown. The frond is at least bipinnate and in the type specimen consists of a well-defined lower segment that is fertile; the area above is sterile. The pinnae are closely spaced and many overlap. The fertile pinnules are large and *Alethopteris-* or *Callipteridium*-like in form; they are characterized by elongate soruslike bodies that are superimposed on the pinnules from midvein to margin and mask the venation. Available information does not clearly show, however, whether the genus is a true fern or a seedfern. The distal sterile segment of the frond is characterized by smaller or more reduced pinnules that are alethopteroid in form and venation. The genus is known in the United States from many localities in western Pennsylvania and adjacent States where it occurs in the Monongahela Formation. Present information indicates that it ranges as low as the shale beds a short distance above the Pittsburgh coal and as high as the youngest coal in the Monongahela in the Georges Creek coal basin, Maryland, where it occurs about 100 feet below the provisional base of the Dunkard Group. Locality: From shale a short distance above a coal, probably correlative with the Pittsburgh bed, in the vicinity of St. Clairsville, Ohio. USNM 12710.

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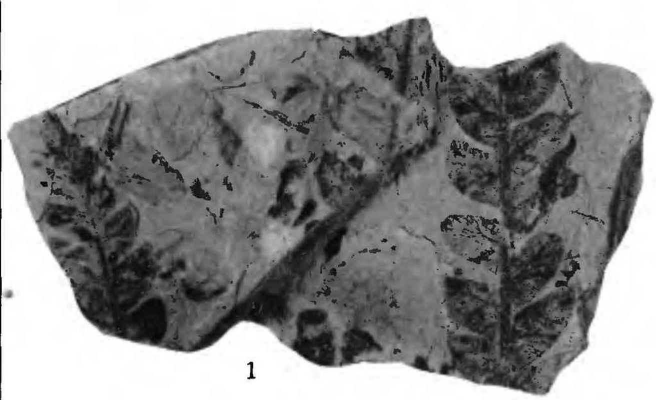
ZONE 12, ZONE OF *DANAEITES* SPP.



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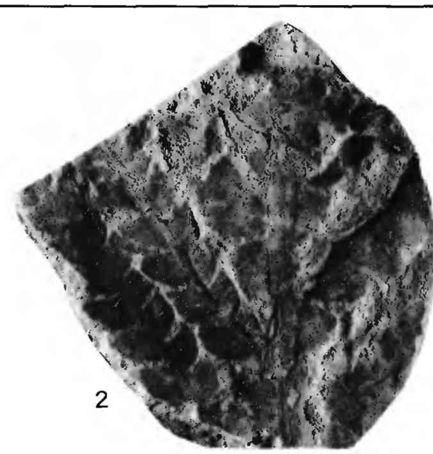

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ZONE 11, ZONE OF *LESCUROPTERIS* SPP.

PLATE 12

[All figures natural size]

ZONE 12. ZONE OF *DANAEITES* SPP.

FIGURE 1. *Danaeites emersoni* Lesquereux

A specimen similar to that photographed for plate 11, figure 3, showing parts of fertile pinnae on the right and sterile pinnae on the left. Locality: Strip pit 0.9 mile south of Lonaconing, Md., within 100 feet above the upper limit of the Monongahela Formation. USNM 41764.

ZONES 11 AND 12 (LOCALLY COMBINED). ZONE OF *ODONTOPTERIS* SPP.

2. *Odontopteris reichiana* Gutbier

A small pinna showing the rounded triangular form of the pinnules, which are acutely set and broadly attached to the pinna axis. The venation is open and neuropteroid. Species of *Odontopteris* are abundant in zones 11 and 12 in the Appalachian region but are rarely found in older strata. In the western midcontinent region and the Rocky Mountain region, zones 11 and 12 can not be well differentiated at the present time, owing to the sporadic occurrence of genera and species that characterize these zones in areas further east. However, the composite zone can be recognized by the abundance of several species of *Odontopteris*. Locality: Strata, probably equivalents of the Conemaugh Formation, in the eastern middle anthracite field near Hazelton, Pa. USNM 11267.

3. *Odontopteris pachyderma* Fontaine and White

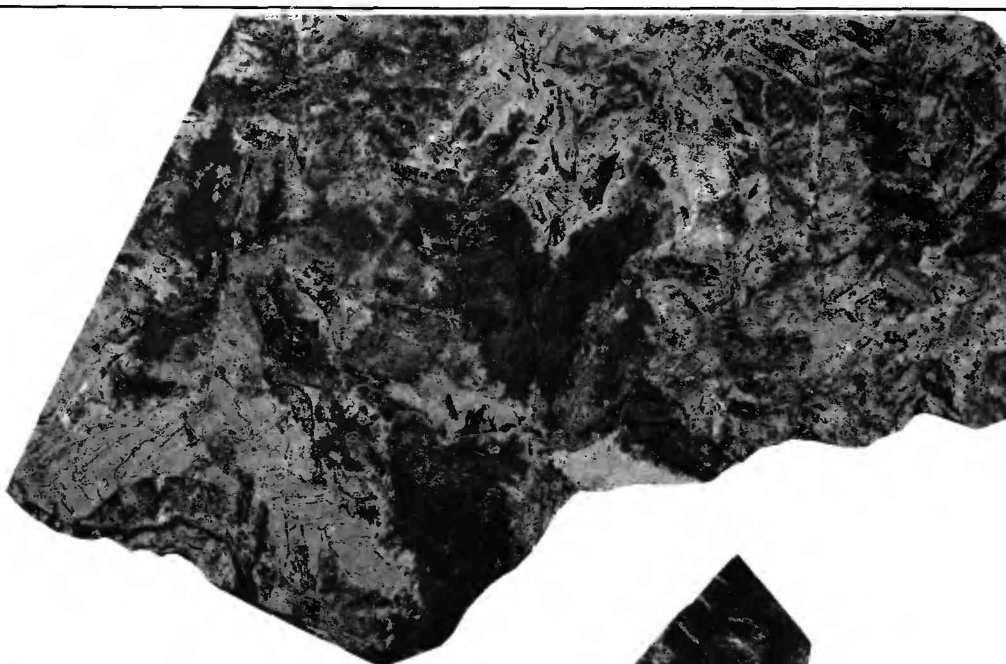
A pinna with crowded pinnules is shown. The pinnules are slightly falcate and some are rhomb shaped. The bases are broadly attached, but the pinnules are set less acutely on the pinna axis of this species than on that of *Odontopteris reichiana*. Locality: Dents Run, W. Va. Shale above Waynesburg coal, Cassville, Monongalia County, W. Va. USNM 2062a.

4. *Mariopteris cordata-ovata* (Lesquereux) White

Parts of several pinnae set on an axis of a higher order are shown. The pinnae are distant, and the angles at the points of attachment are variable. The pinnules are set on the pinnae axes at open angles; they are unlobed except for the inferior basal pinnule on each pinna, which is generally either bilobate or trilobate. The margins are entire, and the venation, except for the coarse midvein, is obscure. The species, which is similar to *Mariopteris occidentalis* White appears initially in zone 10 but extends into zone 11 in the Appalachian region and into zones 11 and 12 combined in the midcontinent region. It is one of the youngest species of the genus. Locality: Strata, probably equivalents of the Conemaugh Formation, in the eastern middle anthracite field near Hazelton, Pa. USNM 41765.

5. *Neuropteris lindahli* White

A specimen littered with abundant pinna fragments and isolated pinnules is shown. On the basis of form of the sterile material, this species appears to be a late member of the alethopteroid group of *Neuropteris*. The pinnules are small, narrowly triangular, and falcate in form. They have cordate bases; the lateral nerves are coarse, close, and curve to form right angles at the pinna margins. This species is common in strata of Late Pennsylvanian age in the western midcontinent region and is known from several localities in the southern part of the Rocky Mountains. Locality: the Bethany Falls Limestone Member of the Swope Limestone, near Kansas City, Mo. USNM 11622.



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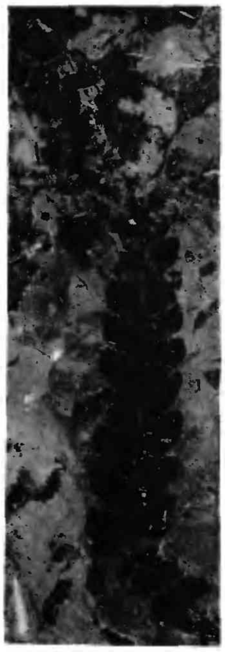

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ZONES 11 AND 12 (LOCALLY COMBINED). ZONE OF *ODONTOPTERIS* SPP.

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ZONE 12, ZONE OF *DANAEITES* SPP.

PLATE 13

[All figures natural size]

ZONE 13. ZONE OF *CALLIPTERIS* SPP.

FIGURE 1. ?*Dichophyllum* sp.

A specimen showing part of a pinna with several finely divided decurrent pinnules. This plant is poorly understood, but is probably related to *Callipteris*. Locality: Lower part of the Abo Formation, the Spanish Queen mine, about 6 miles southwest of Jemez Springs, N. Mex., on the southeast side of the canyon. USNM 41221.

2. *Walchia piniformis* (Schlotheim) Sternberg

A specimen showing a part of a branch on which are borne many smaller branches. The branches are sheathed with the small, falcate, needlelike leaves that are characteristic of the form. Although the genus and species make their first appearances in the Upper Pennsylvanian of the western part of the United States, the genus is most characteristic of the Lower and middle Permian. Locality: Lower part of the Abo Formation, the Spanish Queen mine, about 6 miles southwest of Jemez Springs, N. Mex., on the southeast side of the canyon. USNM 41222.

3. *Gomphostrobus bifidus* Geinitz

Part of a twig bearing the characteristic needlelike leaves, which fork just below the tips. Locality: Lower part of the Abo Formation, the Spanish Queen mine, about 6 miles southwest of Jemez Springs, N. Mex., on the southeast side of the canyon. USNM 41223.

4. *Callipteris lyratifolia* Zeiller

Part of a pinna bearing several highly divided pinnules is shown. This genus and species make their first appearance in the Lower Permian but are found in higher strata. Locality: 1 mile south of Coyote Post Office, Rio Arriba County, N. Mex. USNM 41225.

5. *Callipteris conferta* (Sternberg) Brongniart

Several pinnae with many attached pinnules are shown. The pinnules are decurrent and broadly attached; the venation is distinct. Rachial pinnules are present between pinnae. The venation develops from several bundles at the base of the pinnules; the bundles fork several times as they pass toward the margins. Like *Callipteris lyratifolia* Zeiller, *Callipteris conferta* makes its first appearance in the United States in the Lower Permian but ranges upward into younger Permian strata. Locality: Lower part of the Abo Formation, about 6 miles southwest of Jemez Springs, N. Mex., on the southeast side of the canyon. USNM 41223.

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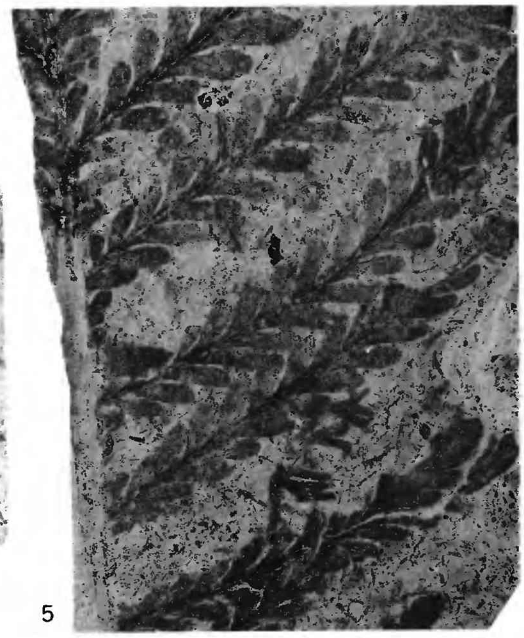

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ZONE 13, ZONE OF *CALLIPTERIS* SPP.

PLATE 14

[All figures natural size]

ZONE 14. ZONE OF THE OLDER *GIGANTOPTERIS* FLORA IN PARTS OF TEXAS, OKLAHOMA, AND NEW MEXICO, EQUIVALENT ZONE OF *GLENOPTERIS* SPP. IN KANSAS, AND EQUIVALENT ZONE OF THE *SUPAIA* FLORA IN NEW MEXICO AND ARIZONA—THE *SUPAIA* FLORA

FIGURE 1. *Supaia sturdevantii* White

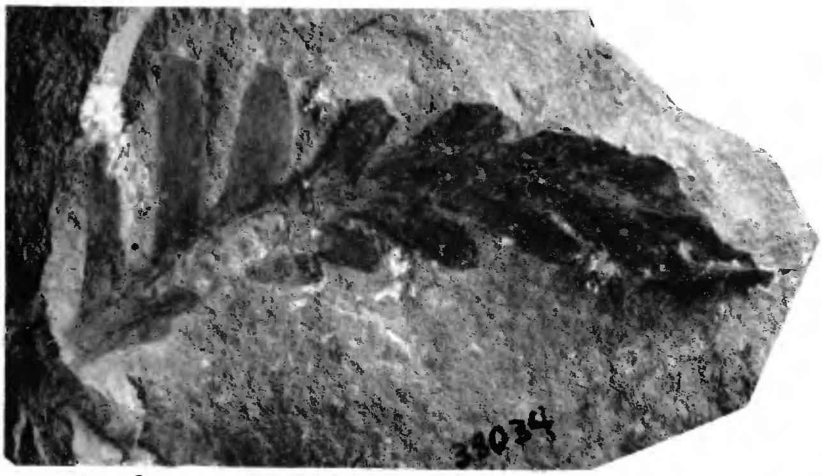
A specimen showing the forked or dichotomous rachis characteristic of the genus. Pinnules are large, are set obliquely to the rachis, overlap, and are alethopteroid in form. Very little is known of the venation, but it also appears to be alethopteroid. The genus *Supaia* with its several species is known only in Arizona and parts of central and western New Mexico, where it occurs in the Hermit Shale and the upper part of the Abo Formation. The genus and its associates appear to be characteristic of strata that are lower or possible middle Leonard in age. Locality: Lower part of Hermit Shale, Bright Angel trail below El Tovar, Grand Canyon National Park, Ariz. USNM 38040.

2. *Supaia compacta* White

A specimen, probably the apical portion of one of the major divisions of the frond, is shown. Note the strongly alethopteroid form of the first two well-preserved pinnules on the left side of the specimen. The venation, although not clearly shown in the illustration, is characterized by a strong midrib, which extends almost to the apex of the pinnule. The terminal of the pinna, although imperfectly preserved, appears to have been rather large. Locality: Hermit Shale, Hermit Basin, 7.5 miles west of Grand Canyon Station, Grand Canyon National Park, Ariz. USNM 38034.

3. *Brachyphyllum tenue* White

Several branching twigs are shown. Although not visible in the photograph, the small branches are sheathed with scalelike leaves similar in gross aspect to some of the modern scale-leaved conifers such as *Juniperus* Linne. Locality: Lower part of Hermit Shale in Hermit Basin, 7.5 miles west of Grand Canyon Station, Grand Canyon National Park, Ariz. USNM 38061.



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ZONE 14, THE *SUPAIA* FLORA.

PLATE 15

[All figures natural size]

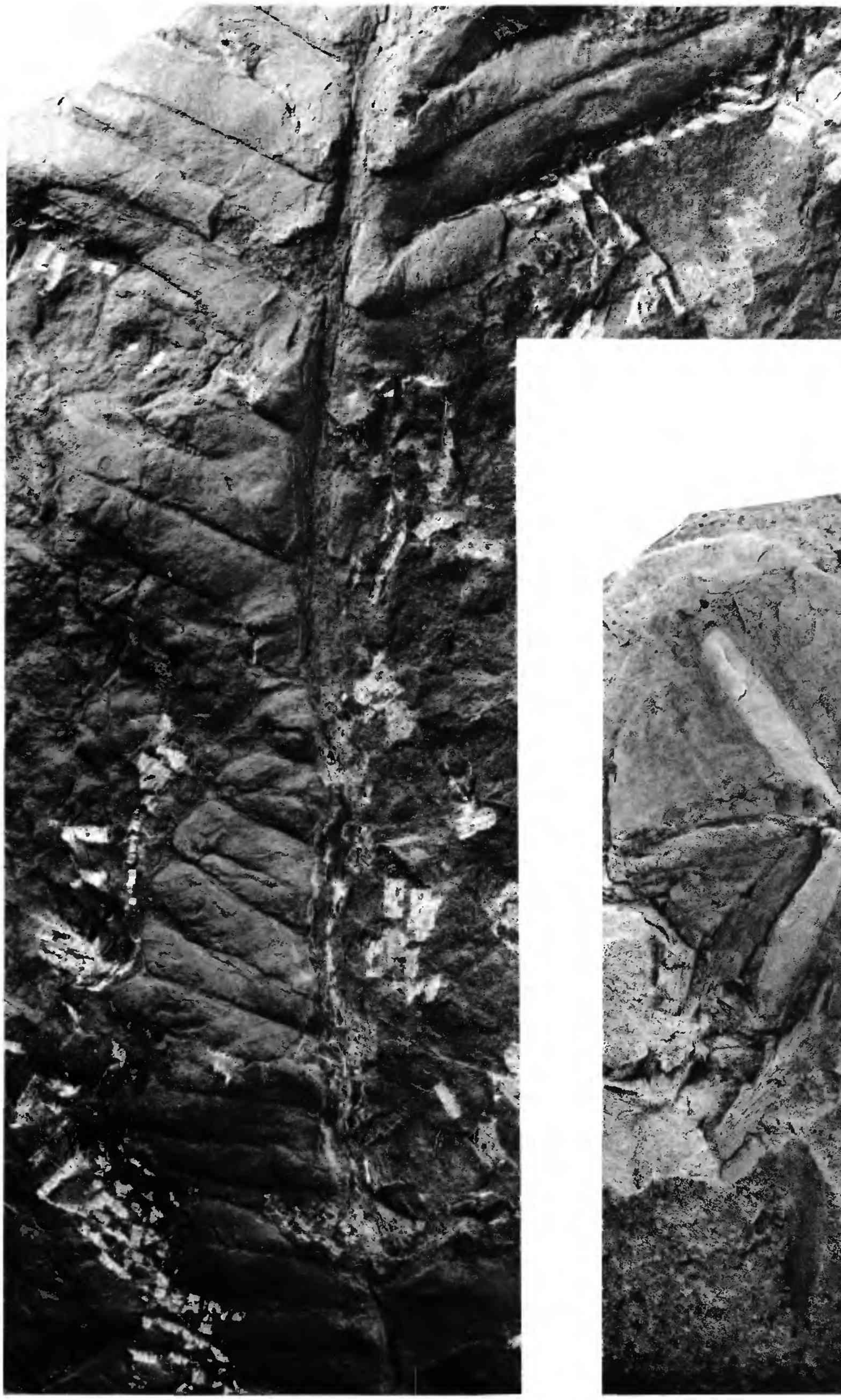
ZONE 14. ZONE OF THE OLDER *GIGANTOPTERIS* FLORA IN PARTS OF TEXAS, OKLAHOMA, AND NEW MEXICO, EQUIVALENT ZONE OF *GLENOPTERIS* SPP. IN KANSAS, AND EQUIVALENT ZONE OF THE *SUPAIA* FLORA IN NEW MEXICO AND ARIZONA—THE *SUPAIA* FLORA

FIGURE 1. *Supaia merriami* White

An illustration of the type specimen showing the large closely spaced alethopteroid pinnules. Note the distinct midvein and the auriculate bases of the pinnules. This is the largest representative of the genus *Supaia* known at the present time. Locality: Lower part of Hermit Shale in Hermit Basin, 7.5 miles west of Grand Canyon Station, Grand Canyon National Park, Ariz. USNM 38033.

2. *Sphenophyllum gilmorei* White

An illustration of a complete whorl of leaves is shown. Note the narrow, elongate form of the leaves; this form contrasts with most of the Late Pennsylvanian and Early Permian representatives of the genus, which are smaller and generally broadly triangular in form. Below the prominent whorl is another only partly exposed. Locality: Near "Red Top," Hermit Basin, at the site of a U.S. National Museum vertebrate-footprint collecting locality, Grand Canyon National Park, Ariz. USNM 38025.



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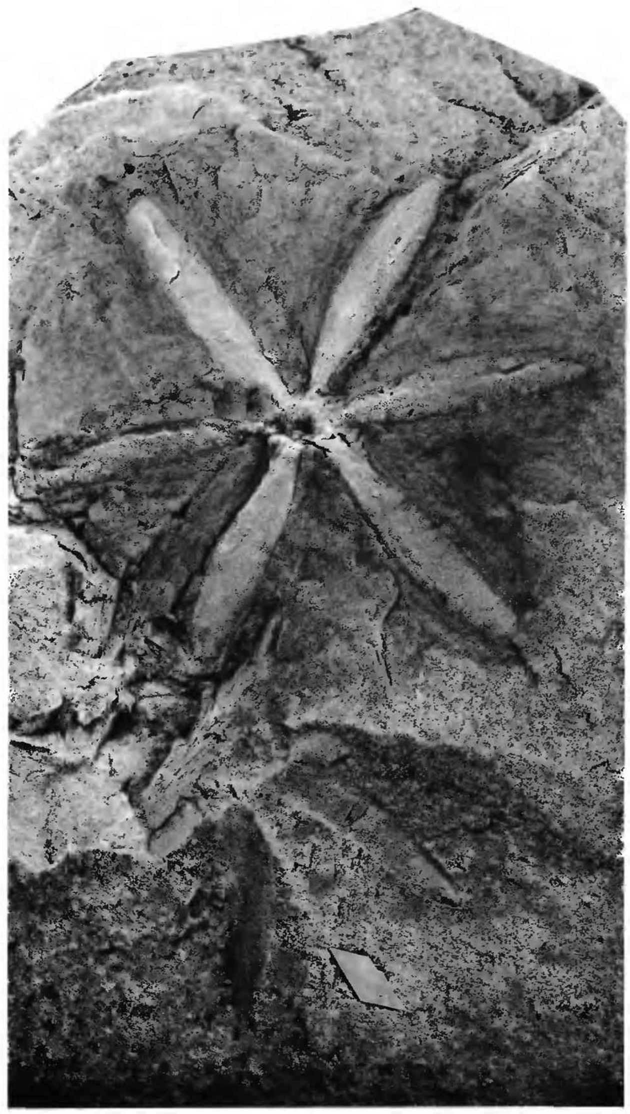

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ZONE 14, THE *SUPAIA* FLORA.

PLATE 16

[All figures natural size]

ZONE 14. ZONE OF THE OLDER *GIGANTOPTERIS* FLORA IN PARTS OF TEXAS, OKLAHOMA, AND NEW MEXICO, EQUIVALENT ZONE OF *GLENOPTERIS* SPP. IN KANSAS, AND EQUIVALENT ZONE OF THE *SUPAIA* FLORA IN NEW MEXICO AND ARIZONA—THE *GLENOPTERIS* FLORA

FIGURE 1. *Taeniopteris newberryana* Fontaine and White

Part of one of the straplike fronds which shows the broad midrib and the closely spaced lateral veins. The laterals depart from the midvein at acute angles but rapidly curve so that they are nearly at right angles both to the midrib and the margin in most of their course. *Taeniopteris newberryana* is a representative of a genus that appears in zone 13 but which reaches its peak of abundance in the United States in zone 14. It is one of the few genera common to the three provincial floras of zone 14. Locality: Wellington Formation, approximately 3 miles south of Banner City, Kans. USNM 8087.

2. *Glenopteris simplex* Sellards

Part of a small pinnate frond is shown. The principal characteristics of this species are its small size and relatively narrow pinnules as compared with the other species such as *Glenopteris splendens* Sellards, illustrated in figures 3 and 4 of this plate. The genus *Glenopteris* resembles in many respects the genus *Supaia*; however, the frond architecture is different. All specimens known and assigned to *Glenopteris* are simply pinnate, without any divisions of the rachis. In *Supaia*, the rachis is divided into two equal forks as shown in figure 1, plate 14. *Glenopteris* is known only from central Kansas, where it cocurs in strata that contain abundant evaporites. Locality: Wellington Formation, near Banner City, Kans. USNM 41766.

3, 4. *Glenopteris splendens* Sellards

The largest known species of *Glenopteris* is shown. Figure 3 illustrates the aspect of the lower and medial parts of a frond, and figure 4 shows the apical region. Note the relatively broad pinnules, as compared to *Glenopteris simplex* Sellards, and the decurrent bases. The apex of the frond is triangular in form and slightly lobate in the lower part. The texture in life was probably very thick, possibly coriaceous. Locality: Wellington Formation, 3 miles south of Banner City, Kans. (fig. 3); 3½ miles southeast of Elmo, Kans. (fig. 4). Figure 3, USNM 8074; figure 4, USNM 41767.

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ZONE 14, THE *GLENOPTERIS* FLORA.

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PLATE 17

[Figures natural size unless otherwise indicated]

ZONE 14. ZONE OF THE OLDER *GIGANTOPTERIS* FLORA IN PARTS OF TEXAS, OKLAHOMA, AND NEW MEXICO, EQUIVALENT ZONE OF *GLENOPTERIS* SPP. IN KANSAS, AND EQUIVALENT ZONE OF THE *SUPAIA* FLORA IN NEW MEXICO AND ARIZONA—THE *GIGANTOPTERIS* FLORA

FIGURE 1. *Gigantopteris americana* White

The base of a frond is shown. Note the equal forking of the frond, a characteristic of this species. Associated with the principal specimen are parts of pinnae of species of *Pecopteris*, some of which are fertile. Locality: Belle Plains Formation, Emily Irish grant, Baylor County, Tex. USNM 41768.

2. *Callipteris* sp., cf. *C. flabellifera* (Weiss) Zeiller

Part of a frond with several pinnae is shown. Note the highly divided nature of the pinnules. Locality: Belle Plains Formation, Emily Irish grant, Baylor County, Tex. USNM 41769.

3, 4. *Odontopteris* cf. *O. fischeri* Brongniart

Two specimens showing fragments of a large species of *Odontopteris*, which is with some reservations assigned to *O. fischeri* Brongniart. Note the large lax pinnules. Locality: Belle Plains Formation, Castle Hollow, near Fulda, Baylor County, Tex. Figure 3, × ½, USNM 41770; figure 4, × ½, USNM 41846.

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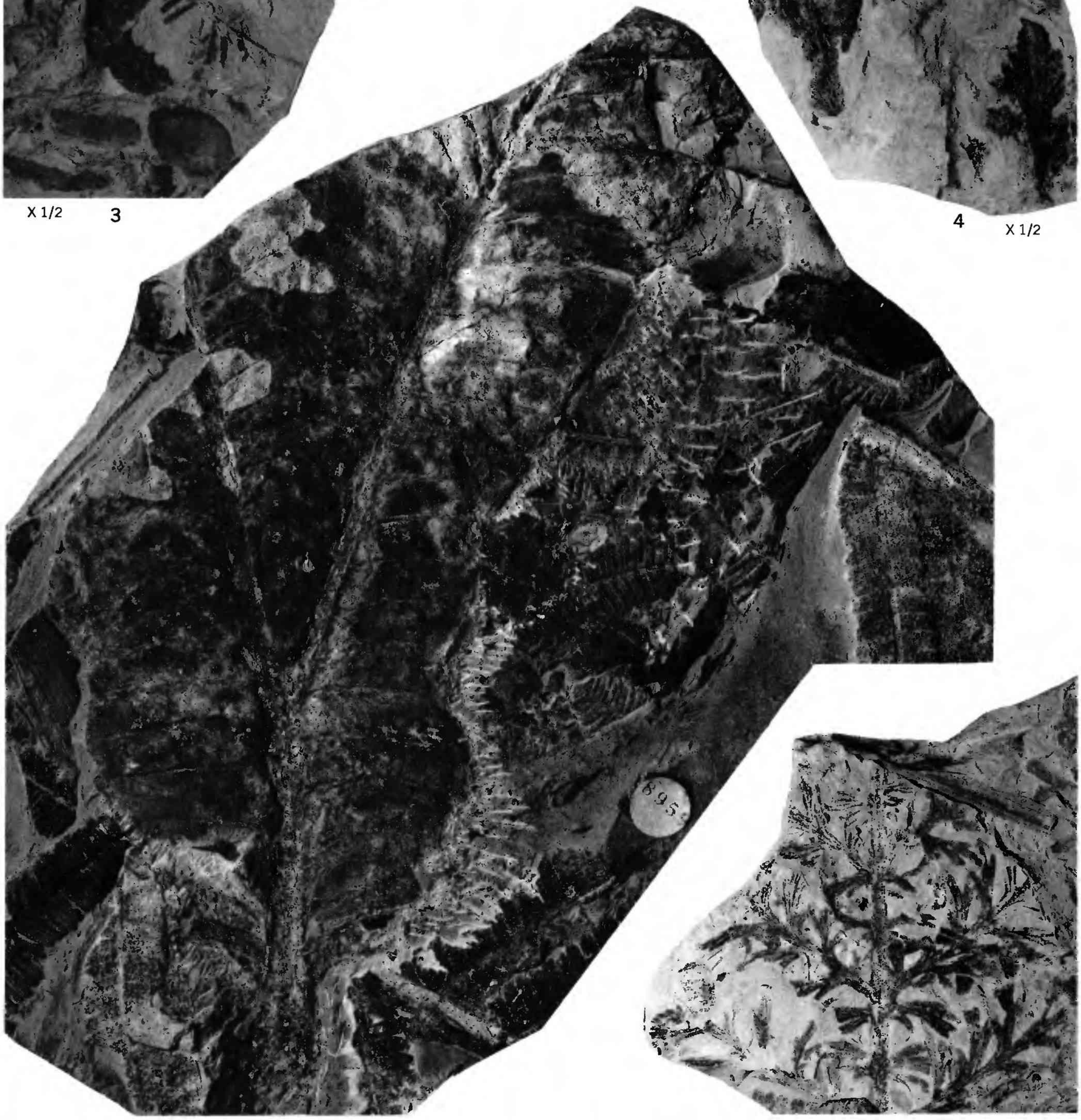
4 X 1/2



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ZONE 14, THE *GIGANTOPTERIS* FLORA.

PLATE 18

[All figures natural size]

ZONE 14. ZONE OF THE OLDER *GIGANTOPTERIS* FLORA IN PARTS OF TEXAS, OKLAHOMA, AND NEW MEXICO, EQUIVALENT ZONE OF *GLENOPTERIS* SPP. IN KANSAS, AND EQUIVALENT ZONE OF THE *SUPAIA* FLORA IN NEW MEXICO AND ARIZONA—THE *GIGANTOPTERIS* FLORA

FIGURE 1. *Gigantopteris americana* White

The apex of one lobe of a frond is shown. Note the characteristic anastomosing venation of the subdivisions of the simple frond. These subdivisions, although suggesting pinnules, are not lobed or otherwise divided. Locality: Lower part of the Clyde Formation, near Fulda, Tex. USNM 41771.

2. ?*Compsopteris* sp.

Part of a pinna is shown, on which are borne large decurrent alethopteroidlike pinnules. Locality: Belle Plains Formation, Godwins Creek, Baylor County, Tex. USNM 41772.

3. ?*Tingia* sp.

Part of a frond bearing crowded pinnae characterized by parallel venation is shown. The specimen was originally assigned to the genus *Tingia*, but because of some details of the fronds, it appears that the generic assignment must be questioned. Locality: Belle Plains Formation, Emily Irish grant, Baylor County, Tex. USNM 41773.

4. *Lobatannularia* sp.

Two whorls of leaves of this equisetaceous genus previously known only from eastern Asia are shown. Note the bilateral symmetry of the leaf whorls, which is one of the principal generic characteristics. Locality. Belle Plains Formation, Emily Irish grant, Baylor County, Tex. USNM 41774.

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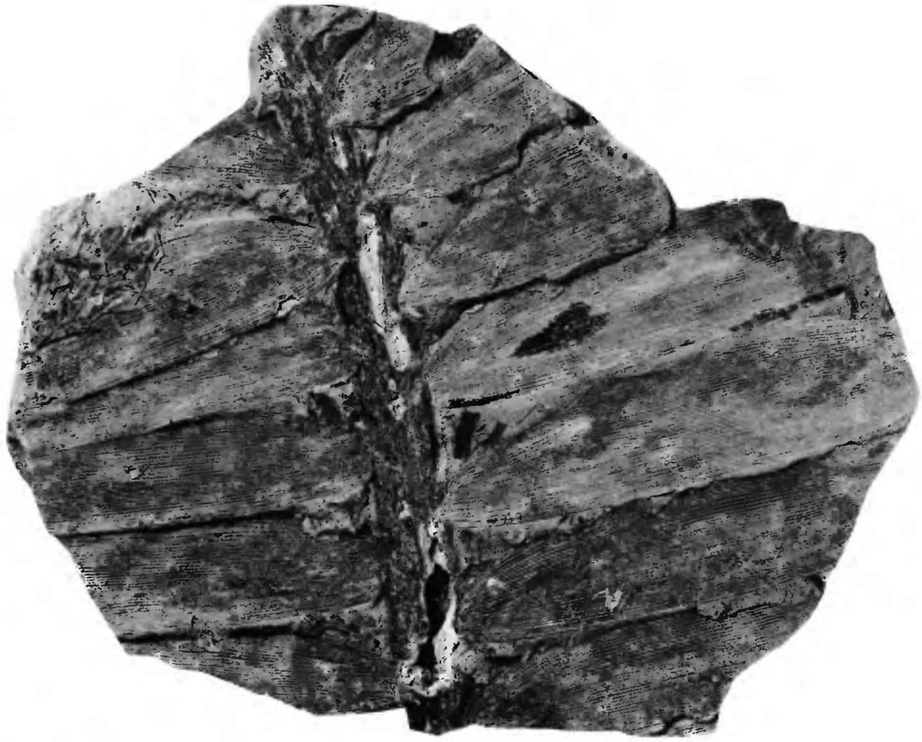

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ZONE 14, THE *GIGANTOPTERIS* FLORA.

PLATE 19

[All figures natural size]

ZONE 15. ZONE OF THE YOUNGER *GIGANTOPTERIS* FLORA

FIGURE 1. *Gigantopteris* n. sp. A.

A fragment of the terminal part of a frond showing four distinct orders of venation. Locality: Medial part of the Lueders Limestone, Lake Kemp spillway, Baylor County, Tex. USNM 41775.

2. *Gigantopteris* n. sp. B.

A dichotomously forked frond is shown. Note that there are only three orders of venation. Locality: Lower part of Vale Formation, south of Lawn, Taylor County, Tex. USNM 41776.

3, 4. ?*Brongniartites* sp.

Two specimens are shown, figure 3 showing the apical part and figure 4, the basal part of the somewhat lobate pinnules. Locality: Lower part of Vale Formation, 2 miles east of Abilene, Taylor County, Tex. (figure 3); south of Lawn, Taylor County, Tex. (figure 4). Figure 3, USNM 41777; figure 4, USNM 41848.

5, 6. *Callipteris* cf. *C. adzvensis* Zallesky.

Two specimens showing fragments of pinnae-bearing callipteroid pinnules. Locality: Lower part of Vale Formation, 2 miles east of Abilene, Tex. Figure 5, USNM 41778; figure 6, USNM 41847.

7. ?*Compsopteris* sp.

A subapical fragment showing the broadly attached decurrent pinnules, the distinct midvein, and the acute lateral veins. Locality: Lower part of the Vale Formation, south of Lawn, Taylor County, Tex. USNM 41779.

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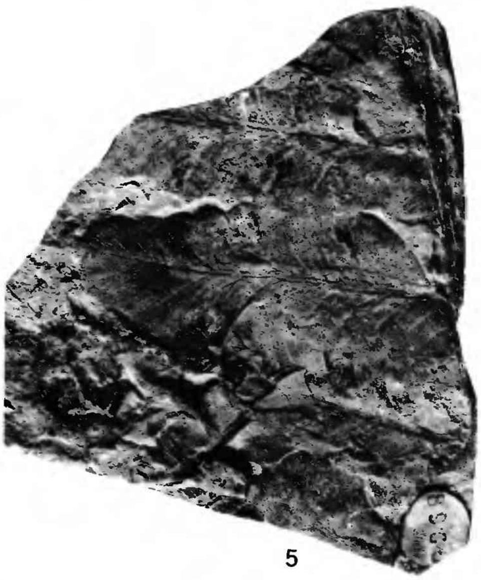

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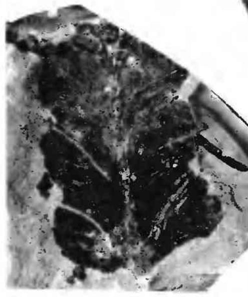

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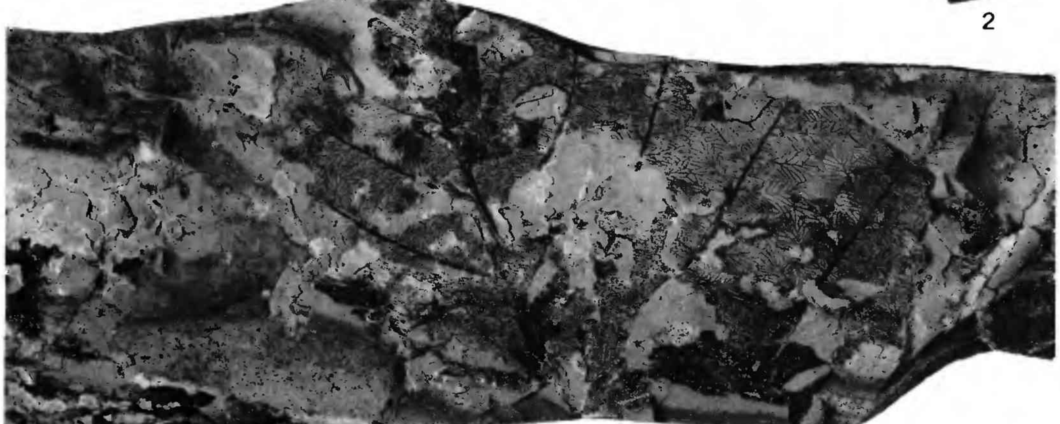

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ZONE 15, ZONE OF THE YOUNGER *GIGANTOPTERIS* FLORA