Additions to the Flora of the Spotted Ridge Formation in Central Oregon

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

A SHORTER CONTRIBUTION TO GENERAL GEOLOGY

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A SHORTER CONTRIBUTION TO GENERAL GEOLOGY

ADDITIONS TO THE FLORA OF THE SPOTTED RIDGE FORMATION IN CENTRAL OREGON

By SERGIUS H. MAMAY and CHARLES B. READ

ABSTRACT

The U. S. Geological Survey's previously undescribed collection of fossil plants from the Spotted Ridge formation (Pennsylvanian) in central Oregon is fully described and illustrated. This includes three new species: *Mesocalamites crookensis*, n. sp., *Phyllotheca paulinensis*, n. sp., and *Dicranophyllum rigidum*, n. sp. The collection also contains an abundance of *Pecopteris oregonensis* Arnold and *Mesocalamites hesperius* (Arnold) Mamay and Read, as well as a minor representation of a few other plants, some problematical. The flora contains unusually few species, and comparisons of its components with other Pennsylvanian floras prompt the conclusion that on the basis of the fossil plants alone, the precise age of the Spotted Ridge formation within the Pennsylvanian cannot be determined with any great degree of confidence.

INTRODUCTION

In 1938 S. A. Berthiaume and C. W. Merriam discovered abundant fossil plants in a sequence of upper Paleozoic sedimentary rocks exposed on the ranch of Orin Mills, about 15 miles southeast of Paulina, in Crook County, Oreg. The following year Merriam and Read revisited the locality and made a large collection of the fossil plants. The announcement of this discovery was published by Read and Merriam (1940); this preliminary report included a tentative list of the components of the flora, along with a short discussion of their geographic relations and stratigraphic implications.

The geology of this region was later described in a report by Merriam and Berthiaume (1943), in which this Paleozoic sequence was divided into three stratigraphic units: the Coffee Creek, Spotted Ridge, and Coyote Butte formations. On the basis of marine invertebrate fossils, the Coffee Creek formation was assigned to the lower Carboniferous, and the Coyote Butte formation, to the Permian. The interposed Spotted Ridge formation, however, was found to be barren of invertebrate fossils; and consequently, the determination of its age was made on the basis of its fossil plant contents. This formation was assigned to the Pennsylvanian, with Pottsville age provisionally indicated. A more detailed account of the stratigraphy of this region is given on page 212.

In 1949 Chester A. Arnold and a group from the University of Michigan visited this locality and made a collection of the fossil plants. This collection was recently described by Arnold (1953), who has advised us (1954, oral communication) that the University of Michigan collection was obtained at the site of Read and Merriam's original excavation; thus, there is no doubt that the two collections represent portions of the same flora.

Arnold described two new species. The first, *Pecopteris oregonensis* Arnold, is a delicate fernlike plant with dactylothecoid fructifications and highly variable foliage; fragments of this plant make up all but a small part of the total plant material in both the University of Michigan and the U. S. Geological Survey's collections. The other, *Calamites hesperius* Arnold, is a calamarean stem species based on internal casts; the foliage and fructifications are unknown. Arnold also briefly described the detached vegetative and reproductive parts of *Phyllotheca* sp.; although he made no specific determination, Arnold reiterated the opinion given by Read and Merriam that the *Phyllotheca* material most closely resembles the Turkish species *P. rallii* Zeiller.

In their preliminary analysis of this flora, Read and Merriam listed the genera *Asterophyllites*, *Calamites*, *Dactylotheca*, *Dicranophyllum*, *Phyllotheca*, and *Sphenopteris* (several species), as well as "Material referable to two new genera of cordaitalean affinities" and "some problematica not definitely assignable at present" (Read and Merriam, 1940, p. 109). Arnold, however, included the dactylothecoid fructifications, as well as sterile foliage reminiscent of certain sphenopterid species within the specific limits of *Pecopteris oregonensis*. Arnold reported neither *Asterophyllites* nor cordaitalean material; and although fragments of *Dicranophyllum* and *Phyllotheca* were present in the University of Michigan's collection, they were appar-

ently too incomplete and poorly preserved to warrant full description or specific determinations.

The U. S. Geological Survey's collection of Spotted Ridge plants has not yet been described in full detail; nor, to the best of the writers' knowledge, have further collections of this material been made. It thus seems that the publication of a full description of this collection and complete illustration of the flora, as a supplement to Arnold's studies, should constitute a note of more than casual interest. The flora is especially significant in view of the rarity of Pennsylvanian plant records in the Western United States, as contrasted with their abundance in the Eastern and Midwestern States, and because of the presence of certain floristic components that occur only rarely in any of the known Pennsylvanian floras. A detailed knowledge of the flora of the Spotted Ridge formation also appears desirable as a complement to Merriam and Berthiaume's description of the geology of the area involved, especially since their determination of the age of the Spotted Ridge formation was so entirely dependent on this fossil-plant collection. The descriptions that follow are presented for the purpose of amplifying as much as possible our knowledge of the Spotted Ridge flora, primarily by discussion of those floristic elements not found by Arnold.

STRATIGRAPHY OF THE GRINDSTONE-TWELVEMILE CREEKS PALEOZOIC INLIER

The Grindstone-Twelvemile Creeks Paleozoic inlier, Crook County, Oreg., comprises parts of T. 18 S., Rs. 24 and 25 E., and T. 19 S., Rs. 24 and 25 E., and is about 15 miles southeast of Paulina. On the Upper Mills Ranch in an area of about 20 square miles, strongly folded Mississippian, Pennsylvanian, and Permian strata are exposed. Resting unconformably on these older rocks are less strongly folded Triassic and Jurassic strata. Nearly horizontal middle and late Tertiary extrusive volcanic and pyroclastic rocks apparently once completely overlay the Paleozoic and Mesozoic sequence but have now been locally eroded.

First observed and reported by Packard (1928, 1932), the general stratigraphy and structure of the Paleozoic inlier was first described in some detail by Merriam and Berthiaume (1943). The following statement of the stratigraphic sequence is transcribed from their more detailed account.

COFFEE CREEK FORMATION, LOWER CARBONIFEROUS

General description.—The Coffee Creek formation is named for exposures on a minor tributary of this name which enters Grindstone Creek south of Wade Butte. At the type section in sec. 30, T. 18 S., R. 25 E. ¼ mile east of the spring at Mills sheep camp a line of limestone outcrops trend roughly northeast-southwest. In general the formation consists of well-bedded fairly pure limestones, carbonaceous limestones, argillaceous to sandy limestones, and calcareous sandstone. Exposures of the type Coffee Creek area were traced intermittently along the strike for a distance of about 1¼ miles from locality 93 on the south to locality 98 on the north. * * *

Thickness.—Estimates of thickness are greatly handicapped by deformation, and nowhere has the base of this formation been recognized. Conservative figures of 900 to 1000 feet are based on width of outcrop in the anticlines of Coffee Creek, and north of Coyote Butte, where in the last instance the strata stand in nearly vertical position.

Stratigraphic relations and age.—The Coffee Creek formation represents the oldest Paleozoic division recognized in this region. Judging from the lithologic and paleontologic criteria its relationship to the overlying Spotted Ridge Pennsylvanian is one of disconformity. Overlap of the partly land-laid Spotted Ridge upon the Coffee Creek is suggested by distribution of the two units, though stratigraphic evidence is inadequate. In some localities the Coffee Creek is directly overlain by either Permian or Triassic beds. These unconformities are discussed below. The age of the *Gigantella* horizon is based on the listed fauna and is Lower Carboniferous, roughly Viséan, in terms of the British succession. That the lower sands of this division are not older than Lower Carboniferous is attested by presence of the product *Striatifera*, not known in strata of greater age. The preliminary faunal list is as follows:

Dibunophyllum oregonensis Merriam
Lithostrotion (Lithostrotion) packardi Merriam
Lithostrotion (Siphonodendron) oregonensis Merriam
Campophyllum readi Merriam
Gigantella sp.
Striatifera sp.
Spirifer cf. *striatus* (Martin)
Tetrataxis sp.
Small loxonemoid gastropods
Lithistid sponge spicules

All but the spirifer are very abundant, *Striatifera* the commonest form ranging throughout. *Gigantella* has been found only in the key limestone bed about 45 feet below the top of the formation as shown at locality 2, where the bed is crowded with these shells in association with the corals listed. The Foraminifera, small gastropods, and sponge spicules are abundant at the same horizon; they are silicified and can be prepared by the acid-etching treatment.

SPOTTED RIDGE FORMATION, PENNSYLVANIAN

General description.—Sediments of the Spotted Ridge formation are exceedingly variable in both vertical and horizontal direction, ranging from compact mudstones and cross-bedded sandstones to very coarse boulder conglomerates. Locally much bedded chert is present. The members thicken and thin in various directions or may pinch out completely within a short distance. Good exposures are rare because the outcrop belts are in alluviated valleys or somewhat depressed areas between strike ridges formed by more resistant Permian rocks. The best exposures are in the type section on the west flank of Spotted Ridge, extending south about 2 miles to locality 83.

Plant-bearing sandstones and mudstones.—Sandstones with much carbonaceous material and recognizable plant remains appear to range throughout the formation, while the lenticular plant-bearing mudstones were found only in the upper part. The lowest sands with plants occur at locality 96 near the Coffee Creek contact. These basal deposits are sands of medium-grain and light neutral-gray color on fresh surface, weathering to various tones of limonite brown. Feldspar grains are abundant. Plant remains range from finely divided carbonaceous debris to flattened stems several inches in length.

That a similar facies persists locally or recurs in some situations is indicated by the presence of plant-bearing beds of much the same character at locality 108 within about 75 feet of the top of this division, possibly 900 feet stratigraphically above the locality first mentioned.

Lenticular distribution of sedimentary types is apparent within the plant-bearing deposits. At the main plant locality on the west side of Spotted Ridge are fine sandstones, siltstones, and mudstones in varying order within a thickness of 5 feet. Intergradation from one layer to another is recognized. Following the same approximate horizon southward a distance of ½ mile to locality 7 one finds crossbedded sandstone lenses within a heavy conglomerate including 2-foot boulders. Some of the finer sands here contain plant remains in direct association with small nuculid bivalves, small gastropods, and what appears to be a scaphopod about ½ inch in length.

The lenticular mudstones and siltstones at locality 115 are of an unusual shade of medium-grayish olive green. Lamination is usually not well defined, and fissility is undeveloped. The sediment is very compact and brittle. In general the plants lie more or less parallel to bedding though occasional leaves and stems are decidedly oblique in position. The plants occur as coaly films; stems are much flattened but retain evidences of vascular structure. Impressions of leaves below the carbonaceous films are sharply defined. The fine state of preservation of the dark leaves surrounded by a relatively light matrix lends added value to the plants for study purposes. While certain tongues or lenses within the plant-bearing beds are marine or brackish it is believed that most of the sediments in this facies are land-laid, though an estuarine origin in part is not unlikely. The plants do not appear to have suffered transportation; in fact, some calamite stalks with whorls of twigs appear to be essentially in position of growth. * * *

Thickness.—In view of intense folding and lack of continuous outcrop it was not found possible to arrive at accurate figures regarding thickness. Variability in lithology from place to place along the outcrop belts suggests great differences in thickness of the entire section and of its individual members. This applies particularly to the conglomerates, and to the cherts, which last are entirely absent at certain localities in horizons where they would be expected. Judging roughly from width of outcrop the formation at the type section, extending through locality 115, is probably 1000 feet thick. Southward along Twelvemile Creek the thickness is at least 1000 feet, while on the north slope of Coyote Butte it may, with the included cherts, exceed 1500 feet.

Stratigraphic relations and age.—The lowest exposed Spotted Ridge beds recognized lie in the vicinity of locality 96 where plant-bearing sands were found within a few feet of a well-exposed limestone bed of the *Gigantella* horizon and therefore near the top of the Coffee Creek Lower Carboniferous. Uplift and emergence following deposition of the purely marine upper Coffee Creek is suggested by the probable terrestrial or estuarine nature of these lower Spotted Ridge deposits. Nothing conclusive has, however, been determined regarding the magnitude of the break separating Coffee Creek from Spotted Ridge beyond the fact that the marine faunas of the upper Coffee Creek are of Lower Carboniferous age, while floral evidence suggests a Lower Pennsylvanian age for the upper Spotted Ridge beds.

The Coyote Butte Permian is unconformable upon the Spotted Ridge. Judging from fossil evidence there is in all probability a hiatus representing a portion of the Lower Permian and perhaps most of the Upper Pennsylvanian. A sharply defined contact between Spotted Ridge sandstones and relatively pure limestone of the Coyote Butte is exposed at locality 105 in the southwestern portion of the area. There is here a slight angular discordance between the two divisions. The Coyote Butte formation is regarded as marine in contrast to the partly estuarine, terrestrial and alluvial or delta-plain character of the underlying Spotted Ridge.

While no determinable marine fossils were discovered in the Spotted Ridge formation, reliable evidence regarding its age is provided by the flora found at locality 115 in a horizon within the upper 400 feet. * * *

Read and Merriam conclude that the flora is Lower Pennsylvanian, stating, however, that the possibility of its being Upper Pennsylvanian cannot be completely ruled out. If the flora ultimately proves to be Lower Pennsylvanian, it is likely that no great gap exists between the Coffee Creek and Spotted Ridge formations.

COYOTE BUTTE FORMATION, PERMIAN

General description.—The youngest Paleozoic beds of the area comprise a sequence in which massive limestones form the most conspicuous exposures. These produce prominent ridges, buttes, and small circular hills or knobs subsidiary to the main ridge slopes. Steeply dipping strata forming the crest of Coyote Butte near the southern limit of the map constitute the type section of the division. The Coyote Butte beds here lie in the north limb of a tight syncline overturned toward the south. Another bold outcrop of the formation is found in the belt of limestone extending north-northeast about 4 miles from the vicinity of Tuckers Butte to the spring at locality 92. A third area of Permian beds includes the limestone exposures in the northeast portion of the map, one tongue of which extends southwest beyond Twelvemile Creek where it is covered by Tertiary lava.

At the type section the lower portion of the Coyote Butte is generally a light olive-gray limestone, often crinoidal and locally containing abundant fusulinids. Higher in the section, at the summit of Coyote Butte, the limestone becomes purer, finer-grained, deep olive-gray and more distinctly bedded. In this upper portion there are fewer fusulinids, while brachiopods are common. * * *

Limestones of the Coyote Butte formation are interbedded with large amounts of sandstones. Furthermore the discontinuous nature of some of the limestone exposures leads to the impression that these deposits are lenticular within the more arenaceous facies. Generally speaking, exposures of the sands are poor, while the limestones form prominent linear or circumscribed exposures. Northeast of locality 123 in the center of the map several zones of sandstone float alternate with fusulinid limestones. * * *

Thickness.—At the type section on Coyote Butte approximately 900 feet of the Permian beds is exposed. Estimates of thickness on Spotted Ridge and north of Tuckers Butte are approximately the same. However, exact thicknesses cannot be given since bedding is poor and folds within the massive limestone are difficult to work out. Where the formation is largely arenaceous the exposures are poor. Unconformable relation of the Permian to overlying beds further eliminates true thickness estimation.

Stratigraphic relations and age.—The Coyote Butte formation is unconformable on the Spotted Ridge Pennsylvanian, as suggested by pinching out of the Pennsylvanian strata in sec. 5, T. 19 S., R. 25 E., where the contact between Coyote Butte limestone and the Lower Carboniferous Coffee Creek formation is apparently depositional. At locality 105 north of Tuckers Butte an exposure of the lower contact of the Permian shows a slight angular discordance and a definite truncation of the conglomeratic and sandy beds of the underlying

formation. On the basis of lithology and position the latter beds are presumed to be the Spotted Ridge formation. Furthermore, on the west side of Spotted Ridge and at several other localities the basal Coyote Butte strata are very pebbly limestones and calcareous conglomerates, probably indicating reworking of subjacent Pennsylvanian clastics.

Fusulinids, corals, and brachiopods from the Coyote Butte formation indicate a Permian age for these beds. Several faunal zones are undoubtedly represented but have not been differentiated in view of the complex structure and lenticularity of sedimentation. More refined studies of structure, stratigraphy, and sedimentation will be required to work out the details of this zonation. Since the Spotted Ridge plant-bearing beds a short distance below the Coyote Butte formation are regarded as Lower Pennsylvanian, a hiatus of some magnitude is indicated between the two formations. Nearly all the localities in the lower part of the formation have yielded a new species of *Parafusulina*. In addition, species of *Schwagerina* are found at several localities as well as forms tentatively referred to as *Fusulinella* and *Triticites*. Field evidence shows that several of the fusulinid types are either associated or occur in almost the same horizon. The fusulines imply that the Coyote Butte is not lowest Permian.

Dr. G. Arthur Cooper is now completing a detailed study of the Coyote Butte brachiopods and reports that most of the species are of Asiatic affinity; a few are almost exact identities with Russian forms from the Urals and Timan. According to Cooper the brachipods indicate Lower Permian. The following identifications were supplied by Cooper:

Productus cf. *P. mammatus* Keyserling
P. aff. *P. porrectus* Kutorga
Avonia tuberculata Schellwien
Linoproductus cf. *L. sinuata* King
Juresania aff. *J. juresanensis* Tschernyschew
Waagenoconcha n. sp.
Krotovia pustulata Keyserling
Keyserlingina sp.
Marginifera cf. *M. involuta* Tschernyschew
Rhynchopora n. sp.
Camarophoria mutabilis n. var.
C. biplicata Stuckenberg
C. karpinskyi Tschernyschew
Notothyris nucleola Kutorga
Notothyris n. sp.
Martiniopsis sp.
Spiriferella n. sp.

In a recent study of rugose corals from the Coyote Butte formation Merriam (1942) has described the following forms:

Waagenophyllum washburni Merriam
Waagenophyllum ochocoensis Merriam
Waagenophyllum sp. a.
Waagenophyllum sp. b.
Lithostrotion (*Lithostrotionella*) *occidentalis* Merriam
Lithostrotion (*Lithostrotionella*) *berthiaumi* Merriam

The species of *Waagenophyllum* support a Permian age and point to an Old World relationship of the faunas.

The ammonoid *Eoasianites merriami* Miller and Furnish was found in the region covered by the present survey, but whether it came from the Spotted Ridge Pennsylvanian or the Coyote Butte is not known. According to Miller and Furnish * * * it appears to be of either Upper Pennsylvanian or Lower Permian age.

SYSTEMATIC DESCRIPTIONS

Division LYCOPSIDA

?Lepidodendrid branchlet

Plate 36, figure 13

This small specimen represents the terminal part of a slender leafy twig, probably of lepidodendrid affinity. It is 4.5 cm long, with a maximum diameter of 6 mm, measured so as to include the leaves in the foliated part. The lower half or so of the specimen bears no appendages or scars of attachment; on the upper half, however, there are a number of small (reaching 4 mm in length), closely imbricated leaves, whose shape cannot be made out satisfactorily.

A part of the upper half of the specimen was apparently defoliated before preservation, and in this part a few vertically elongated, spirally arranged depressions may be seen faintly (pl. 36, fig. 13,); these are strongly suggestive of lepidodendrid leaf cushions.

Aside from Arnold's observation of a single impression of a stigmarian rootstock in the University of Michigan's collection, the specimen discussed here, if properly identified, represents the only suggestion of the presence of an arborescent lycopodiaceous element in the Spotted Ridge flora.

Division SPHENOPSIDA

Genus MESOCALAMITES Hirmer

In their monograph of the calamitaleans of western Europe, Kidston and Jongmans (1917) recognized that certain species of *Calamites* were characterized by the occurrence of directly superposed ribs at some of the nodes, in contrast to the more typically alternating ribs of most of the species. These forms with superposed ribs were segregated, without nomenclatural distinction, into a group referred to as "Section II" (1917, p. 188); it was pointed out that they represent a morphologically and chronologically intermediate stage between the typical *Calamites* and the older, supposedly more primitive *Asterocalamites*, in which all the ribs are superposed.

In a subsequent publication Hirmer (1927, p. 382) gave formal recognition to the six species placed in Kidston and Jongmans' "Section II" of *Calamites* (*C. roemeri* Goeppert, *C. cistiiformis* Stur, *C. taitianus* Kidston and Jongmans, *C. haueri* Stur, *C. ramifer* Stur, and *C. approximatiformis* Stur), erecting the new genus *Mesocalamites* for their accommodation. This treatment may prove objectionable to some paleobotonists on the grounds that there is insufficient comparative knowledge of the foliar and fruiting parts to warrant a generic separation of *Mesocalamites* from *Calamites*. In supporting Hirmer's adoption of the name *Meso-*

calamites, however, the present writers feel that this is justifiable from the standpoint of convenience in referring to two types of calamarian pith casts that may be readily distinguished from each other on the basis of nodal organization. It is simpler and less confusing to use the descriptive designation *Mesocalamites* than the noncommittal term "Section II of Calamites."

Mesocalamitean pith casts, in most cases not too well preserved, constitute a conspicuous element in the U. S. Geological Survey's collection of Spotted Ridge plants. Most of these conform closely with Arnold's description of *Calamites hesperius*, but a few specimens clearly indicate that more than 1 and probably 3 species are actually present in this assemblage.

Although *Mesocalamites* is mentioned in Arnold's discussion of this species, it is used only as an informal group designation. In conformity with the authors' views regarding the desirability of maintaining Hirmer's distinction between pith casts of *Calamites* and *Mesocalamites*, the following nomenclatural adjustment is proposed.

Mesocalamites hesperius (Arnold) Mamay and Read, n. comb.

Plate 34, figure 3

Calamites hesperius Arnold, 1953, Palaeontgraphica, Band 93, Abt. B, p. 62–63, pl. 24, figs. 1, 6–8.

Although a few specimens in the U. S. Geological Survey's collection are rather larger than any reported by Arnold, most of the specimens present nothing in the way of features that might suggest a necessity for expansion or emendation of Arnold's original diagnosis. A specimen of *Mesocalamites hesperius* from the U. S. Geological Survey's collection is shown in plate 34, figure 3.

Mesocalamites crookensis Mamay and Read, n. sp.

Plate 34, figures 4, 4a

This description is based on a single specimen, which consists of one side of a flattened internal stem cast. Although the specimen is not well preserved, it nonetheless clearly exhibits the more critical features upon which the identification of calamitean species is chiefly based; that is, the organization of the ribs and nodes.

The specimen is a straight segment of the stem, 14 cm long, with a maximum width of 2.0 cm. It seems probable that the entire width of the stem is represented, for differences in width of the fragment are negligible throughout its length. Nine nodes are present, with eight complete internodes and an incomplete one at either end of the specimen. The internodes are all shorter than the width of the specimen, ranging only from 1.4 to 1.5 cm in length. The specimen shows no evidence of branch scars, tubercles, or leaves.

The ribs are essentially straight. They range from 1.0 mm to more usual widths of 1.5 mm and are separated from each other by distinct grooves. The number of ribs on the exposed side of the specimen ranges from 10 to 12 on each internode. The nodes are clearly defined but lack any distinguishing features other than the transverse grooves that mark their positions. The overall aspect of this specimen is shown in plate 34, figure 4.

This specimen is interesting chiefly because the ribs are preponderantly in direct superposition at the nodes, thus providing a close approach to the type of nodal organization that distinguishes *Asterocalamites* from the true *Calamites*. Alternation of the ribs is, in fact, evident at only 4 of the 9 nodes present in the specimen. In each of these 4, only 3 or 4 of the total of 10 or 12 ribs may be seen to alternate with those of the next internode. The few ribs that do show alternation have bluntly pointed or rounded ends, while the preponderantly nonalternating ribs are distinctly truncated at the nodes. (See pl. 34, fig. 4a.) Some of the ribs can be traced through nearly the entire length of the specimen without an alteration occurring; most of the ribs may, in some part of the specimen, be followed over 3 or 4 nodes before finding an alternation.

Among the six species included by Hirmer in *Mesocalamites*, *M. crookensis* may be most closely compared to *M. approximatiformis* on the basis of the relative rarity of alternating ribs common to both of these species. However, the regular occurrence of tubercles at the ends of the ribs of *M. approximatiformis*, and their apparently complete absence in *M. crookensis* in itself seems to constitute a sufficient basis for distinguishing the two species; but aside from this difference and that of relative sizes, the holotype of *M. crookensis* compares very closely to the specimen of *M. approximatiformis* shown in text figures 79 and 80 of Kidston and Jongmans' monograph (1917, p. 205).

M. crookensis is distinguished from *M. hesperius* on the basis of the broader (2.5–3.0 mm) ribs, longer (2.3–3.5 cm) internodes, the presence of tubercles at the apical ends of the ribs, and the apparently higher frequency of alternating ribs in *M. hesperius*. Arnold makes no mention of the relative frequencies of alternating and superposed ribs, but his photographs of the holotype of *M. hesperius* (1953, pl. 24, figs. 1, 6, 7, and 8) show a much more nearly equal distribution of the two than present in *M. crookensis*.

Insofar as they are presently known on the basis of the limited amount of material at hand, the features of *Mesocalamites crookensis* are summarized below.

Specific diagnosis.—Internal casts at least 2 cm in diameter; internodes reaching 1.5 cm in length, consistently wider than long, and differing little in length in the same specimen. Ribs straight, lacking tubercles, 1.0–1.5 mm wide, and separated by distinct

grooves. Ribs preponderantly superposed, usually continuous over several nodes; alternating ribs with bluntly pointed apices, superposed ribs truncated. Branch scars not known.

Holotype.—USNM 40708.

Mesocalamites sp. indet.

Plate 34, figures 1, 1a, 2

The presence of still a third mesocalamitean species in this flora is indicated by a few specimens which, although too fragmentary for positive specific determination, display some features that strongly oppose their identification with either *M. hesperius* or *M. crookensis*.

The largest specimen, shown in plate 34, figure 2, is a fragment of the flattened impression of a stem, 13 cm long; the widest part of the specimen measures 1.7 cm, but it is not clear whether this represents the entire width of the specimen or not.

Only two nodes are preserved; the intervening internode is quite long, measuring 5.8 cm. The ribs are straight and very narrow in proportion to their length, in no instance exceeding 1.0 mm (and most typically from 0.5–0.7 mm) in width. The nodal relations of the ribs cannot be made out in this specimen.

The fragmentary specimen shown in plate 34, figures 1 and 1a, is 4.8 cm long and contains only 1 node (the 2 nearly transverse lines, 1 near each end of the specimen, are not nodes, but fractures in the matrix); the internodes were thus at least 2.8 cm long, measured from the single node to the farthest end of the specimen. As in the specimen described in the preceding paragraphs, the ribs of this one are proportionately narrow, measuring no more than 0.6–0.8 mm in width, and chiefly on this basis it is assumed that both specimens represent the same species.

Although it is only a small fragment, this specimen clearly exhibits nodal superposition of its ribs, which limits the possibilities of its generic identity to *Mesocalamites*. As shown in plate 34, figure 1a, all the ribs are in direct superposition, and some of them converge toward a common point on the nodal line, as frequently occurs in the immediate area of calamitean branch scars. In this instance, however, there is no clear evidence of a branch scar, unless the shallow depression present at the point of convergence of the ribs may be interpreted as such.

Even though their superposed ribs indicate a relationship of these specimens to both *Mesocalamites hesperius* and *M. crookensis*, they appear to represent a different species by virtue of the great length of the internodes and the proportionately small width of the ribs. On the other hand, they show some resemblances to both *M. ramifer* (Stur) Hirmer, as illustrated by Kidston and Jongmans (1917, pl. 141, fig. 4), and *M. cistiiformis* (Stur) Hirmer (compare with Kidston and Jongmans, 1917, pl. 142, fig. 2, and pl. 147, fig. 1), but more satisfactory specimens are necessary before either of these two species can be positively identified in the Spotted Ridge flora.

Genus PHYLLOTHECA Brongniart

Although more than 2 dozen species of *Phyllotheca* have been previously reported from different parts of the world, to the best of the writers' knowledge, the Mills' Ranch locality is the only source of this genus known in the United States at present.

Phyllotheca actually constitutes a problematical and poorly understood genus, in spite of the frequency with which it has been recorded in the literature. According to Seward's (1898, p. 281–283) discussion of this genus, it can be distinguished from the related calamarian genus *Annularia* only on the basis of relative development of the leaves of one whorl and the attitude of the whorls; in *Phyllotheca* the basally fused leaves of any one whorl are all the same size and spread equally in all directions from the supporting axis, but those of *Annularia* are unequally developed and tend to lie in one plane.

On the basis of this distinction the Oregon material is referable to *Phyllotheca;*[1] it is described below in detail because of the unusual nature of some specimens that illustrate the actual organic continuity between stems, leaves, and fructifications. Such a continuity was apparently not demonstrable in the University of Michigan's collection, for which reason Arnold made no definite specific determination.

Phyllotheca paulinensis Mamay and Read, n. sp.

Plate 34, figures 6–8, plate 35, figures 1–6

Phyllotheca sp. (cf. *P. rallii* Zeiller), Arnold, 1953, Palaeontographica, Band 93, Abt. B, p. 63, pl. 24, fig. 2–5, 1953.

With the exception of the fern *Pecopteris oregonensis* Arnold, *Phyllotheca paulinensis* appears to have been the most ubiquitous element of the Spotted Ridge flora, judging from the large number of fragments in the U. S. Geological Survey's collection. Most of these consist of isolated leaves or parts of leaf whorls. Detached cones are abundant, and there are also a few fairly large stem fragments, some with lateral branches and fructifications attached.

The general attitude of the leaves is shown in plate 34, figures 6 and 7, where they can be seen arising from

[1] The phyllothecoid affinity of the Turkish species *Phyllotheca rallii* Zeiller, which the Oregon material very closely resembles, was questioned by Gothan (1927, p. 150), primarily on the basis of the organization of the cones of *P. rallii*. As the result of a restudy, as yet unpublished, of the Carboniferous floras of Turkey, Jongmans has recently shared Gothan's views; he has expressed the opinion that *P. rallii* is a peculiar form of *Annularia*, probably related to *A. radiata* (oral communication delivered before the Eighth International Botanical Congress, Paris, 1954). The present writers, however, prefer to tentatively consider both *P. rallii* and the Oregon material as truly phyllothecoid, in the absence of clearly demonstrable unequal formation of leaves or foliar mosaics.

the stem fragments at several of the nodes. The leaves generally stand out from the stem at a nearly perpendicular angle, with their tips gently bending upward to describe a shallow saucerlike whorl.

The leaves range in length from 5 mm on the smaller branchlets (pl. 34, fig. 6) to 1.5 cm on the larger axes (pl. 34, figs. 7, 8; pl. 35, figs. 3, 4). All the leaves of any given whorl, however, appear to be equally developed. Their basal widths range from about 0.75 mm to 1.5 mm, but this does not seem to be consistently proportional to length, for the shorter leaves are usually relatively broader than the longer ones. The leaves are consistently widest at their bases and taper gently toward their tips, without any abrupt narrowing of the lamina.

The basal fusion of the leaves into the collarlike structure that constitutes one of the distinguishing features of *Phyllotheca* is difficult to demonstrate because, in instances where the leaf whorls are attached to a stem fragment, the presence of the stem itself obscures this feature. However, in a few whorls that were compressed in the plane of the node that bore them, the fusion can be seen between 3 or 4 members of a whorl (pl. 34, fig. 8, and pl. 35, fig. 3). The fusion is restricted to the very basalmost parts of the leaves and results in an extremely narrow collar that could easily be overlooked; the collar has not been observed to exceed 1.5 mm in width.

Although none of the specimens include a complete foliar whorl compressed in such a way that would facilitate the determination of the exact number of leaves in a whorl, one nearly complete whorl (pl. 35, fig. 4) contains parts of 20 leaves, and less complete ones contain from 12 to 18. It thus seems likely that 2 dozen or more leaves constitute the full foliar complement of a node. The venation of the leaves is not preserved.

Most of the numerous cones are detached specimens, but a few were preserved in organic connection with leafy stem fragments, so that there exists no doubt concerning the relationship of these parts.

The cones differ considerably in size; some are only 2.5 cm or so in length (pl. 35, fig. 2), but others reach lengths of 7 cm (pl. 35, fig. 6). The largest specimens are incomplete, suggesting that total lengths of considerably more than 7 cm may have been attained. The smallest specimens are only 6 or 7 mm wide, measured between the tips of the extended sterile appendages, while one incomplete specimen (pl. 35, fig. 5) is nearly 2 cm wide. The average width, however, is about 1 cm.

The sterile appendages (bracts) are clearly shown by every cone specimen, but determining the number of bracts to a whorl has not been possible. In the larger specimens the whorls of bracts are usually spaced about 2 mm apart, and the free parts extending beyond the sporangia reach 4 mm in length (pl. 35, fig. 6). They usually stand out from the cone axis at nearly a right angle, with their tips gently bent upward toward the apex of the cone.

None of the critical details of the sporangia were observed; and it was impossible to isolate spores by chemical maceration, although several attempts were made with the more promising specimens. The fertile parts of the cones merely appear as dark masses interposed between the whorls of bracts (pl. 35, figs. 1, 5, and 6); in some places these masses show rounded outlines or a series of rounded depressions or protuberances that indicate the original positions of the sporangia. In this connection, see the specimens shown in plate 34, figure 5. Each specimen consists of a circularly arranged group of small rounded bodies less than 0.5 mm in diameter. In the better specimen, shown at the bottom of the photograph, there appear to be 8 or 9 of these objects, which may represent sporangia; opposite each there is a faint line which probably indicates the presence of an accessory organ, perhaps a subtending bract. These two specimens quite possibly represent whorls of *Phyllotheca* sporangia that were compressed transversely to the axes of the cones that produced them, exposing the sporangia in such a way that the individuals may be made out fairly well. If so, however, these must have been produced by very small cones, for the circlets each measure only 2 mm or so in diameter, which is significantly smaller than the width of the smallest cone specimens present in the collection. There is also the further possibility that these represent the fructification of still another genus of articulates.

The attachment of cones to vegetative parts is clearly illustrated in plate 35, figure 1. Here the terminal part of a slender branch fragment is shown, with parts of four cones attached. The largest of these is 5.5 cm long in its incomplete condition and appears to represent a direct continuation of the tip of the vegetative axis; from the base of this cone arises a second, rather smaller one. The two nodes below these cones are apparently sterile, since only the ordinary foliar leaves are seen here. Each of the next two lower nodes, however, is fertile, one cone arising from each. In all cases where lateral cones have been seen, they are sessile, arising directly from the axil of a foliar whorl.

The large specimen shown in plate 35, figure 2, is of interest in that it bears at least one slender lateral branch, to which three small cones are attached; this branch is seen arising from the left side, at about the middle of the specimen. A short distance below this branch is another, also fertile; although the actual organic connection of this branch to the main axis cannot be seen, their relative positions strongly suggest an original organic connection. At some places on the specimen, ordinary foliage arises from the nodes. The attachment of sterile foliage to the stem, however, may

be seen still more clearly in the specimen shown in plate 34, figure 6. This specimen is 17 cm long and contains 21 nodes, from several of which arise small sterile lateral branches; the remainder of the nodes show parts of ordinary foliar whorls.

The largest stem fragment, shown in plate 35, figure 2, lacks part of its width through nearly half of its total length of approximately 24 cm, but at either end the specimen appears to be nearly complete. Its width ranges from 2 to 3 cm, but this may be due to relative degrees of compaction at different parts of the specimen. The internodes average about 1.5 cm in length and are thus consistently wider than long. Details of the ribbing and nodal organization are not clear. At the upper part of plate 35, figure 2, the ribs appear very narrow, but at the bottom of the same illustration they are appreciably wider; they seem to alternate at some of the nodes and continue uninterruptedly over others. The stems of *Phyllotheca paulinensis* thus display nodal features of Hirmer's *Mesocalamites*, but in the absence of information regarding the relative frequencies of alternating and superposed ribs, there is no clear basis for a comparison to the pith casts referred to *Mesocalamites* earlier in this paper.

The proposal of the new specific name *Phyllotheca paulinensis* for the Oregon material is based largely on comparisons with the three previously described species that are known in the fertile condition: *P. deliquescens* Schmalhausen (1879), *P. uluguruana* Gothan (1927), and *P. rallii* Zeiller (1899). The fructifications of *P. deliquescens* and *P. uluguruana* closely resemble each other in the presence of elongated fertile zones between the sterile whorls of bracts, to which large numbers of fertile units were attached at random. In this feature these species stand apart from *P. rallii* and *P. paulinensis*, in which the arrangement of both sterile and fertile whorls is much more compact, each internode producing only one whorl of fertile units. Although the cones of *P. rallii* and *P. paulinensis* thus show a typically calamostachyan organization in this respect, the reference of these species to *Phyllotheca* seems preferable on the basis of leaf characters, which are typically neither annularian nor asterophyllitean.

P. paulinesis is extremely similar to *P. rallii*. However, the two species are distinguishable from each other on the basis of the following points of contrast: Internodes of *P. paulinensis* do not exceed 2 cm in length and are consistently wider than long, but those of *P. rallii* are from 4 to 8 cm long and always longer than wide; cones of *P. paulinensis* reach 7 cm or more in length, but those of *P. rallii* reach a maximum length of 4 cm; cones of *P. paulinensis* are borne sessile in the axils of foliar whorls, but those of *P. rallii* are pedicellate.

The known characters of *Phyllotheca paulinensis* are summarized below.

Specific diagnosis.—Largest known stem fragments to 3 cm in width; internodes averaging 1.5 cm in length, consistently wider than long; ribs apparently alternating or directly superposed at the nodes. Leaves produced as many as 20 or more in a whorl; leaves 0.5–1.5 cm long, basally 0.75–1.5 mm wide, tapering gently toward their tips; basally fused parts of leaf whorls producing a narrow sheath, usually not more than 1.5 mm wide. Cones 2.5–7 cm or more in length, 6 mm to nearly 2 cm wide, measured between tips of bracts; bracts extending to 4 mm beyond fertile units, produced in whorls usually 2 mm apart; sterile whorls apparently separated by single whorls of fertile units, but mode of attachment of sporangia and nature of spores unknown; cones produced terminally on side branches or laterally, the lateral ones borne sessile in the axils of foliar whorls.

Syntypes.—USNM 40710–40718.

Genus ASTEROPHYLLITES Brongniart

Cf. A. equisetiformis (Schlotheim) Brongniart

Plate 36, figures 11 and 12

The surfaces of several slabs in the U. S. Geological Survey's collection are covered with numerous specimens of this delicate foliage; the best of this material is shown in plate 36, figure 12.

Most specimens consist of detached parts of foliar whorls; however, one very unsatisfactorily preserved specimen, not illustrated here, shows the attachment of leaves to the axis. The specimen contains 6 internodes, each about 1 cm long and 8 mm wide; each node bears a few leaves, but it is not possible to determine the full number of leaves produced by a node. The ribbing and nodal organization of this specimen are obscure.

The leaves range from 4 to 12 mm in length. They are very narrow, scarcely exceeding 0.5 mm in width in the larger specimens. The leaves taper gently, terminating in sharp points; the acicular appearance of the leaves is shown best in plate 36, figure 11, which shows the tip of a small branchlet, thickly clothed with small, immature leaves.

Because of its imperfect preservation (and particularly in the absence of branching foliated axes that would demonstrate what differences exist between the leaves produced by the different orders of branches), this material cannot with any degree of confidence be specifically determined. There is little doubt, however, that its reference to the genus *Asterophyllites* is correct. The specimens are somewhat reminiscent of some of the smaller leaved examples of *Asterophyllites equisetiformis*, which is perhaps the most common species of this genus.

Division PTEROPSIDA

Genus PECOPTERIS Brongniart

Pecopteris oregonensis Arnold

Plate 36, figures 1–7

This species comprises perhaps 75 percent of the plant material in the U. S. Geological Survey's collection and is briefly mentioned here for the purpose of clarifying one point in Read and Merriam's preliminary report of 1940. They tentatively listed "several species of *Sphenopteris*" and "*Dactylotheca*" as components of the flora (1940, p. 109). Arnold, however, has treated the sphenopteroid foliar elements as variants of the more typically pecopterid pinnules of *Pecopteris oregonensis*, and the "*Dactylotheca*" as the fructification of that species. Careful reinspection of the U. S. Geological Survey's collection has revealed no basis for variance with Arnold's treatment of these elements. It is thus apparent that truly sphenopterid leaves are absent from the Oregon flora, and all the fernlike foliage with its abundant fructifications almost certainly belongs to the single species *Pecopteris oregonensis*. Several specimens of this species are illustrated in plate 36, figures 1–7.

Arnold's description of this species may be amplified by the U. S. Geological Survey's collection with regard to one minor point. Arnold described the aphlebiae of *P. oregonensis* as being "only one centimeter or more long." Several specimens in the U. S. Geological Survey's collection, however, illustrate that these appendages were sometimes larger, more conspicuous structures. While many of the specimens do fall within the size range given by Arnold, they are typically well over 2 cm in length (pl. 36, fig. 6), and 1 incomplete specimen, shown in plate 36, figure 5, measures 3.3 cm to its broken tip. If it had been complete, this particular aphlebia would probably have been more than 4 cm long. In this respect, the aphlebiae of *P. oregonensis* compare much more closely with those of *Dactylotheca plumosa*, as illustrated by Kidston (1924, pt. 5, pl. 93, figs. 2 and 3).

Genus DICRANOPHYLLUM Grand'Eury

This genus, still of problematical affinities, now contains at least 24 species, with occurrences having been reported in Asia, western Europe, Great Britain, Australia, and North America. *Dicranophyllum* is found chiefly in strata of Pennsylvanian or Permian age, although Dawson (1881) reported one species (*D. australicum* Dawson) from the Devonian of Australia. There is considerable doubt that the reference to *Dicranophyllum* is correct in the latter instance.

Dicranophyllum is rare in North American rocks. Before Read and Merriam's announcement of its presence in the Oregon flora, only six other occurrences had been recorded. These were *D. dichotomum* Lesquereux (1880, p. 553), *D. dimorphum* Lesquereux (1880, p. 554), *D. glabrum* (Dawson) Stopes (1914, p. 79; Bell, 1940, p. 132), *D.? garnettensis* Elias (1936, p. 12), and some questionable specimens doubtfully referred to *Dicranophyllum* by White (1899, p. 272).

Dicranophyllum rigidum Mamay and Read, n. sp.

Plate 37, figures 3–10a

This species is represented in the U. S. Geological Survey's collection by a fairly large number of specimens, including several large fragments of stout branches, apparently with most of their leaves preserved intact. Most of the material, however, consists of detached leaves and small stem fragments, some partly denuded of their leaves before preservation. None of the specimens demonstrate the fruiting habit of this plant.

The branch fragments range up to about 1 cm in diameter, but most of the specimens are more slender than this, usually measuring only 2–5 mm in thickness. In only one specimen has branching been observed; however, the type of branching (sympodial or monopodial) cannot be determined from this specimen.

Details of the leaf cushions are not well preserved in this material; in only one specimen, shown in plate 37, figure 4, can they be seen at all. The exposed surface of this branch fragment appears to have been completely decorticated before preservation and shows only a faint pattern of shallow leaf cushion impressions that give the specimen a superficially lepidodendroid aspect through their vertical elongation and spiral disposition. As shown in this figure, the phyllotaxy is a fairly close spiral.

The leaves were apparently persistent, for the decorticated stem fragment shown in plate 37, figure 4, is the only specimen in the collection in which the leaves are not attached. The leaf bases are decurrent, a feature that is best seen in the smaller branches, where the leaves are not very densely arranged. Decurrence of the leaves is illustrated in plate 37, figures 3, 9, 10, and 10a.

The leaves differ considerably in length, ranging from about 1.5 to 4.5 or 5 cm long, and the stoutest specimens are about 1.5 mm wide at the base. Some examples of the longer leaves may be seen in plate 37, figure 6. The branch fragment toward the right of this figure is densely covered with leaves, which makes it difficult to follow any individual leaf from its tip to the point of its attachment to the axis. However, it is quite evident that some of the leaves approach 5 cm in length. In contrast to these, the leaves shown

in plate 37, figures 10 and 10a, are not only much more loosely arranged on the axis but are also much shorter, measuring only 1.5 cm or so in length.

The specimen shown in plate 37, figure 9, is of interest because it represents the apex of a branch, preserved before complete elongation of the axis and extension of the leaves. This fragment is 4 cm long, and its apical half is so densely covered with leaves that it is difficult to distinguish the individual leaves from each other. The identity of this specimen as *Dicranophyllum* is nevertheless established by the forked tips clearly visible in some of the leaves. These leaves average about 2 cm in length, and their straightness gives the impression that they must have been fairly rigid in life, perhaps as much so as the needles of a spruce or fir. The same impression is lent by most of the other leaves in the collection, including the longer specimens.

The chief distinguishing characteristic of *Dicranophyllum* (repeated bifurcation of the leaves) is well illustrated in plate 37, figures 7, 7a, 8, and 8a. The smaller leaves bifurcate twice, resulting in four essentially equal divisions at their tips. This point, however is not clearly demonstrable in the longest leaves, for it is difficult to trace the entire length of one leaf in the longest specimens. These bifurcate at least twice; in consideration of their greater length, however, it is quite possible that they were more divided than the smaller leaves.

Isolated leaves, each with a double bifurcation, are shown in plate 37, figures 7 and 8. The specimen shown in figure 8 probably represents part of one of the longer leaves; this fragment is 15 mm long, and each of the 4 ultimate segments is about 5 mm long. In the latter feature this specimen differs from that shown in plate 37, figure 7, for there the ultimate divisions are considerably shorter (less than 2 mm long), and more spinelike. Despite such differences as this, however, all the complete leaf specimens in the collection appear to be consistent in the following features: The two foliar segments resulting from each bifurcation always include a fairly narrow angle (usually between 30° and 40°), and each bifurcation of the lamina occurs above the middle of the foliar segment involved.

Details of the venation are difficult to determine because of faulty preservation. Some of the leaves contain coalified median streaks that give the impression of broad midveins when viewed with the naked eye. (See pl. 37, fig. 7.) These streaks may be as much as half the width of the lamina; they divide in accordance with the foliar divisions and proceed almost to the tips of the leaves. If these are vascular strands, there is no evidence that more than one was present in each laminar division.

Although several of the previously recorded species of *Dicranophyllum* are too incompletely known for a satisfactory comparison to the Oregon material, the latter can be distinguished from most species primarily on the basis of leaf size, even though other points of contrast also exist. Several species have leaves that are considerably larger than those of *D. rigidum;* in this respect, the greatest contrast is shown by *D. striatum* Grand'Eury (1877) and *D. latifolium* Sterzel (1907), leaves of which have been reported to exceed 20 cm in length. In the opposite extreme, we find the 2 species *D. domini* Nemejc (1929) and *D.? brevifolium* Kawasaki (1931), whose relatively small dimensions preclude a conspecific identification with *D. rigidum;* neither of these 2 species produced leaves longer than 17 mm.

With regard to leaf size, *D. rigidum* may perhaps be most closely compared to *D. gallicum* Grand'Eury (1877), the most completely understood representative of this genus. Although the leaves of these two species correspond rather closely in size, they differ in manner of foliar division, those of *D. rigidum* displaying a consistently more symmetrical pattern of bifurcation than those of *D. gallicum.*

Dicranophyllum rigidum is so named with reference to the generally rigid aspect of the leaves, and is diagnosed below.

Specific Diagnosis.—Foliage apparently persistent, rigid, arranged in closely crowded spiral phyllotaxy, and seated upon slightly elevated vertically elongated leaf cushions. Leaves 1.5–5.0 cm long, not more than 2 mm wide at their bases. Shorter leaves bifurcating only twice; the resultant four ultimate divisions sharply pointed, 2 mm or less in length; longest leaves possibly bifurcated more than twice, with ultimate segments reaching 5 or 6 mm in length. All bifurcations essentially symmetrical and occurring beyond the middle of the dividing segment; members of each division including an angle of approximately 30°–40°. Vascularization of leaves apparently consisting of a single median vein, bifurcating according to laminar divisions. Reproductive organs unknown.

Syntypes.—USNM 40733–40740.

It should be pointed out here that in view of the range of leaf size, some authors may prefer the treatment of the two extremes as distinct species, but such a distinction cannot, in the writers' opinions, be clearly demonstrated with the present material. The fact that several examples of leaves of intermediate length are present in the collection suggests, rather, that a single variable species is represented, possibly complicated by genetic polymorphism or by ecologically stimulated variation of the foliage.

PROBLEMATICA

?Cordaianthus Grand'Eury (cf. C. longibracteatus Florin)

Plate 36, figure 10

This tentative determination is offered on the basis of the single specimen illustrated in plate 36, figure 10, which appears to represent the top part of a poorly preserved cordaitean inflorescence. The axis of the fragment presents a rather slender appearance, being 5.5 cm long and only 2.5 mm wide at its base. It bears about a dozen alternately arranged bractlike appendages, which arise from the axis at intervals of 7–11 mm. The bracts depart at wide angles and assume gently ascending positions. The largest bract, apparently complete, is 2.8 cm long; the most, however, are incomplete, consisting of only the basal parts.

A small budlike structure, 3–4 mm long, may be faintly seen in the axil of nearly every bract. The preservation of these structures is especially poor; but although their organizational details are completely obscured and no actual fruiting organs are preserved, they are sufficiently consistent in relationships of their size and position with the subtending bracts that they can scarcely be considered to be the results of accidental preservation. Even in the absence of any knowledge of the critical details, the gross appearance of this specimen is strongly reminiscent of a *Cordaianthus* inflorescence, with its sterile bracts and axillary dwarf shoots.

A tentative comparison to *Cordaianthus longibracteatus* Florin is suggested here, on the basis of the long bracts present in this specimen. In certain other features, such as its more slender main axis and less crowded appendages, the Oregon specimen presents a somewhat less robust, more lax aspect than that of *C. longibracteatus* (cf. pl. 36, fig. 10, with Florin, 1950, pl. 1, fig. 1); these contrasting features suggest that the Oregon specimen might actually be determinable as a new species of *Cordaianthus*, were it more satisfactorily preserved.

Cf. Schizopteris trichomanoides Goeppert

Plate 36, figures 8–9

The specimens illustrated in plate 36, figures 8 and 9, are mentioned here because of a notable similarity to a specimen figured by Zeiller (1892, pl. 1, fig. 8) under the binomial *Schizopteris trichomanoides* and apparently accepted by him as the remains of a genuine fern.

The Oregon material consists of several fragments of a repeatedly bifurcated structure that are preserved as a dark stain on the surface of the rock, with only here and there a thin fleck of carbonaceous residue to suggest a truly vegetable origin. The largest fragment (pl. 36, fig. 9) is a fan-shaped structure with a dozen or more ultimate divisions, which are the result of regular bifurcation at intervals of 3–7 mm. The individual segments are narrow and straplike, not exceeding 2 mm in width, and essentially equal in dimensions to their counterparts resulting from the bifurcations. (See pl. 36, fig. 8.) In some parts of the specimens there are indications of a narrow dark band traversing the middle of the segments, suggesting a median nerve or some other type of mechanical thickening in the original organism. There is no indication of attachment to an axis, for the basal parts of the fragments are not present.

Numerous examples of similarly bifurcated structures have been recorded in paleobotanical literature, as, for example, *Schizopteris dichotoma* Gumbel (see Zeiller, 1892, pl. 1, fig. 7) or *Marchantites erectus* (Leckenby) Seward (Seward, 1898, fig. 49). However, the comparison made here is suggested because the overall appearance of the Oregon material seems to resemble most closely Zeiller's figure of *Schizopteris trichomanoides*.

The question of natural affinities of such fossils is difficult. They have been variously interpreted as lichens, liverworts, algae, and ferns, but in many instances, as in the present one, there has been little more than the gross outline of the plant preserved as a basis for its systematic interpretation.

Roots of unknown affinity

Plate 37, figures 1–2

These structures are briefly brought to attention here because they constitute a conspicuous element among the other plant fragments in the Spotted Ridge flora and because certain features of appearance could possibly lead to misinterpretation and the unwarranted assumption of a nonexistent element in the flora.

The collection contains numerous fragments of long, straplike organs measuring from 2 mm to 2 cm or more in width. (See pl. 37, fig. 2.) The longest fragments reach 7 cm in length; these show little difference in width throughout their length. They are preserved as very thin carbonaceous films, and one of their more conspicuous features is the finely striated nature of their surface, best shown in plate 37, figure 1. The striations are very closely spaced and run parallel to the length of the fragments. In most instances the edges of the specimens are smooth and unbroken; their overall appearance at first gives the impression that we are dealing with a group of poorly preserved small to medium parallel-veined leaves, perhaps of cordaitean affinity.

Other features, however, establish these specimens as roots rather than leaves. Each specimen contains a single thick, usually centrally located strand, which is without doubt the vascular system of the root. This

structure is clearly shown in plate 37, figure 1. The absence of any considerable substance to the specimens suggests that compaction of the specimens was preceded by nearly complete decay of the cortical tissues, with the result that the vascular system is clearly seen and is only slightly obscured by the remains of the dermal layer, represented by the parallel striations. In some specimens the central strand crosses diagonally from one side of the root to the other, while the fine striations of the dermal layer uninterruptedly follow their courses parallel to the length of the root. Such a displacement in position of the vascular strand would not be unusual if, by decay of the surrounding cortical tissues, the strand were deprived of organic connection with the dermal layers.

The specimen shown in plate 37, figure 1, is of further interest in that it illustrates the departure of a lateral rootlet from the right side of the specimen; the vascular strand of the lateral rootlet may be seen originating from the central strand of the parent root. The surface of this specimen also contains several circular punctations that are interpreted as scars of attachment of rootlets.

Although the rootlike nature of these specimens is quite obvious, it is not possible to correlate them with any of the foliar species already described.

DISCUSSION

The composition of the Spotted Ridge flora now may be systematically summarized as follows:

Lycopsida
- ?Lepidodendroid branchlet
- Stigmarian rootstock

Sphenopsida
- *Asterophyllites* sp. (cf. *A. equisetiformis*)
- *Mesocalamites hesperius*
- *Mesocalamites crookensis*
- *Mesocalamites* sp. indet.
- *Phyllotheca paulinensis*

Pteropsida
- *Pecopteris oregonensis*
- *?Cordaianthus* (cf. *C. longibracteatus*)
- *Dicranophyllum rigidum*

Problematica
- Cf. *Schizopteris trichomanoides*
- Undetermined roots

It again should be emphasized here that the flora is strongly dominated by four of the above-named elements (*Mesocalamites hesperius*, *Phyllotheca paulinensis*, *Pecopteris oregonensis*, and *Dicranophyllum rigidum*); all the other entities are represented in the collection by single or, at the most, a very few specimens. It is our opinion that this floristic picture is not an artificial one that has been distorted by insufficiently thorough collecting, for the U. S. Geological Survey's collection is a large one, extremely rich in plant fragments. The Spotted Ridge flora is, then, of primary interest from the point of view of its relatively few recognizable species as compared with the highly diversified plant assemblages that are more usually characteristic of the Pennsylvanian period. The pteridosperms and sphenophylls are completely lacking; the lycopods and cordaitaleans are only weakly represented by a few questionable specimens and a single species represents the ferns.

The small number of species present in the flora stimulates even further interest when one compares the dominant forms with other Carboniferous floras—American or European—for the purpose of deriving conclusions regarding the geologic age of the Spotted Ridge formation. It soon becomes apparent that, apart from the limited composition of this assemblage, it is further unique because its dominant elements cannot be compared to any American flora of well-established stratigraphic position. The problem of the geologic age of this flora is, therefore, much more complex than it first appears and demands a reconsideration of the few identifiable species contained in the assemblage.

Read and Merriam (1940) expressed the opinion that this flora is of early Pennsylvanian age; at the same time, however, they allowed the possibility of a late Pennsylvanian age designation. This opinion was based in part on negative evidence; that is, the apparent absence from the flora of certain genera diagnostic of strata of late Pennsylvanian age. Arnold (1953, p. 67) also stated the opinion that the flora most likely represents early Pennsylvanian time.

A consideration of the geologic occurrences of those species which can be most favorably compared with the Spotted Ridge flora reveals a conflicting and rather puzzling set of circumstances, described below.

1. *Mesocalamites* is a genus that appears to be restricted to strata of Pottsville or pre-Pottsville age. Kidston and Jongmans (1917, p. 188) point out that with the exception of *M. romeri*, which is known to occur in the basal part of the European Lower Carboniferous, the species belonging to this group are characteristic of the upermost part of the Lower Carboniferous (equivalent to the American Mississippian). To this may be added the evidence of known North American occurrences, cited by Arnold (1953, p. 62–63); *Mesocalamites* has been reported from the Pottsville of Pennsylvania and West Virginia, the Canso group (lower Pennsylvanian) of Nova Scotia, and the Namurian of Greenland. On the basis of similarities of *M. hesperius* and *M. crookensis* to previously described members of this genus, then, one might readily assume a lower Pennsylvanian or even upper Mississippian age for the Spotted Ridge formation, especially if the associated floristic elements were not known.

2. Insofar as it is presently understood, primarily on the basis of detached foliage or defoliated stem fragments, the genus *Phyllotheca* has predominantly Permian or early Mesozoic stratigraphic distribution. *P. paulinensis*, however, most closely resembles *P. rallii*, a species that is known only from the Westphalian A of Turkey. Thus, the evidence of *Phyllotheca paulinensis* appears to support an early Pennsylvania age assignment for the Spotted Ridge formation.

3. *Pecopteris oregonensis* is perhaps the most enigmatic element in the flora, from the standpoint of stratigraphic significance. Although it combines features reminiscent of several European species, its overall aspect is suggestive of a closer relationship to *Pecopteris plumosa* (Kidston's *Dactylotheca plumosa*) than to any other species. This would seem to suggest Pottsville age, according to present information on North American floras; White (1900, p. 884) has reported this species from the Sewanee coal of Tennessee, and Bell (1944, p. 84) has reported it as a common element in the Cumberland group (lower Pennsylvanian) of Nova Scotia. In Great Britain, where this species is much better understood, however, it is known to range throughout the entire upper Carboniferous; and, according to Kidston (1924, p. 391), "In the Radstock Series it occurs as a common and characteristic plant." It thus appears that little confidence may be placed in *Pecopteris oregonensis* as an age indicator.

4. The presence of *Dicranophyllum* injects an element of decidedly late Pennsylvanian affinity into the Spotted Ridge flora. In the absence of satisfactory North American records of this genus, this again is largely based on the known stratigraphic occurrences of European species. In Europe *Dicranophyllum* is well known from many localities, and although several species have been reported from Permian strata, Seward (1919, p. 93) has pointed out that it is more characteristically a Stephanian (upper Pennsylvanian) genus. Read and Merriam (1940, p. 111) suggest that the presence of *Dicranophyllum* in the Oregon flora may be interpreted as indicating a mesic upland facies instead of younger age. Although such a possibility should not be denied, the great preponderance of the fern *Pecopteris oregonensis* would seem to discourage that interpretation.

The set of facts presented above impresses the present writers with the apparent futility of attempting to determine the stratigraphic position, within the Pennsylvanian, of the Spotted Ridge formation. A reliable interpretation of this paleontologic situation is doubtless hindered by imperfections in our understanding of the stratigraphic ranges of North American Paleozoic plants and their relationships with European floras and by the uniquely limited specific composition of the flora. As it now stands, however, the floristic evidence appears to weigh almost as heavily for a late Pennsylvanian age determination as for an early one. For these reasons, it is the writers' opinion that pending the discovery of more complete paleontologic evidence, the age of the Spotted Ridge formation should be designated simply as Pennsylvanian, without further speculatory qualification.

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PLATES 34–37

PLATE 34

[All figures natural size unless otherwise indicated on plate]

FIGURES 1–2. *Mesocalamites* sp. (p. 216).

1. Fragment of a mesocalamitean pith cast, containing one node. USNM 40705.

1a. Same specimen, enlarged to show the superposed ribs and convergence of the ribs toward a common point on the nodal line.

2. Fragment of a mesocalamitean pith cast, containing two nodes and one complete internode. Note the long, narrow ribs. USNM 40706.

3. *Mesocalamites hesperius* (Arnold) Mamay and Read, n. comb. (p. 215). Fragment of pith cast, shown for comparison with *Mesocalamites crookensis* Mamay and Read. USNM 40707.

4, 4a. *Mesocalamites crookensis* Mamay and Read, n. sp. (p. 215).

4. General view of the holotype. USNM 40708.

4a. Part of the holotype enlarged to show the preponderant superposition of the ribs at the nodes.

5. Two whorls of small (?) sporangia, possibly from an articulate cone. In the whorl shown at the bottom of the photograph, the faint lines opposite the sporangia are suggestive of subtending bracts. USNM 40709.

6–8. *Phyllotheca paulinensis* Mamay and Read, n. sp. (p. 216).

6. A large stem fragment, showing attachment of lateral branches and foliage. Syntype, USNM 40710.

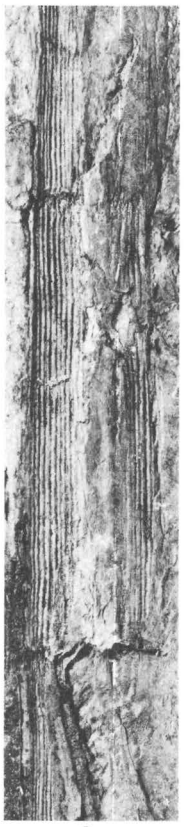
7. A stem fragment with a small lateral branch attached, showing the general attitude of the leaves. Syntype, USNM 40711.

8. A specimen with four leaf whorls; basal fusion of leaves is shown in the two lowermost whorls. Syntype, USNM 40712.

1

X 2

1a



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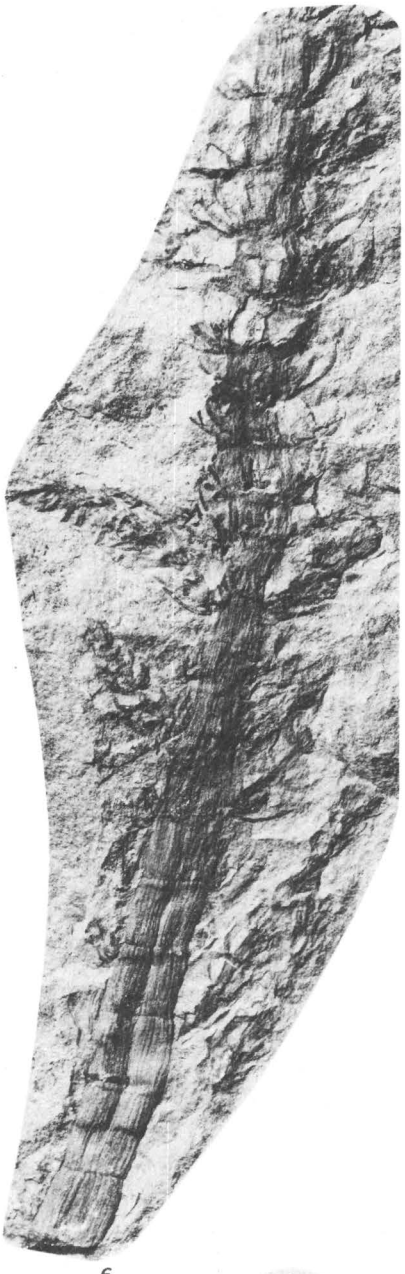
3



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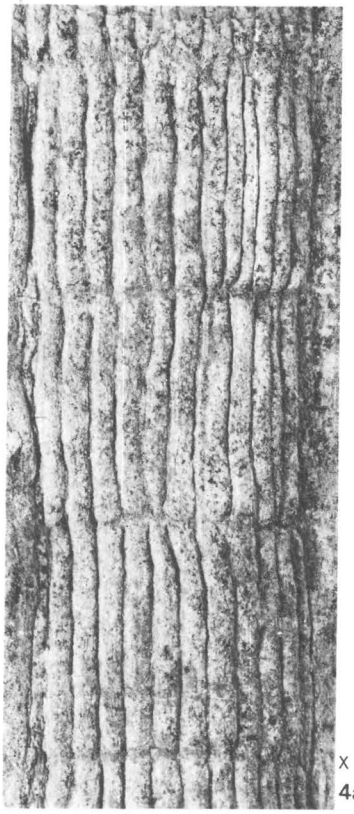


X 2

4a

5 X 8

7

8

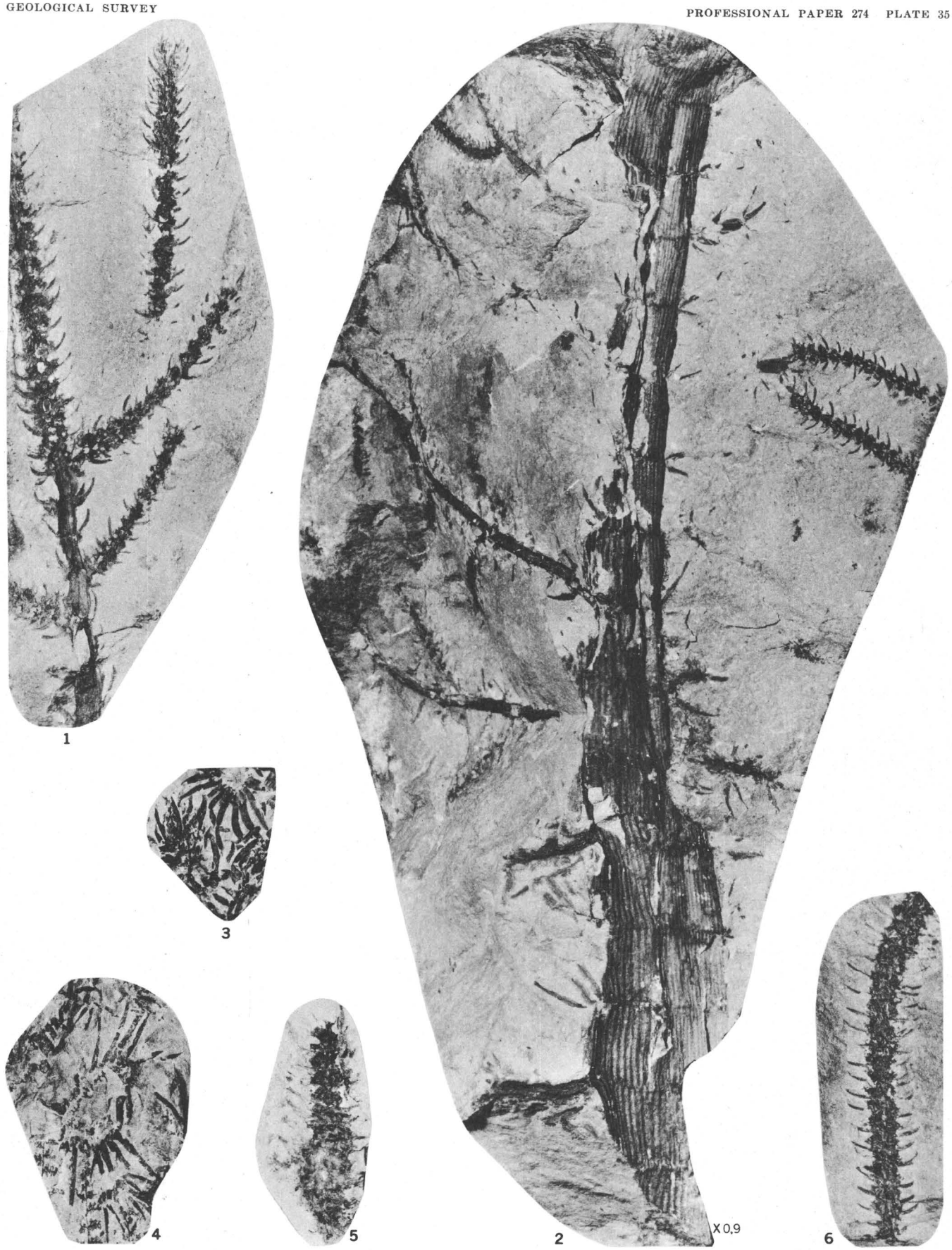
MESOCALAMITES AND *PHYLLOTHECA*

PLATE 35

[All figures natural size unless otherwise indicated on plate]

FIGURES 1–6. *Phyllotheca paulinensis* Mamay and Read, n. sp. (p. 216).

1. Fragment of an axis bearing a terminal cone and three lateral ones, with interposed sterile whorls. Syntype, USNM 40713.
2. Large fragment of a stem (slightly reduced), showing the attachment of leaves, lateral branches, and cones. The branch departing from about the middle of the left side of the axis bears three small cones. Syntype, USNM 40714.
3. Part of a foliar whorl, showing basal fusion of the leaves. Syntype, USNM 40715.
4. A foliar whorl containing parts of at least 20 leaves. Syntype, USNM 40716.
5. Fragment of an unusually thick cone. Syntype, USNM 40717.
6. An unusually long cone fragment, showing distribution and attitude of the bracts. Syntype, USNM 40718.



PHYLLOTHECA PAULINENSIS MAMAY AND READ, N. SP.

PLATE 36

[All figures natural size unless otherwise indicated on plate]

FIGURES 1–7. *Pecopteris oregonensis* Arnold (p. 219).

1. Fragment of rachis, showing surface punctations and spinelike emergences. USNM 40719.
2, 3. Specimens of sterile foliage, illustrating differences in size and shape of pinnules. Figure 2, USNM 40720; figure 3, USNM 40721.
4. Fertile specimen; laminar tissues apparently decayed before preservation, leaving only the sporangia. USNM 40722.
5, 6. Large aphlebiae. Figure 5, USNM 40723; figure 6, USNM 40724.
7. Frond fragment, illustrating the typical aspect of this species. USNM 40725.

8–9. Cf. *Schizopteris trichomanoides* Goeppert (p. 221).

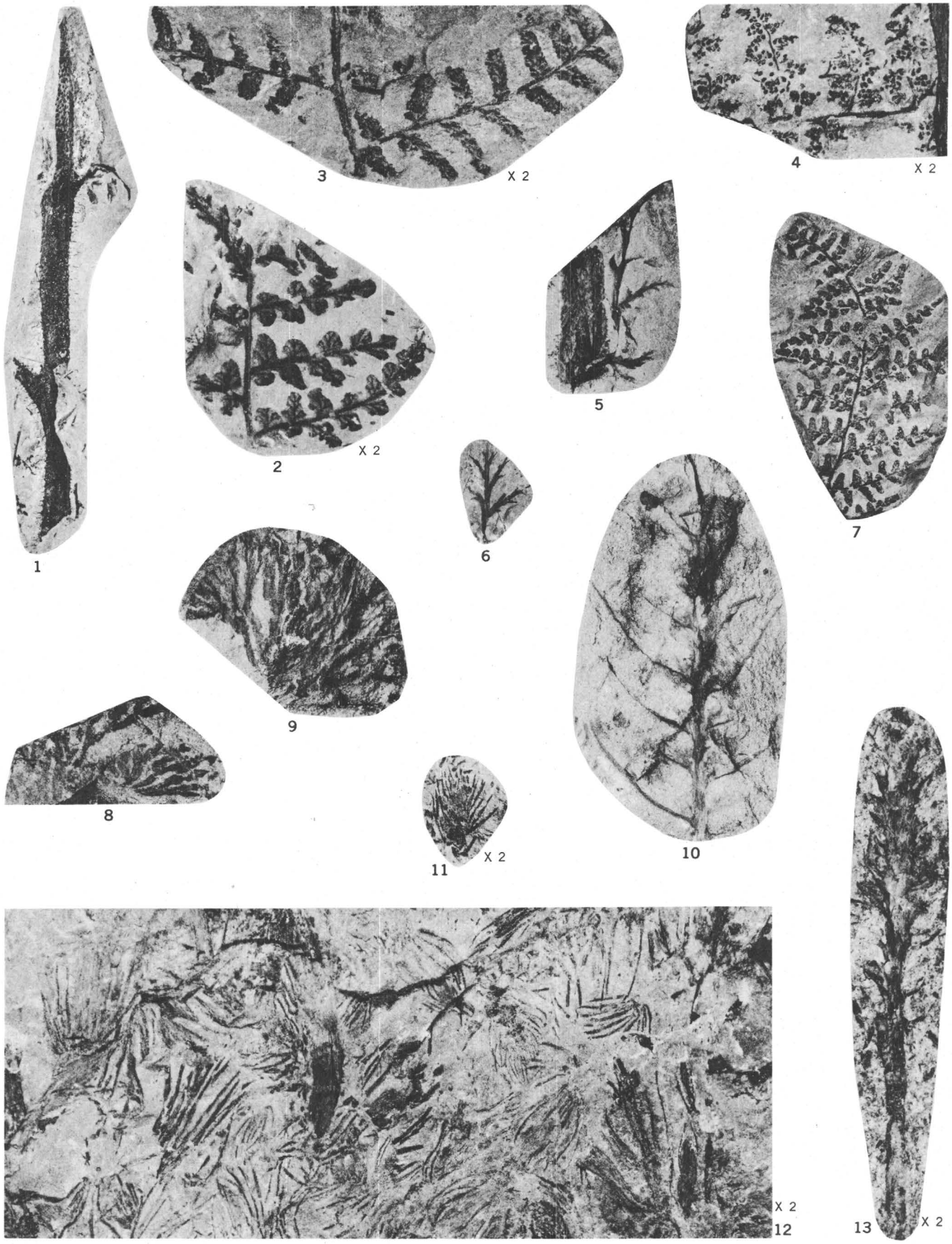
8. Specimen showing the pattern of repeated bifurcations. USNM 40726.
9. Fragment showing fanlike general outline. USNM 40726.

10. Cf. *Cordaianthus longibracteatus* Florin (p. 221).
Fragment of an axis bearing several bracts and faintly preserved axillary budlike structures. USNM 40727.

11–12. Cf. *Asterophyllites equisetiformis* Brongniart (p. 218).

11. Tip of a vegetative branch, thickly covered with young leaves. USNM 40728.
12. Rock slab bearing numerous specimens of foliage and fragments of two poorly preserved axes. USNM 40729.

13. ?Lepidodendroid branchlet (p. 214).
Slender axis bearing small leaves and showing faint surface ornamentation reminiscent of *Lepidodendron* leaf cushions. USNM 40730.



PECOPTERIS, *?SCHIZOPTERIS*, *?CORDAIANTHUS*, *ASTEROPHYLLITES*, AND ?LEPIDODENDROID BRANCHLET

PLATE 37

[All figures natural size unless otherwise indicated on plate]

FIGURES 1–2. Undetermined roots (p. 22).

1. Specimen showing the median vascular strand, longitudinal striations of the dermal layer, and circular punctations on the surface. A lateral rootlet is shown departing from the left margin of the specimen; the connection of the vascular strand of the lateral rootlet with that of the parent root is also shown. USNM40731.
2. Rock slab containing several root fragments of different sizes. USNM 40732.

3–10a. *Dicranophyllum rigidum* Mamay and Read, n. sp. (p. 219).

3. Fragment of a foliated axis, showing decurrent leaf bases. Syntype, USNM 40733.
4. Fragment of a defoliated axis, showing vertically elongated leaf cushions. Syntype, USNM 40734.
5. Fragment of a long, slender axis, bearing loosely arranged leaves. Syntype, USNM 40735.
6. Rock surface bearing two axes. The axis toward the right is densely covered with long leaves, some of which bifurcate twice toward the left. Syntype, USNM 40736.
7, 7a. Single leaf. Note the spinelike ultimate divisions, as contrasted with the longer ones shown in figures 8 and 8a. Syntype, USNM 40737.
8, 8a. Single leaf, showing twice-bifurcated lamina with four ultimate segments. Syntype, USNM 40738.
9. Tip of an axis, thickly clothed with leaves. Note the rigid aspect of the foliage. Syntype, USNM 40739.
10, 10a. Fragment of a leafy axis. Note the bifurcation of the leaves, their shortness, and their lax arrangement as compared with the specimen shown in figure 6. Syntype, USNM 40740.

UNDETERMINED ROOTS AND *DICRANOPHYLLUM RIGIDUM* MAMAY AND READ, N. SP.