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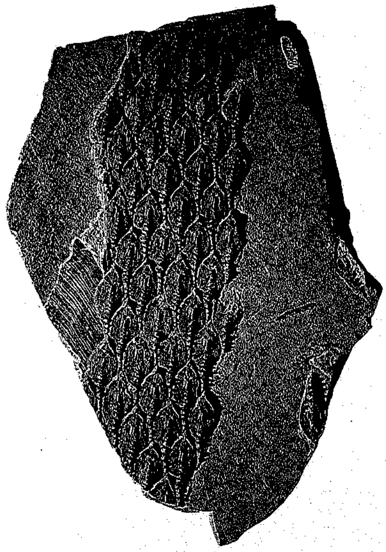

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CONTENTS

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Cover: *Lepidodendron* sp. from the Manning Canyon Shale Formation. Donated by Gary Harris to the BYU paleobotanical lab.

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Flora of Manning Canyon Shale, Part III: Sphenophyta

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ABSTRACT

Fossil sphenophyte remains commonly occur in the compression flora from the upper beds of the Manning Canyon Shale Formation in central Utah. This flora, of possible lowermost Pennsylvanian age, contains the genera and subgenera *Sphenophyllum, Archaeocalamites, Calamites ("Mesocalamites"), Asterophyllites, Annularia, Paracalamostachys,* and *Palaeostachya.*

INTRODUCTION

The diversified compression flora in the Manning Canyon Shale Formation contains many sphenophyte plant remains (table 1; Tidwell 1962, 1967). This formation, of Late Mississippian-Early Pennsylvanian age, and its equivalents are exposed in central and northern Utah, around the Uinta Mountains and southward almost to the Uncompaghre Plateau of Colorado (Sadlick 1957). As part of this flora, Tidwell (1962, 1967) reported *Calamites ("Mesocalamites") hesperius, C. ("M.") cistiiformis* Stur, *Asterophyllites equisetiformis, A. charaeformis, A. longifolius* and *Calamostachys* (?) sp. The specimens considered to be *Asterophyllites equisetiformis* and *A. charaeformis* by Tidwell (1967) are referred to another species in this paper. In addition, specimens attributed to *Tingia (T. placida)* were described. Subsequent collections of this form from the Manning Canyon Shale, however, suggest that they may not be assignable to *Tingia,* but instead represent an undescribed genus.

Additional collections of sphenophytes have been made from this formation subsequent to these reports. The sphenophyte collections contain calamitean pith casts and various genera of leaf remains and cones. This new material is described and the material obtained earlier is reconsidered. Only impressions are considered in this paper. Attempts at obtaining spores were not successful and, thus, the affinities of the cones are not definite.

PREVIOUS INVESTIGATIONS

Sphenophytes of Mississippian and Pennsylvanian age have been reported from various localities in western United States.

The oldest of these floras described by Arnold and Sadlick (1962) is the Mississippian flora of the Uinta Mountains in northeastern Utah. It contains specimens of *Archaeocalamites* that were later referred to *A. radiatus* by Lacey and Eggert (1964).

Calamitean pith casts have been noted in strata referred to the Heath and Cameron Creek Formations of central Montana (Easton 1964) and may also be Mississippian.

In the Watahomigi Formation, lowest member of the Supai Group in Grand Canyon, Arizona, an assemblage of *Walchia, Taeniopteris, Neuropteris, Cordaites,* and *Calamites* were mentioned by White (1929) and McKee (1982). Billingsley and McKee (1982) recorded a small collection of fossil plants containing five specimens of sphenophytes from the basal unit of the valley-fill deposits below the Lower Pennsylvanian Watahomigi Formation in western Grand Canyon. These deposits have been subsequently named the Surprise Canyon Formation (Billingsley and Beus 1985). The sphenophyte fragments were identified by S. H. Mamay as parts of a phyllothecoid plant and may be Mississippian in age.

Read (1934) identified *Calamites* sp. and *Asterophyllites longifolius* (Stnb.) Brongniart from the Lower Pennsylvanian Belden Shale in the Mosquito Range near Leadville, Colorado. Gould (1935) mentioned *Calamites* and *Lepidodendron* from the Coffman Conglomerate Member of the Maroon Formation of Colorado that he tentatively dated as Pennsylvanian. Arnold (1941) reported *Asterophyllites charaeformis* (Stnb.) Goeppert from the Arkansas River Canyon at Wellsville, Colorado, and *Calamites gigas* Brongniart from the Maroon Formation near Trout Creek Pass of Colorado. Furthermore,

Table 1. Sphenophytic species in the Upper Manning Canyon Shale flora.

Sphenophyllum stclairii[R] sp. nov.
Archaeocalamites radiatus[C] (Brongt.) Stur
Calamites ("Mesocalamites") roemeri[A] Geoppert
Calamites ("Mesocalamites") cistiiformis[A] Stur
Calamites ("Mesocalamites") cf. *ramifer*[R] Stur
Calamites semicircularis[C] Weiss
Calamites[R] sp.
Asterophyllites unguis[A] Jongmans and Gothan
Asterophyllites longifolius[A] (Stnb.) Brongniart
Annularia subradiata[R] Stockmans and Williere
cf. *Paracalamostachys* sp.[R]
Palaeostachya maglonniensis[R] (Stockmans and Williere) comb. nov.

A = abundant
C = common
R = rare

Arnold (1956) described *Calamites huerfanoensis,* based on material from the Upper Pennsylvanian Sangre de Cristo Formation of south central Colorado.

Calamites (Mesocalamites) hesperius Arnold, *Calamites (M.) crookensis* (Mamay and Read) Boureau, *Asterophyllites equisetiformis* (Schl.) Brongniart, *Calamites (Mesocalamites)* sp. and *Phyllotheca paulensis* Mamay and Read have been recorded from the Pennsylvanian Spotted Ridge flora of central Oregon (Arnold 1953, Mamay and Read 1956). *Calamites cisti* Brongniart, *C. distachyus* Sternberg, and *C. cruciatus* Sternberg are present in the flora of the Fountain Formation in Colorado (Jennings 1980).

STRATIGRAPHY AND COLLECTING LOCALITIES

The Manning Canyon Shale Formation is predominately shale with interbedded limestone, orthoquartzic sandstone, and some siltstone. The lower portion of the formation consists primarily of shale with some limestone and quartzite, whereas the upper half is predominately quartzose sandstone with shale and limestone interbeds.

According to Welsh and Bissell (1979), the Manning Canyon Shale was deposited in mixed deltaic, estuarine, and nearshore marine environments. In contrast to the Diamond Peak–Chainman flysch, which filled in the Antler foreland basin west of the Great Blue carbonate bank, the Manning Canyon Shale Formation represents clastics that prograded westward from the Doughnut trough across the interior of the Chesterian carbonate bank. These clastic sediments terminated the Upper Mississippian carbonate bank in Utah with near sea-level swamps. Typical luxuriant Mississippian-Pennsylvanian floras then developed, grew, and died in the quiet waters of these coastal swamps. Climate was fairly uniform, generally warm, moist, and wet—possibly subtropical. Flooding would silt up and choke the swamps in addition to diluting swamp water, thus aerating, oxygenating, and accelerating plant decay. Stable, nearshore, uniform environments existed during development of these swamps.

The plants in the upper portion of the Manning Canyon Shale appear to have been deposited near their place of growth. On shale surfaces that were examined, plant remains have an apparently random distribution, although an occasional layer shows a weak current lineation (Tidwell 1962). Further evidence of their lack of long-distance transport is provided by the many large fronds that have been collected, *Stigmaria* that has been found with rootlets attached, and *Calamites* that retains tufts of leaves and cones intact (figs. 34, 43).

The Manning Canyon Shale flora represents the most diversified flora of Carboniferous age presently known in western North America. Plant fossils from this formation consist of stem impressions, portions of fronds, isolated seeds, and other disassociated plant remains. As presently understood, it contains 43 genera and 103 species (Tidwell 1967, Tidwell and others 1974, Webster and others 1984).

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

The specimens of sphenophytes in this report were collected from clay pits in the Manning Canyon Shale Formation on Lake and Traverse Mountains as noted previously by Tidwell (1962, 1967). They are located (1) on Lake Mountain near Pelican Point about 13 mi (22 km) southwest of Lehi in the SE 1/4, section 12, and NE 1/4, section 13, T. 7 S, R. 1 W, and the SW 1/4, section 7, T. 7 S, R. 1 E, Utah County, Utah (Soldier's Pass Quadrangle); (2) on Lake Mountain near Burnt Canyon in the NE 1/4, section 3, T. 6 S, R. 1 W, Utah County, Utah (Saratoga Springs Quadrangle); and (3) on Traverse Mountain in section 9, T. 5 S, R. 1 W, Utah County, Utah (Jordan Narrows Quadrangle).

SYSTEMATIC PALEOBOTANY

Order Sphenophyllales
Genus *Sphenophyllum* Brongniart

According to Crookall (1969), *Sphenophyllum* was a small plant, rarely exceeding one meter in height and one centimeter in diameter. Although species of *Sphenophyl-*

lum were important in floras of Carboniferous age, they are not common in the Manning Canyon Shale Formation. Leaves of *Sphenophyllum* are usually broad, often divided, and their veins bifurcated. *Sphenophyllum tenerrimum* has rather filamentous and segmented leaves of only one type. However, most other *Sphenophyllum* species are heterophyllous, having one leaf type that is entire and another that is more or less divided. These leaf types may both occur on the same branch of the plant.

Sphenophyllum stclairii sp. nov.
figs. 1, 2, 3

Description. Stem 1.5–2.0 mm broad, jointed, internodes up to 1.2 cm long, internodes very long compared to axil width, distinctly ribbed, most passing through rather than alternating at nodes; nodes slightly enlarged; leaves narrowly wedge shaped, of nearly equal length near base of axis, 10–12 mm long, 1.0–2.0 mm wide near apex, very small at point of attachment, 6–8 (generally 6) per whorl, spread out and upward, generally divided by shallow angular sinus into two more or less equal, obtusely pointed lobes or teeth, lateral margins straight or slightly concave; single vein at base, divides at moderate angle 3/4 distance to apex, each branch vein entering a tooth.

Etymology. This species is named in honor of Dr. Larry St. Clair of the Department of Botany and Range Science, Brigham Young University, for his continued support of this study.

Locality. Manning Canyon Shale Formation; "clay pits" on Lake Mountain about 13 miles southwest of Lehi, Utah (Tidwell 1967).

Holotype. BYU 3163, Paratype: BYU 3170.

Discussion. Sphenophyllum stclairii is somewhat similar to the heterophyllous leaf forms of *S. cuneifolium* Sternberg that are divided into two lobes (forma *saxifragaefolium* and forma *amplum* Kidston). However, the majority of the leaves of *S. cuneifolium* are entire and broadly wedge shaped.

Sphenophyllum lescurianum White, *S. fasciculatum* (Lesq.), and the divided leaf form of *S. angustifolium* Germar are close to *S. stclairii*. They differ from *S. stclairii* in that, although they have bilobed leaves near their apices, their leaves become 3–4 lobed in the lower parts of their axes. This condition has not been observed in *S. stclairii*.

Another form similar to *S. stclairii* is *S. sublaurae*, which was first described by Purkynova (1970) from the Namurian A of Czechoslovakia. This latter species differs from *S. laurae* Jongmans by its smaller size and from *S. stclairii* by its cuniform leaves being cut by a median incision with each of the two resulting segments being further subdivided into two teeth.

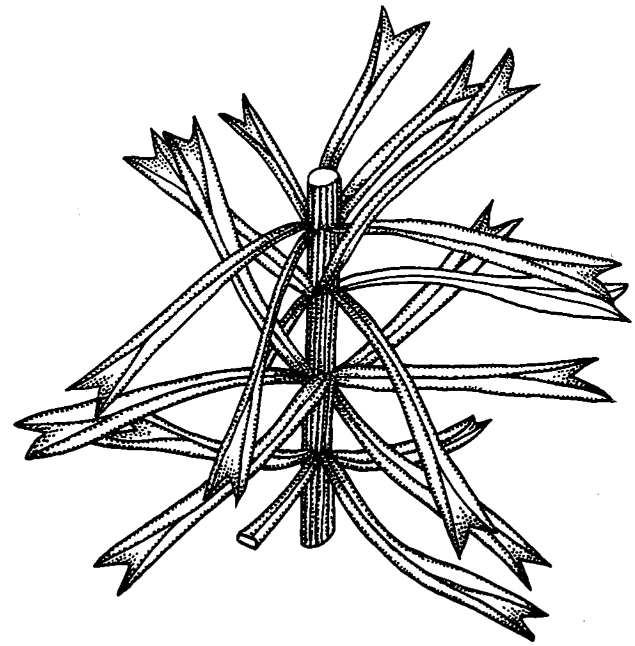


FIGURE 1.—*A reconstruction of a portion of* Sphenophyllum stclairii *sp. nov.*

Order Equisetales
Genus *Archaeocalamites* Stur
Archaeocalamites radiatus (Brongt.) Stur
figs. 4, 5, 6, 7

Calamites radiatus Brongniart 1828. Prod. d'Hist. vég. foss. I:122, pl. 26, figs. 1, 2.
Archaeocalamites radiatus (Brongt.) Stur 1875. Culmflora I, Abh. k. k. Geol. Reichsanst. 8, pl. 1, fig. 308, pl. 2, 3, 4; pl. 5, figs. 1, 2; Boureau 1964, Traité Paléob. III:209, figs. 186, 187, 188; Tidwell 1967, Brigham Young Univ. Geol. Studies 14:23–28, pl. 8, fig. 9.

Discussion. Leaf impressions assignable to *Archaeocalamites* occur infrequently in the Manning Canyon Shale. Incomplete specimens up to 8 cm long that divide into 3 or 4 more or less even dichotomies have been collected. The distance between dichotomies ranges from slightly less than 1 cm to over 2 cm. *Archaeocalamites radiatus* is the only species of *Archaeocalamites* from which the leaf-bearing shoots are known. The division of the leaves by repeated bifurcations is contrary to the general leaf types found in the Equisetales. Both the undivided part of the archaeocalamitean leaf and its segments are extremely narrow, more or less filiform. Halle (1925) points out that the leaves of this species are given off in great numbers in radially symmetrical nodes. They are ascending or slightly spreading, attaining lengths of up to 12 cm or more. They regularly bifurcate into two similar halves with the entire leaf having a uniform appearance. Halle (1925) states that the branching of this species is sparse, and its lateral shoots are finely divided.

The evolution of dichotomizing leaf types similar to *Archaeocalamites* is a progressive reduction in the number of dichotomies from a number of divisions in the leaves of *Archaeocalamites* to two in *Dichophyllites* and eventually one in both *Sphenasterophyllites* (division near middle) and *Autophyllites* (division near apex) (Boureau 1964). At the same time, examination of individual specimens of *Archaeocalamites* reveals a progressive reduction in the numbers of dichotomies distally. Thus, a single specimen may exhibit all of these forms of foliage. In the archaeocalamitean specimens from the Manning Canyon Shale, the considerable variation in the number of dichotomies illustrates this. Furthermore, it should be noted that the specimens from the Manning Canyon Formation lie very near the top of the stratigraphic range of *Archaeocalamites*. The many dichotomies of some leaves indicate the absence of a trend toward a reduction in their number. At the same time it should be noted that specimens with no dichotomies (*Asterophyllites*) coexisted with them.

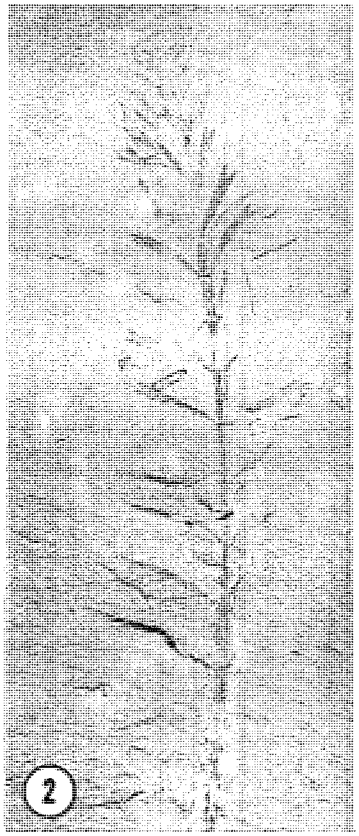
Range. Archaeocalamites radiatus has been reported from the Lower Carboniferous up into Namurian A. The upper range of this species was mistakenly given as Westphalian A in Tidwell (1967, p. 18) and Webster and others (1984, p. 415).

Figured specimens. BYU 3164, 3165, 3172, 3173.

Genus *Calamites* Suckow

Taxa based on pith casts and impressions are defined upon the arrangement of the primary bundles through the nodes. Two genera and one informal subgenus of compressions, defined according to whether the ribs were believed to alternate or to pass directly through the nodes, have been reported from the Manning Canyon Shale (Tidwell 1967, 1975). Specimens in which all the ribs alternate were assigned to *Calamites;* those with some ribs passing directly through the nodes and some ribs alternating were assigned to the genus or subgenus "*Mesocalamites*" and those with all their ribs passing directly through the nodes were termed *Archaeocalamites*. All calamitean stems, however, exhibit to some extent

FIGURES 2, 3.—Sphenophyllum stclairii *sp. nov., 2, X1.0 (Holotype BYU 3163); 3, X1.0 (paratype BYU 3170).*
FIGURES 4, 5, 6, 7.—Archaeocalamites radiatus *(Brongt.) Stur, 4, axis illustrating ribs passing through the nodes, X1.0 (BYU 3172); 5, axis having leaves attached at a node, X0.5 (BYU 3173); 6, axis with leaves attached at four nodes, X1.0 (BYU 3165); 7, leaf showing dichotomies typical of this species, X1.0 (BYU 3164).*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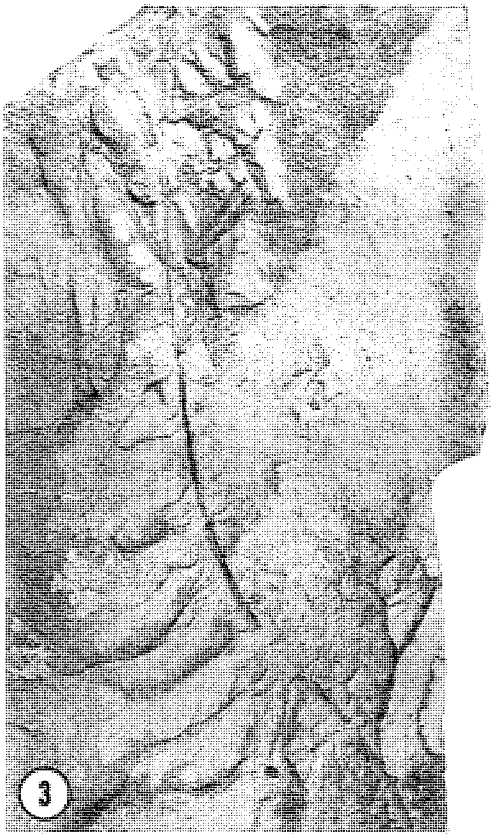
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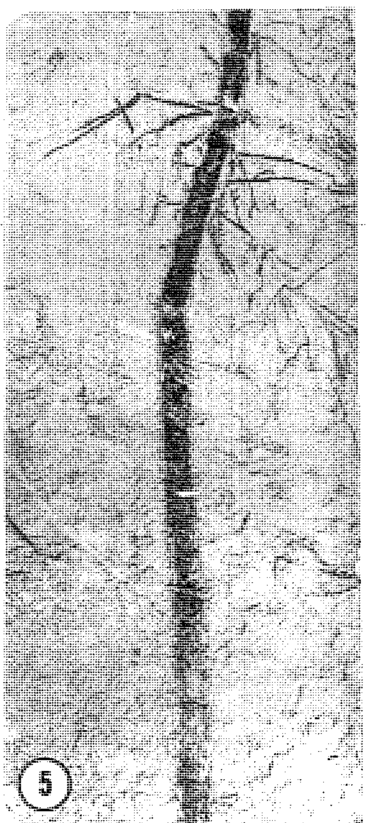
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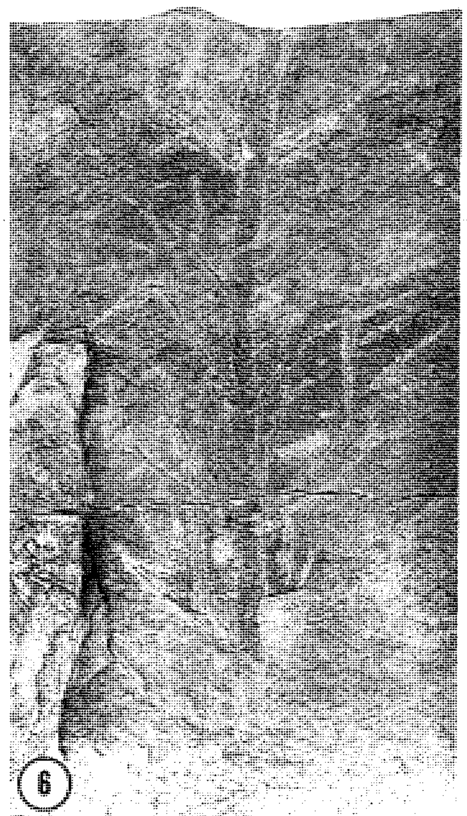
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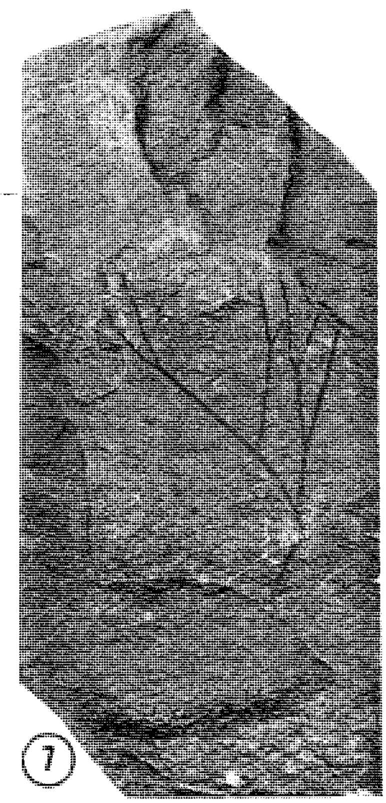
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both alternation and nonalternation. This comes about as a result of the fact that the number of vascular bundles in the plants changes distally. As long as the number of vascular bundles distal to a node is not the same as that below, neither consistent alternation nor nonalternation is possible.

In their study of a petrifaction that they assigned to *Archaeocalamites*, Smoot and others (1982) also considered the use of vascular bundle arrangement as the only generic character in classifying fossil sphenophytes as a questionable practice and thought it should be abandoned. Furthermore, they thought that the three genera of *Calamites* related to petrified material cannot be distinguished except on an anatomical basis. However, Good's (1975) investigations have called even the supposed distinction between the genera *Calamodendron* and *Arthroxylon*, whose stems are anatomically preserved, into question. The concept that a single form of stem is sometimes associated with several cone forms, and the fact that several species based on stems can probably be referred to plants with a single calamitean cone type, suggest that established structurally preserved stem taxa are, for the most part, of relatively little value in plant systematics (Good 1975). The accepted or "unaccepted" criteria for "valid" species of *Calamites* in casts are probably entirely arbitrary and should be taken in a pragmatic sense (Darrah 1969).

Both morphologically and stratigraphically, stems placed in the genus or subgenus *"Mesocalamites"* appear to be intermediate between *Archaeocalamites* and *Calamites*. Based upon the lack of consistency of the stem and other organs, it is clear that *"Mesocalamites"* does not constitute a true systematic entity. We have, however, retained *"Mesocalamites"* as an informal designation for pith casts that illustrate its form.

Calamites ("Mesocalamites") roemeri Goeppert
figs. 15, 16, 17, 18

Calamites (Mesocalamites) hesperius Arnold, Tidwell 1967, Brigham Young Univ. Geol. Studies 14:24.

Description. Internodes from 3 to 4 cm wide and from 3 to 7 (usually 5) cm long; internodes generally longer than broad, sometimes broader than long; ribs approximately 1 mm across on longer forms, straight or flexuous, mostly straight, alternating or passing straight through nodes, forming sharp angles or more commonly rounded at nodes; furrows straight, broad; tubercles oval, large, 1 mm across, at upper ends of ribs.

Discussion. Calamites ("M.") roemeri is represented by pith cast compressions generally without branch scars. Specimens of this species were originally placed in *Calamites ("M.") hesperius* Arnold (Tidwell 1967). However, specimens in subsequent collections from the Manning Canyon Shale show notable differences between the two. The internodes of the Manning Canyon Shale specimens of *C. ("M.") roemeri* are usually longer than broad, sometimes two times longer, as compared to broader than long in *C. ("M.") hesperius*. This is somewhat out of character for *C. ("M.") roemeri*, as well. The other characteristics of this species, however, are the same as in these specimens, and the internodes of *C. ("M.") roemeri* can also be longer than wide (Crookall 1969). The ribs are broader and form more acute angles at the nodes in *C. ("M.") hesperius* than in *C. ("M.") roemeri*.

Calamites ("M.") roemeri is very close to *C. ("M.") hesperius*. They may, in fact, represent the same taxon.

Figured specimens. BYU 3166, 3168, 3171, 3177.

Calamites ("Mesocalamites") cistiiformis Stur
figs. 8, 9

Calamites cistiiformis Stur 1887, Culmflora, II, Abh k. k. Geol. Reichsanst. 8(2):200; pl. 4, fig. 5, 6; Jongmans 1915, Foss. Cat., II(5):243–244. Kidston et Jongmans 1917, A monograph, 1:192–195.

Mesocalamites cistiiformis, Hirmer 1922, Handb. Paläob. I:382.

Calamites (Mesocalamites) cistiiformis, Boureau 1964, Traité Paléob. III:245; Tidwell 1967, Brigham Young Univ. Geol. Studies 14:26, pl. 9, figs. 10, 11.

Discussion. The internodes of *Calamites ("M.") cistiiformis* are typically markedly longer than broad, but there is considerable variation in this character. Its ribs are straight, alternating, or passing through the nodes. Furrows in this species terminate in rounded points, and ribs attain widths of 1 mm. Tubercules are distinct. Branch scars are generally lacking in our specimens.

Although *C. ("M.") cisti* and *C. ("M.") cistiiformis* are very similar, nonalternation of some ribs in *C. ("M.") cistiiformis* separates it from *C. cisti*.

Many of the specimens from the Manning Canyon Shale, attributable to *C. ("M.") cistiiformis*, are nearly identical to the specimen of *Calamites* sp. illustrated by Mamay and Read (1956) as pl. 34, fig. 2, from the Spotted Ridge Formation of Oregon.

Range. Boureau (1964) reported *Calamites ("M.") cistiiformis* from the Namurian, and absent in the Westphalian A, of Great Britain, Holland, Belgium, and from the Ruhr to Asia Minor, thus agreeing with Gothan, Leggewie, and Schonefeld (1959). Kidston and Jongmans (1917) reported this species from the Carboniferous of Austria, Germany, Great Britian, The Netherlands, and Asia Minor. Bell (1944) recorded this species from the Canso Formation of Namurian A age of Nova Scotia. It also occurs in the latest Mississippian of the Illinois Basin (Jennings and Fraunfelter 1986).

Figured specimens. BYU 3167, 3176.

Calamites ("Mesocalamites") cf. *ramifer* Stur
fig. 14

Discussion. Ribs of this species are generally about 1 mm across but can be up to 2.5 mm wide in larger specimens. The ribs are either straight or flexuous and either alternating or passing straight through the node. Ovoid tubercles about 2 mm in diameter occur at the upper ends of ribs. Nodes generally bear from 1–5 oval or subcircular branch scars that measure 4–5 mm across.

Calamites ("M.") ramifer is similar to *C. ("M.") roemeri* Goeppert. In *C. ("M.") roemeri*, the ribs are always straight and have a distinct narrow central furrow, whereas the ribs of *C. ("M.") ramifer* are either straight or flexuous, and the latter species lacks a central furrow. Further, the branch scars of *C. ("M.") roemeri* are verticillate and about 1 cm in diameter. *Calamites ("Mesocalamites") ramifer* has from 1–5 branch scars at each node, and they are only about 4–5 mm across.

Lesquereux (1879) included two distinct species from the coal flora of Pennsylvanian under the name of *C. ramifer*. Crookall (1969), however, considered them to be a form of *C. carinatus* Sternberg.

Range. Syntypes of *C. ("M.") ramifer* are from the Namurian of Austria. This species is rare in Britain, occurring only in the Upper Limestone Group (Namurian) of the Carboniferous Limestone Series of Scotland (Crookall 1969).

Figured specimen. BYU 3169.

Calamites semicircularis Weiss
figs. 19, 20

Calamites semicircularis Weiss, Kidston and Jongmans 1917, A monograph. I:44–49, pl. 40, fig. 4; Crookall 1969, Mem. Geol. Surv. Gr. Brit. Palaeont. IV(5):676, pl. 138, fig. 2; pl. 142, fig. 1.

Calamites (Calamitina) semicircularis Boureau 1964, Traité Paléob. III:289.

Discussion. The specimens from Lake and Traverse Mountains localities are stem surface impressions, rather than pith casts. Internodes in this species vary greatly in length. The internodal dimensions of the specimens in this flora vary from 22–58 mm in length by 30–45 mm in width. The whorled branch scars are irregularly placed and are separated laterally by 8 mm. The scars are placed below the nodal line, causing the nodal line to be displaced upward. Branch scars are usually subcircular, subtriangular, or oval in shape and variable in size (7–20 mm wide by 5–23 mm high). Umbilici, where preserved, are generally only a little above the center of the branch scar. Ribs on pith casts are straight with their angle at the nodes being obscure.

The branch scars in *C. semicircularis* differ from those in the closely related species *C. wedekindi*. In the former species, the scars are generally semicircular, subtriangular, or subcordate, are of variable size and position, and they lack the inner circular furrows. In *C. wedekindi* they are oval, fairly constant in size, generally contiguous, and, when preserved, their umbilici are surrounded by a furrow.

Range. This species is reported rare from the Lanarkian (Namurian) and Westphalian of Britain and from Westphalian A and B of Germany, The Netherlands, and Belgium (Crookall 1969, Kidston and Jongmans 1917).

Figured specimens. BYU 3184, 3190.

Calamites sp.
figs. 10, 11, 12, 13

Three specimens from the Manning Canyon Shale are simply referred to *Calamites* sp. and appear to represent rhizomes.

The specimen shown in figure 10 has internodes that are about the same in both length and width. The internodes are only slightly variable, measuring 15–20 mm.

The specimen illustrated in figure 11 is somewhat larger and has internodal lengths of 20–30 mm. There are branch scars at some nodes, and though they are somewhat variable, they are nearly circular in outline. A central circatrix is present surrounded by radiating ridges.

The specimen illustrated in figures 12–13 is particularly interesting. Roots diverge from each node, and many branches are present on the same bedding plane. Some of these branches look as if they may be attached to the large, root-bearing axis. The smaller branches are themselves branched and bear leaves of the *Asterophyllites unguis* type.

Figured specimens. 3162 (fig. 12), 3186 (fig. 10), 3188 (fig. 11).

Genus *Asterophyllites* Brongniart
Asterophyllites unguis Jongmans and Gothan
figs. 23, 24, 25, 26, 27, 28, 29, 30

Asterophyllites unguis Jongmans and Gothan 1925, Fossiele Planten. Meded. 1:67, pl. 10, figs. 2–8.

Asterophyllites charaeformis (Stnb.) Goeppert, Tidwell 1967, Brigham Young Univ. Geol. Studies, 14:27, pl. 9, fig. 1.

Asterophyllites sp. A. Tidwell 1962, Brigham Young Univ. Geol. Studies, 9(2): 98, pl. 4, figs. 6, 8.

Asterophyllites equisetiformis (Schl.) Brongniart, Tidwell 1967, Brigham Young Univ. Geol. Studies, 14:27, pl. 4, fig. 1; pl. 9, fig. 2.

Discussion. Axes with branches bearing whorls of leaves similar to those assigned to *A. unguis* by Jongmans and Gothan (1925) are common in the Manning Canyon Shale flora. Some of the leaves in these specimens lie in the same plane as the branches and some do not. Leafy branches of the first order have internodes 2.3 cm long by 1.5 to 2.0 cm wide and give rise to branches of the second order. Branches of the last order originate from branches of the second order. These branches often occur in the axil of the larger leaves. The long leaves on these branches are linear, somewhat spreading, and are about the same length as the internodes. The branches of the last order have internodes that are 2–8 mm long by .25–.5 mm wide and bear whorls of leaves. Leaves are 2–5 mm long, filiform, uninerved, often but not always curving upward in upper half toward the axis with 8–10 leaves per whorl.

Leaf whorls on some of the larger specimens of *A. unguis* in the Manning Canyon Shale, when compressed in the right plane, have the form of *Phyllotheca*. *Phyllotheca paulinensis* Mamay and Read from the Spotted Ridge Formation of Oregon is the closest species geographically and in age to *A. unguis*. They differ from each other in the larger size, different branching pattern, and the bending of the leaf tips to form a shallow saucerlike whorl in *P. paulinensis* that was not observed in the Manning Canyon specimens. No cones attributable to the latter specimens have been, as yet, collected.

In the Ruhr of Germany, *A. unguis* has been found associated with *Calamostachys bosselensis* Leggewie and Schonefeld and *Calamites ("M.") haueri* Stur; neither of these latter forms have been collected in this flora.

Range. Asterophyllites unguis has been reported from the Namurian B and C (Boureau 1964).

Figured specimens. BYU 3161, 3181, 3182, 3183.

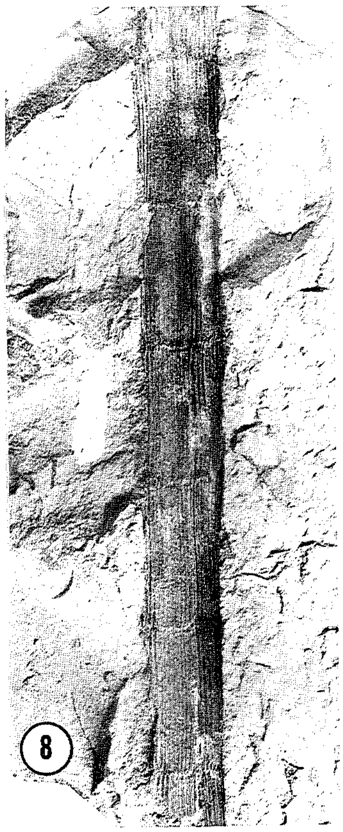
Asterophyllites longifolius (Stnb.) Brongniart
figs. 21, 22

Bruckmannia longifolia Sternberg 1825, Versuch der Flora der Vorwelt, 1(4):45, pl. 59, fig. 1.

Asterophyllites longifolius (Stnb.) Brongniart 1828, Prod. d'Hist. veg. foss. I:159–176. Lesquereux 1880, Coal Flora, 2nd Geol. Surv. Pennsylvanian Rpt. of Prog. P., I:36; Abbott 1958, Bull. Amer. Paleont., 38(174):303, pl. 40, fig. 53; pl. 42, fig. 60; chart I; Tidwell 1962, Brigham Young Univ. Geol. Studies, 9(2):98, pl. 4, fig. 7; Tidwell 1967, Brigham Young Univ. Geol. Studies, 14:27, pl. 4, fig. 6.

FIGURES 8, 9.—Calamites ("Mesocalamites") cistiiformis *Stur., 8, X0.5 (BYU 3167); 9, X1.0 (BYU 3176).*

FIGURES 10, 11, 12, 13.—Calamites *sp., 10, appears to be a rhizome with an attached branch, X1.0 (BYU 3186); 11, possible rhizome, note branch scar, X1.0 (BYU 3188); 12, rhizome(?) with roots attached (left) and possible branches (right), X0.5 (BYU 3162); 13, enlargement of figure 12, X1.0.*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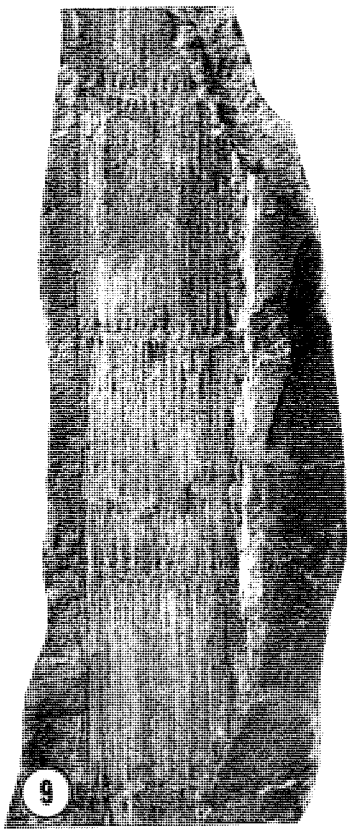
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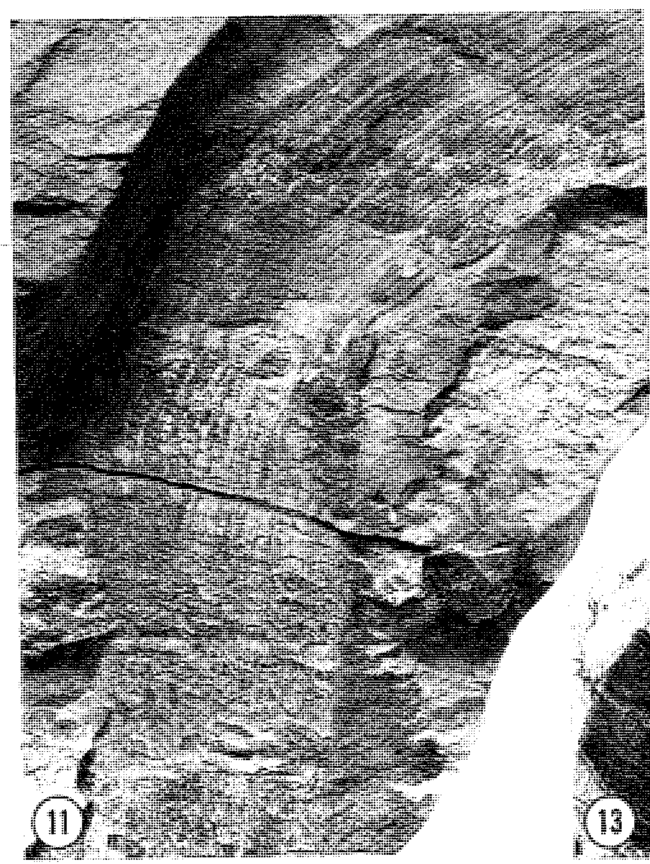
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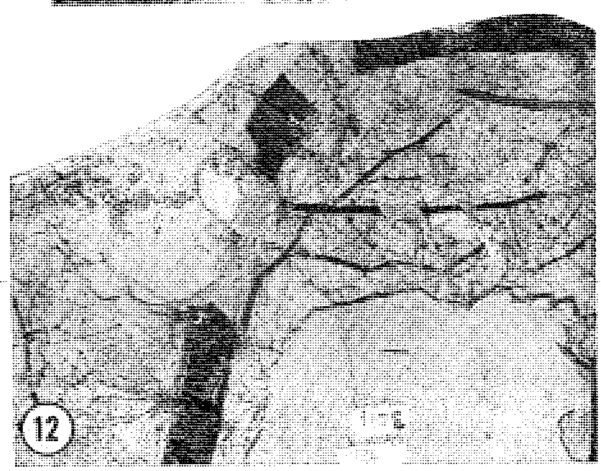
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Discussion. Asterophyllites longifolius is common in the flora from the Manning Canyon Shale. The axes in the Manning Canyon Shale flora with *A. longifolius* attached are small compressions (3–4 mm wide) with relatively smooth outer surfaces. Longitudinally, these outer surfaces are finely striated. The internode length of these axes measures .9–2.0 cm long. European specimens indicate that ribs are broad and pass mostly through the nodes, that furrows are wide, and that branch and cone scars occur on the nodal line. The foliage is verticillate, single veined, and setaceous. The leaves on the Manning Canyon Shale specimens are similar to those reported for *Calamites jubatus* Lindley and Hutton in Europe (up to 18 cm) but are shorter (4–5 cm). They both maintain an almost upright position, spreading gently outward like a fan near the top of the stem and extending beyond it.

Range. The age range of *Asterophyllites longifolius* is Pottsville to Upper Allegheny in America (Abbott 1958) and even pre-Pottsville beds. In Europe, it occurs in Westphalian A-C of Great Britain (Crookall 1969) and the Namurian of Belgium (Stockmans and Willière 1952–53).

Figured specimens. BYU 3174, 3180.

Annularia subradiata Stockmans and Williere
figs. 24, 32

Annularia subradiata Stockmans and Willière 1953. Publ. Assoc. Étud. Paléont. et Strat. Houillères No. 13, Texte (1953):176, Atlas (1952), pl. 26, fig. 9–9a.

Discussion. Specimens of this species are rare in the Manning Canyon Shale and consist of 9 to 12 leaves per whorl. The leaves vary from 6 to 8 mm in length and are slightly fused at their bases. The internodal length between leaf whorls is from 5 to 7 mm.

This species is similar to *Annularia microphylla* Sauveur, but the latter species has more than 9 leaves per whorl. *Annularia subradiata* is also close to *A. galioides* (L & H) Kidston, but the wider expansion toward the apices of the leaves of *A. galioides* are more pronounced than in *A. subradiata.*

Annularia subradiata has been reported in association with *Calamostachys laxa* Stockmans and Willière and *Calamites ("M.") ramifer* (Boureau 1964).

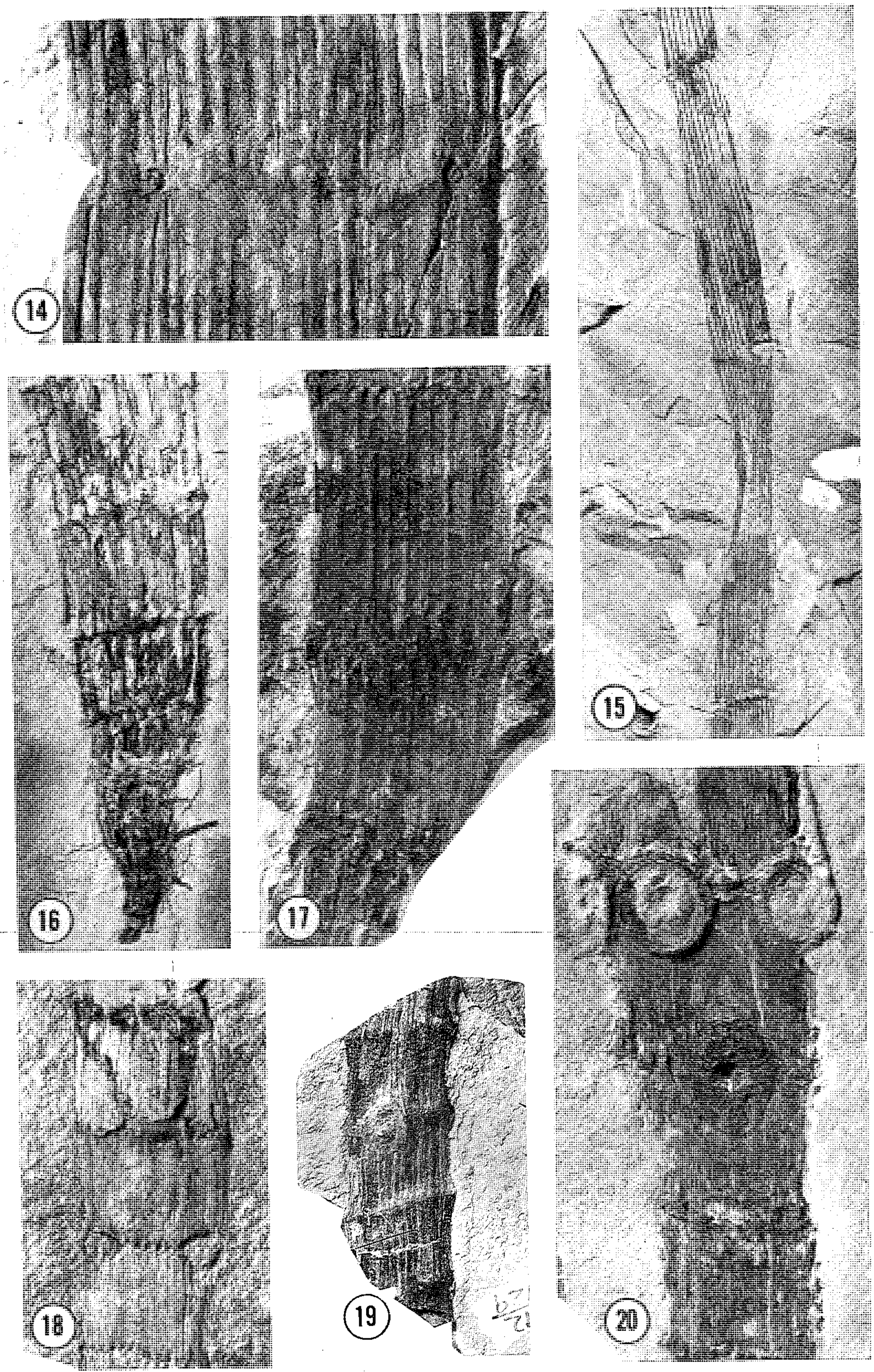
Range. This species has been reported from the Namurian into the Westphalian (Boureau 1964).

Figured specimen. BYU 3175, 3185.

FIGURE 14.—Calamites ("Mesocalamites") *cf.* ramifer *Stur, node with two branch scars. Note ribs converging on scars, X1.0 (BYU 3169).*

FIGURES 15, 16, 17, 18.—Calamites roemeri *Goeppert, 15, axis showing three nodes with long internodes, X0.5 (BYU 3171); 16, specimen of a base of an axis showing how the internodes are shorter near the base and elongate upward, X1.0 (BYU 3168); 17, specimen with three nodes, X1.0 (BYU 3166); 18, note the leaf and branch scars, X1.0 (BYU 3177).*

FIGURES 19, 20.—Calamites semicircularis *Weiss, 19, X1.0 (BYU 3178); 20, axis with branch scars at two nodes, X1.0 (BYU 3190).*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Genus *Paracalamostachys* Weiss
cf. *Paracalamostachys* sp.

Discussion. An incomplete specimen assigned to *Calamostachys* was described and illustrated by Tidwell (1967). This is reassigned to the genus *Paracalamostachys* Weiss, because the position of the sporangiophores is obscure. It is possible that it is equivalent to better preserved material identified as *Paleostachya.*

Specimen number. USNM 42885 (see Tidwell 1967, p. 28).

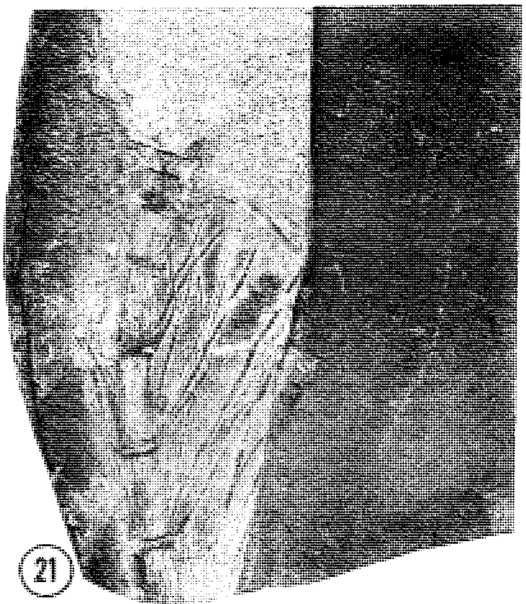
Palaeostachya maglonniensis (Stockmans and Willière) comb. nov.
figs. 33, 34, 35, 36

Calamostachys paniculatus Bureau (*non* Weiss) 1914, Étud. Gîtes Min. de la France, Bassin de la Basse Loire II:230–231, pl. 68, figs. 2–4.
Calamostachys williamsonia Stockmans and Willière (*non* Weiss), 1953, Publ. Assoc. Étud. Paléont. et Strat. Houillères No. 13, Texte (1953):186–187, Atlas (1952), pl. 40, figs, 2–3; pl. 46, figs. 11–15.

Description. Axis 8.5 mm wide, outer surface with longitudinal striations; pith casts 6.5 mm wide, with internodes 2.8–3.5 cm long; ribs straight, .75 mm wide, sharp; 6 whorled branches at each node; 14–21 leaves subtending branches; leaves 17 mm long; nodes constricted; cones produced in whorls on axis 1.2 mm in width at intervals of .3–1 cm; cylindrical stalk up to 1.25 mm long; cones 2.2–3.5 cm long, 3–5 mm broad; cone axes faintly striated longitudinally, .3–.5 mm across, internodes 1–2 mm long, bearing alternate whorls of sterile bracts and sporangiophores; 6–10 sterile bracts per whorl, bracts linear, 2.5–7 (ave. 4) mm long, .1–.25 mm broad; sporangiophores given off at angle to bracts, each appears to bear 4 ovoid sporangia, sporangia measure about 1 mm across. No spores preserved.

Discussion. The major difference between this specimen of *Palaeostachya* and previously described forms is the lack of a long stalk on these cones. They are essentially sessile in their attachment. The upper portions of these cones are either sterile or the sporangia were not preserved.

FIGURES 21, 22.—Asterophyllites longifolius *(Stnb.) Brongniart, 21, long leaves typical of this species attached at the nodes, X1.0 (BYU 3180); 22, note leaves fanning outward from the nodes on an axis, X1.0 (BYU 3174).*
FIGURES 23, 24, 25, 26.—Asterophyllites unguis *Jongmans and Gothan, 23, small specimen bearing two opposite branches, X1.0 (BYU 3161); 24, whorl of leaves around a transverse section of the axis. The leaves can be observed in side view on the primary and secondary order of branching, X1.0 (BYU 3185); 25, enlargement of figure 24, X2.0; 26, axis with several branches having attached leaves, X1.0 (BYU 3181).*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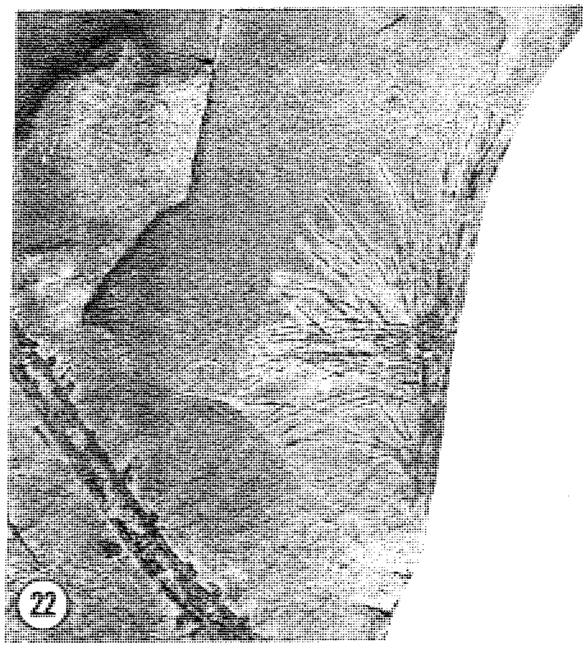
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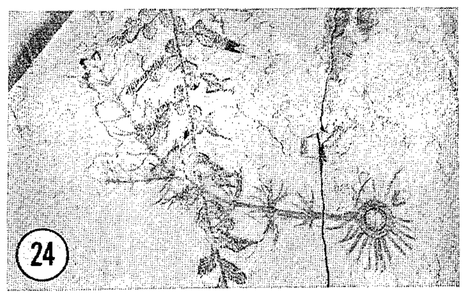
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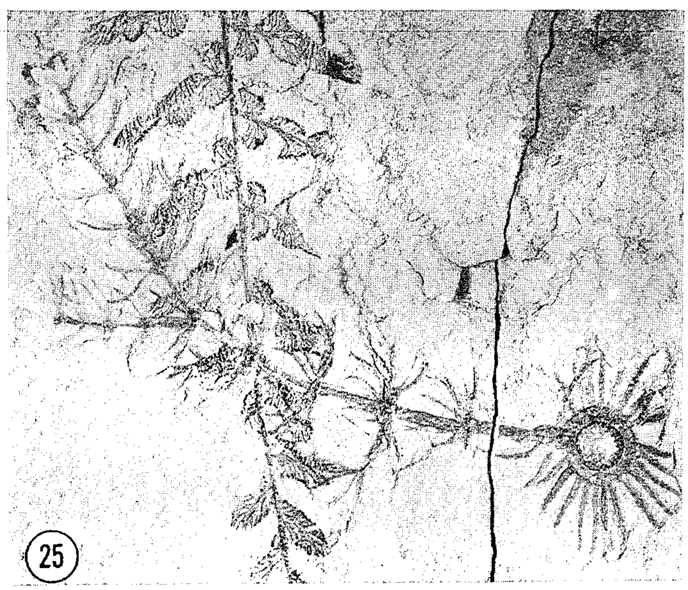
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Palaeostachya maglonniensis differs from *Palaeostachya ettingshauseni* Kidston from Namurian of Great Britain by the larger size and fewer cones per whorl of *P. ettingshauseni*.

Figured specimen. BYU 3179, 3187, 3189.

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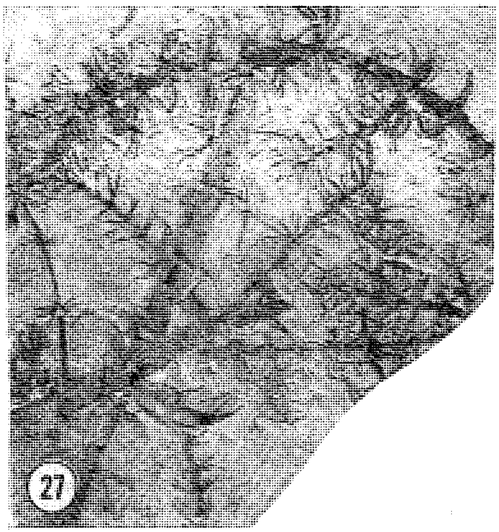
FIGURES 27, 28, 29, 30.—Asterophyllites unguis *Jongmans and Gothan, 27, specimen showing leaf variability, X1.0 (BYU 3182); 28, enlargement of figure 27, X2.0; 29, X1.0 (BYU 3183); 30, enlargement of figure 29, X2.0.*

FIGURES 31, 32.—Annularia subradiata *Stockmans and Williere, 31, leaves radiating from three nodes, X2.0 (BYU 3184); 32, X2.0 (BYU 3175).*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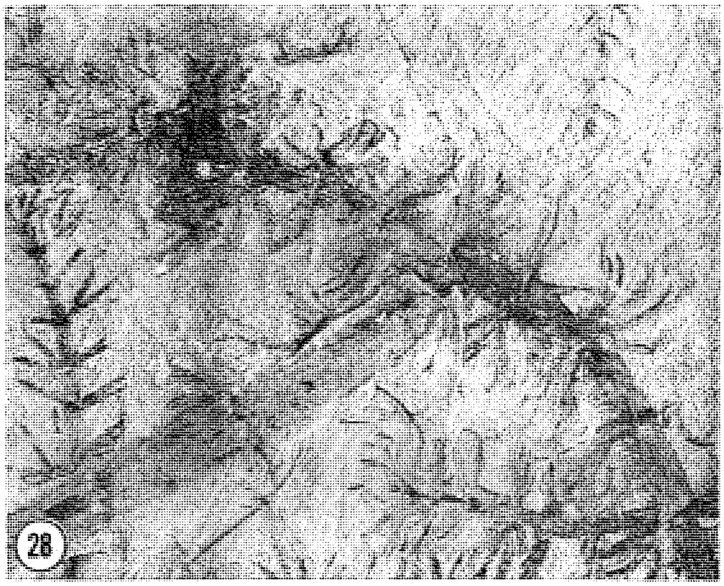
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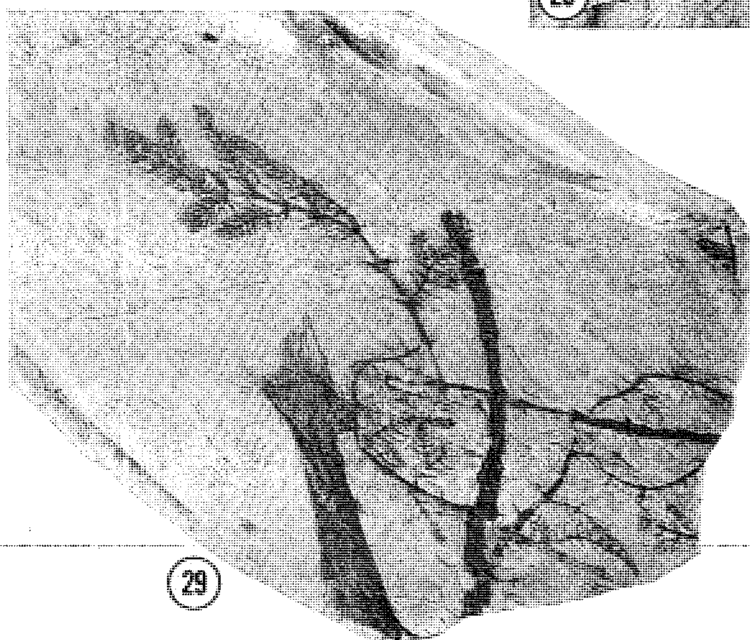
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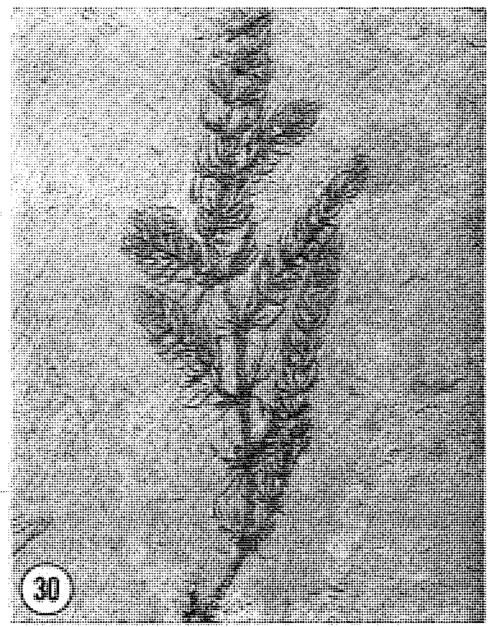
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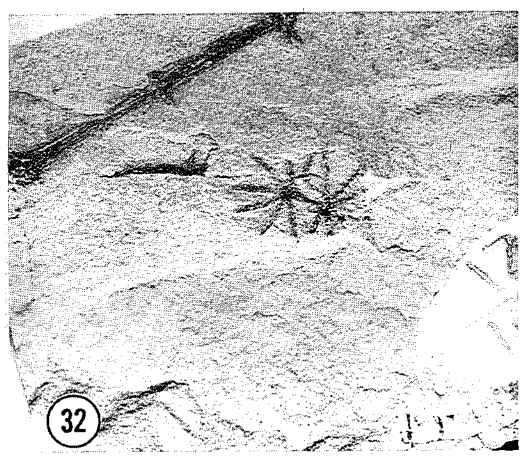
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FIGURES 33, 34, 35, 36.—Palaeostachya maglonniensis *(Stockmans and Williere) comb. nov., 33, cones arising in whorls at the nodes of the second order of branching, X1.0 (BYU 3189); 34, cones in whorls on second order of branching, X0.6 (BYU 3187); 35, enlargement of figure 34, X1.0; 36, X2.0 (BYU 3179).*

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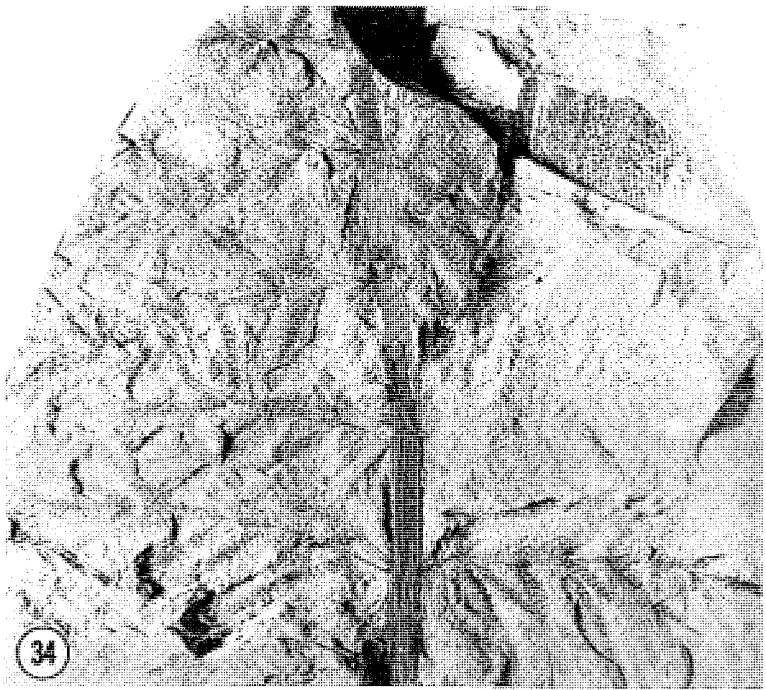

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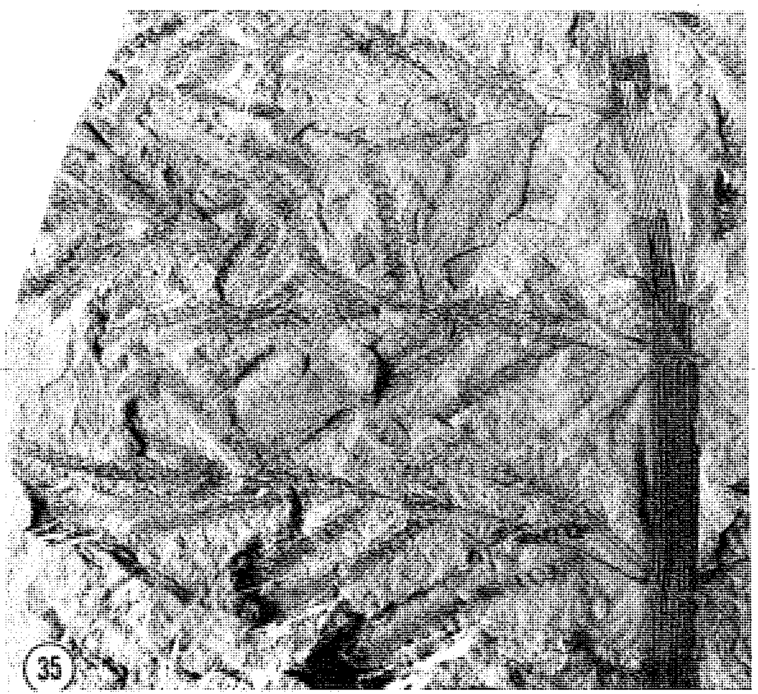

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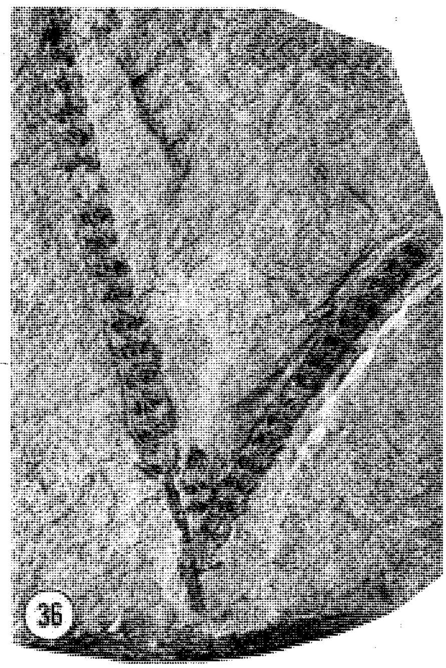

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