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Contents

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An Early Pennsylvanian Flora from the Manning Canyon Shale, Utah*

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ABSTRACT.—The Manning Canyon Shale on the eastern slope of Lake Mountain, located within Township 7 South, Range 1 West, contains an Early Pennsylvanian flora within its upper shales. The most abundant plant specimens are those which are more readily preserved, stems, portions of fronds, detached pinnules and bits of wood with a few isolated seeds scattered throughout. *Alethopteris* is the most abundant form with *Neuropteris* second and *Calamites* third.

The flora consists of three species of *Neuropteris,* five species of *Alethopteris,* one species of *Sphenopteris,* one species of *Cordaites,* two species of *Calamites,* two species of *Asterophyllites,* two species of *Lepidodendron,* one species of *Cornucarpus,* one species of *Pterispermostrobus* and one possible *Cardiocarpus.*

The Manning Canyon Formation is composed of shales with quartzites, sandstones, and limestones which appear to have been deposited in an embayment with transgressive-regressive cycles alternating between lagoonal and paludal environments.

The plants have been deposited near their place of growth as suggested by their random distribution and orientation on the bedding planes of several large slabs of shale that were sectioned and mapped. The flora and rock types indicate a fresh or brackish swamp environment.

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*A thesis submitted to the Faculty of the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science.

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all figures x1

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FIG. 4.—(?) *Cardiocarpus* sp.; BYU 434.
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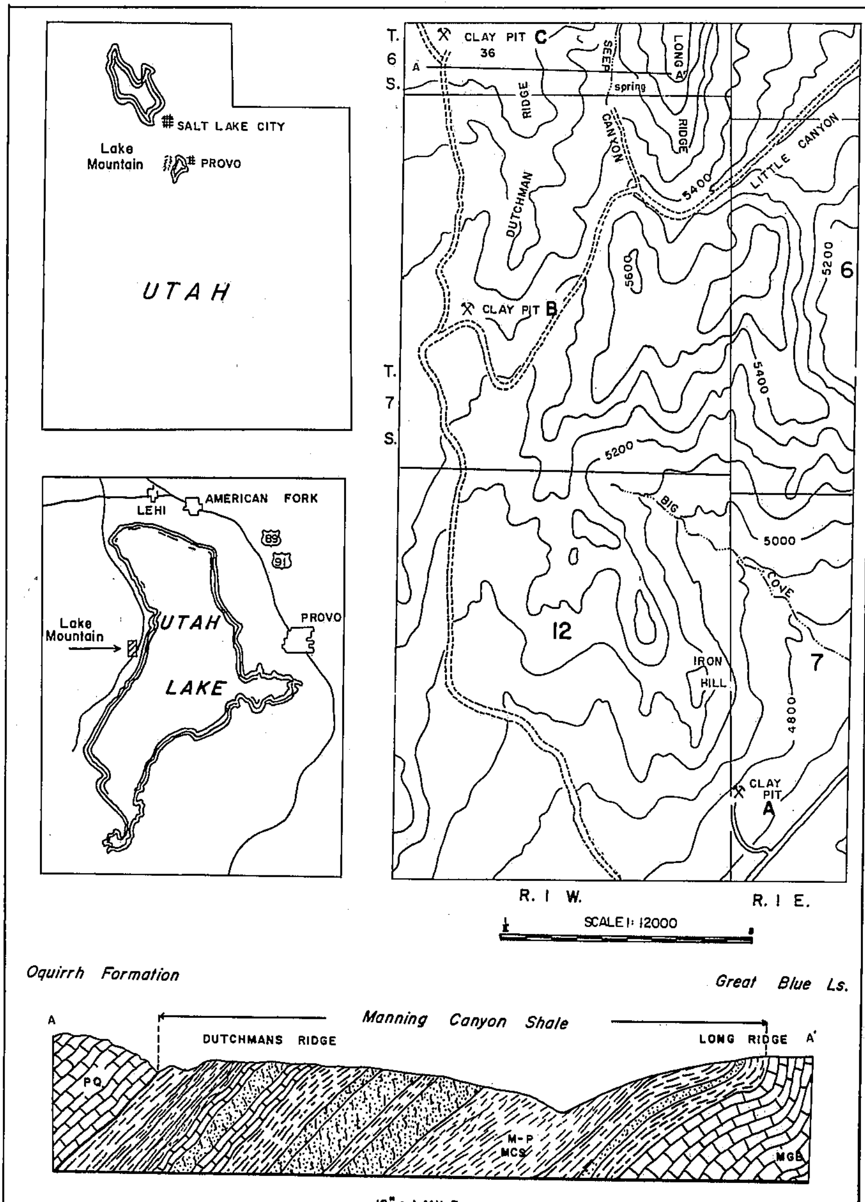
INTRODUCTION

Purpose

The Manning Canyon Shale is a time-transitional formation and contains both Mississippian and Pennsylvanian rocks. The formation contains, in upper



TEXT-FIGURE 1a.—Index maps showing area of study and collecting.
1b. Cross-section A-A of the Manning Canyon Shale on Lake Mountain.

shales, an Early Pennsylvanian flora. Presence of these plants has been mentioned by Gilluly (1932), Moyle (1958), Hyatt (1956), Calderwood (1951 *ms.*), but a detailed study of the stratigraphy and paleoecological conditions concerning this flora has not previously been reported. The purpose of the present study is to define the occurrence and ecology and a preliminary systematic investigation of the flora.

Location

The Manning Canyon Shale is exposed at many localities in central and northern Utah. Exposures of this formation along the eastern slopes of Lake Mountain comprise the principal area of study. Lake Mountain lies 12 miles directly west of Provo, on the western edge of Utah Lake (Text-fig. 1).

Fossil plants were collected from clay pits being excavated by local brick companies. Plant remains obtained from the pits on Lake Mountain were more abundant and less fragmentary than those found in exposures of this formation elsewhere.

Fossils of the present report were collected in three closely associated clay pits on Lake Mountain. The pits are located approximately thirteen miles southwest of Lehi, Utah. They include: Clay pit A, locally known as the Jackrabbit Claim, located in the SW¼, SW¼, Section 7, T. 7 S., R. 1 E.; clay pit B, the Overcross Claim, in NE¼, SW¼, Section 1, T. 7 S., R. 1 W.; clay pit C is located north of the Overcross Claim in SW¼, SW¼, Section 36, T. 6 S., R. 1 W.

Previous Work

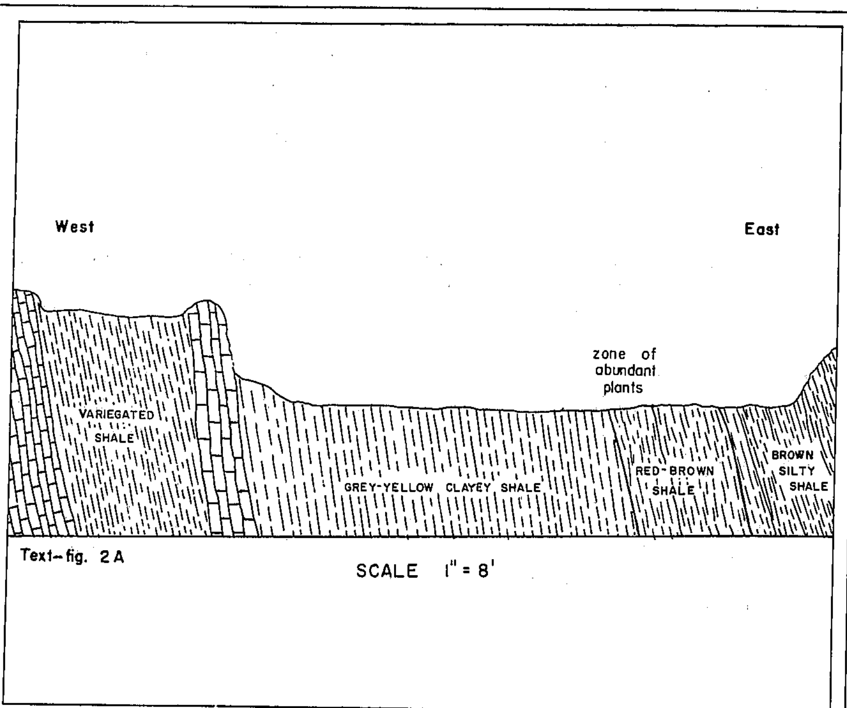
Gilluly (1932) named the formation from outcrops in Manning Canyon in the Oquirrh Mountains. Nolan (1935), Bissell & Hansen (1935), Baker (1947), Calderwood (1951 *ms.*), McFarland (1955), Sadlick (1955*ms.*), Croft (1956), and Pitcher (1957) have measured and studied complete or partial sections of the formation at various localities. Robertson (1940 *ms.*) studied the selenium content of the formation. Hebertson (1950 *ms.*) attempted to determine the origin, method of deposition and correlation of the Manning Canyon Shale in central Utah. Orneales (1953 *ms.*) and Hyatt (1956) made an evaluation and classification of its clay shales. The sedimentation and paleoecology of the formation formed the basis of a study by Moyle (1958) with emphasis on its type section in Soldier Canyon.

ACKNOWLEDGMENTS

For assistance during this study, the writer extends acknowledgment to Drs. J. Keith Rigby, David L. Clark, Harold J. Bissell, Jess R. Bushman, of the Department of Geology; Kent McKnight of the Department of Botany for their advice and guidance, and to Dr. Glenn Moore of the Department of Botany for many informative discussions.

Richard Link drafted the final illustrations; Harold Kaufman, Ferd Meyer and Donald Prince assisted in the field, Carol Grimaud and Susan Paugh helped in the preparation of the final manuscript.

The writer is also indebted to his wife Ann, for her constant help and encouragement.



TEXT-FIGURE 2a.—Cross-section of clay pit A on Lake Mountain.
2b. Clay pit A showing location of abundant plant zone, Manning Canyon Shale.

TECHNIQUES

Field Procedures

Detailed sections in pit A and pit C were measured with a tape and correlated to Moyle's Lake Mountain section (1958).

Plant specimens were collected from the clay pits, and several large blocks of the shale were removed from clay pit A for more extensive study. Initial plant collections were sprayed with spray plastic, but such treatment obscured detail. Later unsprayed collections proved to be substantial enough after drying and were not coated.

The large slabs were split along parallel bedding planes; location, orientation and distribution of plant fragments were determined.

Specimens were checked against illustrations and descriptions from paleobotanical literature of the Carboniferous.

Differential-thermal analysis was utilized to determine the type of clay minerals present.

STRATIGRAPHY

The Manning Canyon Shale crops out in northern and central Utah. The formation lies within two physiographic provinces, the Great Basin Province and the Central Rocky Mountains.

The type area of the formation is located in the Oquirrh Mountains, Utah (Gilluly, 1932), but is poorly exposed there. Moyle (1958) noted as did Gilluly (1932), that the section in Soldier Canyon is more complete and refers to it as the "type" section of the Manning Canyon Shale.

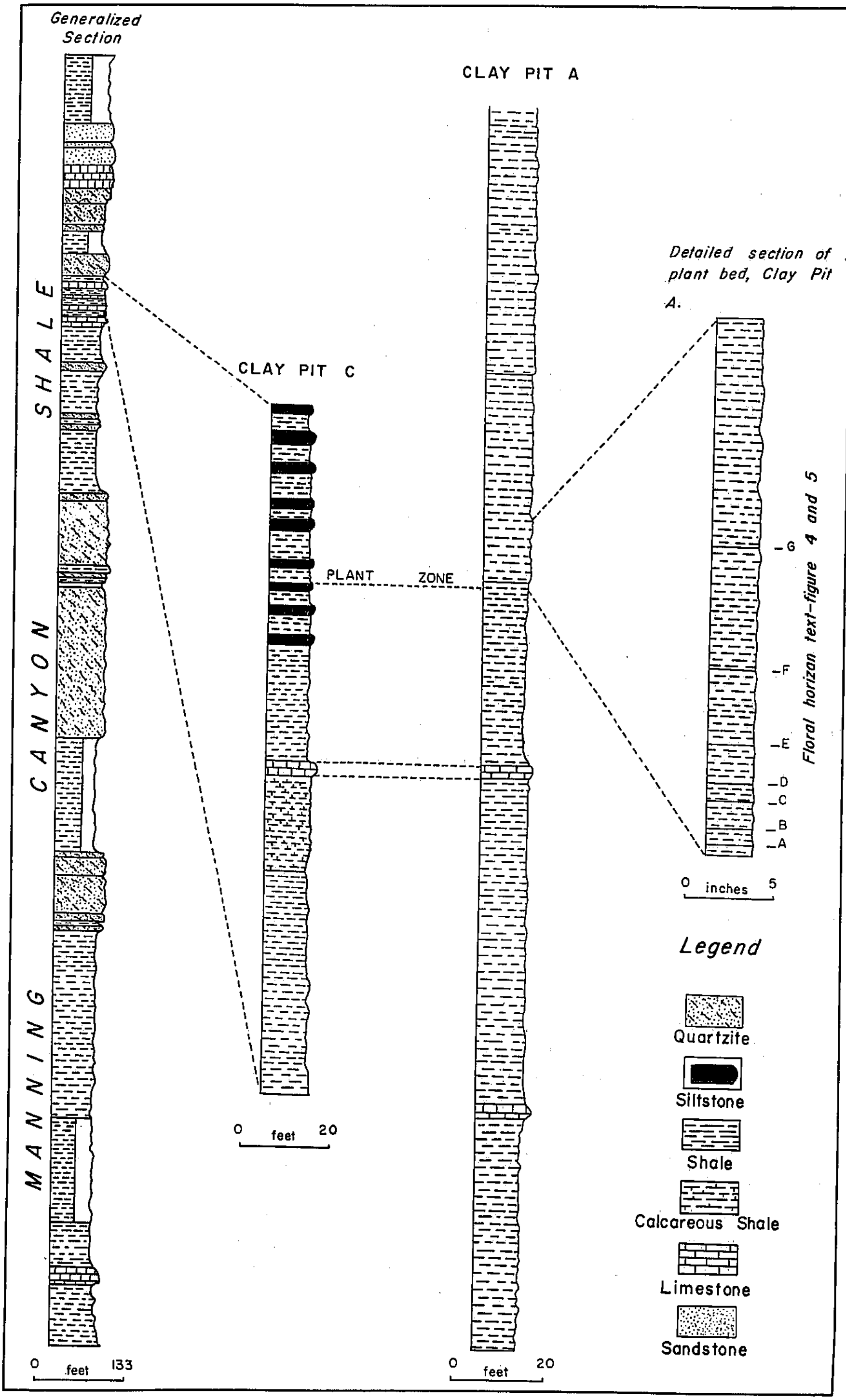
The formation on Lake Mountain is generally a slope former, covered by quartzite, sandstone, and limestone debris. The lower part of the formation consists largely of shale with some limestone and quartzite, whereas the upper half is predominantly quartzitic with a number of shale and a few limestone beds. Lithologic summary of the Lake Mountain section is as follows: (after Moyle, 1958)

Rock Type	*Thickness in feet*	*Percentage*
Shales	1231	64.5
Quartzites, arkoses and graywackes	600	31.4
Limestones	79	4.1
Total	1910	100.1

The Manning Canyon Shale is bounded at its base by the ridge-forming, Upper Mississippian Great Blue Limestone and at its top by the Lower Pennsylvanian part of the Oquirrh Formation. The upper Manning Canyon Shale and the lower Oquirrh Formation are not well exposed and the contact is gradational.

The clay pits on Lake Mountain are characterized by calcareous shales, clay shales, silty shales and thin-bedded limestones.

Clay pit A: The east-west section measured across clay pit A totals 275 feet. Base of the section (west boundary) is a medium to light gray, medium brown-weathering, fine-grained, orthoquartzite (Text-fig. 2). The top of the section (east boundary) is at the last exposed clay beneath the overburden from the excavation of the pit (BYU locality 12057).



TEXT-FIGURE 3.—Stratigraphic section of Manning Canyon Shale, Lake Mountain with relationships of clay pit A and clay pit C.

Unit No.	Description	Thickness in feet	Feet Above Base
6	Shale (top covered): Medium reddish-brown, weathers light brown, silty, some plant remains and pelecypods.	60	275
5	Shale. Medium red-brown, weathers light red-brown, contains a few lenticular siltstone beds and nodules, platy, contains abundant, well-preserved plant fragments	48	215
4	Shale: Yellow-brown to green-gray, weathers light yellow-brown to light gray, clayey, cross laminated, contains plant fragments	40	167
3	Limestone: Dark blue-gray to black, weathers medium gray, dense, lithographic, contains calcite stringers, weathers slabby	4	127
2	Shale: Variegated, medium to light yellow-brown, medium to light red-gray, red-brown, weathers light gray or light red-gray and yellow-brown, clayey	70	123
1	Limestone: Medium to dark gray, weathers light to medium gray, fine grain, contains calcite stringers, weathers with a rough surface, thickens to the orthoquartzite in one isolated area resembling channeling; partially covered with Lake Bonneville conglomerates	53	53

Clay pit B: Plant remains not as abundant as in pit A or pit C (BYU locality 12058).

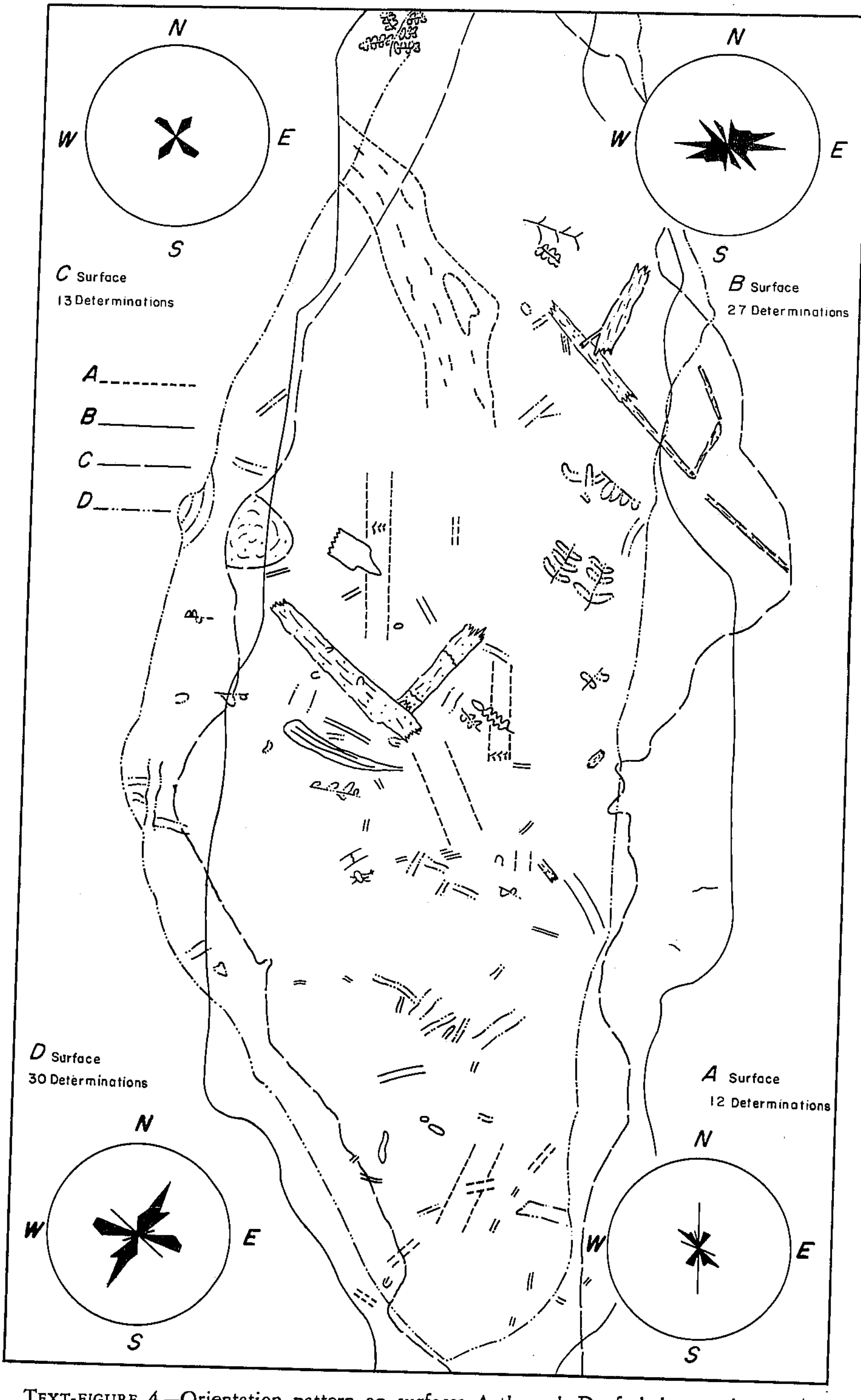
Clay pit C: The boundaries were taken at a medium brown, platy weathering, orthoquartzite as the base and a dark to medium gray, weathering light to medium gray, thin- to medium-bedded, fine-grained limestone as the top (BYU fossil locality 11027).

Unit No.	Description	Thickness in feet	Feet Above Base
5	Shale: Medium gray to medium yellow-gray, weathers light yellow-gray, clayey, interbedded siltstone beds 2-4 inches thick, siltstone contains plant impressions	51	149
4	Shale: Medium gray-green, some red-browns, weathers light gray to light brown, clayey	26	98
3	Limestone: Dark gray to black, weathers light to medium gray, fine grain, lithographic, contains calcite stringers, weathers platy above and below main bed	3	72
2	Shale: Black to dark gray, weathers medium gray, calcareous, silty, platy	21	69
1	Shale: Variegated, reddish-brown, light to medium gray, light yellow-gray, medium green-gray, weathers light reddish-brown, light gray and light yellow-brown, silty	48	48

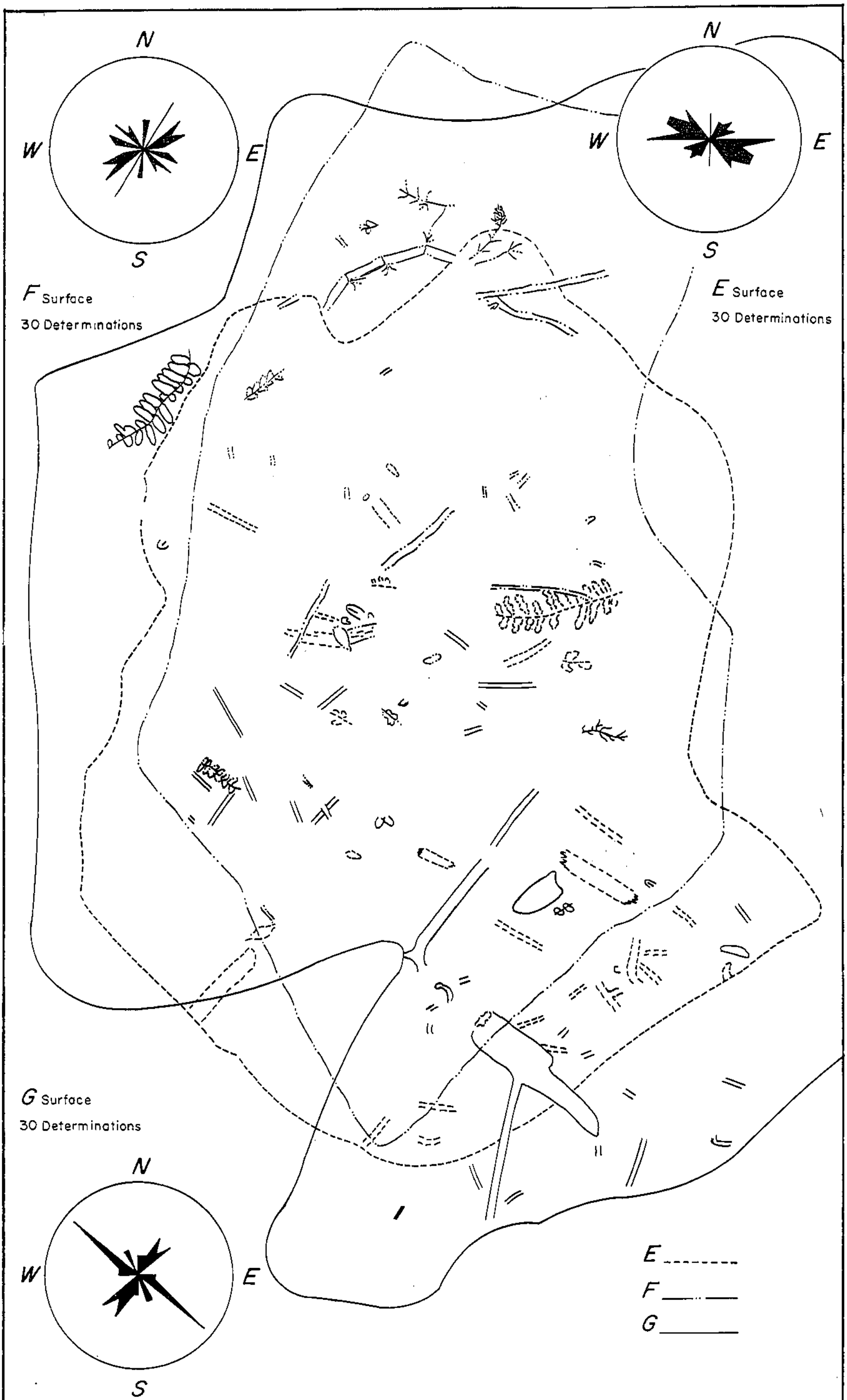
Plant remains are found in units no. 4, 5, and 6 in clay pit A and occur principally as impressions in unit no. 5 of clay pit C.

PALEOECOLOGY

The Manning Canyon Shale probably was deposited in an embayment which was alternating lagoonal and paludal, dominantly marine to the west, non-marine to the east and south. Moyle (1958) placed depositional condi-



TEXT-FIGURE 4.—Orientation pattern on surfaces A through D of shale sample. x1/2



TEXT-FIGURE 5.—Orientation pattern on surfaces E through G of shale sample. x½ tions as both near-shore and shallow infraneritic on an unstable shelf directly adjacent to the more negative part of the geosyncline.

The embayment was bordered by four Late Paleozoic areas which were sources of the Manning Canyon Shale sediments in their initial uplift.

Sediments which accumulated in Oquirrh and Lake Mountain areas were possibly derived from the Western Utah Highland (Bissell, 1962) along the southwestern border of the embayment. The northern part of the embayment probably received sediments from the Northeastern Nevada Highland (Bissell, 1962) in northeastern Nevada and northwestern Utah.

Moyle (1958) stated that much of the Manning Canyon sediments may have resulted from erosion of the emerging Emery Uplift of east-central Utah. The Uncomphagre Uplift far to the southeast may have provided some sediments for the Manning Canyon Shale embayment as well.

The depositional environment of the Manning Canyon Shale was that of near shore transgressive-regressive cycles. Three zones of terrestrial fossils and the cyclic nature of sedimentation suggests several oscillations of the strand line (Moyle, 1958).

The general pattern of the variation in the sediments (Text-fig. 3) from silty, sandy and clayey shales to shales containing calcareous material, indicates two overall vertical sequences with a lateral shift from near-shore to a deeper marine (Moyle, 1958). Small cyclothems which have been found in association with thin coal seams suggest that local transgressive-regressive action of the sea was limited at times both vertically and horizontally.

The fossil plants indicate a paludal environment in which they grew and were deposited with the sediments. They appear to have been deposited near their place of growth. On the shale surfaces that were sectioned (Text-figs. 4 & 5) their remains have a random distribution, although an occasional layer shows a weak current direction. As further evidence of their lack of movement many large fronds have been uncovered. *Stigmaria* have been found with rootlets attached, and *Calamites* are present with tufts of leaves and cones intact.

Within the vertical sequence of the plant-bearing shales plant associations occur with dominant plant types at different horizons. The zone sectioned was composed predominately of *Alethopteris* and *Neuropteris*, with *Calamites*, *Lepidodendron*, *Diplothmema*, and *Cordaites* as minor components. Seeds appear throughout the layers, although at some horizons they are more abundant.

Above the alethopteris-neuropteris assemblage zone stratigraphically, is a calamites-cordaites assemblage zone. The calamites belong to the *Asterophyllites* genus. No *Annularia* leaf types have been found.

Differences in dominant plant associations are probably due to unstable conditions of the rapidly changing environment.

In summary, the lagoon may have passed through a cycle of development which involved a progressive silting sequence. Sediments were derived from slowly emerging positive areas of low relief. Precipitation was variable with an occasional dry period occurring, limiting vegetation. Such a limitation of vegetation would result in thin coal seams and lessen the possibility of extensive reduction of oxides and hydroxides of iron accounting for red-brown and yellow-gray pigments of the shales. The smaller amount of organic material in relation to inorganic material in the Lake Mountain section may explain the unaltered composition of plant materials even through lithification (Twenhofel, 1939).

As lagoon silting continued, small islands appeared followed by invasion of a swamp flora. The lagoon eventually became completely filled with silt, with the swamps possibly connected by tidal channels in the paludal environment. An encroaching sea in which limestone was deposited covered the swamps and completed the cycle.

FLORA

The most abundant plant specimens are those that are more readily preserved. These consist of stems, portions of fronds, detached pinnules and bits of wood with a few isolated seeds scattered throughout the sediments.

Alethopteris is the dominant form with *Neuropteris* second and *Calamites* third, in abundance. Isolated specimens of *Diplothmema, Lepidodendron,* and other genera are also present.

Plants generally occur on bedding planes and vary with different types of sediments. In pink silty shale (Text-fig. 2), plants are abundant, parallel bedded and are evenly distributed over the surfaces (Text-figs. 4 & 5). They are not found in definite layers in the gray-yellow clay shales, but occur sporadically and are commonly chopped off by joints or cross-laminations. Although the state of preservation in the yellowish shale is poor, fiber and cellular structure is still present in most cases, and the plants tend to deteriorate when exposed to air.

Although some of the specimens may be new species, the flora appears to be Early Pennsylvanian (Westphalian A & B).

SYSTEMATIC PALEONTOLOGY

Genus NEUROPTERIS Brongniart 1822

Neuropteris gigantea Sternberg
pl. 1 fig. 7

Osmunda gigantea STERNBERG, 1821, 'Versuch' v. i, fasc. ii, p. 33, pl. xxxii.
Neuropteris gigantea STERNBERG *ibid.,* v. i, fasc. iv, p. xvi.
For a complete synonymy see Crookall, 1959.

Description.—Specimen at hand fragmentary. Pinnules flat, falcate, alternate, nearly right angles to the rachis, contiguous, sessile, slightly cordate at base, rounded apex; 25 mm long, 8 mm wide. Strong mid-vein continuous to nearly two thirds pinnule length. Lateral veins arise from midrib at a sharp angle and subdivide several times to form very fine, very close veinlets.
Repository.—BYU 406.

Neuropteris heterophylla Brongniart
pl. 1 figs. 3, 8

Lithosmunda minor SCHEUCHZER, 1709, 'Herbarium Diluvianum', p. 15, pl. iv, fig. 3.
Neuropteris heterophylla STERNBERG, 1833, 'Versuch', v. i, faxc. v-vi, p. 73.
For a more complete synonymy see Crookall, 1959.

Description.—Bi- to tripinnate. Pinnules alternate, oblique, ovate to oblong, attached by single point, those on upper pinnae odontopteroid, 15 mm long, 7 mm wide. Pinnules have a distinct midrib with lateral veins distinct, close (35 to 40 per cm), arising at an acute angle, oblique, strongly arched on some, divides two or three times, contacts margins obliquely. Unipinnate near apex with the terminal pinnule lanceolate or rhomboidal, 30 mm. long, 6 mm wide, sharply to bluntly pointed, slightly lobed on margins.
Discussion.—*N. heterophylla* and *N. tenuifolia* are similar. *N. heterophylla* differs from *N. tenufolia* in having stronger and fewer lateral veins and in having pinnules shorter in relation to width.
Repository.—BYU 407.

Neuropteris sp. A cf. *N. falcata*
pl. 1 figs. 1, 9

Description.—Fronds at least bipinnate. Secondary pinnae linear lanceolate. Pinnules alternate, linear to linear lanceolate (6:1), rather erect, distant, shortly stalked, although sessile and sometimes decurrent on upper pinnae, base asymmetrical. Margins slightly crenulate on some specimens, converging to a bluntly pointed, and in some, a sharply pointed apex. Venation is clearly marked. Strong midrib extending five-sixths to nearly the length of the pinnule. Lateral veins thick, close (30 per cm) arise acutely, arch fairly strongly and meet the margins at nearly right angles (85 to 90°).
Repository.—BYU 408.

Genus CYCLOPTERIS Brongniart

Cyclopteris dilatata Lindley & Hutton
pl. 1 fig. 6

Cyclopteris dilatata LINDLEY & HUTTON, 1883, Fossil Flora, v. ii, pl. XCIV.
Neuropteris dilatata WHITE, 1893, U.S. Geol. Surv. Bull. 98, p. 96, pl. XLII.
For a more complete synonymy see Crookall, 1959.

Description.—Single, isolated, simple, entire, more or less orbicular leaflets. Veins radiate from base, arching, branching two or three times. No midrib.
Discussion.—These specimens come from clay pit A, although some highly fragmental specimens are found in Provo Canyon. White has stated the asymmetrical auriculate forms with marginal attachments may be rachial pinnules of *Neuropteris*, although the majority of preserved materials are *Alethopteris*.
Repository.—BYU 409.

Genus ALETHOPTERIS Sternberg, 1826

Collected *Alethopteris* specimens are similar in some respects to the *A. lonchitica-A. decurrens* and *A. davreuxi-A. valida* groups, but differ from both.

The specimens have oblique venation and lack the continuous midrib which contrasts with the right-angle venation and continuous midrib of *A. lonchitica*, but is similar to *A. davreuxi*. The shape of the pinnules resembles *A. davreuxi*, but the specimens have sharp, distinct sinuses not unlike *A. lonchitica*, but differs from the rounded sinuses of *A. davreuxi*.

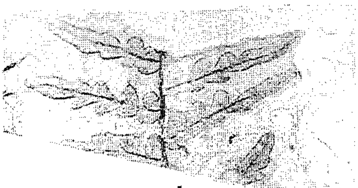
EXPLANATION OF PLATE 2
all figures x1

FIG. 1.—*Alethopteris* sp. E; BYU 414.
FIG. 2.—*Alethopteris* sp. C; BYU 412.
FIG. 3.—*Alethopteris* sp. E; BYU 414.
FIG. 4.—*Aneimites* (*Wardia*) *tenuifolius* var. *difoliodatus* White; BYU 426.
FIG. 5.—*Alethopteris* sp. B; BYU 411.
FIG. 6.—*Alethopteris* sp. A; BYU 410.
FIG. 7.—*Alethopteris* sp. B; BYU 411.
FIG. 8.—*Alethopteris* sp. B; BYU 411.
FIG. 9.—*Alethopteris* sp. D; BYU 413.

EXPLANATION OF PLATE 3
all figures x1, except figures 1, 2, 3, 4 x2

FIG. 1.—*Cardiocarpon* sp. B; BYU 431.
FIG. 2.—*Cardiocarpon* sp. B; BYU 431.
FIG. 3.—*Cardiocarpon* sp. A; BYU 430.
FIG. 4.—*Cornucarpus* sp. A; BYU 432.
FIG. 5.—*Sphenopteris* (Diplothmema) *spinosa;* BYU 420.
FIG. 6.—*Diplothemema subdecipiens White;* BYU 418.
FIG. 7.—*Diplothemema trifoliolata* (Artis); BYU 416.
FIG. 8.—*Diplothemema spectabilis* White; BYU 417.
FIG. 9.—*Diplothemema obtusiloba* (Brngt.); BYU 419.

PLATE 2



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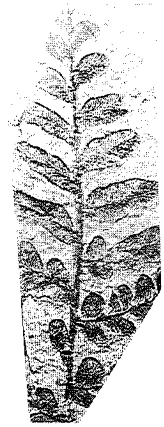

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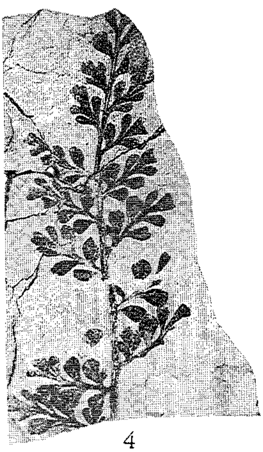

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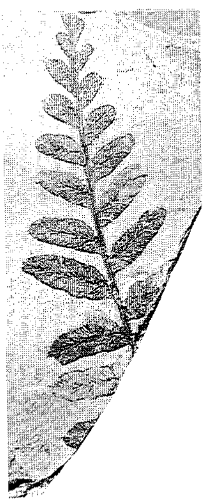

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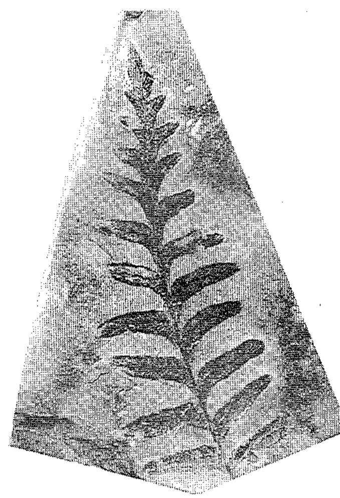

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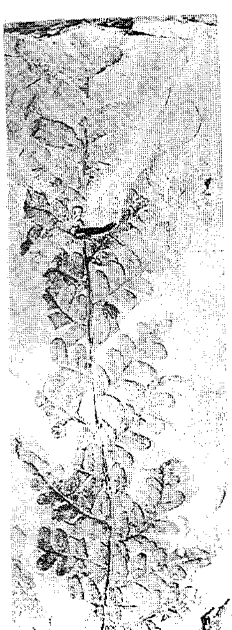

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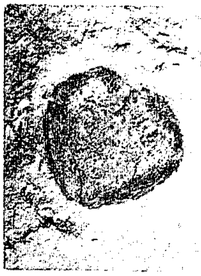
PLATE 3



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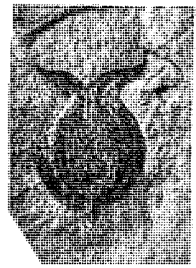

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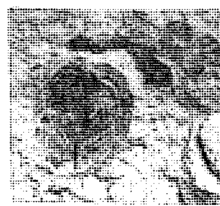

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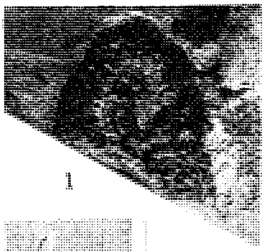
PLATE 4



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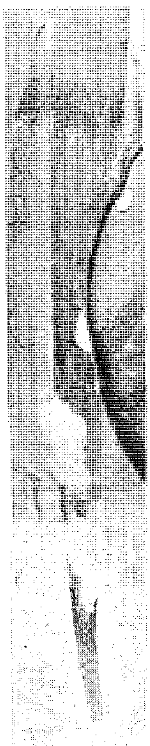

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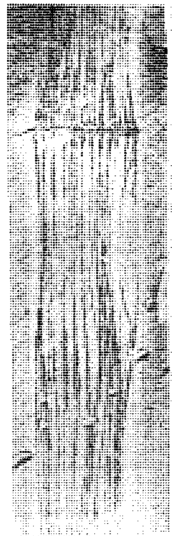

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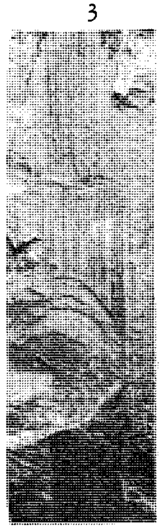

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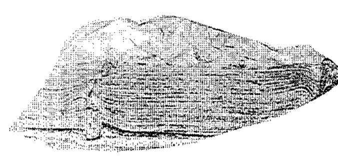

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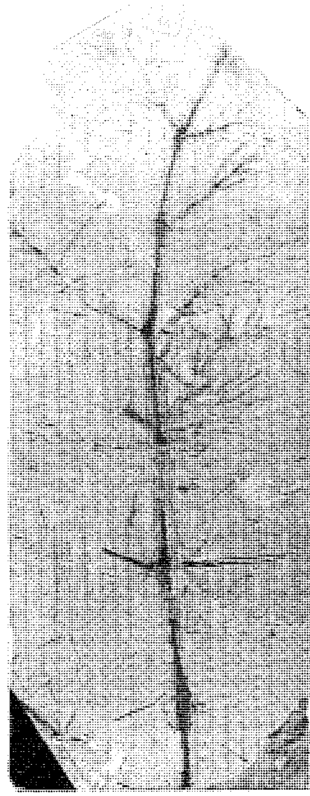

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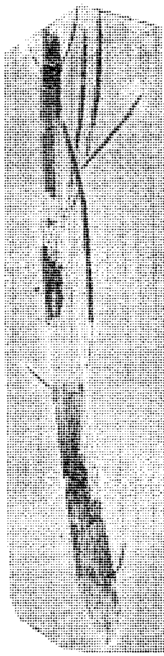

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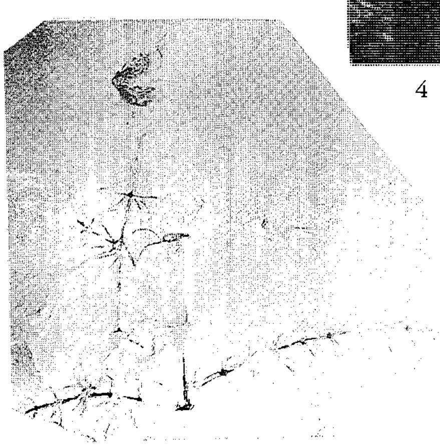

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PLATE 5

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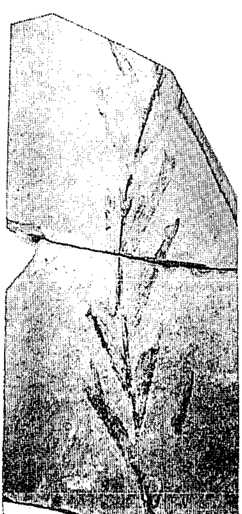

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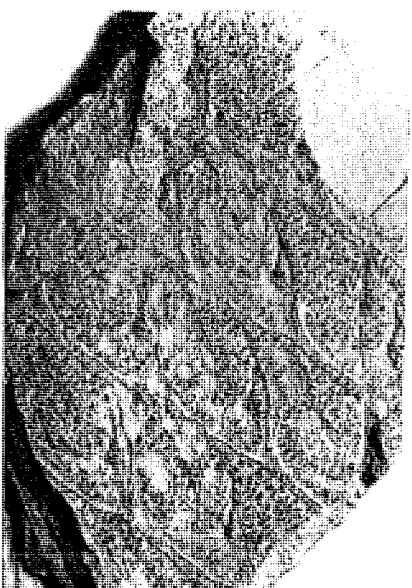

4

Alethopteris sp. A.
pl. 2 fig. 6

Description.—Tripinnate, probably quadripinnate. Secondary pinnae elongate triangular. Pinnules oblong, entire, simple; 10 mm long, 3 mm wide; apex blunt, obtuse to pointed. Pinnules attached to complete base. Margins parallel, tapering to apex; lower margin decurrent, upper margin contracted near base. Adjacent pinnules distant. Siuus distinct and sharp. Venation is distinct. Midrib continuous through 2/3 of the pinnule; lateral veins are relatively thick, arise obliquely, forks 2-3 times, contacts the margins obliquely. Terminal pinnule lanceolate with slightly lobed margins; 10-12 mm long, 4 mm wide.
Discussion.—Sp. A differs from the similar sp. C in the disymmetrical relationship of the pinnules in the latter.
Repository.—BYU 410.

Alethopteris sp. B
pl. 2 figs. 5, 7, 8

Description.—Pinnules simple, entire, elliptical to oblong, alternate, oblique, attached by whole of base. Upper margin strongly contracted near base, lower margin strongly decurrent, thus giving the appearance of a swollen midsection, apex bluntly rounded or tapering to a sharper rounded apex. Midrib strong, decurrent, continuous to 1/2 to 2/3 of the pinnule. Lateral veins arise at an acute angle, arching slightly, striking the margins obliquely (45°). Secondary veins leave the pinnae-rachis directly, paralleling the lateral venation. Sinus sharp and distinct. Tertiary rachis flexuous.
Discussion.—Very similar to sp. A, but the pinnules of sp. B have a different shape and leave the rachis at a more oblique angle. The separation of adjacent pinnules in sp. B is less. The upper margin of sp. B is also more contracted.
Repository.—BYU 411.

Alethopteris sp. C
pl. 2 fig. 2

Description.—Bi- to tripinnate. Pinnae triangular to lanceolate. Pinnules oblong, entire, simple; 7-11 mm long, 2-4 mm wide. Margins parallel, appear slightly swollen in center; lower margin decurrent, upper margin strongly contracted near base. Sinus indistinct. Pinnules separated by 2 mm. Pinnae disymmetrical, bearing on one side comparatively long and narrow pinnules oblique to the rachis, and on the other, shorter, broader pinnules with rounded apex and at right angles to the rachis. Midrib distinct for two-thirds distance of pinnule. Lateral venation thick, distinct, distant, arises obliquely, arches slightly, subdivides two to three times before meeting the margins obliquely.
Discussion.—Pinnules are not as long in relation to width in sp. B as in sp. C. Pinnules

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EXPLANATION OF PLATE 4
all figures x1 except figure 2 x1/2

FIG. 1.—*Cordaites communis* Lx; BYU 421.
FIG. 2.—*Cordaites communis* Lx; BYU 421.
FIG. 3.—*Calamites sp.* B; BYU 423.
FIG. 4.—*Calamites* sp. A.; BYU 422.
FIG. 5.—*Calamites* sp. A; BYU 422.
FIG. 6.—*Asterophyllites longifolius* Brgnt; BYU 424.
FIG. 7.—*Asterophyllites longifolius* Brgnt; BYU 424.
FIG. 8.—*Asterophyllites* sp. A; BYU 425.
FIG. 9.—*Pterispermostrobus* sp. A; BYU 433.

EXPLANATION OF PLATE 5
all figures x1

FIG. 1.—*Stigmaria verrucosa* Martin; BYU 429.
FIG. 2.—*Lepidodendron* sp. A; BYU 427.
FIG. 3.—Unidentified plant; BYU 435.
FIG. 4.—*Lepidodendron* sp. B; BYU 428.

are more distant and oblique in the latter. Lateral veins of sp. C are closer, finer and arch stronger and contact the margins at more nearly a right angle than the veins in sp. A.
Repository.—BYU 412.

Alethopteris sp. D
pl. 2 fig. 9

Description.—Tripinnate. Pinnules elliptical to oblong, some linear; apex bluntly pointed to rounded; 5-7 mm long, 2 mm wide; alternate, right angle; decurrent, upper margin contracted near base. Pinnules appear closely spaced, 1 mm to contiguous. Midrib flexuous on some pinnules, continuous for two-thirds pinnule. Lateral venation distinct, flexuous on some pinnules, arises acutely, arching, subdividing two to three times, and striking the margins obliquely. Tertiary rachis flexuous.
Discussion.—Sp. D appears similar to sp. A. The flexuous rachis, midrib and venation in the former differs from the latter. The acutely arising lateral veins of sp. D also contrasts with sp. A. Sp. D differs from sp. B in the former having flexuous midrib and rachis and pinnules at right angles and smaller. Sp. D is similar to *Neuropteris flexuous* except that sp. D pinnules are completely attached.
Repository.—BYU 413.

Alethopteris sp. E
pl. 2 fig. 3

Description.—Bi- to tripinnate. Pinnae triangular. Pinnules simple, toothed, entire near upper portion of pinnae, 5 to 15 mm long, 1 to 3 mm wide, linear to linear lanceolate, alternate, slightly oblique; attached by whole of base with margins tapering to apex, upper margin slightly contracted, lower margin slightly decurrent. Sinus sharp and distinct. Adjacent pinnules distant. Midrib broad and extends nearly to apex. Lateral veins oblique arching slightly, distant, thick. Subsidiary veins enter direct from pinnae-rachis paralleling lateral veins.
Discussion.—*Alethopteris* sp. E has toothed pinnules, and thick, distinct venation which separates it from *Alethopteris* sp. F.
Repository.—BYU 414.

Alethopteris sp. F
pl. 1 fig. 2

Description.—Pinnules simple, entire, oblong, slightly convex upper surface, alternate, attached slightly oblique to rachis by whole of base, distant. Upper margins strongly contracted near base, lower margins decurrent, apex rounded. Sinus sharp, distinct. Midrib distinct, decurrent from rachis, continuous nearly three-fourths of the pinnule. Secondary veins flexuous, clearly marked, arise from midrib at wide angle, forks near midrib, again one-half the distance to margin and occasionally near margin, arching, striking the margins at nearly right angles (85°). Subsidiary veins enter from rachis.
Repository.—BYU 415.

Genus DIPLOTHMEMA Stur 1877

Diplothmema trifoliolata (Artis)
pl. 3 fig. 7

Filicites trifoliolata ARTIS, 1825, Antediluvian Phytology pl. 1.
Diplothmema trifoliolata WHITE, 1943, U.S. Geol. Surv. Prof. Paper 197, p. 98, pl. 32.
Description.—Tertiary pinnae alternate, opens at nearly right angles, ovate lanceolate, narrow flexuous rachis. Pinnules alternate, small, oblique, uppermost ovate-cuneate, remainder ovate, constricted near base. Largest are lobed forming three to five ovate lobes, becoming pediculate with the terminal lobe larger and unequally deltoid. Venation indistinct, although primary nerve is strongly decurrent.
Repository.—BYU 416.

Diplothmema spectabilis White
pl. 3 fig. 8

Diplothmema spectabilis WHITE. 1943, U.S. Geol. Surv. Prof. Paper 197, p. 96, pl. 29.
Description.—Tripinnate. Pinnae oblique, alternate, linear lanceolate. Pinnules small,

distant, alternate, leave the rachis at nearly right angles, ovate to ovate deltoid, laciniate forming three to five distant, cuneate, broadly attached lobes. Nervation generally not too strong, although one specimen has very strong venation, primary vein originates low, subdivides two to three times. Each lobe contains three or four veins.
Discussion.—The specimens lack teeth, although small sublobes are present.
Repository.—BYU 417.

Diplothmema subdecipiens White
pl. 3 fig. 6

Diplothmema subdecipiens WHITE, 1943, U.S. Geol. Surv. Prof. Paper 197, p. 95, pl. 11.
Description.—Specimen fragmental illustrating only four pinnules. Pinnules cuneate, decurrent, slightly distant, narrowly constructed at base, bevipedicullate, alternate, open. Apices obliquely truncate or bisublobate. Venation obscure, primary veins appear to begin at a low angle, forking at a wide angle. Lateral veins fork two or three times as they curve outward.
Discussion.—Similar to *D. cheathami,* but the specimen lacks the crenulate edges of the former.
Repository.—BYU 418.

Diplothmema obtusiloba (Brongniart)

Sphenopteris obtusiloba BRONGNIART, 1829, Histoire des vegetaux fossiles, p. 204, pl. 3, fig. 2.
Diplothmema obtusiloba STUR, 1877, Die culm-flora, K.-k. geil. Reichsanstalt Abh., B. 8, Heft. 2, p. 230; WHITE, 1943, U.S. Geol. Surv. Prof. Paper 197, p. 97, pl. 30, fig. 4, pl. 35, figs. 7, 9.
Description.—Tri- to quadripinnate. Secondary pinnae ovate to oblong-lanseolate. Pinnules alternate, broadly cumeate to ovate, trilobed along margins, not divided too deeply; close, sometimes contiguous, irregularly crenate, decurrent. Nervation indistinct, although one specimen has a strong midrib originating low on the rachis and branches outward towards the margins.
Repository.—BYU 419.

Genus SPHENOPTERIS Brongniart, 1822

Sphenopteris (Diplothmema) spinosa Goppert
pl. 3 fig. 5

Sphenopteris spinosa GOPPERT, Gatt. Foss. pfl., lief. 4, p. 70, pl. 12.
Sphenopteris (Diplothmema?) sponisa MIKLAUSEN, 1949 *ms.,* unpublished Ph.D. Thesis, University of Pittsburgh, p. 30, pl. IV.
For more complete synonymy see Miklausen (1949).
Description.—Tripinnate. Pinnae deltoid lanceolate, alternate, attached by broad, although constricted footstalk; pinnules decurrent, divided into four or five lanceolate spreading segments with obtuse points, most are entire, although some bear on short rounded or obtuse lobe and are attached by broad base. Strong midrib on some specimens which branches into parallel veinlets and arches to the lobe margins.
Discussion.—The several specimens are closely similar to *Eremopteris missouriensis* White, based on White's idea of variation of pinnules dependent upon position within the frond. *S. spinosa* has a prominent midvein which is characteristic of the genus and lacking in *Eremopteris.* In the arrangement of the veinlets the specimens at hand approach more to that of *Sphenopteridium,* but vary in the form of the pinnules.
Repository.—BYU 420.

Genus CORDAITES Unger 1850

Cordaites communis (?) Lesquereux
pl. 4 fig. 1, 2

Cordaites communis LESQUEREUX, 1878, Proc. Amer. Phil. Soc., v. 17, p. 320; WHITE, 1899, U.S. Geol. Surv. Monograph xxxvii, p. 260, pl. III, fig. 1.
Description.—Leaf spatulate in outline, tapering to a thickened base, apex broadly rounded or obtuse. Specimen 22 mm long, 20 mm wide to 5 mm wide at base. Nervation

irregular, strong, readily discernible, although very close together. Near the base weaker intermediate nerves lost in leaf tissue. Nerves or striae about nine per centimeter. Several specimens.
Discussion.—The apex was not attached to illustrated leaf, but was closely associated, therefore both are placed as *C. communis* (?) Lesquereux. Numerous other similar specimens lacking the apex and base, but having irregular nervation are provisionally placed in this species.
Repository.—BYU 421.

Genus ANEIMITES White 1943

Aneimites (*Wardia*) *tenuifolius* var. *difoliatus* White
pl. 2 fig. 4

Aneimites (*Wardia*) *tenufolius* var. *difoliatus* WHITE, 1943, U.S. Geol. Surv. Prof. Paper 197-c.

Description.—Specimen small. Pinnules oblong in larger and cuneate in smaller forms, 5 to 10 mm long, 2 to 5 mm wide. Contracted to a narrow base; divided into two or three unequal cuneate lobes which are obliquely truncated or rounded. Obscurely striated with nervation indistinct, curving slightly to margins.
Repository.—BYU 426.

Genus CALAMITES Suckow, 1784

Calamites sp. A
pl. 4 figs. 4, 5

Description.—Rare impressions with indication of straight ribs curving into nodes which sharply constrict the internodes. Specimen 30 mm between nodes. No indication of branch scars.
Repository.—BYU 422.

Calamites sp. B
pl. 4 fig. 3

Description.—An impression, 70 mm long. Ribs divide and anastamose form lenticular interspaces. Ribs appear to broaden to form branch scars.
Repository.—BYU 423.

Genus ASTEROPHYLLITES Brongniart, 1822

Asterophyllites longifolius Brongniart
pl. 4 fig. 6, 7

Bruckmannia longifolia STERNBERG, 1825, Versuch, v. i, tent., pl. 29, fasc. r, pl. iviii.
Asterophyllites longifolius BRONGNIART, 1828, Prodome, p. 159; READ, 1934, U.S. Geol. Surv. Prof. Paper 185-D, p. 83, pl. 16.

Description.—Leaves approximately 33 mm long and covering one internode and most of another (20 mm between internodes). Due to preservation the whorls contain an unequal number of leaves. Leaves curve outward on some and parallel the rachis on others. Some may be distorted due to preservation. Venation is obsured by plant tissue.
Repository.—BYU 424.

Asterophyllites sp. A
pl. 4 fig. 8

Description.—Whorls of linear acutely pointed leaves, attached to nodes of the axis bearing them. Whorls commonly spread with upward curved course, 2 to 4 between nodes, 8 to 20 per whorl. Median vein not preserved. Several specimens in collection.
Discussion.—Venation is too indistinct to determine whether this specimen should be grouped with *A. equisetiformis* or *A. longifolius*. The leaves are smaller than in either of these two related forms.
Repository.—BYU 425, 426.

Genus LEPIDODENDRON Sternberg, 1820

Lepidodendron sp. A

pl. 5 fig. 2

Description.—Transversely diamond shaped. Bolsters prominent. 10 mm long, 5 mm wide. Rhomboidal leaf scar located in upper three-fifths of bolster; wider than high; lateral angles acutely pointed and lower angles obtusely rounded. Cicatricules not preserved. Lower field strongly keeled with well marked transpiratory areas. Two specimens.
Repository.—BYU 427.

Lepidodendron sp. B

pl. 5 fig. 4

Description.—Bolsters prominent, contiguous, rhomboidal with rounded sides and pointed ends, 14 mm wide and 30 mm long. Acute ends asymmetrical; median line straight or slightly curved. Leaf scars about two-fifths of bolsters. Leaf scars rhomboidal with lateral angles and lower angle acute; the lower forming a sharp apex; top obtusely angled. Leaf scar situated on right side of bolster. Right lateral angle of scar touches right margin of bolster and occupies one half distance to the left margin. Circutricules subcircular, larger in center, situated below middle of leaf scar. Lower field appears not to contain conspicuous heels although one bolster has evidence of a faint heel. Two fragmental specimens.
Discussion.—Close to *L. aculcatum,* but differs in the shape and position of the leaf scar, and the lack of heels in the specimens at hand.
Repository.—BYU 428.

Genus STIGMARIA Brongniart, 1822

Stigmaria verrucosa Martin

pl. 5 fig. 1

Phytolithus verrucosus MARTIN, 1809, Outlines of an attempt to establish a knowledge of extraneous fossils on scientific principle, p. 203, 1809; Pertificata derbiensis, p. 23, pls. 11-13; STEINHAUER, 1818, Amer. Phil. Soc. Trans., vol. 1, p. 268, pl. 4, figs. 1-4.
Variolaria ficoides STERNBERG, 1820, Flora der Vorwelt, vol. 1, fasc. 1, p. 24, pl. 40, figs. 1-3.
Stigmaria ficoides BRONGNIART, 1822, Mus. hist. nat. Mem., vol. 8, pp. 228, 239, p. 1 fig. 7.
Stigmaria verrucosa MILLER, 1877, Amer. Paleozoic fossils, p. 40, 1877; WHITE, 1899, U.S. Geol. Surv. Mon. 37, pp. 244-245; READ, 1934, U.S. Geol. Surv., Prof. Paper 185-D, p. 82.
Description.—The few, rather large-sized specimens show well the spirally disposed circular scars of rootlets, each with a raised upper rim and a central cicatrix. Several appendages (rootlets) are still attached.
Repository.—BYU 429.

Genus CARDIOCARPON Brongniart, 1828

Cardiocarpon sp. A

pl. 3 fig. 3

Description.—Seed oval outline, truncate to cordate at base, 8 mm long, 7 mm wide with greatest width near center. Nucellus cordate, cordate at base, apex acute. Inner and outer integuments appear to be present. Nucellus divided by a broad, flattened ridge extending from microphyle to base. Wings less than 1 mm at base, and about 2 mm wide at apex, sharply emarginate apex.
Repository.—BYU 429.

Cardiocarpon sp. B

pl. 3 fig. 1, 2

Description.—Seed ovate to cordate outline. Size varies slightly from 15 mm long, 11 mm wide to 10 mm long, 10 mm wide for smaller specimens. Greatest width occurs slightly below center on some specimens and nearer the base on others. Base is cordate,

although one specimen has an obtuse-rounded shape. Two reniform depressions occur near the basal walls of the nucellus. Wings are 0.5 to 1 mm wide near base and expanding to 1 to 2 mm at the apex. Nucellus cordate in outline, pointed above.
Discussion.—These specimens are separated from *C. cardatum* by the larger size and the two depressions near the base.
Repository.—BYU 431.

Genus CORNUCARPUS Arber

Cornucarpus sp. A
pl. 3 fig. 4

Description.—Broadly oval outline, base slightly rounded and pointed. 10 mm long, 8 mm wide with greatest width near center. Nucellus oblanceolate, obtuse base tapering to an uncut apex. The seed appears to have an inner and outer integument. Micropyle extends into the upper end of the nucellus. Wings are 1 mm wide near base, increase to 1.5 mm near apex and expand beyond into long narrow whip-like projections that could be horns.
Discussion.—These specimens may vary from the genus *Cornucarpus* in the extent and shape of the so-called projections. The specimen lacks the median longitudinal ridge and the below-center position of the nucellus of *C. arberi.*
Repository.—BYU 432.

Genus PTERISPERMOSTROBUS Stopes

Pterispermostrobus sp. A
pl. 4 fig. 9

Description.—Oblong or lanceolate outline, rounded base, apex acute, 6 mm long, 2 mm wide. Nucellus was oblong, ribbed, forming a depression. Wings were not present.
Discussion.—The specimens are tentatively placed with this genus. They do not have the five-toothed "cupule," although the specimens may be of an earlier stage. The specimens were stalked, but not attached. Therefore, the bifurcation of the stalk as in *Pterispermostrobus bifurcatus* is indeterminate.
Repository.—BYU 433.

Genus CARDIOCARPUS Seward, 1917

(?) *Cardiocarpus* sp.
pl. 1 figs. 4, 5

Description.—The specimens are oblong in outline, 10-20 mm long, 5-7 mm wide, One specimen has two longitudinal ridges through the center.
Discussion.—The specimens are tentatively placed in this genus because of similar longitudinal section.
Repository.—BYU 434.

Unidentified Plant
pl. 5 fig. 3

Description.—The specimen is 64 mm long and 15 mm wide and consists of rachis or stem from which leaflets or pinnules arise acutely. The pinnules or leaflets are linear and appear relatively broad at the apex, 15 mm long, 2 mm wide. The base of the "leaflet" is completely attached and not decurrent. Venation is parallel and arises from the main stem.
Repository.—BYU 435.

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