Acer (Wolfe and Wehr, 1987; Wolfe and Tanai, 1987), and a new generic name appears to be war:..nted for them.

Leaves of "Acer" arcticum closely resemble those of "Ampelopsis" acerifolia (Newberry) Brown (e.g., Hickey, 1977), with which they have been compared by Wolfe and Wehr (1987) and Wolfe and Tanai (1987), and it appears likely that the two taxa are closely related. The association between leaves with this morphology and Deviacer samaras lends support to their relationship with extant Sapindaceae or Aceraceae, rather than with extant Ampelopsis (Vitaceae).

At Joffre Bridge Roadcut, the "Acer" arcticum leaves are found in the same layers with the Deviacer samaras, and both organs may well have been produced by the same plant. It appears unlikely that the parent plant was common at Joffre Bridge Roadcut, however. The leaves are rare, and the few specimens are fragmentary and tattered, suggesting that they suffered a moderate distance of transport. The samaras are more common at the site, likely because they are more robust, but they, too, appear to have survived moderate transport.

Order GERANIALES

Family OXALIDACEAE

Genus Averrhoites Hickey

Averrhoites affinis (Newberry) Hickey

(Plate 10, Figs. 77, 78)

Description: Leaflets are asymmetrical, ovate, at least 120 mm long and 35 mm wide, with a length-to-width ratio of about 3.5 (Fig. 77). Leaf apices are acute, bases are acute to obtuse and asymmetrical, and margins are entire. Venation is pinnate, brochidodromous to eucamptodromous. Primary vein is straight to curved, and much thicker than the secondaries. Secondaries diverge at an angle of about 75°, curving upward toward the apex, sometimes arching and joining the superadjacent secondary (Fig. 78). Intersecondaries are common. Higher order venation not apparent on these specimens.

Occurrence: Eight specimens of detached leaflets, from the Channel-Fill Siltstone and Lower Lacustrine Sequence (Units 3-4).

Discussion: Pinnately compound leaves with this type of architecture were first assigned to Sapindus affinis and Sapindus membranaceous by Newberry (1898). Their assignment to Sapindus was questioned by a number of authors, and Hickey (1977), studying leaves from the Golden Valley Formation of North Dakota, concluded that the leaves more closely resembled those of extant Averrhoa carambola Linnaeus. Hickey erected the genus Averrhoites "for leaves whose architecture is similar to the modern genus Averrhoa", but noted that it was "not meant to indicate close taxonomic affinity".

The specimens of A. affinis from Joffre Bridge Roadcut are all detached leaflets, few of which are well preserved, but they resemble those described and illustrated by Hickey (1977). Specimens collected nearby around the mouth of the Blindman River are better preserved, and more clearly exhibit the secondary and tertiary venation that Hickey described. Leaflets of A. affinis have also been described from the Sentinel Butte Formation of North Dakota (Crane et al., 1990), and from the Ravenscrag Formation of Saskatchewan (McIver and Basinger, 1993).

At Joffre Bridge Roadcut, Averrhoites leaflets are rare. They are found in the Channel-Fill Siltstone and Lower Lacustrine Sequence (Units 3-4), among the more common remains of other woody dicots that inhabited riparian and floodplain environments, such as Joffrea and Platanus.

Subclass INCERTAE SEDIS

"Viburnum" cupanioides (Newberry) Brown

(Plate 10 , Figs. 75, 76)

Description: Leaf laminae are ovate to elliptic, 2.9-12.6 mm long, 1.5-8.5 mm wide, with a length-to-width ratio of 1.6-2.2 (Figs. 75, 76). Leaf apices are acute, obtuse or rounded. Bases are cordate, obtuse or rounded and often slightly asymmetrical. Petioles are missing from many of the specimens because they curve out of the plane of the leaf blade. Margins are entire in the basal 30-90% of the leaf, and toothed in remainder (Fig. 76). Teeth are serrate and obtuse, sinuses are angular to rounded. Venation is pinnate. The primary vein is straight and moderately thick. Secondaries are straight to gently curved, diverging from the primary at angles of 50°-60°, and often branching once, or occasionally twice. Most of the secondaries are craspedodromous, terminating in tooth apices; the basal 1-2 pairs of secondaries are camptodromous and terminate before reaching the entire portion of the margin. Tertiary veins are percurrent. Higher order veins and areolation are not well preserved.

Occurrence: At least 150 specimens of leaves and leaf fragments have been recovered. They are most common in the Concretion Zone (Unit 6a) at the base of the Upper Lacustrine Sequence, and occasionally are found in the Channel-Fill Siltstone and Lower Lacustrine Sequence (Units 3-4).

Discussion: Bell (1949) collected leaves of this type near the old Joffre Bridge (G.S.C. locality 3462), and near the mouth of the Blindman River. He assigned them to Populus carneosa (Newberry) Bell, which he based on Phyllites carneosus Newberry (1898), and he placed Phyllites cupanioides Newberry (1898) in synonymy. Brown (1962) reassigned those specimens and others from the Fort Union Group to the genus Viburnum, using the specific epithet of P. cupanioides.

Hickey (1977) described similar leaves from the Golden Valley Formation of North Dakota as "Viburnum" cupanioides, adding the quotation marks to indicate that he considered their assignment to Viburnum to be questionable. He stated that, based on the leaf morphology and venation, Viburnum is "a plausible generic assignment for this form, and is retained pending further study", but he also noted their resemblence to "some of the modern leaves of the genus Hamamelis". Other workers (e.g., Crane et al., 1990); S.L. Wing, pers. comm.) have also noted a similarity to some of the Hamamelidaceae, but the systematic relationship of these leaves remains uncertain at present.

The leaves from Joffre Bridge Roadcut conform very closely to the descriptions published by Bell (1949) and Hickey (1977), and thus are assigned to "Viburnum" cupanioides, sensu Hickey, retaining his caution about their affinity.

At Joffre Bridge Roadcut, the "Viburnum" leaves are common in the lacustrine sediments of the Concretion Zone (Unit 6a), which was deposited in very shallow water, near shore. Joffrea leaves, Osmunda pinnules, Glyptostrobus branches and cones, Metasequoia foliage, fragments of Zingiberopsis leaves, and the remains of a lilialean monocot, are also found in that unit.

Genus Wardiaphyllum Hickey

Wardiaphyllum datur efolium (Ward) Hickey

(Plate 11 , Figs. 82, 83)

Description: Leaves simple, petiolate, ovate to wide elliptic, about 8.0-11.5 mm long, 5.0-8.0 mm wide, with a length-to-width ratio of about 1.5 (Fig. 82). Apices are acute to acuminate. Bases are rounded to truncate, decurrent along the petiole, and often slightly asymmetrical. Margins are entire below the basal secondaries, and in the apical 10-25% of the lamina, but are otherwise distinctively toothed. Teeth are prominent, sharp, narrow, and somewhat irregularly spaced (Fig. 83). Sinuses are rounded. The teeth often curve toward the apex, but their orientation varies, particularly for the basal teeth. Venation is pinnate, semicraspedrodromous. The primary vein is straight and unbranched. Secondaries diverge at angles of about 40°, forming loops by joining superadjacent secondaries at acute angles; the basal pair of secondaries may be downcurved if the base is truncate. Tertiary veins are percurrent, originating on both sides of the secondaries. Quaternary veins are orthogonal to tertiaries, forming pentagonal areoles. Quinternary veins branch once or twice, and have freely ending tips. A fimbrial vein is present.

Occurrence: About 20 leaves, mostly fragmentary, have been recovered from the Channel-Fill Siltstone and Lower Lacustrine Sequence (Units 3-4).

Discussion: Leaves with this morphology from Seven Mile Creek, Montana, were originally described and illustrated by Ward (1887) as ?Credneria daturaefolia. Cockerell (1908) discussed their resemblance to Populus. Bell (1949) collected similar leaves from the Paskapoo Formation near Rocky Mountain House, Alberta, and assigned them to Populus? daturaefolia (Ward)

Cockerell. Bell noted that, although there is resemblance to some species of Credneria and Populus, "the true taxonomic relationship of the species remains decidedly questionable". Brown (1962) agreed that "the identity of these leaves remains as doubtful as when Ward described them."

Hickey (1977) found that Ward's specimens differ greatly from the original generic description and illustration of Credneria Zenker, a taxon that was originally erected for Upper Cretaceous leaves from Germany. Hickey therefore erected the genus Wardiaphyllum, of uncertain affinity, for Ward's specimens. Hickey found "no convincing modern analogue" for these leaves, but noted some similarity to the Platanaceae in the proportions of the marginal teeth, and in the details of the tertiary and quaternary venation (Hickey, 1977). Until an association with fruits or other organs can be demonstrated, the affinity is likely to remain obscure.

The leaves from Joffre Bridge Roadcut closely resemble those described and illustrated by Ward (1887), Brown (1962) and Hickey (1977), and are thus assigned to Wardiaphyllum. These leaves are not common at Joffre Bridge Roadcut, but are occasionally found in the Channel-Fill Siltstone and Lower Lacustrine Sequence (Units 3-4), with the remains of woody dicots from riparian and floodplain environments, such as Joffrea and Platanus. Wardiaphyllum leaves have also been found at the Munce's Hill (One Jaw Gap) locality (Ti_4 age) near Joffre Bridge Roadcut.

Genus Fortuna McIver & Basinger

Fortuna marsilioides (Bell) McIver & Basinger

(Plate 11 , Figs. 85, 86)

Description: The leaves are very wide obovate, triangular; bilaterally symmetrical; 24-33 mm long, 28-34 mm wide, with a length-to-width ratio of 1:1; rounded apex; acute base; and no petiole (Fig. 85, 86). The margin is entire in the basal half, becoming toothed in the apical half; the teeth are obtuse and serrate, becoming dentate toward the apex. The venation is actinodromous, reticulate, basal (Fig. 86). There are eight primary veins; secondaries diverge at acute angles and become subparallel to the primaries; detailed venation features are poorly preserved.

Occurrence: Seven leaves have been recovered from the Upper Lacustrine Sequence, at the base of the Aquatic Plant Zone (Unit 6b).

Discussion: The Fortuna leaves from Joffre Bridge Roadcut resemble those described from the Upper Cretaceous (Maastrictian) St. Mary River Formation along the Oldman River north of Cowley, Alberta (Bell, 1949; McIver and Basinger, 1993); from the St. Mary River Formation on the east bank of the river across from the St. Mary Reservoir spillway (Stockey and Stockey, 1993); from the Paleocene Paskapoo Formation at the mouth of the Blindman River near Joffre Bridge Roadcut (McIver and Basinger, 1993); and from the Paleocene Ravenscrag Formation of Saskatchewan (McIver and Basinger, 1993).

Bell (1949) originally described specimens from the Oldman River locality as Antholithes (Nymphaeites?) marsilioides. McIver and Basinger (1993) named the genus Fortuna and presented an amended diagnosis based on better-preserved material from the Paleocene localities noted above. They reinterpreted its rosettes as four simple leaves, rather than as sepals or bracts of a flower as Bell had done. The leaves from Joffre Bridge Roadcut are detached.

Although the lateral margins of the leaves from Joffre Bridge Roadcut appear entire, like those from the Oldman River locality, this is probably the result of poor preservation, as McIver and Basinger (1993) suggest for some of their specimens. The Paleocene Fortuna leaves that they describe all reveal a toothed margin. Similarly, some of the best-preserved leaves from the St. Mary Reservoir Spillway locality exhibit small, delicate teeth along the lateral margins, but they are often covered by the surrounding matrix (Stockey, pers. comm.).

Although they are rare at the site, the Fortuna leaves from Joffre Bridge Roadcut support the interpretation of an aquatic or semi-aquatic habit for this plant (McIver and Basinger, 1993). They were found in a greenish grey lacustrine claystone (Unit 6b), associated with the remains of free-floating aquatic plants (Spirodela, Ricciopsis and Azolla), and fragments of lilialean leaves.

Unidentified Aquatic Leaf

(Plate 13 , Figs. 93, 94)

Description: None of the specimens are complete, but these leaves appear to be symmetrical and orbiculate (Figs. 93, 94), about 20 mm long and wide. The leaf lamina has a fairly delicate, membranaceous texture. Leaf apices are obtuse, and the bases are missing or very poorly preserved on these specimens. The margin is toothed. The teeth are regularly spaced, with rounded sinuses, convex sides, obtuse apices, and dark glandular tips of the chloranthoid type (having a medial vein "braced" by two prominent laterals which join it; Hickey and Wolfe, 1975). Venation appears to be palinactinodromous, with about 8-10 primary veins diverging from a point near the base, branching dichotomously about 3 times before terminating at the marginal glands. Secondaries diverge at acute to right angles and curve to run subparallel to the primaries, ultimately joining primaries or other secondaries to form a reticulate network. Tertiaries diverge at high angles, forming an orthogonal reticulate pattern. Quaternary veins are rarely preserved, but appear to diverge from the tertiaries at right angles and end freely within the rectangular areoles without curving or branching.

Occurrence: Ten fragmentary specimens of leaves have been recovered from the Upper Lacustrine Sequence, at the base of the Aquatic Plant Zone (Unit 6b).

Discussion: These leaves are rare at Joffre Bridge Roadcut, and were found at the base of the Aquatic Plant Zone, with remains of the Spirodela-like plant, Glyptostrobus twigs, and scattered Osmunda pinnules and fragments of Zingiberopsis leaves. This setting and their delicate texture suggest that they may have been the floating leaves of an aquatic plant. However, they are fragmentary and the leaf bases are missing or poorly preserved, so nothing is known about their mode of attachment. Given this limited evidence, it is not possible to draw any meaningful conclusions about the structure or affinities of their parent plant at present.

Unidentified Leaf 1

(Plate 10 , Figs. 80, 81)

Description: Two leaves, both fragmentary. Apices are not present, and shape and size are uncertain. Lamina is greater than 40 mm long and 30 mm wide. Base appears to have been cuneate (Fig. 81). A few small, rounded serrations are present on the margin (Fig. 80). Venation is acrodromous. About six primary veins diverge from the base, and most branch once near the base. Secondaries diverge at shallow angles and become subparallel to the primaries. Tertiaries diverge at nearly right angles. Higher order veins form a random reticulate network.

Occurrence: There are two fragmentary leaves preserved on a single slab (S16,943). Their exact stratigraphic position is not known, but the matrix is consistent with the Channel-Fill Siltstone or Lower Lacustrine Sequence (Units 3-4)

Unidentified Leaf 2

(Plate 10 , Fig. 79)

Description: A single fragment of a leaf, 28 mm long and 6mm wide, with an acute apex and entire margin (Fig. 79). Venation is brochidodromous. The primary is sinuous. The secondaries diverge alternately at high angles, sometimes branching once before joining supra-adjcaent secondaries or the fimbrial vein. Higher order venation is obscure.

Occurrence: One fragmentary leaf apex, S12,132, has been recognized. Its exact stratigraphic position is not known, but the matrix is consistent with the Channel-Fill Siltstone or Lower Lacustrine Sequence (Units 3-4).

Class LILIOPSIDA
Subclass ALISMATIDAE
Order ALISMATALES
Family ALISMATACEAE
Genus Alismaphyllites Knowlton
Alismaphyllites grandifolius (Penhallow) Brown

(Plate 15, Figs. 107, 108)

Description: The specimens are fragments of large leaves with entire margins (Figs. 107, 108). There are four subsets of parallel veins, designated A, B, C, and D in order of decreasing strength, which are regularly spaced and form the pattern ADCDBDCDA over an interval of 3-4 mm. The weak veins of the D subset are discontinuous, sometimes curving to join adjacent veins or transverse veins at acute to right angles. There are several subsets of discontinuous transverse veins that cross the parallel vein subsets at acute to right angles. The strongest reach lengths of up to 25 mm before terminating against veins of the A subset. The weakest extend only between D subset veins. Areoles range from quadrangular and polygonal to lenticular (Fig. 108).

Occurrence: About 10 fragmentary leaves have been recovered from the Concretion Zone (Unit 6a) and the base of the Aquatic Plant Zone (Unit 6b) in the Upper Lacustrine Sequence.

Discussion: These leaves appear to be conspecific with those described by Penhallow (1902) as Majanthemophyllum grandifolium. Penhallow's material came from outcrops near the mouth of the Blindman River, not far from Joffre Bridge Roadcut, where leaves of this kind are more common and much better preserved.

Berry (1926) and Bell (1949) referred additional material from the Paskapoo Formation to Majanthemophyllum, although Bell noted that the affinity of these leaves was uncertain and the assignment was questionable.

Brown (1962) observed that the tertiary venation excludes these leaves from the genus Majanthemophyllum (Liliaceae). Comparing them to leaves of some species of Alisma, Echinodorus, Aponogeton and Potamogeton, he referred them to Alismaphyllites (Alismataceae), and suggested that they might be related to the Miocene fossils Alisma macrophyllum Heer and Potamogeton nordenskioldii Heer from Spitzbergen (Heer, 1876).

The Alismaphyllites leaves from Joffre Bridge Roadcut are uncommon and fragmentary, and thus can add little to our understanding of the plant that bore them or its affinities, although further study of the material from the Blindman River area would likely be productive. Like those from the Blindman River, the specimens from Joffre Bridge Roadcut are found in lacustrine sediments, associated with the remains of Zingiberopsis and aquatic plants, a setting that is consistent with their having been produced by a plant that grew along the shore of the lake or in shallow water.

Subclass ARECIDAE

Order ARALES

Family ARACEAE

Spirodela-like monocot

(Plate 12 , Figs. 87-92)

Description: Each plant consists of a single orbiculate to very wide ovate leaf-like body with an entire margin (Figs. 87, 88), typically 15-20 mm in diameter but reaching a maximum of 40 mm. Dorsal and ventral surfaces are pubescent, with hairs 0.2-0.4 mm long. A node or centrum up to 3 mm in diameter is located in basal to central region (Figs. 88, 89). "Daughter" plants arise from two pouches adjacent to the centrum (Fig. 91). Venation is campylodromous (Fig. 87). Twelve to 14 curved primary veins radiate from the node, converging distally with a marginal vein. Numerous (usually about 25-30) simple, unbranched filiform rootlets, about 0.2 mm wide and up to about 15 mm long, radiate from the centrum beneath the dorsal surface. A single primary root up to 3 mm wide and 40 mm long, bearing filliform lateral rootlets, also issues from the node (Figs. 88, 89). A stolon about 3.5 mm wide, reaching lengths of more than 40 mm, is also connected at the node. The pollen is monoporate, with a circular polar outline, a subcircular to ovate equitorial outline, and a diameter of 20-25 μm (Fig. 90). The wall is 1.5 μm thick and consists of three layers: the foot layer and tectum are homogeneous and of equal thickness, separated by a very thin infratectal layer of granular material (Fig. 92). The sculpturing is echinate. The echinae are connate in shape, about 2.0 μm tall, and constricted at the base; the bases are convex at the inner surface of the tectum, but do not penetrate to the foot layer (Fig. 92). There is no evidence of an endexine (differentially staining layer).

Occurrence: More than 300 specimens have been recovered from a thin bed of claystone at the base of the Upper Lacustrine Sequence (Unit 6).

Discussion: This fossil shares many features with the extant genus Spirodela Schleiden: the single floating leaf-like body; the node or centrum from which the veins and roots originate; the two reproductive pouches adjacent to the centrum; the numerous unbranched filiform rootlets; and lemnaceous pollen morphology and ultrastructure. However, the plant body is much larger and more strongly pubescent than those of living Spirodela, and it posseses a large, branched primary root and a very long stolon. The branched root excludes this fossil from the genus Spirodela, and also from the family Lemnaceae, in which roots are filiform and unbranched, or absent (Hillman, 1961; den Hartog and van der Plas, 1970). It is therefore necessary to erect a new genus for this fossil, and despite its obviously close relationship to the Lemnaceae (as demonstrated by pollen morphology, for example), to place it in the family Araceae. Various fossils that have been assigned to Spirodela scutata Dawson share some, but not all, of the characters seen in this fossil from Joffre Bridge Roadcut, and thus although it is likely that they are closely related, they are not here placed in synonymy.

For more than 150 years, most botanists have held that the genus Spirodela was derived from the free-floating aroid Pistia L. by reduction (e.g., Schleiden, 1839; Engler, 1877; Arber, 1919, 1920; Maheshwari, 1958; Sculthorpe, 1967), and it is interesting that the branched root that excludes this fossil from the Lemnaceae resembles the roots seen in extant Pistia. It is therefore tempting to suggest that this fossil supports the traditional view. However, recent work on pollen morphology and ultrastructure (Landolt, 1986; Tarasevich, 1990; Grayum, 1990, 1992), and molecular studies (Duvall et al., 1993; Grayum, pers. comm.) indicate that the relationship between Spirodela and Pistia may not be as close as was previously believed, and the matter clearly merits further study.

Fossils resembling Spirodela and Pistia have been found in Alberta, Saskatchewan, Montana, Wyoming and North Dakota. Pistia-like forms first appear in strata of Upper Cretaceous age, and have been referred mainly to the taxon Pistia corrugata Lesquereux. Spirodela-like forms appear somewhat later, in lowermost Paleocene strata, and have been referred mainly to Spirodela scutata Dawson.

Unfortunately, there has been a moderate amount of confusion about the matter. Some of Dawson's specimens are not available, and Lesquereux's types included specimens of unrelated genera (Knowlton, 1900). A few authors (e.g., Lesquereux, 1878; Ward, 1887) argued that the two taxa were conspecific, while others (i.e., Brown, 1962; Krassilov, 1973) placed Spirodela scutata in synonymy with taxa that appear to be unrelated, as discussed below.

Most authors have concluded that Spirodela scutata and Pistia corrugata are distinct entities, however (e.g., Dawson, 1886; Berry, 1935; McIver and Basinger, 1993), and those names continue to be used. Pistia corrugata includes obovate, pubescent leaves with acrodromous venation, like those of extant Pistia; and Spirodela scutata includes orbiculate to reniform thalli with numerous rootlets and campylodromous venation. The fossils assigned to Spirodela scutata differ significantly from extant Spirodela, however, and their assignment to the living genus is questionable (Hickey, 1977; McIver and Basinger, 1993).

Spirodela scutata was first described from Wood Mountain, Saskatchewan, as Lemna (Spirodela) scutata by Dawson (1875). Dawson (1875, 1886) described the plant bodies as round or "kidney-form" to tri-lobed, up to one inch in diameter, with entire or slightly undulate margins, and numerous filiform roots "proceeding from a round spot" near the margin. He described the venation as "veinless or with very faint veins" radiating from "marginal or submarginal thickened spot" (Dawson, 1886). His plates show plants with unbranched rootlets radiating from a node, and a plant bearing two attached daughter plants. Significantly, branched roots that resemble the primary root of the Joffre Bridge plant were apparently associated with, but not attached to, one of the specimens that Dawson (1875) illustrated. Dawson (1875) described them as "roots with pinnate or radiating rootlets ... which are very common in these beds". It thus appears possible that a branched root may have been part of Dawson's plant, but the evidence is not conclusive.

Lesquereux (1878) referred two specimens from Point of Rocks, Montana, to Lemna scutata Dawson, and then proceeded to argue that L. scutata was conspecific with Pistia corrugata, which he described from the same locality. He argued that the material should be referred to the genus Pistia because of the "radicles, coming out in bundles from linear rootlets". However, none of Lesquereux's specimens proved to resemble Dawson's (Knowlton, 1900).

Ward (1886, 1887) referred specimens from Burn's Ranch, Montana to Lemna scutata and illustrated their venation, including the marginal vein. Ward's illustrations show a branched root that may be attached to one of the plants, but again the evidence is not conclusive.

Berry (1935) reviewed Dawson's and Lesquereux's work, and concluded that the two taxa are "perfectly distinct" entities. He noted that the use of the name Lemna should be dropped in favor of Spirodela.

Bell (1949) assigned specimens of Paleocene age from Alberta to Spirodela scutata, and reexamined Dawson's specimens. He described the venation, pubescence, and the imprint of "nearly equidimensional cell-like areas that may represent aerenchymatous tissue", and like Dawson (1875), he commented on the branched root, a "primary root or stem, 1 to 1.5 mm wide, [that] is also commonly associated with the plant body as if attached at its axial node."

Brown (1962) placed Spirodela scutata in synonomy with Hydromystria expansa (Heer) Hantke, along with several other taxa (Hiraea expansa Heer, Nymphaeites brownii Dorf, and Carpites verrucosus Lesquereux). He described the leaves as "sessile, or nearly so at nodes on a succulent prostrate stem or runner", and the roots only as "feathery rootlets [which] may sometimes be seen at the nodes". Brown added that he did not consider the assignment to be "completely appropriate" because the specimens clearly lack petioles, and it was not adopted by subsequent authors.

Krassilov (1973) proposed the name Limnobiophyllum Krassilov for "the leaves previously described from the Cretaceous-Paleocene of North America as Lemna (Spirodela), Nymphaeites, Carpolithes [sic] and Hydromystria", and he placed the material of Dawson (1875), Dorf (1942), Bell (1949), and Brown (1962) in synonymy with Limnobiophyllum scutatum (Dawson) Krassilov. Krassilov appears to have based his diagnosis largely on specimens from the Amur region of Siberia. Described as reniform leaves densely covered with "cylindrical protuberances" 0.2 mm in diameter, 0.3 mm high, and "notched at the apex", there is no evidence of pubescence, venation or roots in Krassilov's diagnosis and illustrations, and thus his material could not be conspecific with Spirodela scutata.

Chandrasekharam (1972, 1974) described ten specimens from the Genesee locality in central Alberta, and assigned them to Spirodela scutata, describing their venation, pubescence, and possible aerenchyma. The Genesee specimens were examined during the preparation of this thesis, and small unbranched rootlets can be seen attached to the centrum of some of the specimens. Branched roots, much smaller and more delicate than those of the Joffre Bridge plant, lie near a few of the specimens but are not attached (i.e., UAPC-ALTA S1534), and again it is not clear whether they were actually part of the plant.

Hickey (1977) described an "unidentified aquatic plant" from the Golden Valley Formation in North Dakota that exhibits many of the features of the Joffre Bridge plant: an orbicular, pubescent leaf-like thallus with two daughter thalli attached, and filiform rootlets radiating from a centrum along with a much longer and stouter primary root or stem. Because the venation was not discernable, Hickey declined to make a more certain identification. He noted, however, that the assignment of the fossil forms to the modern genera Lemna and Spirodela was inappropriate.

McIver and Basinger (1993) also observed that the fossil forms differ from extant Spirodela, citing their larger size, shape and coarse pubescence. They referred 15 specimens from Ravenscrag Butte, Saskatchewan, to Spirodela scutata and presented an emended diagnosis. The specimens from Ravenscrag Butte, like those from Genesee, lack evidence of a branched root. They were preserved in lacustrine clay, along with other aquatic plants, including one that was referred to Pistia corrugata by McIver and Basinger (1993).

The Joffre Bridge plant resembles Dawson's (1875, 1886) description of Spirodela scutata in its general shape and filiform rootlets that radiate from the centrum. It also produced daughter plants from two pouches adjacent to the centrum, as Dawson's plant appears to have done. Its venation closely resembles that described and/or illustrated for Spirodela scutata by Dawson (1886), Ward (1886, 1887), Bell (1949), Chandrasekharam (1972, 1974) and McIver and Basinger (1993). However, it is clearly distinguished from Spirodela scutata and from extant Spirodela by the long, stout, branched primary root that is attached at its centrum. It also appears to have reached larger sizes and been more robust than Spirodela scutata. The Joffre Bridge plant most closely resembles Hickey's (1977) "unidentified aquatic plant", which appears to possess a similar stout primary root, as well as two attached daughter plants, and it is unfortunate that venation is not discernable on that specimen.

The Joffre Bridge plant appears to have lived much like the Lemnaceae of today. Modern Lemnaceae float on or just below the surface of quiet bodies of fresh water, and are often found with Riccia and Azolla in quiet ponds and ditches (Landolt, 1986; Hillman, 1961). Driven by winds, the plants can accumulate along shorelines or on mudflats, sometimes piling up to thicknesses of several centimetres (Clark, 1979). The deposit at Joffre Bridge Roadcut probably records such an occurrence. Remains of the Spirodela-like plant are very abundant in a thin layer at the base of the Upper Lacustrine Sequence, along with occasional Ricciopsis thalli, scattered Osmunda pinnules and a few dicot leaves. The plants likely had become concentrated and stranded along the shore of the oxbow lake, where they became covered by fine clay and thus were preserved.

Although flowering is rare in living Spirodela (Schleiden, 1839; Saeger, 1929; Landolt, 1957), lemnaceous pollen, some of it in anther-like clumps, is abundant in the sediments that include these fossils, and in at least one case the remains of two anthers appear to be attached to a plant. The pollen resembles that of living Lemnaceae (Erdtman, 1952; Landolt, 1986; Tarasevich, 1990) in its size, shape, ornamentation, and single pore, differing only in the well-developed annulus surrounding the pore (Fig. 90), and the poorly developed collumellate layer that is represented only by a thin layer of granular material (Fig. 92).

The size, shape, ornamentation, and the single annulate pore of the pollen from this fossil strongly resemble those described in the fossil pollen genus Pandaniidites Elsik (Hotton et al., 1994). The fossil differs only in the thin infratectal layer, which consists only of granular material rather than "irregular granules to short collumellae" (Hotton et al., 1994) in Pandaniidites, and in the lack of thickening or depression of the exine beneath the echinae as reported for Pandaniidites by Jarzen (1983) and Hotton et al. (1994). Jarzen (1983), Hotton et al. (1994) and others have argued that Pandaniidites was produced by a plant with pandanaceous affinities, as its name implies, and have used its occurrence in the late Maastrictian and Paleocene sediments of mid-continental North America to support the interpretation that a tropical to subtropical climate prevailed across the Cretaceous-Tertiary boundary. Sweet (1986 and pers. comm.) has argued for a lemnaceous affinity, which would not imply a frost-free climate. The material from Joffre Bridge Roadcut lends strong support to Sweet's hypothesis, and the affinity of Pandaniidites, like the phylogeny of the Lemnaceae, clearly merits further study in light of this new evidence.

Subclass ZINGIBERIDAE
Order ZINGIBERALES
Family ZINGIBERACEAE
Genus Zingiberopsis Hickey
Zingiberopsis attenuata Hickey & Peterson

(Plate 15, Figs. 109, 110)

Description: The specimens are fragments of large leaves with entire margins. The venation includes a midrib or costa about 10 mm wide, which consists of about 12 separate parallel strands. A set of numerous parallel veins diverges from the costa at shallow angles, and consists of three discrete subsets of veins, designated the B, C and d subsets in order of decreasing strength by Hickey and Peterson (1978). The veins are arranged according to the pattern BdCdB and are regularly spaced about 0.2 mm apart. A set of transverse veins connects adjacent parallel veins. Transverse veins are straight to slightly sigmoidal, spaced 0.5-1.2 mm apart, and are perpendicular to oblique to the parallel vein set.

Occurrence. About 12 specimens of leaf fragments have been recovered from the Concretion Zone (Unit 6a) and the base of the Aquatic Plant Zone (Unit 6b) in the Upper Lacustrine Sequence.

Discussion: These specimens are fragmentary, but clearly exhibit features that are consistent with Zingiberopsis attenuata: a costa composed of individual strands; sets of numerous, closely spaced parallel veins of three strengths that diverge from the costa at a low angle; and transverse veins that are often oblique to the parallel veins.

More complete specimens of leaves of this taxon have long been known from localities near the mouth of the Blindman River. They were first described as a "dubious species" by Penhallow (1902). Bell (1949) described them as Cannophyllites magnifolia (Knowlton) Bell. Hickey and Peterson (1978) noted that, although the features of these leaves fall within the very generalized definition of Cannophyllites Brongniart, that name is preoccupied by a Carboniferous seed fern and thus is inappropriate. They assigned the specimens from the Blindman River area to Zingiberopsis attenuata, a new species of the genus Zingiberopsis which Hickey (1977) had erected based on material from the Golden Valley Formation of North Dakota.

The phylogeny and fossil record of the Zingiberales have been reviewed by Kress (1990). The venation of Zingiberopsis is similar to that of certain members of the Zingiberaceae, although the lack of evidence of a ligule (Tomlinson, 1969) casts some doubt on this affinity, as does the possible orientation of the epidermal cell walls (Daghlian, pers. comm.).

At Joffre Bridge Roadcut, the Zingiberopsis material is found in the shallow-water sediments at the base of the Upper Lacustrine Sequence, suggesting that the plant grew near the margins of the lake. Associated taxa include forms that grew rooted in shallow water (the lilialean plant and Fortuna), and free-floating plants that had accumulated near the lake margin (the Spirodela-like plant and Ricciopsis), as well as leaves of other members of the lakeshore plant community ("Viburnum", Glyptostrobus, Metasequoia, and Osmunda).

Subclass INCERTAE SEDIS
Lilialean Monocot

(Plate 14 , Figs. 101-103, 112)

Description: The leaves are preserved only as fragments. The lamina is typically 15-50 mm wide, with parallel sides (Fig. 103), and was probably ensiform; the total length is not known. The margin is entire. The venation is parallel and appears to consist of three sets, here designated the A, B and C sets in order of decreasing strength. The veins are commonly arranged according to the pattern ACCBCCA, although there is some variation. The strong veins of set A are generally spaced 1.0-1.2 mm apart, although the spacing decreases near the margin. No crossveins can be discerned.

One specimen shows the leaves apparently emerging from a rhizome (Figs. 101, 102). The rhizome is about 55 mm long and about 30 mm high, and is densely covered by round root-scars. Nearly 20 roots, still attached to the rhizome, are 3 mm wide and in excess of 70 mm long.

Occurrence: Fragments of these leaves are very common near the base of the Upper Lacustrine Sequence, in the Concretion Zone (Unit 6a) and the lower part of the Aquatic Plant Zone (Unit 6b). The specimen showing the leaves associated with a rhizome was recovered from the Concretion Zone.

Discussion: The affinity of this plant is uncertain. The lack of crossveins excludes the leaves from the genus Typha, with which long, linear leaves are often compared. The shape of the leaves, their venation, and the associated rhizome with its round root-scars and long roots, are more comparable to those of some of the Liliales. The extant Liliales include many perennial herbs from rhizomes, bulbs or corms, which have narrow, parallel veined leaves with open, sheathing bases (Cronquist, 1981).

Heer (1870) described the fossil Iris latifolia from the Miocene sediments of Spitzbergen as having leaves with similar shape and venation, and a rhizome with round root-scars and long roots. However, the rhizome of Heer's plant shows some evidence of segmentation in his illustrations, an observation that was confirmed by R.A. Stockey who examined Heer's specimens of Iris latifolia in 1995 (Stockey, pers. comm.). There is no evidence of segmentation in the rhizome of the plant from Joffre Bridge Roadcut.

Its occurrence near the base of the Upper Lacustrine Sequence indicates that this monocot grew rooted in very shallow water at the edge of the oxbow lake. It is associated with the remains of Glyptostrobus, Metasequoia, "Viburnum", Joffrea, Osmunda, and Zingiberopsis.

Class INCERTAE SEDIS

Unidentified Seed or Fruit

(Plate 13, Figs. 97, 98)

Description: The body is oribculate to reniform, 8.0-12.0 mm in diameter, reaching thicknesses of up to about 1.0 mm. The margin is a smooth, continuous rim about 0.2-0.3 mm wide, broken by a single notch or sinus up to 0.5 mm deep and wide (Figs 97, 98). The surface ornamentation consists of irregular, lenticular protrusions about 0.1 mm wide and up to 2.5 mm long, that radiate away from the sinus. Fragments of carbonaceous material adhere to the surface of some of the specimens.

Occurrence: About 45 specimens have been collected from the Channel-Fill Siltstone and Lower Lacustrine Sequence (Units 3-4).

Discussion: The shape and thickness of these bodies, with their distinct rim, notch, ornamentation, and carbonaceous coating, suggests that they were fairly robust, woody seeds or fruits, as does the absence of any trace of venation, attachment, or roots. They are found among the remains of Joffrea and other riparian taxa, suggesting that they may have been produced by a riparian plant.

These fossils show some resemblance to the taxon Porosia verrucosa (Lesquereux) Hickey (Araceae), which has a similar size, shape, and rim (e.g., Hickey, 1977; Crane et al., 1990; McIver and Basinger, 1993). In Porosia, however, the body is "composed of a carbonaceous groundmass, permeated with tubules oriented at right angles to the surface" (Hickey, 1977), which produce a distinctive surface texture quite different from the lenticular protrusions seen on the specimens from Joffre Bridge Roadcut. Porosia verrucosa is known from the Blindman River area near Joffre Bridge Roadcut, and permineralized specimens of P. verrucosa have been recovered from ironstones of Maastrictian age near Drumheller, Alberta (Fig. 5 of Aulenback and Braman, 1991; R. Serbet, pers. comm.). The latter specimens are currently under study by Serbet, and the results of that work may have implications for the specimens from Joffre Bridge Roadcut, as well as for P. verrucosa.

Striated Seed

(Plate 15 , Fig. 112)

Description: Ellipsoidal to oblong seeds, often curved, 3.0-4.2 mm long and 1.0-1.8 mm wide, with rounded or occasionally acute ends. The surface is covered by thin, parallel striations, and remains of carbonaceous material (Fig. 112).

Occurrence: More than 75 specimens have been catalogued from the Channel-Fill Siltstone and Lower Lacustrine Sequence (Units 3-4).

Cone-like Infructescence

(Plate 13, Figs.95, 96)

Description: Globose or subglobose infructescesces about 20 mm in diameter, consisting of clusters of obovate, coalified strucutres. Those structures are obovate in shape, 7-10 mm in length and 3-5 mm wide (Figs. 95, 96), and may represent fruits, or bracts that subtended fruits or seeds.

Occurrence: About 20 specimens, mostly of isolated bracts or fruits, have been recovered from the Concretion Zone (Unit 6a).

Unidentified Branching Aquatic Plant

(Plate 13, Figs. 99, 100)

Description: Linear, parallel-sided axes 0.5-2.0 mm wide that branch dichotomously up to 4 times, and reach lengths of greater than 60 mm (Fig. 100), sometimes radiating in a whorl from the remains of an axis (Fig. 99).

Occurrence: About 30 specimens have been collected from the Concretion Zone (Unit 6a) in the Upper Lacustrine Sequence.

Unidentified Sheathing Structures

(Plate 14, Figs. 104-106)

Description: The structures are 1-4 mm wide, and lengths of up to 75 mm have been found. They are usually curved, sometimes strongly. Round to elliptical scars that may indicate vascular bundles (Rothwell, pers. comm.) give the structures a segmented appearance (Figs. 104, 106). In a few specimens (e.g., S17,079A/B, S16,690, S16,680), the structures are tightly curved around one another, and appear to represent the bases of clasping leaves with opposite phyllotaxis; axillary buds are present on a few of the specimens (Fig. 104) (Rothwell, pers. comm.). None of the specimens shows any discernable thickness; that is, they do not appear to penetrate vertically through the surrounding sediment.

Occurrence: About 25 specimens have been recovered from the base of the Concretion Zone (Unit 6a).

CHAPTER 5

CONCLUSIONS

Joffre Bridge Roadcut is becoming one of the best documented middle Paleocene fossil localities in North America due to long-term efforts by geologists and paleontologists. The age of the strata has been well established; the environments of deposition of the sediments and fossils have been documented in detail; a very large number of specimens has been recovered; and most of the floral and faunal remains have now been studied and described.

A well-established age is of fundamental importance, because it allows the flora and fauna to be compared with those from other sites of similar age throughout the world. In the case of Joffre Bridge Roadcut and neighboring sites in the Red Deer Valley area, this was accomplished through the integration of faunal succession, palynostratigraphic and magnetostratigraphic data in the years immediately before this thesis was undertaken.

The strata at Joffre Bridge Roadcut were exposed where possible and examined in detail during this thesis. The succession of strata was found to record the abandonment of a river channel and its development into an oxbow lake. The assemblages of plant remains showed a clear relationship to sediment type and environment of deposition, which reflects changes in the plant community itself as the local ecosystem changed, as well as changes in the taphonomic processes that were operative.

The benefits of collecting large amounts of material from a site became apparent during the systematic studies done for this thesis. The more common plants are known from hundreds of specimens, which has allowed them to be reconstructed with a high degree of confidence, including the range of morphology of some of their organs. This has led to an improved understanding of the plants and their phylogeny, both for newly recognized taxa such as the Spirodela-like plant, and for those that are generally considered to have been fairly common in central Alberta during the middle Paleocene, such as the taxodiaceous, cercidiphyllaceous and platanaceous taxa. Although the plants that were not commonly preserved at the site, such as "Acer" arcticum and Populus penhallowi, are still poorly known, being represented by only a few specimens, they would likely have remained entirely undetected if a lesser effort had been made. Faunal remains have come to light along with the plant remains and have been studied by others, further increasing our understanding of the middle Paleocene ecosystems of Joffre Bridge Roadcut.

Large numbers of specimens have also been recovered from the Blindman River sites and Munce's Hill in the Red Deer Valley area, and it is recommended that similar studies of the plant remains and their geological settings be conducted for those sites. The strata at those sites are similar in age to those at Joffre Bridge Roadcut, and preliminary examination of the available material indicates that different paleoenvironments are represented, additional taxa are present, and their state of preservation is very good. Information from those sites would add significantly to our understanding of the species diversity, climate, and ecosystems that existed in central Alberta during the middle Paleocene.

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PLATES

PLATE 1

Figure 1. The Crossbedded Sandstone (Unit 7) is the youngest Paleocene stratigraphic unit preserved at Joffre Bridge Roadcut. It likely represents a crevasse splay that prograded into the oxbow lake.

Figure 2. Joffre Bridge Roadcut, looking east, during trenching in August, 1993. The position of the Crossbedded Sandstone (#7) above the excavating equipment, the Mollusc Layer (#5) below the equipment, and the Lower Level Vertebrate Bed (#1) in the ditch near the road sign, are shown by arrows.

Figure 3. The beds of the Upper Lacustrine Sequence (Unit 6), overlying the darker coloured Mollusc Layer (Unit 5) (arrow). The overlying Crossbedded Sandstone was removed during the recovery of fish fossils from the top of the Upper Lacustrine Sequence.

Figure 4. Fossil molluscs, seeds and <u>Metasequoia</u> foliage preserved on a bedding surface from the Mollusc Layer. S38,514. X 1.4.

Figure 5. Large-scale crossbedding in the Fluvial Channel Sandstone (Unit 2) is exposed along the cliffs to the north, directly across the Red Deer River from Joffre Bridge Roadcut.

Figure 6. Rip-up clasts and the fragmentary remains of a leaf from the Fluvial Channel Sandstone. S39,350. X 1.0.

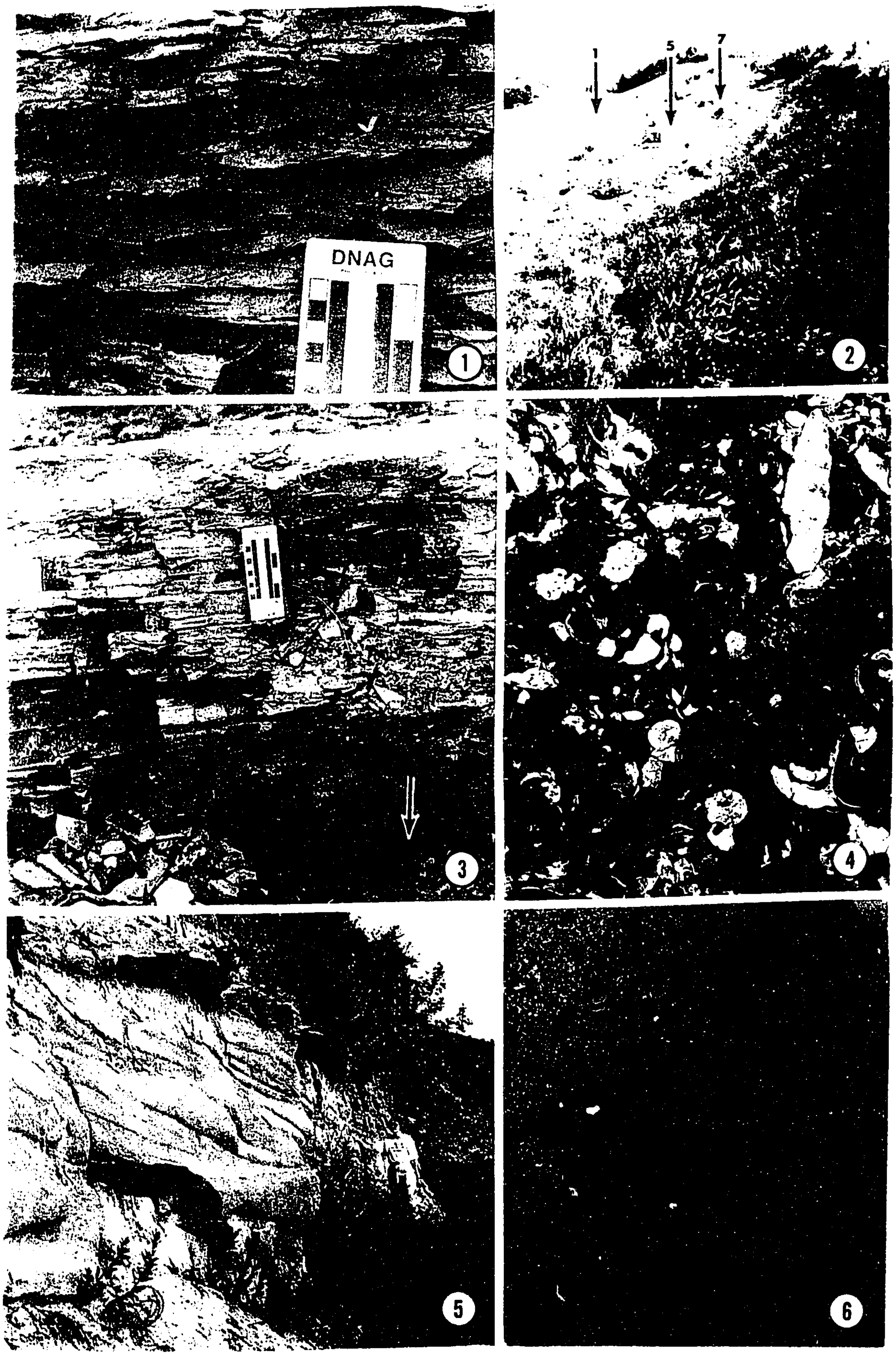
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PLATE 2

Figure 7-10. Ricciopsis Lundblad sp.

7. Thallus with the form of a loose, incomplete rosette. Note dilated regions and dichotomous branching. S17,062B. X 2.0.
8. The dilated region (D) of a thallus. Note the dorsal sulcus (S). The dark material is the remains of cuticle. S17,062B. X 3.5.
9. A thallus with dilated (D) and constricted (C) regions, dorsal sulcus, and remains of cuticle. S11,306. X 3.0.
10. A distinct dorsal sulcus (S). Note the branched, ribbon-like form of the thallus, and the adhering cuticle. S16,332a. X 6.5.

Figure 11. Muscites Brongniart sp.

11. Gametophyte with leaves (arrows). S12,519. X 3.6.

Figure 12-13. Equisetum L. sp.

12. A whorl of partially fused leaves. S9,252. X 4.2.
13. An axis, showing longitudinal ridges and furrows. S11,597. X 5.0.

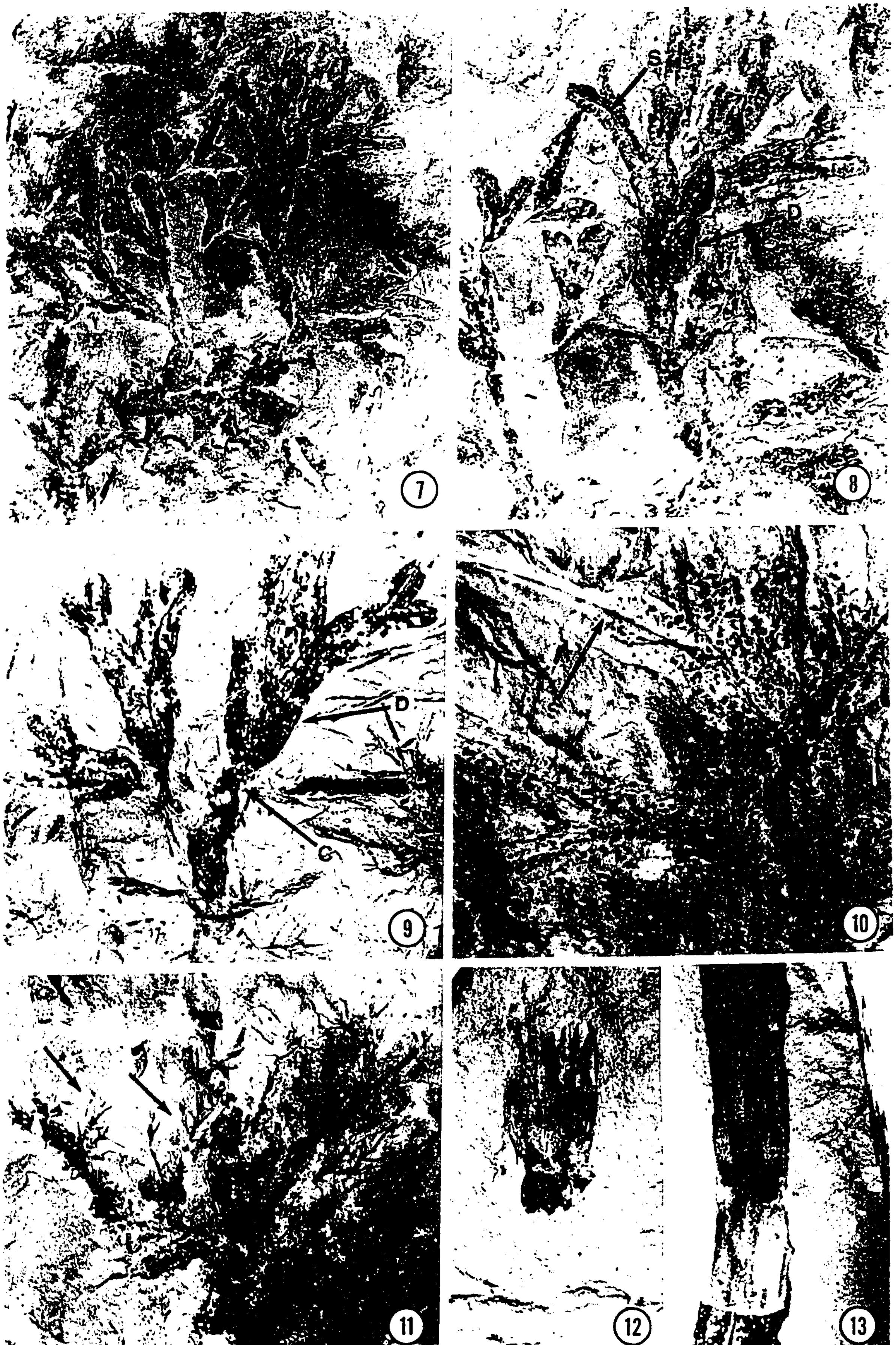
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PLATE 3

Figure 14-16. Osmunda macrophylla Penhallow.

14. Pinnules. Note serrate margin, midvein, and open dichotomous venation. S16,970A. X 2.8.
15. Rachis with alternately arranged pinnules. S16,970A. X 1.5.
16. Detached pinnule. S16,948B. X 3.2.

Figure 17-19. Dennstaedtia blomstrandii (Heer) Hollick.

17. Rachis with alternately arranged pinnules. S16,950. X 1.8.
18. Rachis with alternately arranged pinnules. S16,951. X 1.4.
19. Pinnules with serrate margin and open dichotomous venation. S16,951. X 4.8.

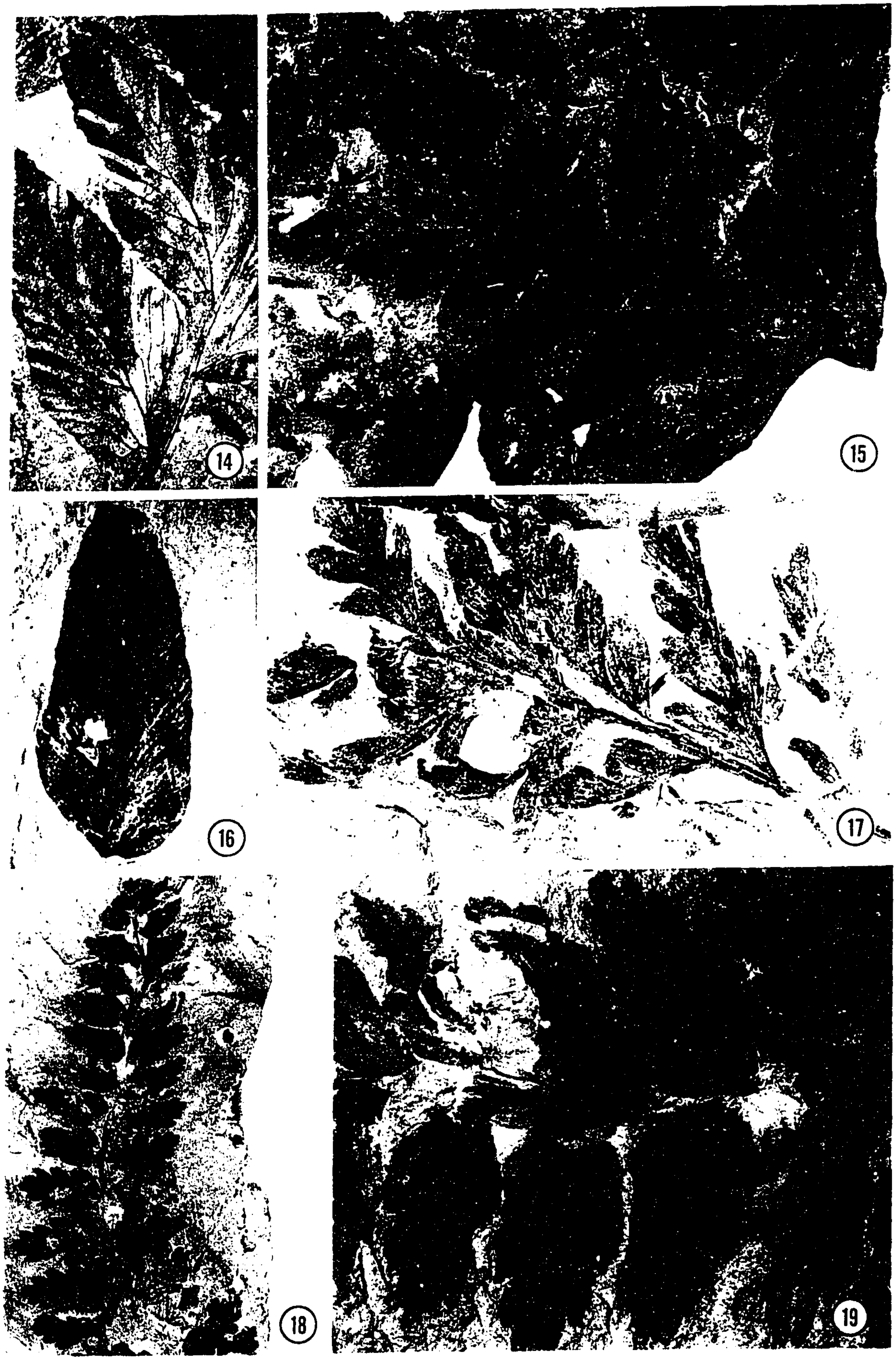
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PLATE 4

Figure 20-33. Azolla stanleyi Jain & Hall.

20. Vegetative sporophyte with crowded, imbricate leaves. S13,349. X 4.0.

21. Fertile sporophyte, with alternately arranged lateral branches. Arrows indicate megaspores. S13,350. X 4.0.

22. Pair of megaspores (arrows) in growth position on sporophyll (S). Note papillate texture of sporophyll. S13,644. X 300.

23. Megaspore complex showing floats (arrows) within the supraspore. X 170.

24. Megaspore with most of the filosum and outermost floats removed. Note conical shape of innermost floats (arrows) held in place by filaments of the filosum. X 180.

25. Filosum filaments. X 2300.

26. Experine surface. X 900.

27. TEM cross-section of megaspore wall showing wall layers: exine (e), inperine (i), experine (o), and filosum (f). X 3600.

28. Massula attached to the filosum of a megaspore complex. Note fluke-tipped glochidia (arrows) projecting from massula surface. X 350.

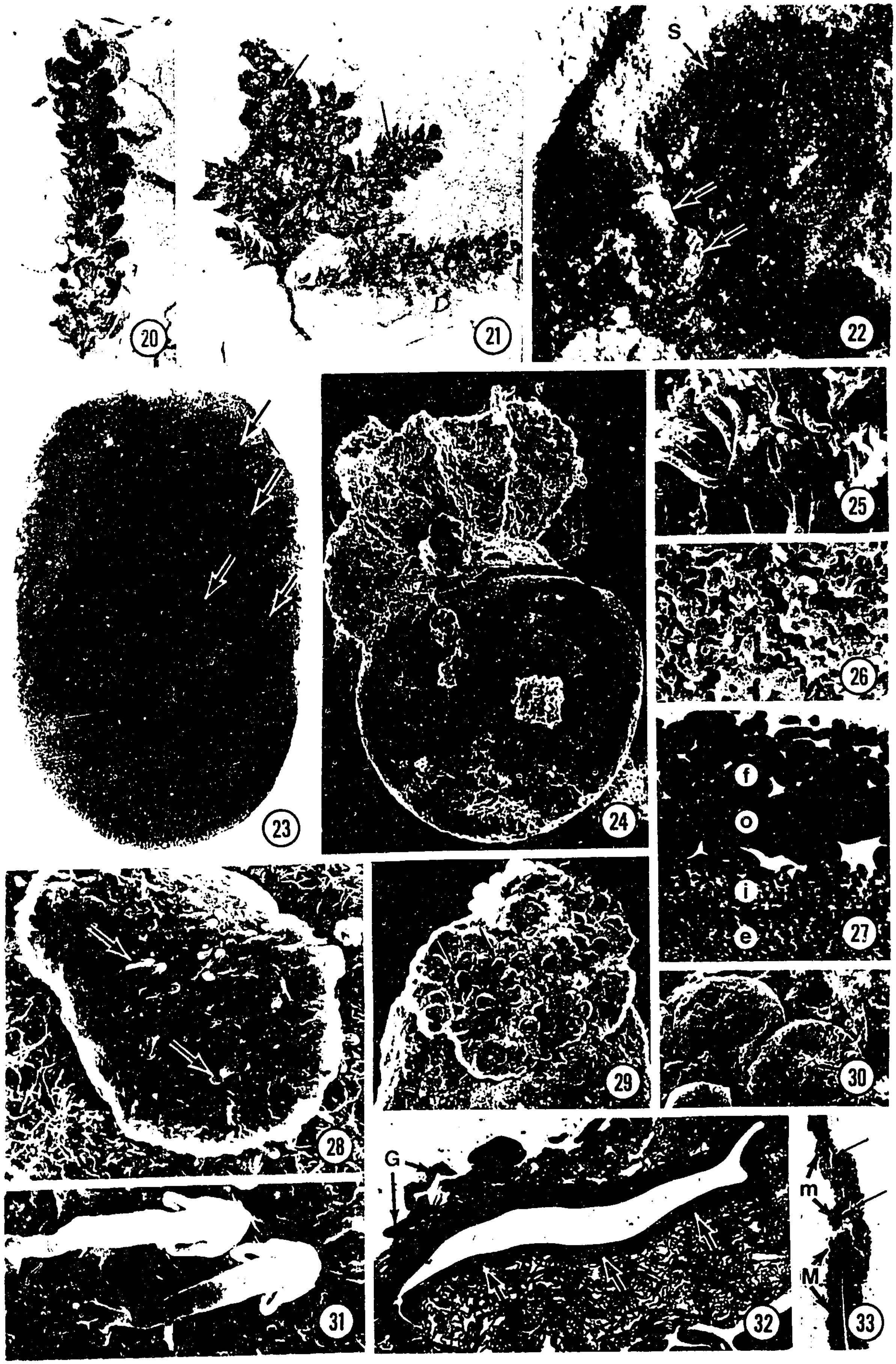
29. Massula attached to a megaspore complex. Massula surface has broken down, exposing microspores (arrows). X 155.

30. Microspores. Note trilete suture. X 900.

31. Fluke-tipped glochidia from the massula in Fig. 28. X 2300.

32. TEM cross-section through a microspore embedded in a massula. Note unlayered microspore wall (arrows), pseudocellular texture of massula, and bases of projecting glochidia (G). X 3600.

33. TEM cross-section of a megaspore (M) with attached massula (m). Microspores (small arrows) are embedded within massula. X 280.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M
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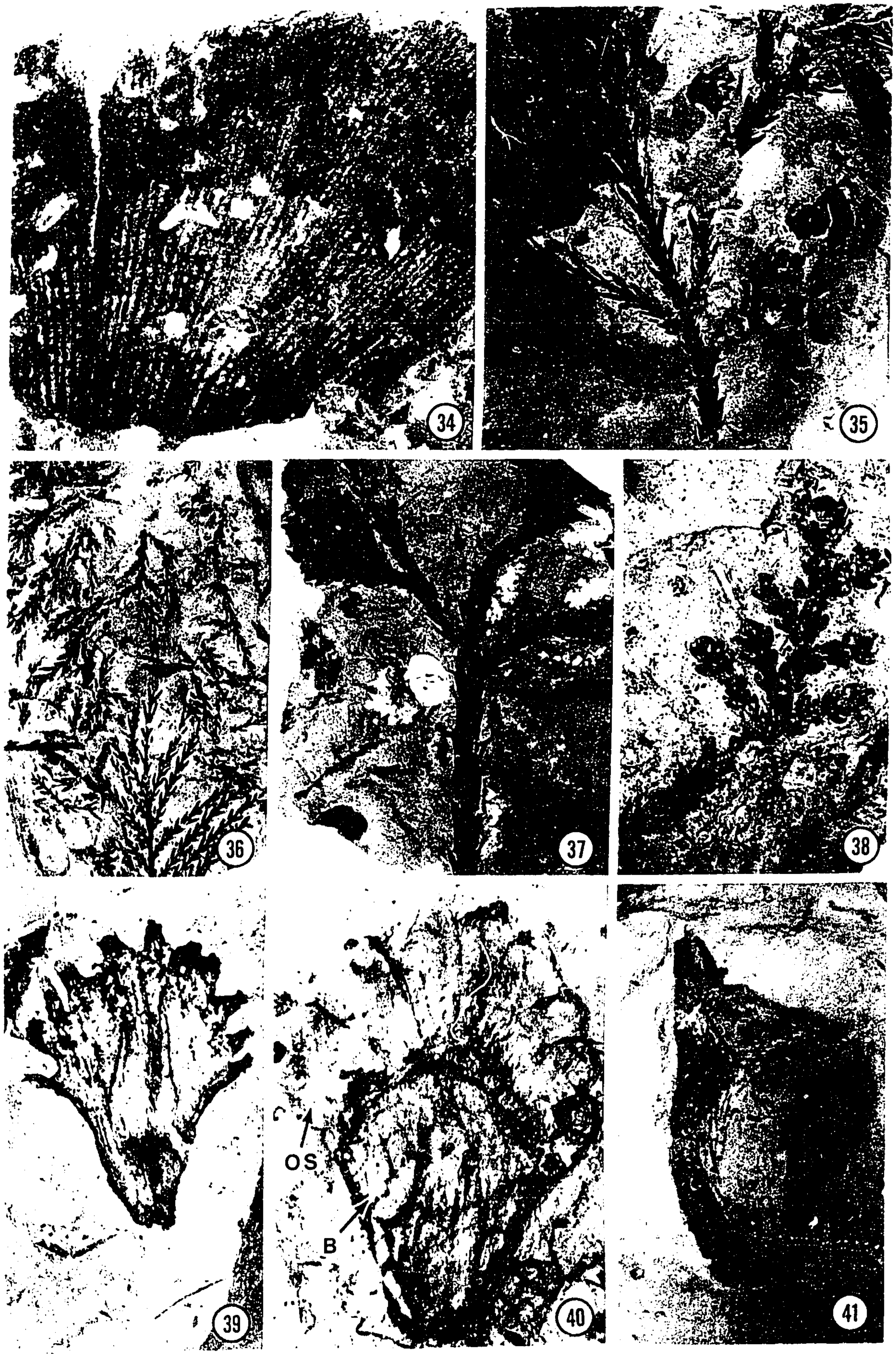
PLATE 5

Figure 34. Ginkgo L. sp. leaf fragment. S13,073. X 3.1.

Figures 35-41. Glyptostrobus europaeus (Brongniart) Heer

35. Branch with foliage and seed cone. (unnumbered) X 1.4.
36. Branches with foliage. S38,505A. X 0.6.
37. Branch with seed cones. S15,667. X 1.1.
38. Branch with pollen cones. S37,101. X 2.6.
39. Ovuliferous scale from a seed cone. S24,558. X 4.6.
40. Ovuliferous scale (OS) and bract (B). S36,989. X 9.0.
41. Winged seed. S36,941. X 6.0.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OS
B
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PLATE 6

Figures 42-47. Metasequoia occidentalis (Newberry) Chaney.

42. Branch with foliage. S11,217. X 2.4.
43. Seed cone. S24,520. X 2.4.
44. Pollen cones. S17,077. X 4.5.
45. Pollen cones with exserted sporophylls. S13,348A. X 1.4.
46. Seed cone. S13,151. X 2.4.
47. Winged seed. S24,534. X 6.0.


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PLATE 7

Figures 48, 49. cf. Meliosma rostellata (Lesquereux) Crane et al.

48. Endocarp, showing keel. S9,909. X 5.2.
49. Endocarp, showing pore. S9,412. X 5.2.

Figures 50-59. Joffrea speirsii Crane & Stockey.

50. Leaf, showing shape and venation. S12,173. X 1.2.
51. Leaf margin. S40,177. X 2.1.
52. Pistillate inflorescences. S12,386. X 1.2.
53. Pistillate inflorescence, with carpels (C). Note abaxially coiled styles (S). S40,075. X 2.1.
54. Associated staminate inflorescence, composed of helically arranged, triangular bracts. S13,419. X 1.6.
55. Infructescence with mature follicles. S38,212. X 1.5.
56. Germinating seeds. Note seed body (s) and wing (w). S11,626. X 3.8.
57. Seedling with two cotyledons (note venation) and the beginnings of the first pair of leaves. S13,306a. X 4.0.
58. Seedling with cotyledons and first leaves. S13,306b. X 4.0.
59. Seedling showing one cotyledon and the first pair of leaves. Note venation and crenate margin. 17,093. X 2.2.

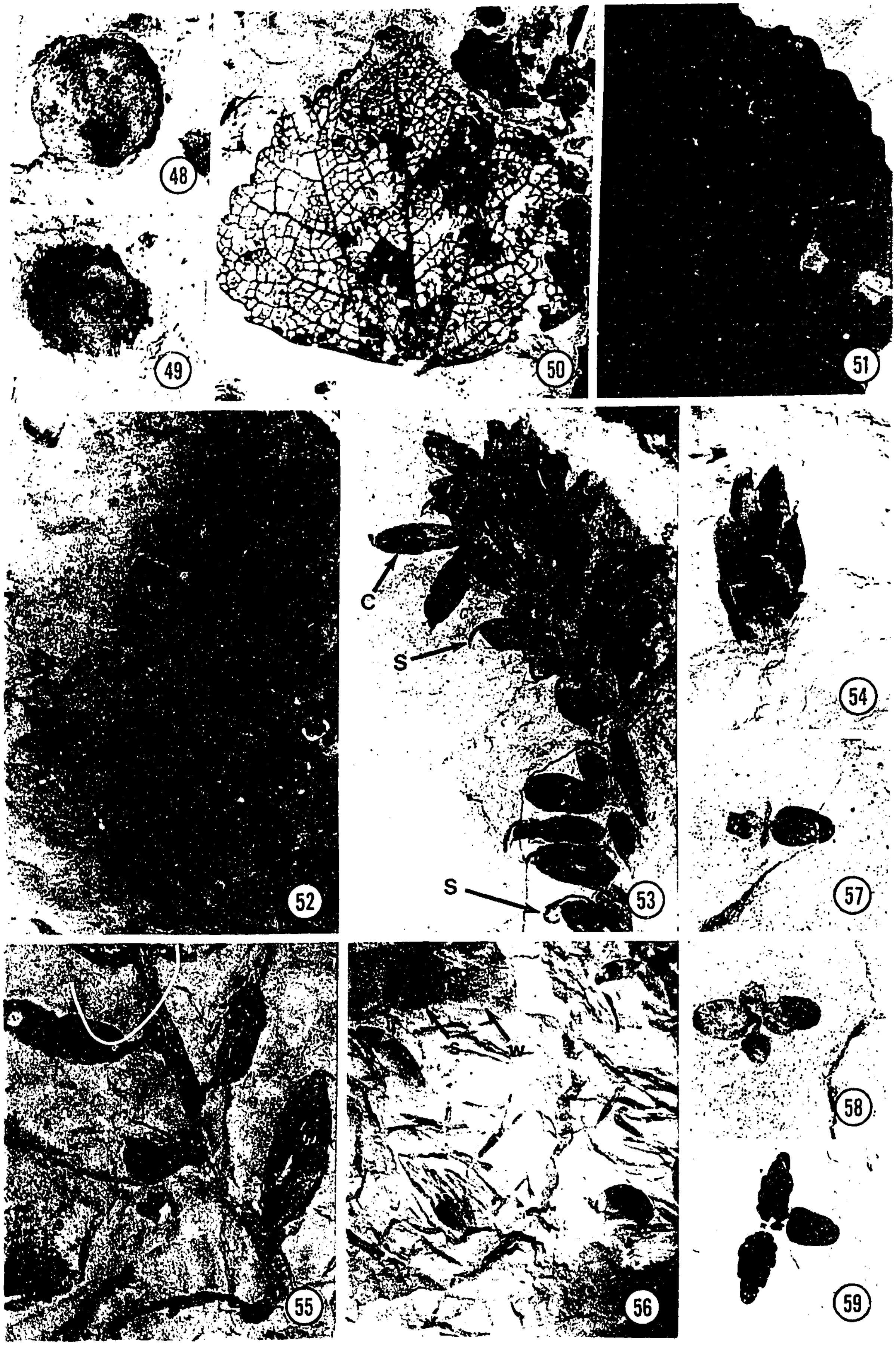
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PLATE 8

Figures 60-66. The Joffre Plane Tree.

Figures 60, 61. Platanus nobilis Newberry.

60. Leaf. S15,735A. X 0.7.
61. Leaf margin, showing venation and teeth. S15,765. X 1.3.

Figures 62, 63. Macginicarpa manchesteri Pigg & Stockey.

62. Infructescences showing attachment. S37,943. X 1.4.
63. Infructescence. Note achenes with curved styles (arrow). S37,948B. X 4.0.

Figure 64. Platanaceous seedling. S12,105. X 6.0.

Figure 65. Platananthus speirsae Pigg & Stockey, staminate inflorescence. S24,832. X 4.0.

Figure 66. Isolated group of platanaceous stamens. Note filaments (f), and cap formed by apical extension of the connective (c). S16,723. X 6.5.

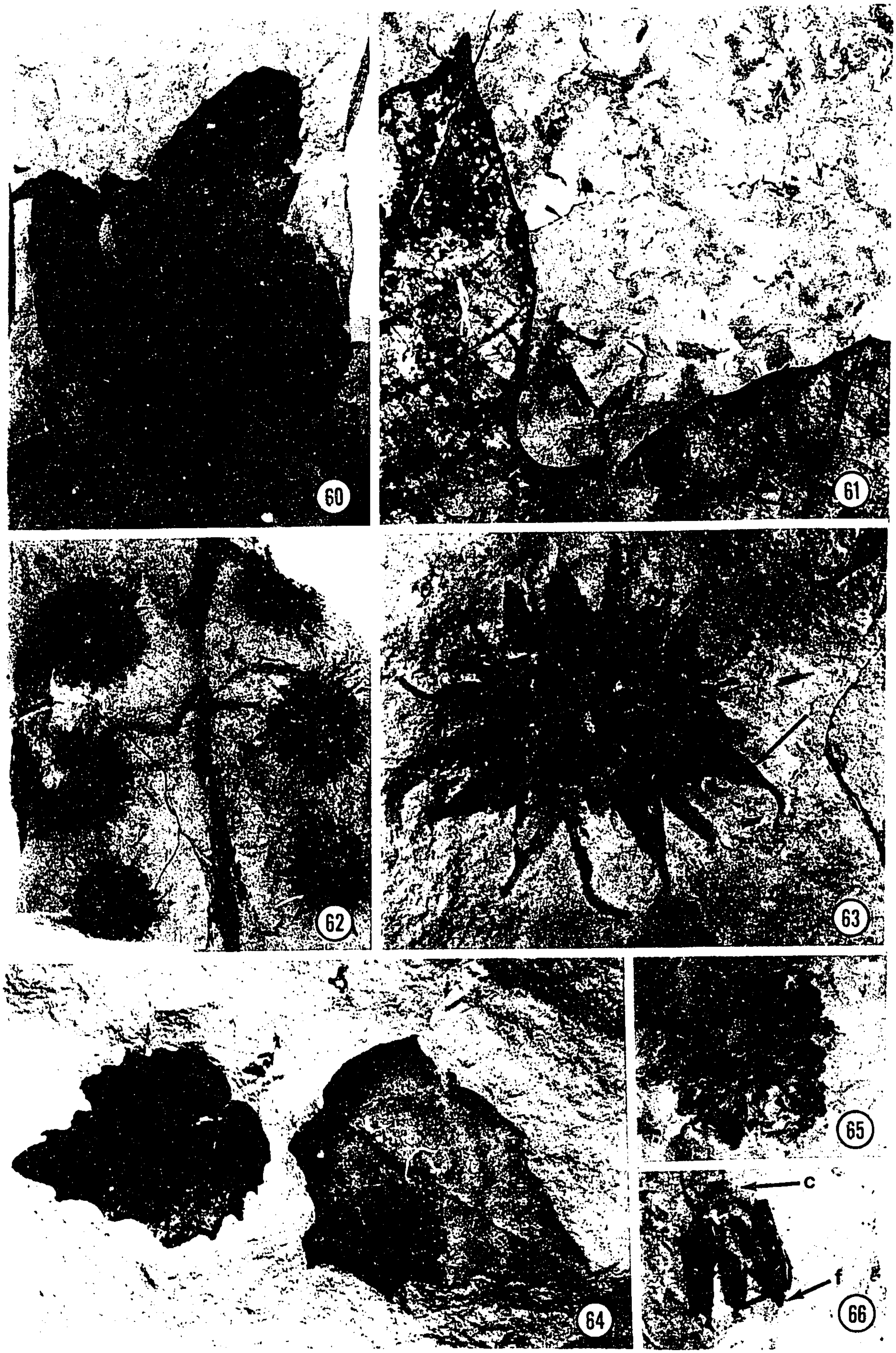
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PLATE 9

Figures 67-69. Chaetoptelea microphylla (Newberry) Hickey.

67. Leaf. S10,587. X 3.0.
68. Leaf. Note venation, and secondary teeth (arrows). S10,588. X 4.5.
69. Leaf. S10,971. X 3.0.

Figures 70, 73. "Acer" arcticum Heer.

70. Leaf margin. S12,060. X 2.0.
73. Leaf base. S12,029. X 1.4.

Figures 71, 72, 74. Deviacer Manchester sp.

71. Samara. Note attachment scar (arrow). S16,623. X 3.6.
72. Samara. S16,626. X 3.6.
74. Exposed nutlet. S16,633. X 5.0.

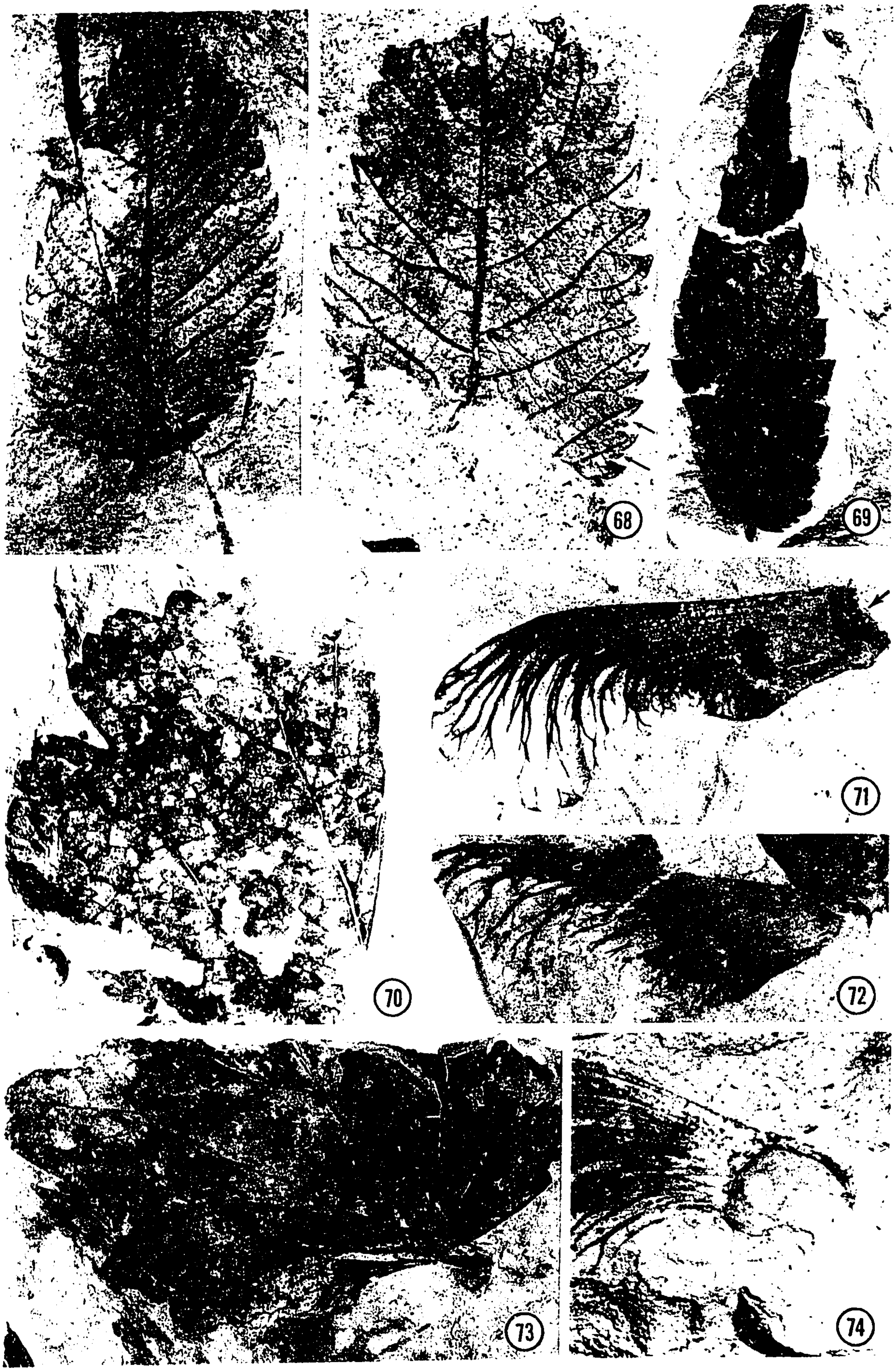
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PLATE 10

Figures 75, 76. "Viburnum" cupanioides (Newberry) Brown.

75. Leaves on slab. S8,043. X 0.9.
76. Three leaves. Note margin and venation. S8,043. X 0.7.

Figures 77, 78. Averrhoites affinis (Newberry) Hickey.

77. Leaf. S15,553. X 2.0.
78. Venation and margin. S37,291. X 2.5.

Figure 79. Unidentified leaf 1. S12,132. X 4.0.

Figures 80, 81. Unidentified leaf 2.

80. Venation and margin. Note small tooth (arrow). S16,943. X 5.2.
81. Leaf base. S16,943. X 3.0.

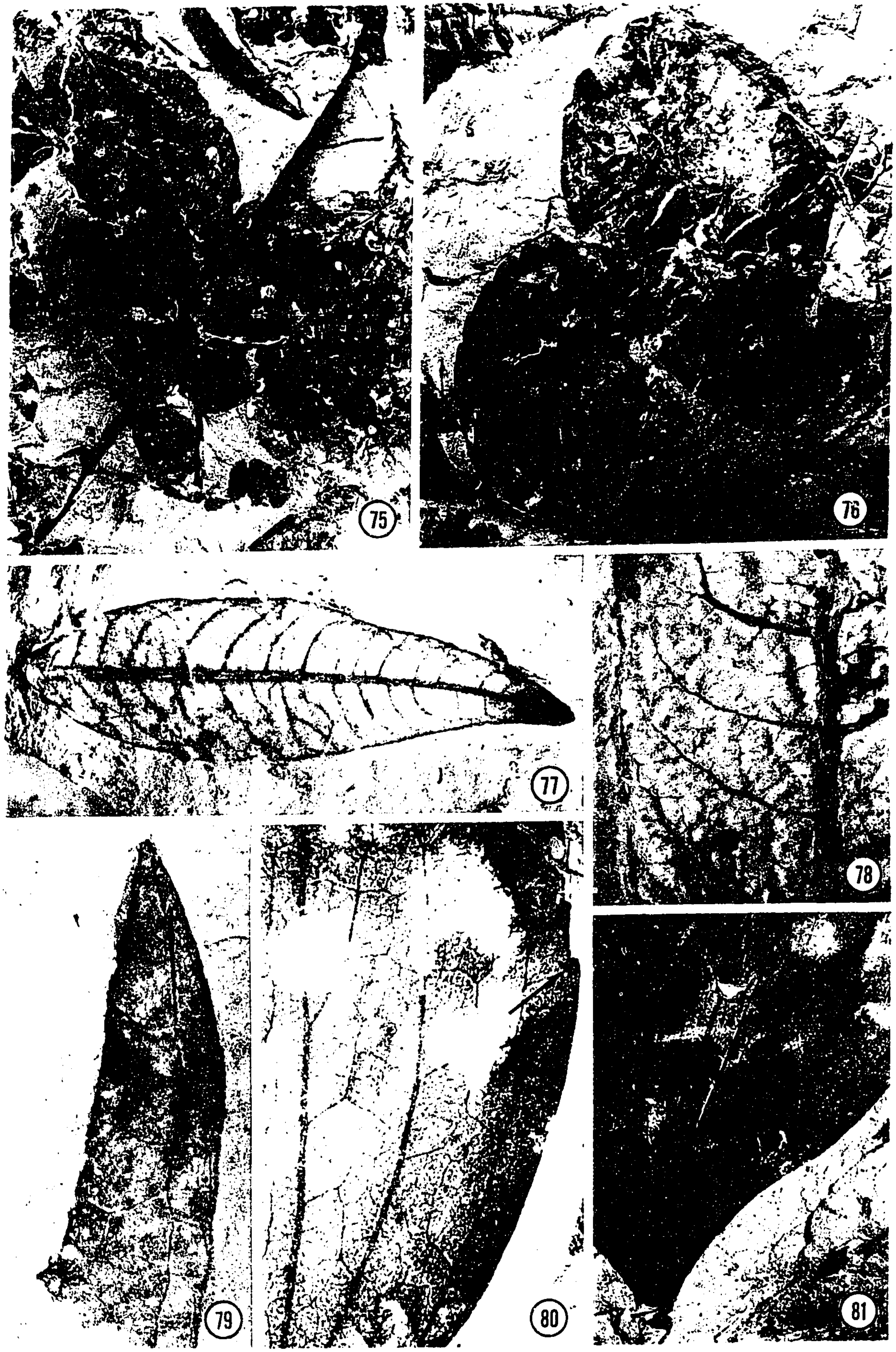

PLATE 11

Figures 82, 83. Wardiaphyllum daturaefolium (Ward) Hickey.

82. Leaf. S15,964B. X 0.9.
83. Venation and margin. S12,089. X 3.0.

Figures 84. Populus penhallowi Bell.

84. Leaf. S40,478. X 1.4.

Figures 85, 86. Fortuna marsilioides (Bell) McIver & Basinger.

85. Leaf with serrate margin. S16,661. X 3.0.
86. Two leaves on slab. S16,660. X 1.4.

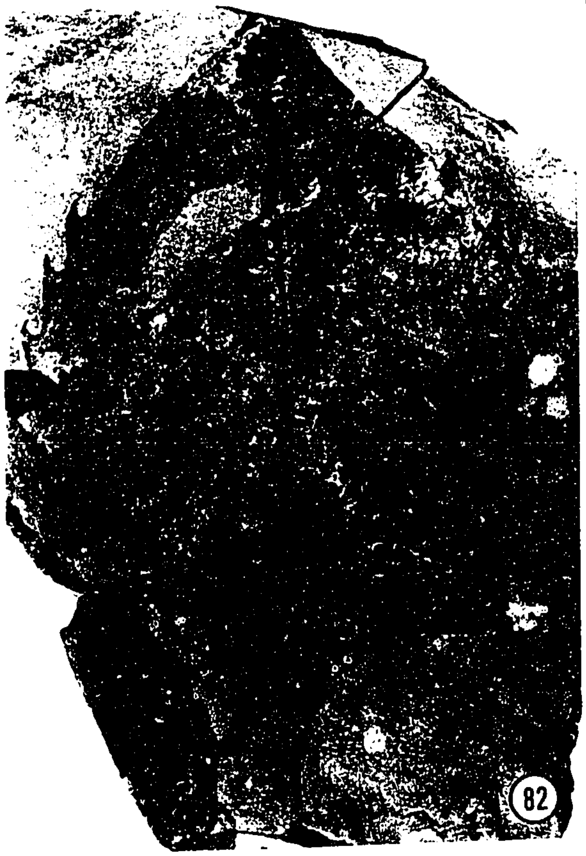
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PLATE 12

Figures 87-92. Spirodela-like monocot.

87. Venation and margin. S37,122A. X 4.1.
88. Thallus showing pubescent surface, centrum (C), primary root (R) and filiform rootlets (r). S12,335B. X 4.0.
89. Thallus with centrum, primary root, and filiform rootlets. Lateral rootlets (arrows) branch from the primary root. S12,335B. X 2.6.
90. Pollen grain. Note single pore and echinae. X 3,500.
91. Thallus with attached daughter plant (arrow). S37,123. X 4.4.
92. TEM cross-section of pollen wall showing foot layer (f) and tectum (t) separated by a very thin laryer of granular/columellar material (arrow). Note echina (e) with slightly constricted base. X 5,700.

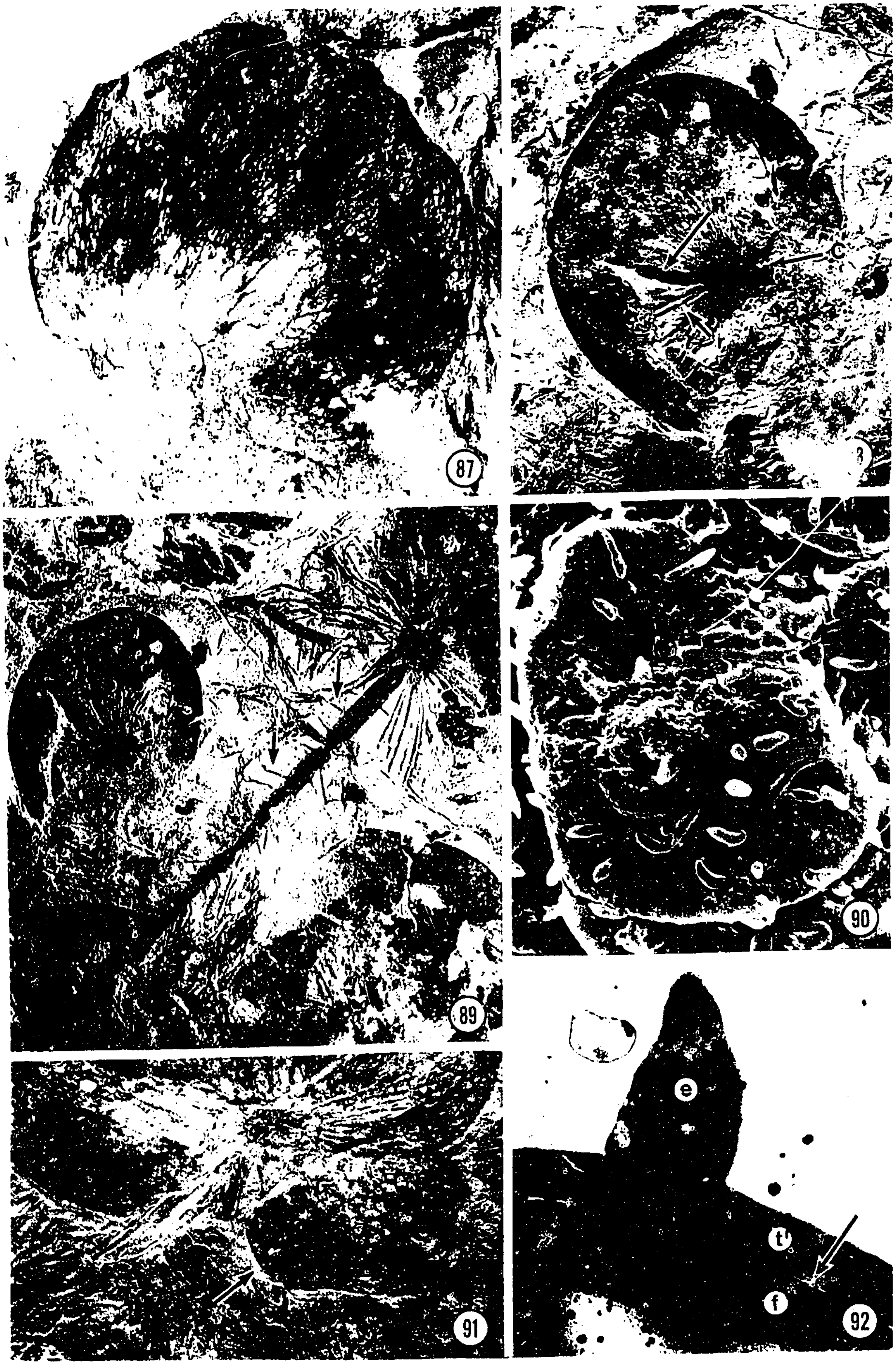
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PLATE 13

Figures 93, 94. Unidentified aquatic leaf.

93. Leaf, showing margin and venation. S11,301. X 4.4.
94. Leaf, showing base. S11,299. X 2.6.

Figures 95, 96. Cone-like infructescence.

95. Broken infructescence. S8,093A. X 2.7.
96. Intact infructescence. Note globose shape. S8,057B. X 2.6.

Figures 97, 98. Unidentified seed or fruit.

97. Seed or fruit, showing notch and ornamentation. S13,346. X 4.2.
98. Seed or fruit, showing rim. S10,859. X 4.7.

Figures 99, 100. Unidentified branching aquatic plant.

99. Branching system, showing axis (arrow), and bud (small arrow). S24,564. X 1.4
100. Branching system. S11,312. X 1.4.

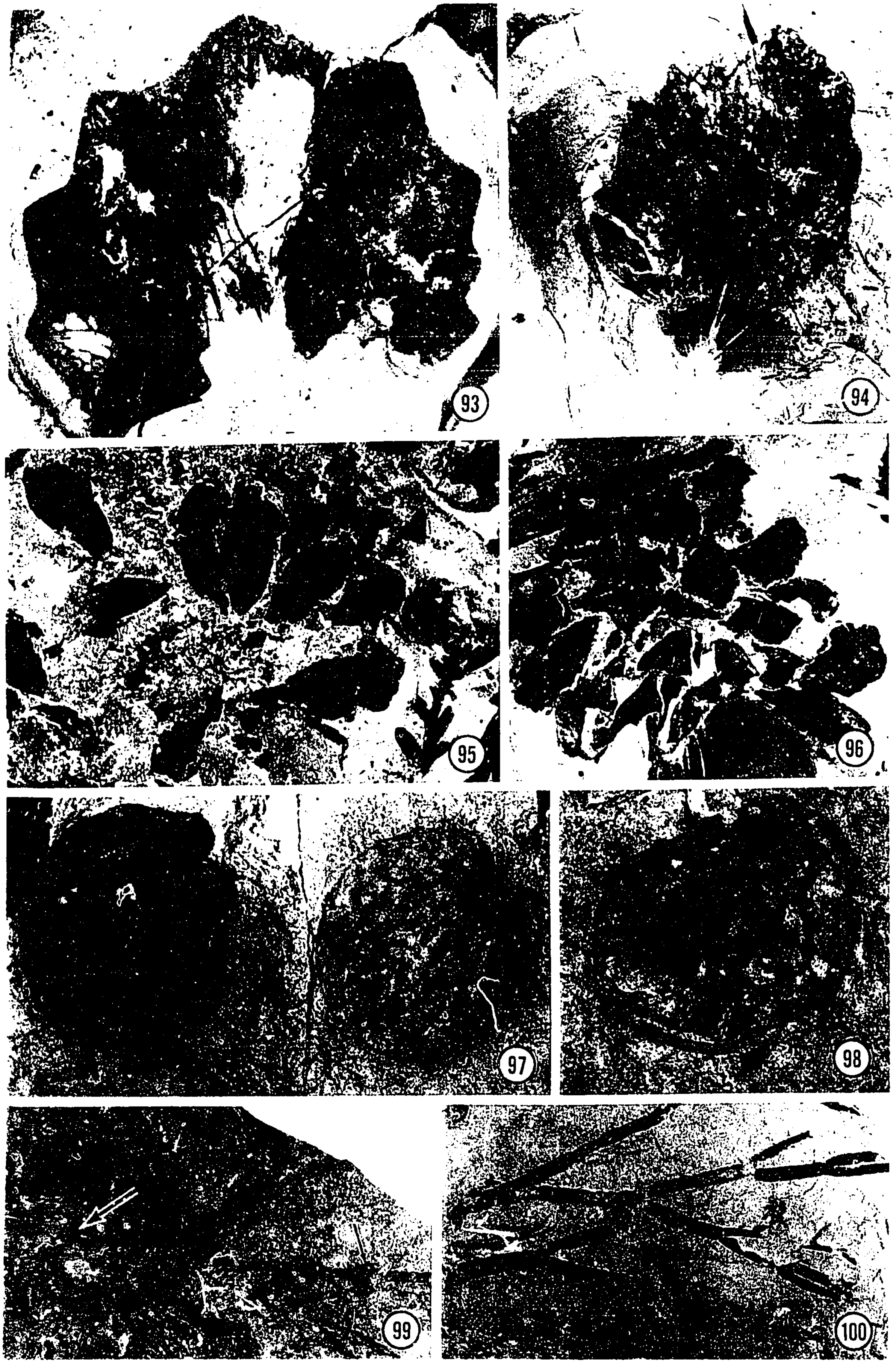
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PLATE 14

Figures 101-103. Lilialean monocot.

101. Specimen with leaves (L), rhizome (R), and roots (r). S39,421. x 0.8.

102. Closer view of rhizome, showing leaves (L), roots (r), and root scars (s). S39,421. X 3.1.

103. Leaf fragment showing venation. Note pattern produced by alternation of weaker and stronger veins S8,057B. X 4.4.

Figures 104-106. Unidentified sheathing structures.

104. Note scars (s), stem (S), and axillary bud (b). S17,179A. X 4.7.

105. Note scars (arrows). S16,682. X4.0.

106. Note segmented appearance produced by arrangement of scars. S40,964B. X 4.7.

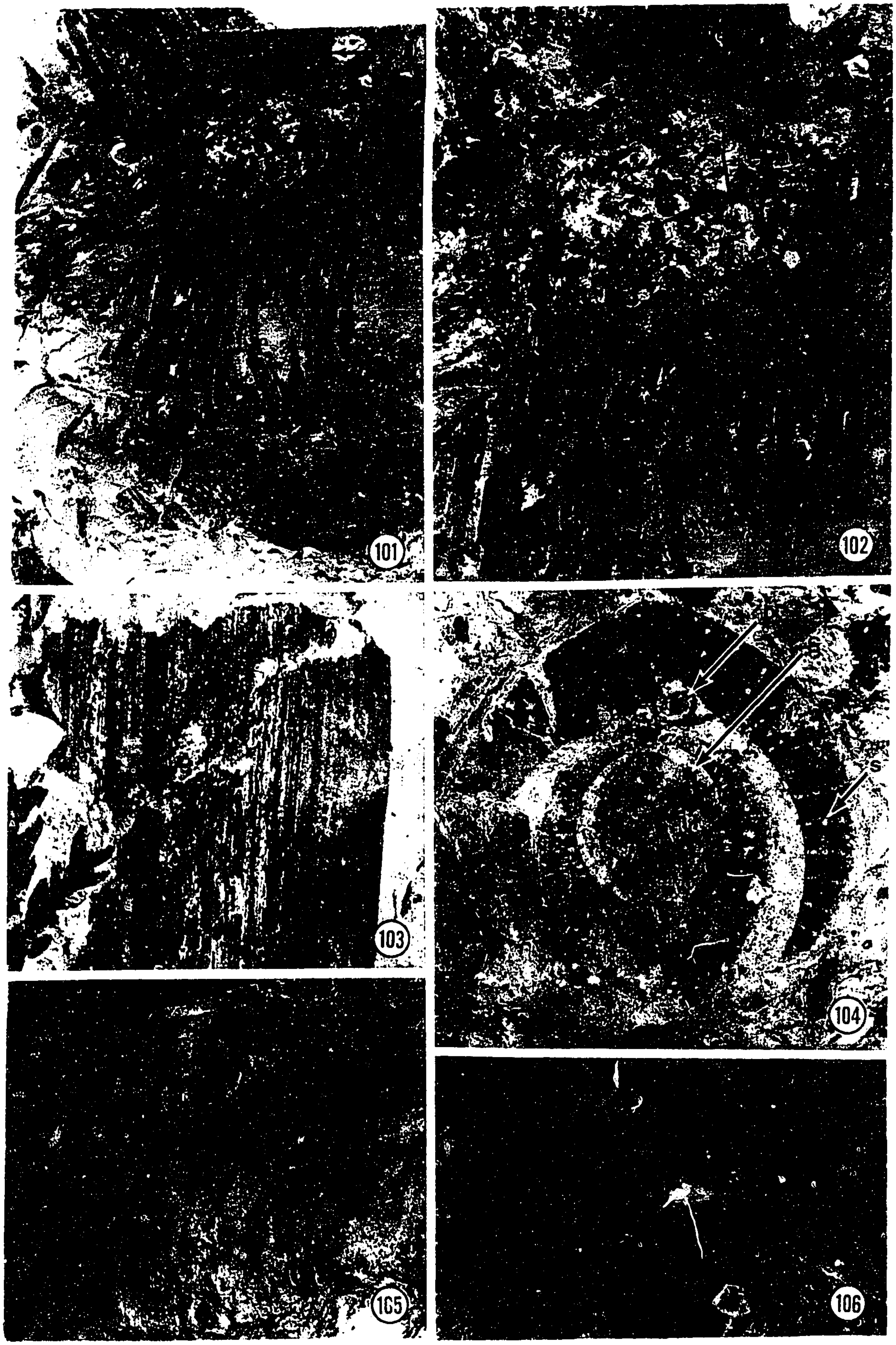
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PLATE 15

Figures 107, 108. Alismaphyllites grandifolius (Penhallow) Brown.

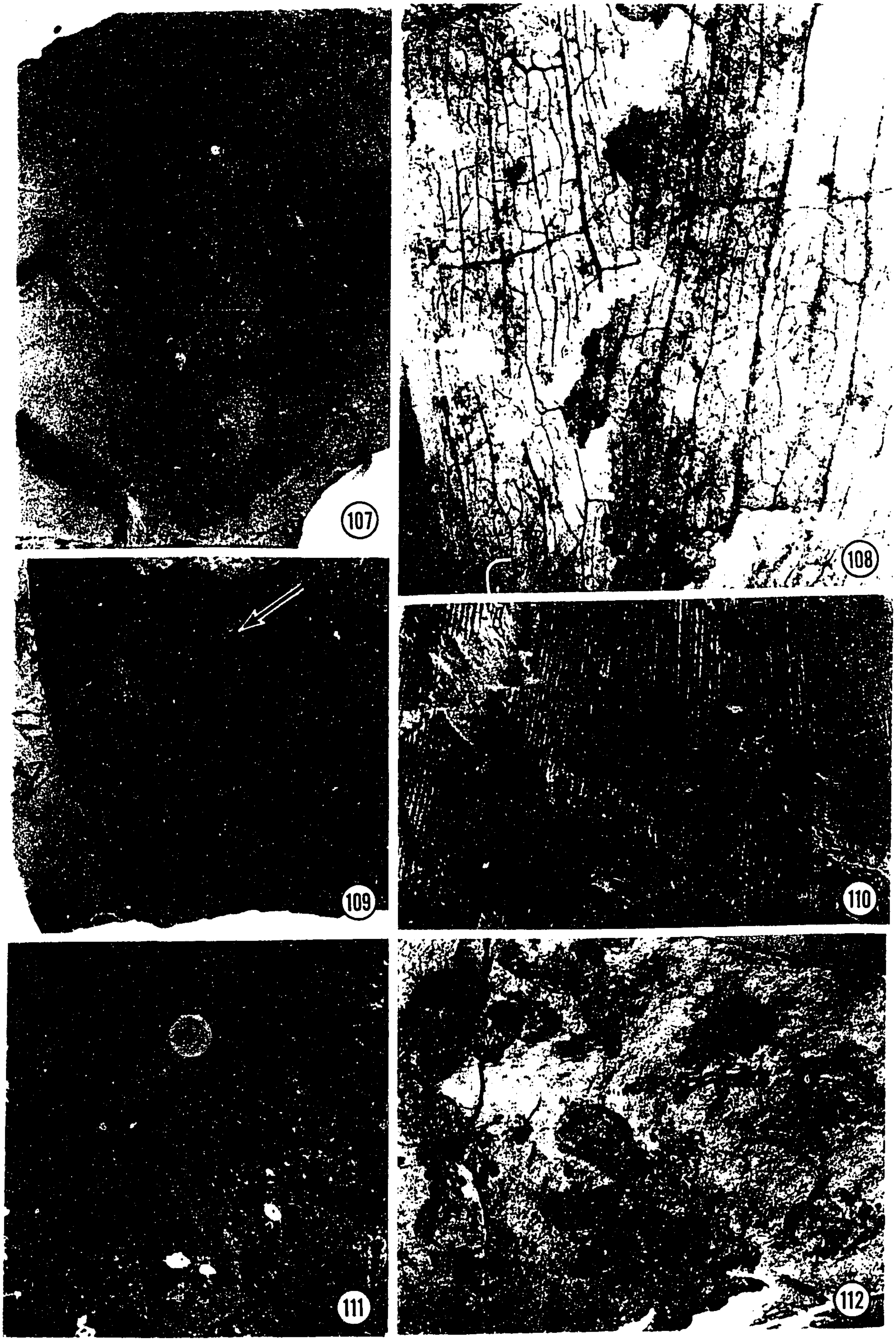
107. Leaf, showing shape and venation. S16,944. X 1.9.
108. Venation. S16,943B. X 4.7.

Figures 109, 110. Zingiberopsis attenuata Hickey.

109. Fragment of a large leaf. Note costa (arrow). S15,564. X 0.6.
110. Venation and margin. S16,973A. X 3.2.

Figure 111. Leaves of lilialean monocot and Glyptostrobus. S15,592A. X 0.6.

Figure 112. Striated seeds. S13,342. X 2.7.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APPENDIX A

GEOLOGICAL DESCRIPTIONS

APPENDIX A

GEOLOGICAL DESCRIPTIONS

UNIT 1: LOWER LEVEL BED

Typical Thickness: 4-8 cm. Elevation: about 830 m.

Lithology: Claystone, medium to dark grey, soft, overlain by 1-2 cm of coal. This is the Lower Level bed described by Fox (1990). Some of the mammal jaws were found oriented more or less vertically in the clay (A. Lindoe, pers. comm.), suggesting that the bedding was disturbed by bioturbation, soil processes or rooting prior to the deposition of the coal. The bed is underlain by a thick, medium grey mudstone that contains small fragments of mollusc shells, fine plant detritus, and root traces.

Facies Relationships: This unit was quarried to the east of Trench 3. A very similar soft claystone that may be correlative with this bed can be seen at the base of the sandstone exposures along the north side of the river.

Flora: None.

Fauna: Mammals described by Fox (1990); crocodile, turtle, salamander and fish bones (Speirs, pers. comm.).

Environment of Deposition: Swamp (coal layer) underlain by clay.

UNIT 2: FLUVIAL CHANNEL SANDSTONE

Typical Thickness: 14 m.

Lithology: Sandstone, lithic (salt and pepper); medium-grained with occasional fine-grained zones; coarser grained at base with small (1-2 cm) mudstone clasts; light grey, weathering to greenish, yellowish, and rusty brown; scattered very large concretions.

Facies Relationships: The sandstone may be thinning toward the west (Trench 1). It is likely correlative with the sandstone exposed along the cliffs across the river from Joffre Bridge Roadcut. That sandstone is more than 10 m thick, medium grained, with epsilon crossbedding, becoming finer grained with planar bedding near the top of the cliffs.

Flora: Poorly preserved, fragmentary Metasequoia, Ginkgo, Joffrea and Platanus leaves; Joffrea follicles; Equisetum rhizomes; fragments of coalified wood; and root traces.

Fauna: Rare molluscs and small fragments of bone.

Environment of Deposition: Fluvial channel; bed-load deposits. Only robust material was preserved.

UNIT 3: CHANNEL-FILL SILTSTONE SEQUENCE

Typical Thickness: 35 cm.

Lithology: Siltstone, tan to light green, thin bedded, with frequent thin interbeds of fine-grained sandstone.

Facies Relationships: Present in the western part of the site.

Flora: Joffrea and Platanus leaves, inflorescences, fruits, seeds and seedlings, Deviacer samaras, Chaetoptelea leaves.

Fauna: Fish scales.

Environment of Deposition: As the active river channel (Unit 2) shifted eastward, the abandoned channel gradually became less active but still received some silt- and sand-laden water. Organs of riparian taxa were washed into this quieter environment and preserved in the silt and mud. Lenses of seedlings indicate that portions of these sediments were at times emergent and then subsequently inundated, burying the seedlings in place.

UNIT 4: LOWER LACUSTRINE SEQUENCE

Typical Thickness: 30 cm.

Lithology: Mudstone, tan to light green, thin bedded, with scattered small mollusc shells, becoming silty toward base.

Facies Relationships: Present throughout western part of site.

Flora: Joffrea and Platanus leaves, inflorescences, fruits, seeds; Deviacer samaras; Chaetoptelea leaves; and various seeds.

Fauna: Insects (dragonfly and beetle wings; larvae; Appendix B).

Environment of Deposition: Lacustrine, an oxbow lake (Lake Speirs) that formed after the abandonment of the fluvial channel (Unit 2).

UNIT 5: MOLLUSC LAYER

Typical Thickness: 6-12 cm (including coal).

Elevation: about 845 m

Lithology: Dark grey to black, coaly, calcareous mudstone, well indurated with calcite cement, hard. Usually overlain and underlain by 0.5-2.0 cm coal. Includes abundant small freshwater bivalve and gastropod shells, as well as plant, insect and vertebrate remains.

Facies Relationships: Present throughout the western part of the site but absent in the east (Trench 3).

Flora: Metasequoia foliage and cones (abundant); Glyptostrobus foliage; Platanus leaves and fruits; fragments of Ginkgo leaves (rare); miscellaneous seeds.

Fauna: Scattered fish scales and bones. Isolated mammal jaws (Fox, 1991). Larvae of Tipulidae (craneflies) (Appendix B).

Environment of Deposition: A marsh, formed during a period of low water level in the oxbow lake (Unit 4), with little flooding or clastic sedimention from the fluvial channel (Unit 2). Small maounts of peat (coal) were deposited. The environment was favorable for molluscs. Cementation by calcite occurred after most of the plant material had become crushed and flattened or coalified.

UNIT 6: UPPER LACUSTRINE SEQUENCE

Typical Thickness: 85 cm.

Lithology: Mudstone, light grey to light green and tan, thin bedded, with traces of bioturbation; grading to siltstone in the upper part with increasing frequency of thin interbeds of silt and fine sand. This sequence includes several important fossiliferous horizons and is subdivided into Units 6a-6d described below.

Facies Relationships: The upper part coarsens gradually upward, developing frequent thin interbeds of silt and fine sand toward the top. This unit is present throughout the western part of the site (Trenches 1 and 2). It is absent at Trench 3, where the equivalent interval is occupied by a greenish-brown siltstone that may be a levee deposit.

Flora: See units below.

Fauna: Mass-death layer of fish remains at top (Unit 6d). Scattered fish scales and shells of small freshwater bivalves and gastropods throughout. Insect remains near base (Units 6a & 6b).

Environment of Deposition: Lacustrine; initially shallow during Units 6a, 6b, becoming deeper and eventually connected to the active channel through a breached levee during Units 6c, 6d.

Unit 6a: Concretion Zone

Typical Thickness: 10-15 cm.

Lithology: Mudstone and claystone, light to medium grey, with plant remains. Includes calcite-cemented mudstone concretions in west (Trench 1); uncemented in east (Trench 2).

Facies Relationships: Present in the western part of the site (Trenches 1 & 2). The concretions lie directly on top of the Mollusc Layer and appear to be present only at the westernmost edge of the site (Trench 1).

Flora: Glyptostrobus branches and cones, Metasequoia foliage, liliacean leaves (abundant); Osmunda pinnules, Joffrea leaves, "Viburnum" leaves (fairly common); fragments of Zingiberopsis leaves, and the cone-like infructescence (uncommon).

Fauna: Insect wings (Appendix B). Scattered fish scales.

Environment of Deposition: Lacustrine; water levels rose, gradually drowning the swamp (Unit 5). Most of the plant material had become crushed and flattened prior to mineralization by calcite.

Unit 6b: Aquatic Plant Zone

Typical Thickness: 10 cm.

Lithology: Mudstone and claystone, light grey at base to light green at top, occasionally silty, with plant and insect fossils.

Facies Relationships: Present throughout the western part of the site.

Flora: Scattered Azolla sporophytes near top. Whole Spirodela and Ricciopsis, rare isolated Fortuna leaves, and fragments of lilialean leaves at base.

Fauna: Insect wings and larvae (Appendix B).

Environment of Deposition: Lacustrine; shallow water, near shore. Azolla and Spirodela are free-floating aquatic genera; ricciaceous liverworts grow in or near shallow water, and some species have a free-floating form; the lilialean monocot and Fortuna grew rooted in shallow water.

Unit 6c: Barren Zone

Typical Thickness: 60 cm.

Lithology: Mudstone, light green and tan, thin bedded, with scattered small mollusc shells, and traces of bioturbation. Thin interbeds of silt and fine sand become common toward top, where siltstone becomes the dominant lithology.

Facies Relationships: Coarsens toward top, with frequent thin interbeds of silt and fine sand. Present throughout the western part of the site.

Flora: Scattered scraps of plant material.

Fauna: Scattered small molluscs and fish scales.

Environment of Deposition: Lacustrine. Coarsening at top reflects influence of prograding crevasse splay (Unit 7) and reconnection with an active fluvial channel.

Unit 6d: Fish Layer

Typical Thickness: 1 cm. Elevation: about 846 m

Lithology: Mudstone, medium grey, silty, thin bedded, rust stained, with abundant remains of freshwater fishes (Appendix B).

Facies Relationships: Present in the western part of the site, where it has been e[illegible]ated over an [illegible] of about 200 square metres to date.

Flora: None

Fauna: Freshwater fish remains described by Williams and Wilson (1988), Wilson and Williams (1991), Murray (in prep.). As of 1991, 45 specimens of an osmerid (smelt), 1,795 specimens of a paracanthopterygian, two articulated specimens of an osteoglossomorph, a few disarticulated bones of an amiid, and one articulated crustacean had been quarried from the Fish Layer by UALVP.

Environment of Deposition: Lacustrine; likely connected to an active fluvial channel through a breached levee.

UNIT 7: CROSSBEDDED SANDSTONE

Typical Thickness: > 150 cm.

Lithology: In west (Trench 2) fine-grained, finely crossbedded sandstone with climbing ripples; scattered large molluscs; large concretions. In east (Trench 3), medium-grained sandstone with mudstone clasts and erosional basal contact.

Facies Relationships: This unit becomes fine-grained and strongly crossbedded westward from Trench 3. The basal contact is erosional at Trench 3, but interfingers with mudstones at Trench 2. Unconformably overlain by glacial till.

Flora: Scattered scraps of leaves and twigs.

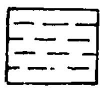
Fauna: Scattered large bivalves.

Environment of Deposition: Crevasse splay, prograding westward from breached levee of active fluvial channel in east (Unit 2), into lake in west (Unit 6). Coarser grained facies at Trench 3 may represent a distributary channel within the splay near the breached levee.

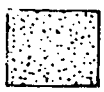
EXPLANATION OF SYMBOLS

 Coal

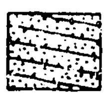
 Coaly mudstone

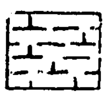
 Mudstone

 Siltstone

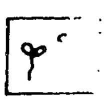
 Sandstone

 Sandstone, with clasts

 Sandstone, crossbedded

 Mudstone, calcareous

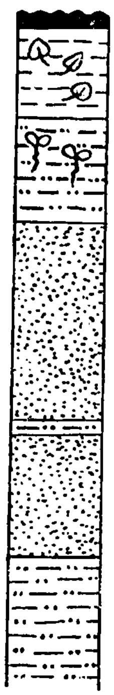
 Fossils: plant material

 Fossils: plant seedlings

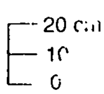
 Fossils: mollusc shells

 Fossils: fish remains

TRENCH 1

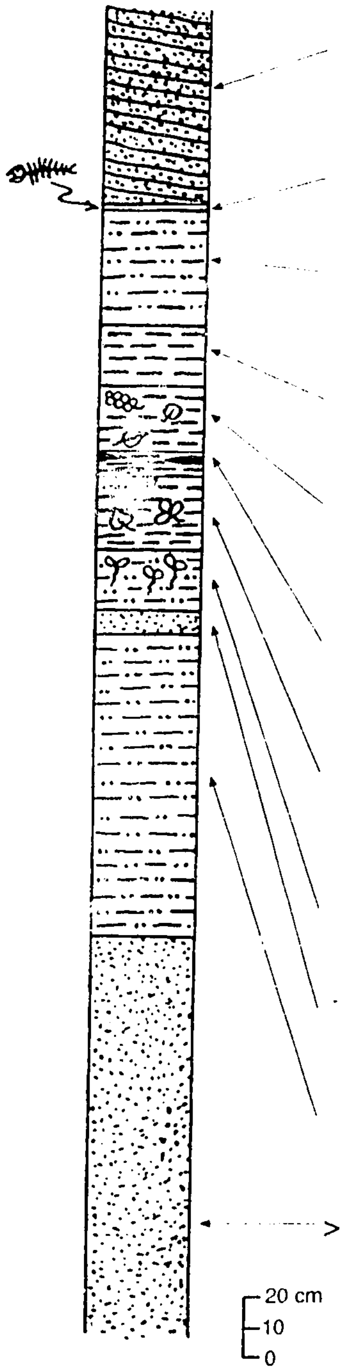


> 3 cm	Mollusc Layer, mudstone, dark grey, carbonaceous to coaly, abundant small bivialves & gastropods.
30	Mudstone, medium grey beds ~ 2 cm thick, plant remains (_Joffrea_ leaves & follicles), scattered small molluscs.
33	Siltstone, grey, with thin interbeds of sand; dicot seedlings.
65	Sandstone, fine-grained, tan to greenish weathering silty, micaceous, beds ~ 1-3 cm thick.
5	Siltstone, grey.
40	Sandstone, as above.
20	Siltstone, medium grey, beds ~ 1-3 cm thick, rare small fragments of plant debris.
> 35	Siltstone, greenish, rare small fragments of plant debris.



TRENCH 1: Near west end of site, 198 m west of Section boundary. Dug by track-mounted backhoe, August 1993. Uppermost beds were removed during previous fossil quarrying.

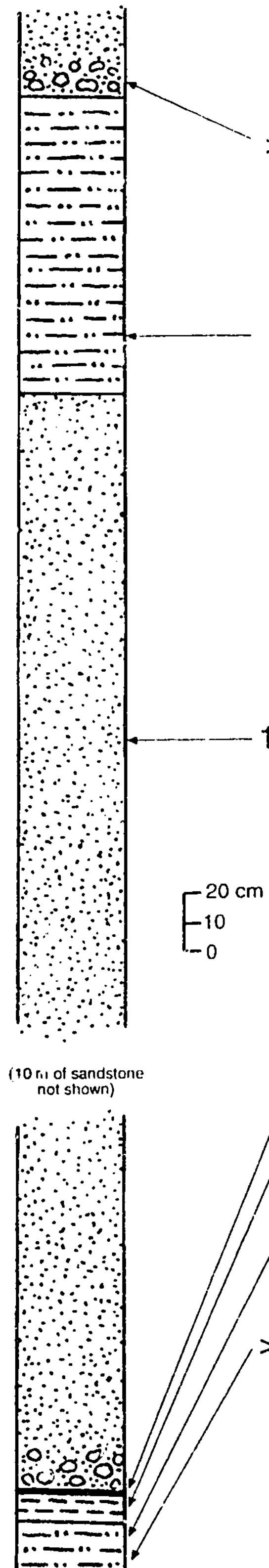
TRENCH 2



> 65 cm	Sandstone, fine-grained, tan, cross-bedded, beds ~2 cm thick, climbing ripples, large concretions; basal contact abrupt.
1	Mudstone, medium grey, silty, Fish Layer at base.
41	Siltstone, tan, frequent interbeds of grey mudstone; beds ~1 cm thick; mildly bioturbated; gradational to mudstone below.
21	Mudstone, medium grey, scattered thin interbeds of tan silt; gradational to unit below.
23	Mudstone & claystone, medium grey, rare silty interbeds; scattered bivalves, <u>Glyptostrobus</u> fragments near base; basal contact abrupt.
7	Mollusc Layer, claystone, dark grey, carbonaceous, 2 cm coal at top; abundant small bivalves & gastropods; basal contact abrupt.
25	Mudstone, medium grey, beds ~2-5 cm thick, scattered small bivalves; gradational into siltstone below.
20	Siltstone, medium grey, scattered thin interbeds of sand, no molluscs; dicot seedlings.
8	Sandstone, fine-grained, tan, micaceous; abrupt upper & lower contacts.
100	Siltstone, medium grey, scattered thin interbeds of tan sand; basal contact abrupt.
> 170	Sandstone, fine- to medium-grained, tan, micaceous, beds ~3-5 cm thick; large concretions; strongly weathered.

TRENCH 2: Near centre of site, 76 m west of Section boundary.
Dug by track-mounted backhoe, August 1993.

TRENCH 3



>30 cm — Sandstone, medium-grained, salt & pepper, brown weathering, with clasts of greenish-grey mudstone, fragments of twigs; base abrupt, cuts into underlying siltstone.

100 cm — Siltstone, greenish-brown; gradational contact with sandstone below.

13.5 m — Sandstone, medium-grained, salt & pepper, light grey. Base coarse-grained, with scattered clasts of grey mudstone, Joffrea fruits, Equisetum rhizomes, fragments of dicot leaves and coalified wood.

1 cm — Coal.

2 cm — Claystone, dark grey, soft; Lower Level Vertebrate Bed of Fox (1990).

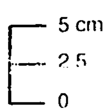
11 cm — Mudstone, medium grey, hard, with small fragments of mollusc shells, coalified wood, Equisetum rhizomes, root traces.

>1.5 m — Siltstone, medium grey, fissile, with fine fragments of plant debris & twigs, root traces.

TRENCH 3: About 10 m east of Section boundary at natural outcrop of uppermost sandstone. Dug by hand, July 1991.

MOLLUSC LAYER SECTION

> 5 cm	Claystone, light grey, scattered small molluscs.
9	Concretion Zone: claystone, medium-grey, containing individual broad, flat, calcite-cemented concretions.
0.5	Clay, soft, browm, weathered, with small molluscs.
1	Coal, weathered, shaley.
6	Mollusc Layer. Claystone, dark grey to black, carbonaceous to coaly, hard, calcite-cemented, with abundant small, white, crushed bivalve & gastropod shells.
1	Clay, soft, brown, weathered.
5	Coal, weathered, with lenses of brown clay.
8	Mudstone, tan, thin bedded, with scattered small molluscs.
> 50	Mudstone, tan, no molluscs.



MOLLUSC LAYER SECTION: About 15 m west of Trench 1; July 1991.

APPENDIX B

FAUNAL REMAINS

APPENDIX B

FAUNAL REMAINS

MAMMALS

JOFFRE BRIDGE ROADCUT, LOWER LEVEL (from Fox, 1991):

Multituberculata: Ptilodus, new species 1 of Krause (1982); Prochetodon, new species; Mesodma pygmaea; Mimetodon silberlingi; Neoplagiaulax, cf. N. hazeni; Neoplagiaulax, new species.

Marsupicarnivora: Peradectes elegans.

Lipotyphla: Litocherus, cf. L. notissimus; Litocherus, cf. L. zygeus; Litolestes ignotus; Erinaceidae, new genus and species. Lipotyphyla, unidentified genus and species.

Dermoptera: Elpidophorus elegans.

Primates: Microsyopidae, unidentified genus and species; Ignacius frugivorus; Carpodaptes hazelae.

Condylarthra: Arctocyonidae, unidentified genus and species; Ectocion wyomingensis.

Pantodonta: unidentified genus and species.

Eutheria, order incertae sedis, Palaeoryctidae: Pararyctes patersoni; cf. Stilpnodon sp.; **Palaeoryctidae**, unidentified genus and species. Pantolestidae: Propalaeosinopa albertensis; Propalaeosinopa septenrionalis.

JOFFRE BRIDGE ROADCUT, UPPER LEVEL (from Fox, 1991):

Lipotyphla: Litocherus zygeus.

Pantodonta: cf. Titanoides

FISH

Recent references concerning fish from Joffre Bridge Roadcut:

Li, G.-q. 1994. New osteoglossomorphs (Teleostei) from the Upper Cretaceous and Lower Tertiary of North America and their phylogenetic significance. Ph.D. thesis, University of Alberta, 200 p.

Li, G.-q. and Wilson, M.V.H. In press. The discovery of Heterotidinae (Teleostei: Osteoglossidae) from the Paleocene Paskapoo Formation of Alberta, Canada. Journal of Vertebrate Paleontology. (Name of species not yet published: Joffrichtys symmetropterus)

Li, G.-q. and Wilson, M.V.H. In press. Phylogeny of Osteoglossomorpha. In: Interrelationships of Fishes Revisited. Edited by: M.L.J. Stiassny, L. Parenti and G.D. Johnson. Acedemic Press, New York.

Murray, A.M. 1994. Description of two new species of basal paracanthopterygian fishes from the Paleocene of Alberta, and a phylogenetic analysis of the percopsiforms (Teleostei: Paracanthopterygii). M.Sc. thesis, University of Alberta, 175 p.

Murray, A.M. In press. A new Paleocene genus and species of percopsid, *Massamorichthys wilsoni (Paracanthopterygii) from Joffre Bridge, Alberta, Canada. Journal of Vertebrate Paleontology. *Name not published yet.

Murray, A.M. and Wilson, M.V.H. Submitted. Phylogenetic relationships of the percopsiform fishes (Teleostei: Paracanthopterygii): order restored. Submitted to Copeia.

Williams, R.R.G. and Wilson, M.H.V. 1988. An osmerid fish from Paleocene freshwater sediments of Alberta. J. Vert. Paleont. **8** (Supp. to No. 3): 28A.

Wilson, M.H.V. 1980. Oldest known Esox (Pices: Esocidae), part of a new Paleocene teleost fauna from western Canada. Can. J. Earth Sci. **17**: 307-312.

Wilson, M.V.H. and Williams, R.R.G. 1991. A new Paleocene smelt (Teleostei: Osmeridae) from the Paskapoo Formation of Alberta, Canada, and comments on osmerid phyolgeny. Journal of Vertebrate Paleontology **11**: 434-451. (Name of species: Speirsaenigma lindoei)

The only other fish taxon known at present from Joffre Bridge Roadcut is Family Amiidae, unidentified as to genus and species and represented by scales and isolated bones only (M.H.V. Wilson, pers. comm.).

Number	Locality Name	System/Period	Series/Epoch	Stage/Age
[illegible]	Joffre Bridge SW Chert Layer	Tertiary	Paleocene	

Stratigraphic Horizon	Formation	Member
Horizon B. Chert & Mollusc Layer	Paskapoo	

Canada Alberta 52°16.1'N 113°35.7'W

black molluscifeferous chert. Road cut on S side of highway 11 (previously HWY 596), W of Joffre Bridge. NE1/4,S13,T38,R26,W4 . 83A/5

12U UN 229940 AS2737-14

Specimen Number	Identification	Material
6236	Tipulidae	"mollusc"
6238	Tipulidae	larva
6250		
6251	Tipulidae	larva
6253		2 pieces
6266		

Number	Locality Name	System/Period	Series/Epoch	Stage/Age
56	Joffre Bridge SW Fish Layer	Tertiary	Paleocene	

Stratigraphic Horizon	Formation	Member
Horizon A. Fish Layer	Paskapoo	

Canada Alberta 52°16.1'N 113°35.7'W

greenish gray silty shale, Fe oxide stained surface. Rd. cut on S side of hwy. 11 (old hwy. 596), W of Joffre Bridge NE1/4,S13,T38,R26,W4 83A/5

12U UN 229940 AS2737-14

Specimen Number	Identification	Material

Number	Locality Name	System/Period	Series/Epoch	Stage/Age
47	Joffre Bridge SW Insect Layer	Tertiary	Paleocene	

Stratigraphic Horizon	Formation	Member
Horizon C. Insect & Plant Layer.	Paskapoo	

Canada Alberta [illegible]16.1'N 113°35.7'W

medium grey mudstone. Rd. cut on S side of hwy. 11 (previously HWY 596), W of Jo[illegible] Bridge (Wighton site4) [illegible] T38,R26,W4 83A/5

[illegible] AS2737-14

Specimen Number	Identification	Material
411	Donacia wightoni	elytra, [illegible]
412	Donacia wightoni	elytra, pt. cpt.
413	Donacia wightoni	elytra, pt. cpt.
414	Donacia wightoni	elytra, pt. cpt.
415	Donacia wightoni	elytra, pt. cpt.
416	Donacia wightoni	elytra
6176	Orthoptera	
6177	Tipulidae	"type specimen"
6181	Aeschna sp.	
6184	Orthoptera	
6190	Anisoptera	wing fragment
6239	Tipulidae	
6243	Tipulidae	larva
6244		
6245		
6246		
6247	Tipulidae	
6248	Tipulidae	
6249		
6254		2 pieces
6268	Odonata	wing

6269		
6270	Odonata	
6271		
6272	Odonata	wing
6276	Coleoptera	pt & cpt
6287	Coleoptera	wing
6296	Heteroptera	
6304		
6305		
6306	Trichoptera	
6307	Trichoptera	
6308	Trichoptera	
6309	Trichoptera	
6310	Trichoptera	
6311	Trichoptera	
6312	Trichoptera	
6313	Trichoptera	wing
6314	Trichoptera	
6315	Trichoptera	
6316	Trichoptera	
6317	Trichoptera	
6318	Trichoptera	
6319	Trichoptera	
6320	Trichoptera	wing, pt & cpt
6322	Trichoptera	
6323	Trichoptera	
6324	Trichoptera	insect wing
6325	Trichoptera	
6326	Trichoptera	
6327	Trichoptera	wing, pt & cpt
6337		wings
6345		wings
6355		wings
6356		wings
6357		wings
6358		wings
6359		wings
6360		wings
6362		
6363		wings
6366		Dennis Wighton's insect collection
6367		Dennis Wighton's insect collection
6370		Dennis Wighton's insect collection
6380	Coleoptera	
6387	Coleoptera	2 pieces
6427		insect larva, 2 pieces, field no. 602
6441		larva
6451		Dennis Wighton's insect collection
6472		Dennis Wighton's insect collection
6473		Dennis Wighton's collection
6474		wings, Dennis Wighton's insect
6475		wings, larva, Dennis Wighton's insect
6476		larva, Dennis Wighton's insect
6477		larva, Dennis Wighton's insect
6478		larva , Dennis Wighton's insect

6479		larva, Dennis Wighton's insect
6480		larva, Dennis Wighton's insect
6481		larva, Dennis Wighton's insect
6482		larva, Dennis Wighton's insect
6483		larva, Dennis Wighton's insect
6484		larva, Dennis Wighton's collection
6485		larva, Dennis Wighton's insect
6486		larva, Dennis Wighton's insect
6487		larva, Dennis Wighton's insect
6488		larva, Dennis Wighton's insect
6489		larva, Dennis Wighton's insect
6490		larva, Dennis Wighton's insect
6491		larva, Dennis Wighton's insect
6492		larva, Dennis Wighton's insect
6493		larva, Dennis Wighton's insect
6535		wing
6536		wing
6544	Tipulidae	larva
6545		larva
6546		larva
6547		larva
6548		larva
6549		larva
6550		wings, 2 pieces, pt. & cpt.
6551		larva
6552		larva
6553		larva
6554		larva
6555		larva
6558		larva
6574	Coleoptera	larva
6575		larva
6577	Coleoptera	larva
6654	Coleoptera	wing, Dennis Wighton's collection
6655	Coleoptera	wing, Dennis Wighton's collection
6656	Coleoptera	Dennis Wighton's collection
6657	Coleoptera	wing, Dennis Wighton's collection
6659	Coleoptera	wing, Dennis Wighton's collection
6660		larva, Dennis Wighton's collection
6661	Coleoptera	wing. Dennis Wighton's collection
6662	Coleoptera	Dennis Wighton's collection
6563	Coleoptera	wing, Dennis Wighton's collection
6664	Coleoptera	wing, Dennis Wighton's collection
6665	Coleoptera	wing, Dennis Wighton's collection
6666	Coleoptera	Dennis Wighton's collection
6667	Coleoptera	Dennis Wighton's collection
6668	Coleoptera	wing, Dennis Wighton's collection
6669	Coleoptera	wing, Dennis Wighton's collection
6670		larva, Dennis Wighton's collection
6671	Coleoptera	wing, Dennis Wighton's collection
6672	Coleoptera	wing, Dennis Wighton's collection
6673	Coleoptera	wing, Dennis Wighton's collection
6674	Coleoptera	Dennis Wighton's collection
6675	Coleoptera	wing, Dennis Wighton's collection
6676	Coleoptera	wing, Dennis Wighton's collection

6678		larva, Dennis Wighton's collection
6679	Coleoptera	wing, Dennis Wighton's collection
6680	Coleoptera	wing, Dennis Wighton's collection
6681	Coleoptera	Dennis Wighton's collection
6682	Coleoptera	wing, Dennis Wighton's collection
6683	Coleoptera	wing, Dennis Wighton's collection
6684	Coleoptera	wing, Dennis Wighton's collection
6685	Coleoptera	Dennis Wighton's collection
6686	Coleoptera	wing, Dennis Wighton's collection
6687	Coleoptera	wings, Dennis Wighton's collection
6688	Coleoptera	wing, Dennis Wighton's collection
6689	Coleoptera	wing, Dennis Wighton's collection
6690	Coleoptera	wings, Dennis Wighton's collection
6691	Coleoptera	Dennis Wighton's collection
6692	Coleoptera	wing, Dennis Wighton's collection
6693	Coleoptera	wing, Dennis Wighton's collection
6694	Coleoptera	Dennis Wighton's collection
6695	Coleoptera	wing, Dennis Wighton's collection
6696	Coleoptera	Dennis Wighton's collection
6697	Coleoptera	Dennis Wighton's collection
6698	Coleoptera	wings, Dennis Wighton's collection
6699	Coleoptera	wing, Dennis Wighton's collection
6701	Coleoptera	wings, Dennis Wighton's collection
6702	Coleoptera	wing, Dennis Wighton's collection
6703		larva, Dennis Wighton's collection
6704	Tipul	larva, Dennis Wighton's collection
6706		wing, Dennis Wighton's collection
6707		wing, Dennis Wighton's collection
6708	Coleoptera	Dennis Wighton's collection
6709		insect? Dennis Wighton's collection
6711		larva, Dennis Wighton's collection
6713		larva, Dennis Wighton's collection
6714		larva, Dennis Wighton's collection
6715		larva, Dennis Wighton's collection
6716		larva, Dennis Wighton's collection
6717		larva, Dennis Wighton's collection
6718		larva, Dennis Wighton's collection
6736	Trichoptera	wing
6737		several specimens
6738		
6739		mollusc
6740		
6741		several specimens
6742		
6743		
6744		
6745		wings
6746		
6747		
6748		
6790		
6791		
8110		bug bits, pt & cpt
8111		bug bits

APPENDIX C

PALYNOLOGY

PALEONTOLOGICAL REPORT
RAPPORT DE PALÉONTOLOGIE

04-ARS-1995

Applied research report on seven middle Paleocene samples from central Alberta (NTS 93N/14; Zone 9, 6190525 N, 367325 E) as requested by G. Hoffman (Department of Botany, B414 Biological Sciences Building, University of Alberta, Edmonton T6G 2E9). Copy to J.F. Lerbekmo (Department of Geology, University of Alberta)

DEPARTMENT OF NATURAL RESOURCES CANADA
MINISTÈRE DES RESSOURCES NATURELLES CANADA

Tricolpites bathyreticulatus Stanley, 1965
Triporopollenites plektosus Anderson 1960
"Virgo" rallus (Stanley, 1965) comb nov.
Ulmipollenites undulosus Wolfe, 1934

GENERAL COMMENTS

These samples are from an important middle Paleocene reference locality, as there is an associated mammalian fauna (Fox, 1990) and the paleomagnetostratigraphy (Lebekmo et. al., 1992) of the section is known.

Age: The upper Joffre locality has been assigned to the middle Tiffanian based on microvertebrates (Ti3; Fox, 1990), the upper part of the 26r magnetozone and the palynological P4 or *Caryapollenites wodehousei* Zone (Demchuck, 1990; Lerbekmo et al., 1992). The *Caryapollenites wodehousei* Zone is distinguished by the first occurrence of two species of *Caryapollenites*, *C. wodehousei* and *C. imparalis* accompanied by a third species *Caryapollenites prodromus* which originates in the underlying *Aquilapollenites spinulosus* Zone. In the eight samples examined only five pollen grains possibly assignable to *Caryapollenites prodromus* were seen out of the nearly 2000 miospores counted and the over 100,000 encountered in the area scanned. No specimens of either *Caryapollenites wodehousei* or *C. imparalis* were seen which highlights the tenuous nature of the application of the *Caryapollenites wodehousei* zone.

The biostratigraphically significant aspects of the upper Joffre Bridge locality are:

- the presence of a relatively small and rounded form of *Tilia*-like pollen (*Intratriporopollenites minimus*) with a diameter of 28.0 (avg. 30.3) 34 μ and a distance of 23 to 32 μ from tip of colp to tip of colp.
- an abundance of *Brevicolporites colpella* with only one specimen of the more evolved species *Phaseoliidites stanleyi* seen.
- an abundance of *Virgo rallus*, *Ulmipollenites undulosus*, and *Aquilapollenites spinulosus*.
- the effective dominance of the Juglandaceae-suite by *M. leffingwellii*, *M. marylandicus*, *M. microfoveolatus*, *M. ventifluminis* and *M. wyomingensis*.
- an absence of *Syncolporites minimus* and near absence of *Triporopollenites plektosus*.

Other comments: G. Hoffman has collected and identified abundant macrofossils of what are considered to be a liverwort and *Spirodela* from the horizon spanned by sample SLA-93-12-2. In addition to sample SLA-93-12-2, matrix directly associated with the macrofossils, as supplied by G. Hoffman, was also run (P3970-8). G. Hoffman's question was whether dispersed liverwort spores were present in the rock matrix. Four specimens of *Zilvisporis* sp. were seen in sample SLA-93-12-2 and several were observed in sample SLA-93-12-7, from below the coal horizons. These are considered to be bryophytic. Single specimens and clumps of a species of an spinous "algal cyst" are abundant in the residue of SLA-93-12-2 and in P3970-8.

Of additional interest was the presence of microsporangial clumps of a spinate, monoporate angiosperm pollen usually referred palynologically to the genus *Pandaniidites*, alluding to a widely held belief that it is derived from the genus *Pandanus* but herein called *Echigraminidites*. The referral of the spinous, monoporate pollen to *Echigraminidites* is based on their having a distinctly two-layered wall and the spine bases restricted to the tectum. As extant *Spirodela* also produces a monoporate spinate pollen, the exceptionally high relative abundance (26 %) of *Echigraminidites* found associated with *Spirodela* plant macrofossils in P3970-8 is strongly suggestive that the source plant for monoporate pollen at the Joffree locality is *Spirodela*. This disallows a tropical or warm temperate climatic argument based on the presence of *Pandanus*-like pollen.

Report 04-ARS-1995

Applied research report on seven middle Paleocene samples from central Alberta (NTS 93N/14: Zone 9, 6190525 N, 367325 E) as requested by G. Hoffman (Department of Botany, B414 Biological Sciences Building, University of Alberta, Edmonton T6G 2E9). Copy to J.F Lerbekmo (Department of Geology, University of Alberta)

The relevant parts of any manuscript prepared for publication that paraphrase or quote from this report should be referred to the Paleontology Subdivision, Calgary for possible revision.

The attached spread sheet and graphics provide the details on the palynological assemblages recovered from the upper part of the Joffre Bridge section in samples collected by A.R. Sweet and O. Catuneanu August, 1993 and from a sample containing plant macrofossils collected by G. Hoffman. The recovery and preservation was good to excellent in all the listed samples.

Sample P3970-1; SLA-93-12-1; C-221822.

Sample P3970-2 and P3970-8; SLA-93-12-2; C-221823.

Sample P3970-3; SLA-93-12-3; C-221824.

Sample P3970-4; SLA-93-12-4; C-221825.

Sample P3970-5; SLA-93-12-5; C-221826;

Sample P3970-6; SLA-93-12-6; C-221827;

Sample P3970-7; SLA-93-12-7; C-221828;

FORMAL TAXA USED IN APPENDIX I

Alnipollenites trina (Stanley) Norton, 1969 emend.
Alnipollenites verus Potonié ex Potonié, 1931
Aquilapollenites spinulosus Funkhouser, 1961
Arecipites microreticulatus Anderson, 1960
Brevicolporites colpella Anderson, 1960
Caryapollenites prodromus Nichols and Ott, 1978
Dyadonapites reticulatus Tschudy, 1973
Fraxinoipollenites variabilis Stanley, 1965
Intratriporopollenites minimus Mai, 1962
"Maceopolipollenites" actinus (Nichols and Ott, 1978) comb. nov.
"Maceopolipollenites" leffingwelli (Nichols and Ott, 1978) comb. nov.
"Maceopolipollenites" marylandicus (Groot and Groot, 1962) comb. nov.
Momipites microfoveolatus (Stanley) Nichols 1973
Momipites wyomingensis Nichols and Ott, 1978
Paraalnipollenites alterniporus (Simpson) Srivastava 1975
Parviprojectus striatus Mtchedlishvili, 1961
Penetetrapites inconspicuus Sweet 1986
Phaesoliidites stanleyii Elsik, 1968
Retitricolpites crassus Samoilovitch 1965
Rhoipites globosus Stanley, 1965

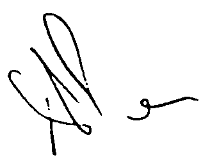
REFERENCES

Demchuck, T.D. 1990. Palynostratigraphic zonation of Paleocene strata in the central and south-central Alberta Plains. Canadian Journal of Earth Sciences, v. 17, p. 1263-1269.

Fox, R. C. 1990. The succession of Paleocene mammals in western Canada. In Thomas M. Brown and Kenneth D. Rose, eds., Dawn of the Age of Mammals in the northern part of the Rocky Mountain Interior, North America: Boulder, Colorado, Geological Society of America, Special Paper 243, p. 51-70.

Lerbekmo, J.F., Demchuck, T.D., Evans, M.E. and Hoye, G.S. 1992. Magnetostratigraphy and biostratigraphy of the continental Paleocene of the Red Deer Valley, Alberta, Canada, v. 40, p. 24-35.

A. R. Sweet



Paleontology Subdivision
Institute of Sedimentary and Petroleum Geology
Calgary, Alberta.

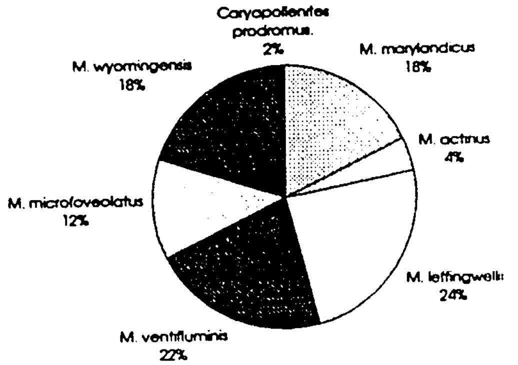
APPENDIX I

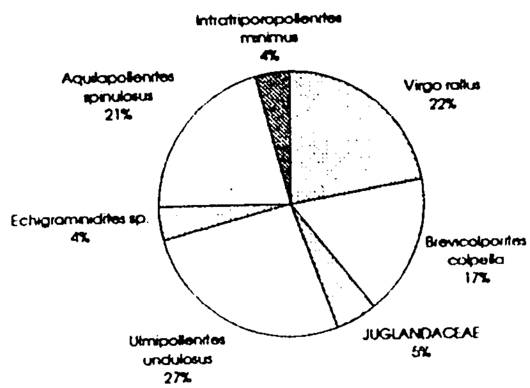
	Joffree Bridge (Upper) (SLA-93-12)								
C no	221822	221823	221824	221825	221826	221827	221828		
P no	3970-1	3970-2	3970-3	3970-4	3970-5	3970-6	3970-7	3970-8	**Total**
TAXA									
Sigmopollis sp.	2	0	0	5	1	1	6		15
Other algae (Shizophacus)	2	C	A	R	0	0	0	2	2
Total others	4	0	0	5	1	1	6		17
									0
Gymnosperms									0
T/C/T	190	202	175	132	161	127	102	222	1089
Bisaccate pollen	2	0	1	1	8	2	2	5	16
Cycadopites sp. (Ginkgo)	R	C	1	4	0	3	R	5	8
Total gymnosperms	192	202	177	137	169	132	104	232	1113
									0
Spores									0
Laevigatosporites sp.	4	9	13	0	8	4	1	5	39
Cyathidites sp.	4	0	0	0	2	1	1	3	8
Osmundacidites sp.	0	R	2	0	1	0	1	2	4
Equisetum sp.	3	0	2	0	0	0	0		5
Bohemiasporis sp. 2	0	0	0	0	0	0	R		
Zilvisporis sp.(Riccia)	0	R	0	0	0	0	R		0
Other miospores	0	0	R	R		R	R		0
Total spores	11	9	17	0	11	5	3	10	56
									0
Angiosperms									0
other Betulaceae	4	4	9	6	14	3	2	5	42
Alnipollenites trina	0	0	0	0	0	0	0		0
Alnipollenites verus	R	0	R	R	S	R	R		0
Paraalnipollenites alterniporus	R	R	0	0	0	R	R	R	0
Momipites/Maceo. /Carya	C	C	0	1	1	2	1	1	50
Maceopolipollenites. actinus	2								2
M. leffingweiii	1	1		6		4			12
M. marylandicus	2	2		1		2	2		9
M. ventifluminis	4			2			5		11
Momipites microfoveolatus	1	1		2			2		6
M. wyomingensis	1	2		1			5		9
Caryapollenites prodromus.	R	R	0	R	0	1	R		1
Ulmipollenites undulosus	R	5	7	4	6	4	6	10	32
Triporopollenites plektosus	0	0	0	0	0	0	R		0
Rhoipites globosus	0	1	16	0	7	3	0	2	27
Nyssapollenites sp.	0	0	R	0	0	0	R		0
Rhus sp.	0	0	0	0	0	0	0		0
Brevicolporites colpella	2	3	6	4	6	R	R	3	21
Phaseoliidites stanleyi?	0	0	0	R	0	0	0		0
Tricolpate pollen	5	12	10	94	22	89	75	22	307

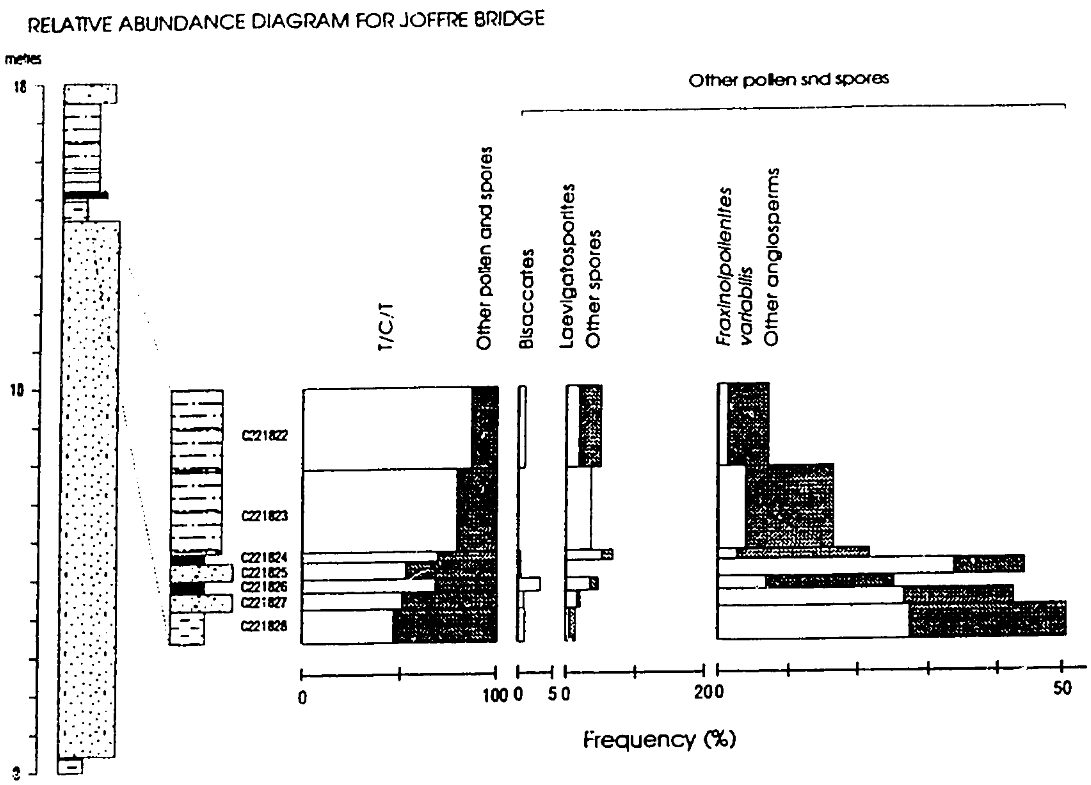
Fraxinoipollenites variabilis	3	10	7	86	18	68	61	21	253
Retitricolpites crassus	0	R	2	0	0	5	R		7
Cercidiphyllum sp.	1	0	1	4	1	14	9	1	30
Tricolpites bathyreticulatus	0	0	0	0	0	0	R		0
Tricolpites lillei Couper in N&H	0	0	0	R	0	0	0		0
Striatopollis sp.	0	0	0	R	0	0	1		1
Other tricolpate pollen	1	2	0	4	3	2	4		16
Liliacidites sp.	0	0	0	0	0	0	3		3
Arecipites microreticulatus	0	0	0	0	0	0	0	8	
Arecipites sp.(margo)	3	18	3	1	0	0	R		25
Echigraminidites sp.	0	R	0	1	0	2	2	26	5
Sparganium sp.	0	0	0	0	0	0	R		0
Erdtmanipollis sp.	R	R	C	C	1	R	C		1
Virgo rallus	2	0	0	2	1	6	16		27
Dyadonipites reticulatus	A	0	0	0	R	0	0		0
Penetetrapites inconspicuus	R	0	0	0	0	1	3		4
Aquilapollenites spinulosus	R	C	5	A	2	5	13		25
Cranwellia subtilis	0	0	0	R	0	2	0		2
Parviprojectus striata	0	0	R	R	0	R	0		0
Intratriporopollenites minimus	R	R	2	R	0	1	2		5
Other angiosperms	0	S	0	2	0	0	0		2
Total angiosperms	16	43	58	115	60	119	123	77	534

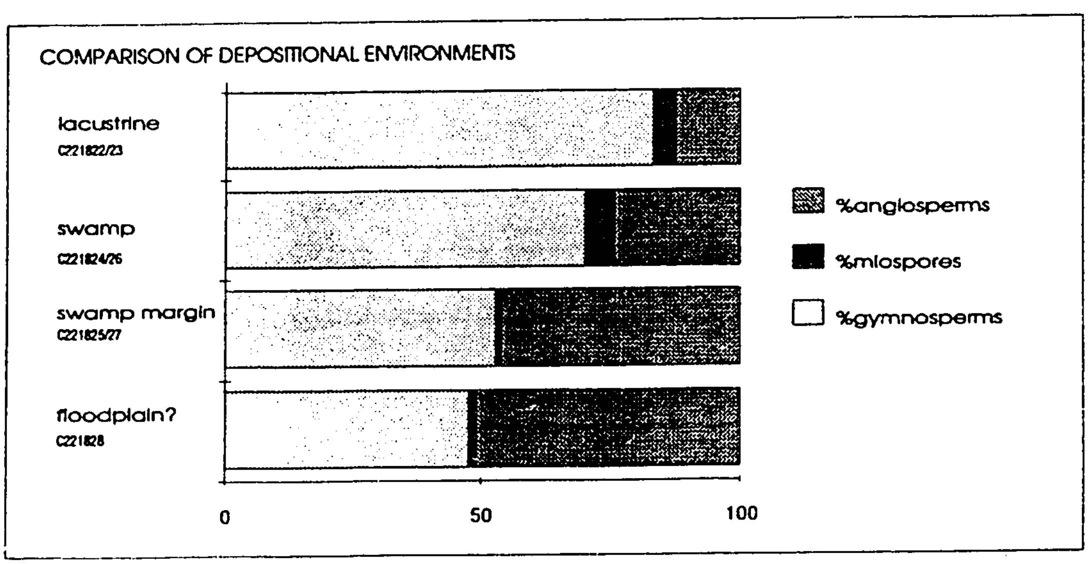
TOTAL1	219	254	252	252	240	256	230		1703
TOTAL2	223	254	252	257	241	257	236		1720
%T/C	86.76	79.53	69.44	52.38	67.08	49.61	44.35		
OSP	13.24	20.47	30.56	47.62	32.92	50.39	55.65		
%BIS	0.91	0.00	0.40	0.40	3.33	0.78	0.87		
%MIO									
%LAE	1.83	3.54	5.16	0.00	3.33	1.56	0.43		
%MOT	3.20	0.00	1.59	0.00	1.25	0.39	0.87		
%FRAX	1.37	3.94	2.78	34.13	7.50	26.56	26.52		
%AOT	5.94	12.99	20.24	11.51	17.50	19.92	26.96		
%gym	87.67	79.53	70.24	54.37	70.42	51.56	45.22		
% mio	5.02	3.54	6.75	0.00	4.58	1.95	1.30		
% ang	7.31	16.93	23.02	45.63	25.00	46.48	53.48		
	Total	%	3970-8	%					
Virgo rallus	27	22.31	0	0					
Triporopollenites plektosus	R	0.00	0	0					
Brevicolporites colpella	21	17.36	3	7.5					
JUGLANDACEAE	6	4.96	1	2.5					
Ulmipollenites undulosus	32	26.45	10	25					
Echigraminidites sp.	5	4.13	26	65					
Aquilapollenites spinulosus	25	20.66	0	0					
Intratriporopollenites minimus	5	4.13	0	0					
Total	121	100.00	40	100					
	lac	swamp	sw mar	fpl					
%gymnosperms	83.60	70.33	52.96	47.71					
%miospores	4.28	5.66	0.98	1.38					
%angiosperms	12.12	24.01	46.06	50.92					
lac=lacustrine									
sw mar = swamp margin									
fpl = floodplain									

Pie diagrams presenting the average relative abundance of: 1 (left hand diagram) - species of Juglandaceae pollen recorded from the Joffre samples. The percentages are based on the total of 50 Juglandaceae pollen specimens (see spread sheet); 2 (right hand diagram) - percentage of a selected group of angiosperm pollen species. The percentages are based on a total of 121 specimens of the selected species (see spread sheet).






RELATIVE ABUNDANCE DIAGRAM FOR JOFFRE BRIDGE
metres
18
10
Other pollen snd spores
T/C/T
Other pollen and spores
Bisaccates
Laevigatosporites
Other spores
Fraxinoipollenites variabilis
Other angiosperms
C221822
C221823
C221824
C221825
C221826
C221827
C221828
0
100 0
5 0
20 0
50
Frequency (%)


COMPARISON OF DEPOSITIONAL ENVIRONMENTS
lacustrine
C221822/23
swamp
C221824/26
swamp margin
C221825/27
floodplain?
C221828
%angiosperms
%miospores
%gymnosperms
0
50
100