

THE MIDDLE MIOCENE ALUM BLUFF FLORA,
LIBERTY COUNTY, FLORIDA

By

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For Daddy,

who grew up under the shade of
a big live oak and taught me
the value of all things in nature

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The Peace of Wild Things

*When despair for the world grows in me
And I wake in the night at the least sound
In fear of what my life and my children's lives may be,
I go and lie down where the wood drake
Rests in his beauty on the water, and the great heron feeds.
I come into the peace of wild things
Who do not tax their lives with forethought
Of grief. I come into the presence of still water.
And I feel above me the day-blind stars
Waiting with their light. For a time
I rest in the grace of the world, and am free.*

-Wendell Berry

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Abstract of Thesis Presented to the Graduate School
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THE MIDDLE MIOCENE ALUM BLUFF FLORA,
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The Miocene flora of Alum Bluff, Liberty County, Florida, is significant because of the relative rarity of Tertiary, and especially Miocene, fossil plant localities in eastern North America. After conducting a paleofloristic study including leaves, seeds, fruits, and pollen at Alum Bluff, implications for understanding Miocene climate, biogeography, and paleoecology of the region were inferred. The first study of the flora of the Alum Bluff site was conducted on leaf impressions by E.W. Berry in the early twentieth century. Berry studied only leaf macrofossils and identified 12 leaf species. Recent collections and further examination of specimens reveals 22 identified taxa, 7 morphotypes of uncertain taxonomic affinity, and 21 examples of unknown taxonomic affinity are also

present in the flora. Berry described the flora as being tropical with some temperate elements found in the Florida panhandle today; however, recent finds such as Paliurus, which is extinct in North America but present in Eurasia today, suggest different floristic affinities and indicate that the flora was warm-temperate. The composition of the flora was compared with modern floras and other Miocene floras to determine the environmental conditions present at Alum Bluff in the Miocene. It was found that the Alum Bluff flora an elm-hickory-cabbage palm forest (similar to that of North central Florida today) occurring along a river or near a river delta. Biogeographical implications of the Florida panhandle region during the Miocene were inferred based on the floral composition of Alum Bluff. The use of fruit, seeds, pollen, and leaves increased the known diversity of the Alum Bluff flora, making it a paleobotanically important case.

INTRODUCTION

Miocene floras are poorly known in eastern North America. In the southeast U.S., Tertiary paleobotanical deposits are even less common, though there are a number of marine Tertiary deposits in the region. The Brandon lignite flora of Vermont, the Brandywine flora of Maryland, and the Alum Bluff flora of Florida are some examples of the few eastern North American Miocene localities with good preservation of macrofossils (Berry 1916, McCartan et al. 1990, Tiffney 1994, Tiffney and Traverse 1994). Due to the rarity of Tertiary fossil plant localities in the southeastern coastal plain and especially in Florida, the Alum Bluff flora is of special interest. Alum Bluff is located in the Florida panhandle about 2 miles north-northwest of Bristol, Florida (30°28'08"N/84°59'10"W) (Fig. 1). The exposure is a steep river cut bluff along the Apalachicola River and is part of a property owned by the Nature Conservancy known as Apalachicola Bluffs and Ravines Preserve.

The pioneering work on the Alum Bluff flora was done by Berry (1916). He identified 12 plant species (based on leaf forms) and one fungal species from the site. Recently collected leaf, seed, and pollen for this study from the same site reveal new taxa not treated by Berry. Berry's work characterized the Alum Bluff flora as being subtropical to tropical, and he made his identifications by comparing the leaves with modern North American genera. Some of the newer

finds from the site evaluated in this study, however, suggest other floristic relationships. A temperate Eurasian genus, Paliurus (Rhamnaceae), extinct in North America today, was recently noted from the site by Manchester (1999). Paliurus has also been found in Eocene to Miocene strata in the Western U.S., since the Eocene in Asia, and in the Oligocene and Miocene of Europe (Manchester 1999). This study also revealed other taxa present at Alum Bluff, including members of the Juglandaceae, Ulmaceae, Fagaceae, Altingiaceae, Pinaceae, Cupressaceae, and a temperate member of the Aquifoliaceae. The presence of Paliurus and the other temperate genera represented suggests more temperate affinities than those Berry described based on his identifications.

The goals of this project were 1) to investigate the overall biodiversity of Alum Bluff based on recent collections, 2) to interpret past climatological and paleoecological conditions of the Alum Bluff region based on the floristic assemblage, and 3) to examine the biogeographical implications and evidence for floral change presented by the Alum Bluff floristic assemblage. To investigate these goals, pollen, fruits, seeds, and leaves were examined from the Alum Bluff sediments.

Modern Flora of Apalachicola Bluffs and Ravines

In order to gain an appreciation of late Tertiary floristic change in southeastern North America, it is useful to compare the Miocene Alum Bluff flora with the flora existing in the region today. The modern flora of the area surrounding Alum Bluff is botanically distinctive (Clewell 1977, James 1961, Harper 1914, Leonard and Baker 1982, Means 1985, 1977, Ward 1979, Wolfe et

al. 1988, Wunderlin and Hansen 2003). In a study using a rarity-weighted richness index to identify hot spots of rarity and richness, the Apalachicola River Valley region of the Panhandle was identified as one of the five hot spots of diversity for the United States (Stein et al. 2000). Also according to Stein et al. (2000), the forests of the Florida panhandle region possess the “largest number of tree species per unit area of any forests in the United States.” Compared with the number of taxa in the fossil flora examined by the author, the modern flora of the area is much more diverse (see Appendix A), however this difference is likely partially due to preservation factors which prevented the entire diversity of the Miocene flora from being preserved.

Today, numerous endemic species are known from the Apalachicola River Valley, and the region also contains many northern species at the southern extreme of their range (or with disjunct occurrences). The reason for this geographic isolation of more northern species along the Apalachicola River corridor is largely because the Apalachicola corridor has been connected to the Appalachian region almost continuously since the late Miocene (Clewell 1977, Harper 1914). The Apalachicola River is the only river in Florida whose watershed is fed mostly by areas outside the coastal plain, namely the Piedmont and Appalachian Region, and thus the route for migration of species has primarily been from these areas. The high proportion of endemic species may be related to both genetic isolation and topography of the area (James 1961, Myers and Ewel 1990, Ward 1979, Wolfe et al. 1988). Unlike most of peninsular Florida, the Apalachicola River Valley is largely protected from fire. Fires cannot

approach from the west because of the river, and fires are slow to spread downslope in the gully-eroded ravines along the eastern bank. Thus, humus accumulates creating a rich growing environment (Clewell 1977, Harper 1914). These conditions would not have been present during the Middle Miocene, however, since the Apalachicola River Valley began to form around this time (Clewell 1977).

Geology

The Apalachicola River is formed by the confluence of the Chattahoochee and Flint rivers at the Georgia/Florida border near the town of Chatahoochee and Lake Seminole. It extends through the Northern Highlands geographic province of Florida and down through the Gulf Coastal Lowlands near Apalachicola, Florida. According to Harper (1914, p. 228),

From its beginning at the southwestern corner of Georgia to about the latitude of Bristol the Apalachicola River has on its east side some of the highest land in Florida ..., which comes out to the river in several places, making steep bluffs. Between these bluffs are deep rich valleys, some of which extend back several miles from the river.

Alum Bluff, first described by Langdon (1889), is one of the bluff exposures characteristic along the Apalachicola. It is considered probably the most conspicuous topographic feature in Florida (Harper 1914, Schmidt 1986), and is characterized by a precipitous face that is about 170 feet high.

The bluff exposes a stratigraphic sequence of Miocene to Pleistocene age sediments (Fig. 2, 3). There are five lithologic units exposed at Alum Bluff including Miocene Alum Bluff Group (Chipola Formation and unconformably overlying undifferentiated beds) (Gardner 1926, Johnson 1989b), the Pliocene

Jackson Bluff Formation, the Plio-Pleistocene Citronelle Formation, and a section of undifferentiated surficial clastics (Schmidt 1986) (Fig. 4). The plant-bearing horizon is in the upper part of the Alum Bluff Group in unnamed beds (undifferentiated stratum) above the Early Miocene Chipola Formation and below the Pliocene Jackson Bluff Formation, and is inferred to be middle Miocene (15-18 million years old) in age (Bryant et al. 1992, Johnson 1989a, Schmidt 1986) (Fig. 5). This stratum is characterized by gray to yellow and white clayey sands (Schmidt 1986). Within the upper portion of this stratum, fossil leaves, roots, seeds, pollen, and wood have been collected. It was observed that there are approximately five fossil plant layers within a half-meter stratigraphic interval in the upper portion of the Alum Bluff Group (undifferentiated stratum) (Fig. 6). A number of age-significant mammals (Hemingfordian or early Barstovian) have also been isolated from the undifferentiated stratum of the Alum Bluff Group including Prosynthetoceras texanas, a protoceratid mammal (Webb et al. 2003), a small anchitherine horse (Bryant et al. 1992, Olsen 1964, 1968), a small rhinocerotid, and an equid known as Merychippus gunteri (Bryant et al. 1992). It is important to note that mammal fossils have not been found in situ with the plant fossils, but rather as outwash from the Alum Bluff Group (undifferentiated) stratum. The underlying Chipola Formation has a rich molluscan fauna, and has been estimated to be about 18.3-18.9 million years old giving a maximum bound for the age of the leaf deposit (Bryant et al. 1992). The Alum Bluff Group (undifferentiated) however, due to the presence of late Hemingfordian or early Barstovian mammals, is estimated to be between 15-18 million years old. The

overlying Jackson Bluff Formation is also a fossiliferous stratum, however it yields marine fossils including bone fragments of dugong, sharks teeth, and numerous mollusks.

The Alum Bluff Group (undifferentiated) is thought to represent deltaic or pro-deltaic sediments (Schmidt 1986). Also, the sandy matrix surrounding fossil plants at Alum Bluff and the presence of trunks of Sabalities in the fossil beds suggests a high energy riverine depositional environment capable of carrying and depositing heavy sediment particles and plant materials (pers. comm. Dilcher 2004). The conspicuous lack of megaspores of heterosporous ferns in sieved material or sediment processed for pollen also indicates a moving-water depositional environment as opposed to a still-water lake or pond environment (pers. comm. Dilcher 2004).

The nomenclatural history of geologic units exposed at Alum Bluff is somewhat confusing and has changed numerous times since the Alum Bluff lithostratigraphy was first described. The Alum Bluff Group, undifferentiated, has been called the "Fort Preston Sand," the Alum Bluff Formation, the Hawthorne Formation, and the Choctawhatchie Stage, among others ([Table 1](#)).

Table 1. Examples of historical names of the stratum currently known as the Alum Bluff Group, undifferentiated and their corresponding publication

Historical Nomenclature	Publication
Oak Grove Sand	Berry 1916
Choctawhatchie Stage	Olsen 1964, 1968
Hawthorne Formation	Campbell 1985, Schmidt 1986
Fort Preston Sand	Puri and Vernon 1964, Bryant et al. 1992
Alum Bluff Group	Gardner 1924, Johnson 1989b
Alum Bluff Group/ Hawthorn Group sands	Rupert 1994
Alum Bluff Formation	Webb et al. 2003

MATERIALS AND METHODS

Macrofossils were collected haphazardly from the plant-fossil bearing strata by exposing fossiliferous platforms on the hillside at Alum Bluff. Care was then taken to extract mostly complete specimens from the excavated areas. Some specimens were collected as very large (ca. 0.3m²) chunks which were allowed to dry in the lab, then broken apart to expose macrofossils. Most of the collections from Alum Bluff were made at the northernmost end of the exposure. Macrofossils collected from Alum Bluff were photographed with oblique lighting using a Nikon Coolpix 995 digital camera. Due to the fragile nature of the specimens from Alum Bluff, some were treated with Paleo-bond Penetrant Stabilizer (manufactured by Paleo-bond, Inc. of St. Paul, MN) to prevent the sandy matrix from crumbling. Others were stabilized with a diluted solution of Elmer's white glue. No glue or Paleo-bond was applied to the face of the fossil itself, but only to the attached matrix. Leaf descriptions were developed using the categorization and terminology set forth in the Manual of Leaf Architecture (LAWG 1999).

Some sediment was processed for pollen in the Paleobotany lab at the Florida Museum of Natural History (FLMNH) using a technique modified from Traverse (1988). Other samples were outsourced for processing by Global Geolabs, Ltd. of Medicine Hat, Alberta, Canada. At FLMNH, the outer surface of 30-200g sediment samples were first scraped away to avoid potential

contamination with modern pollen. The samples were then ground with a mortar and pestle until only loose, coarse particles remained. The sediment was transferred to a plastic beaker, and distilled water was added to make a sediment slurry. Enough 5% HCl was added to cover the sample. No reaction was observed indicating that no carbonates were present, so the HCl was decanted. The sample was washed with distilled water and decanted three times. A volume of 49% HF equaling about one and a half times as much as the sample was then added. The beaker was covered and allowed to sit under a fume hood for 2-4 days. Periodically, the sample was agitated. The sample was then separated into plastic centrifuge tubes and centrifuged for 15 minutes. The HF was decanted and the samples were washed with distilled water three times. Zinc Chloride at a specific gravity of 1.7 was then added. Samples were agitated and centrifuged for 30-45 minutes. Samples were allowed to sit in a test tube rack for 4-10 days without being disturbed. After this period, a small amount of distilled water was added and then siphoned off with the organic matter that had separated from the sediment. The siphoned material was placed in a separate centrifuge tube and washed several times. Several drops of 30% EtOH was added to each tube to retard fungal growth. One to three drops of the organic slurry were then placed on a glass slide with one to two drops of glycerine. The sample was covered with a coverslip, which was rimmed with clear fingernail polish or Canada balsam. Pollen grains and spores were photographed via light microscopy with a Nikon SLR using black and white Technical Pan (ISO 25) or color print film (ISO 100). X and Y coordinates were recorded from the Nikon

Eclipse E600 microscope. For comparison with coordinates of other microscopes, a point placed on a standard biological microscope slide 3 cm from the left edge and 1.5 cm from the bottom edge gives coordinates of 44.2x, 100.2y.

Observations were also made using scanning electron microscopy (SEM). Some preparations were made by placing a 12mm round smooth adhesive pad onto a standard SEM stub, and then placing a drop of pollen slurry on the pad. These SEM stubs were placed in a closed SEM stub box and then allowed to dry on a slide warmer. Other SEM stubs were prepared by placing a small 1.3 cm² piece of tinfoil with adhesive onto a standard 12mm SEM stub. A 12mm round glass coverslip was then placed in the center of the tinfoil square, and the corners of the square were crimped around the coverslip to hold it in place. A drop of pollen slurry was placed on the coverslip. The stubs were placed in a closed SEM stub box and then on a slide warmer or in incubator for several hours to dry. This second method was developed after it was found that the pollen grains and spores tended to sink into the adhesive, obscuring part of the structure. Also, the second method was advantageous in that it enabled a permanent slide to be prepared that can be accessioned into the UF paleobotanical collections. Stubs were sputter coated and observations were made using a Hitachi S-400 Fe-SEM at the University of Florida Electron Microscopy Core Laboratory. After SEM observations were completed, the coverslips were removed from the stubs and inverted onto a drop of Canada balsam on a standard glass microscope slide.

Pollen, pteridophyte spores, and fungi (fruiting bodies and spores) were described using a synthesis of terminology defined by the AASP Workgroup on Fossil Fungal Palynomorphs (1983), Huang (1981), Moore et al. (1991), Traverse (1988), and Weber (1998) (see Appendix B).

Pollen counts were conducted by tallying all pollen grains of specific genera or morphotypes on four slides. The slides were prepared from sediment that was either clay-rich or sand-rich from different levels in the exposure. At least 250 individual grains were counted on each slide. A total of 1,072 grains or spores were included in the percentage calculations. Because this was a random sampling technique, not all genera or morphotypes identified are described in the pollen count summary.

Cuticle analysis was performed on some specimens. The cuticle preparation method used was that of Kvaček (pers. comm. w/ S. R. Manchester 2003), which was modified from Dilcher (1974). Loose cuticle samples were removed carefully from fossils with forceps. The samples were then transferred to a water droplet on a glass slide. A fresh Schulz' solution was then prepared by adding several crystals of Potassium Chlorate to a few drops of concentrated Nitric Acid, making sure the solution was saturated (crystals remained at bottom). Monocot cuticle was treated for 10 minutes, while dicot cuticle was treated for 2-5 minutes. Timing was determined by carefully watching the sample, and then quickly diluting the Schultz solution with distilled water when the cuticles had cleared to a pale brown color (eudicots and magnoliids), or had cleared partially (from black to chocolate brown)(monocot). After diluting the Schulz' solution, it

was pipetted off, and the specimen was washed two to three more times in a similar manner.

Euicot and magnoliid cuticle was then transferred in water to a slide and observed via a dissecting microscope. The abaxial and adaxial cuticles were carefully teased apart with fine needles and the mesophyll was carefully scraped away. A drop of glycerine jelly was added to the slide and a slipcover was placed over it with a ring of clear fingernail polish to keep it in place and to prevent dehydration.

Monocot cuticle was still dark and was treated with a couple drops of NH_3 (ammonia) after the Schulz treatment. The cuticle quickly cleared with this treatment, but remained very fragile. Repeated attempts were made to extract monocot cuticle, each time successively shortening the time in Schultz solution from 10 to 5 to 2 minutes and reducing the amount of ammonia and then eliminating the ammonia treatment entirely. However, despite these efforts, the cuticle disintegrated easily when the attempts were made to pry the cuticle layers apart. SEM observations were also attempted on monocot cuticle, but the cellular structure was obscured. No successful observations of monocot cuticle were made.

Some sediment from Alum Bluff was sieved previous to the start of my investigations. Some of the grey, siltstone bearing black leaf compressions was disaggregated in Hydrogen Peroxide and washed through a series of screens with mesh size grading from 1 mm to 0.33 mm. Only one specimen obtained from the sieving method was found to be taxonomically identifiable.

RESULTS

From the leaf, spore, pollen, fruit and seed observations that were made, 30 taxa have been recognized (Table 4). Seven morphotypes of uncertain taxonomic affinity, and 22 examples of unknown taxonomic affinity were described (Table 4). In addition, 11 leaf morphotypes of uncertain taxonomic affinity, and 17 pollen or spore morphotypes of uncertain affinity were recognized.

Leaf Macrofossils

Sixteen morphotypes were identified from Alum Bluff. Only two of the morphotypes are named to genus, one morphotype is tentatively named to genus (Table 4), and the remaining 12 morphotypes are designated “Morphotype AB1-12.”

In the current description of the flora, most leaves were not named to a specific genus, though the morphology of the leaves is certainly that of species belonging to a more temperate climate, as evidenced by the small leaf size and frequency of leaves with serrate margins.

Carya (Juglandaceae). 10+ specimens. Fig. 7a-f. Leaves presumably compound. Lamina elliptic to ovate, asymmetrical, unlobed microphyll-notophylls, length to width ratio 2-2.4:1. Apex straight to cuneate, base cuneate. Margin serrated, 1 tooth order, 4 teeth/cm, spacing regular, teeth are straight above and may be straight or convex below, sinus angular. Primary vein straight

to curved. Secondaries pinnate, craspedodromous. All secondaries terminate in a tooth. Spacing of secondaries increasing toward base, angle relative to the primary vein also increasing toward base. Tertiaries opposite percurrent, straight vein course, obtuse vein angle relative to primary. Quaternary and higher order veins not well preserved.

The identification of this foliage as Carya is supported by the abundant pollen and nut evidence of the genus at Alum Bluff. The leaves are fragmentary in most cases, however the distinct character of the venation and the asymmetrical lamina base and overall asymmetrical shape of the leaf also lend support to the identification as Carya. Of the modern reference material I observed, characteristic opposite percurrent tertiaries are very similar to the fossil material from Alum Bluff. Also, the tendency of the secondaries to dichotomize near the margin, and the dichotomous branches to enervate two teeth is characteristic of modern Carya. In modern material, occasionally, one or both of the secondary branches branch again and feed into the teeth as well (thus one secondary enervates up to 3-4 teeth). This was observed in the fossil material as well.

Extant Carya ranges from eastern North America to Central America and a few species occur in eastern Asia. There are six species of living Carya in the Apalachicola River Valley. Macrofossils of Carya are known from the Miocene of the eastern U.S. in the Brandon Lignite of Vermont (Tiffney 1994).

Lauraceae. 1 specimen. [Fig. 8a-c](#). Leaves simple. Lamina elliptical, entire microphyll. Apex and base missing. Secondary veins weak

brochidodromous. Tertiary and higher order veins not well preserved. Stomata paracytic, oil cells common.

Cuticle was successfully recovered and processed from this fragmentary Alum Bluff specimen. Before removal, the cuticular material appeared coriaceous (Fig. 8c). Several characteristics of this cuticle suggest that it may belong to a member of the Lauraceae. Before the abaxial and adaxial cuticles were separated, it was noted that the mesophyll contained numerous, large oil cells. One oil cell remained attached with some mesophyll remnant to one cuticle surface (Fig. 8a).

Paliurus (Rhamnaceae). 3 specimens. [Fig. 9a-d](#). Leaves simple.

Lamina elliptical, symmetrical, unlobed microphylls to notophylls. Length to width ratio approximately 1.3:1. Apex missing in all specimens, base acute, straight to slightly concave. Leaf serrate with possibly gland-tipped teeth, 1 tooth order, 3 teeth/cm, spacing regular. Primary veins basal actinodromous with 3 basal veins. Secondaries craspedodromous. Tertiary and higher order veins not well preserved.

The identification of Paliurus leaves at Alum Bluff is tenuous. Though a convincing winged fruit has been found at the site ([Fig. 19g](#)) (Manchester 1999), leaves have proven more troublesome. Though the leaves illustrated here as Paliurus share some common characters with that of modern Paliurus, namely three basal veins arising from the same point and arching toward the leaf apex and serrate margins, identification cannot be confirmed in the leaves due to lack

of preservation of higher order venation and the absence of a leaf apex. The identification presented here is provided as a possible taxon for this morphotype.

Sabalites (Arecaceae). 20+ specimens. [Fig. 10a-e](#), [Fig. 11](#). Large plicate leaved, costapalmate (rachis of leaf continues through where leaf segments begin to diverge to form a narrow point near the midpoint of the leaf) palm fronds, up to 50X50+mm. Individual leaf segments display a prominent midvein. Veins arise at an acute angle from the costa and continue to the of the leaf apex. A small hastula (ligule-like appendage) is evident at the base of the leaf (Fig. 10c). Petiole of leaf large without spines or otherwise armed edges.

Sabalites is probably the most common megafossil found at Alum Bluff. Fan palms of similar form are noted from Tertiary sites from the gulf coastal plain Florida to Texas and from Kentucky and Tennessee (Berry 1916, Daghlia 1978). The large, coriaceous leaves occur in dense overlapping mats within the fossil plant strata. Repeated efforts were made to extract cuticle from Sabalites specimens for more precise generic and species determination with no success. Several large trunks of palm were also observed, and a portion of one of these is illustrated in Fig. 10d. In viewing the trunks in cross section, large, conspicuous fibers typical of palm stems were evident.

The form genus, Sabalites, is used here to describe the costapalmate palm leaves from Alum Bluff. Sabalites was also the name used by Berry in his original description of the flora. Lacking diagnostic characters found in fruits, flowers, or leaf cuticle, identification to a modern genus can not and should not be made (Daghlia 1978, Read and Hickey 1972). Palm leaves from Alum Bluff

may be erroneously named if assigned to a modern costapalmate palm genus such as Sabal in the absence of distinctive fruit, flower, or cuticle characters.

Berry named the species at Alum Bluff Sabalites apalachicolensis, however he named this species essentially as a locality morphotype without specifying of distinctive characters that distinguish the Alum Bluff material of Sabalites from that of other Tertiary deposits. Thus, this species name cannot be confirmed.

Ulmus (Ulmaceae). 10+specimens. Fig. 12a-f. Leaves simple. Lamina elliptic to ovate, symmetrical to slightly asymmetrical at the base, unlobed microphyll-notophylls, length to width ratio 2-2.4:1. Apex straight to cuneate, base cuneate. Margin serrated, 1 tooth order, 4 teeth/cm, spacing regular, teeth are straight above and may be straight or convex below, sinus angular. Secondaries pinnate, craspedodromous, 1 basal vein. All secondaries terminate in a tooth. Spacing of secondaries increasing toward base, angle relative to the primary vein also increasing toward base. Tertiaries alternate percurrent, straight vein course, obtuse vein angle relative to primary. Quaternary and higher order veins are not well preserved.

This is one of only two genera upheld from Berry's (1916) original work on the Alum Bluff flora (Berry designated a new fossil species, Ulmus floridana). In Berry's description of the material, however, he describes the petiole of Ulmus floridana as being "short and stout, about 2.5 millimeters in length." The material that I examined, however, exhibited a significantly longer petiole, being at least 4.0-9.0 mm in length (Fig. 12a, b, e, f). Specimens of Ulmus exhibit secondaries which often dichotomize near the margin. This phenomenon was observed in

modern reference material as well. Unlike the Carya leaves, however, one of the dichotomous branches enervates the tooth, while the other usually feeds into the sinus between the teeth and rarely enervates a tooth. In addition, the alternate percurrent tertiary venation of Ulmus distinguishes it from Carya. This type of tertiary venation is typical in modern Ulmus.

Morphotype AB1. 6 specimens. Fig. 13a-g. Leaves simple. Lamina ovate to elliptical, symmetrical, unlobed microphylls to notophylls, length to width ratio 0.8-2.5:1. Apex obtuse, rounded. Only one specimen of an isolated apex was found (Fig 13g). Apex is missing in all other specimens. Base cuneate to slightly concave. Only fragmented petiole preserved in some specimens. Margin crenate with about 1-1.5 crenations/cm, spacing regular, sinuses rounded. Primary veins are basal actinodromous, five basal veins present. Primaries feed into the large, broad, rounded teeth. Secondaries enervate remaining teeth (craspedodromous) (Fig 13f).

Berry (1916) reported observing but being unable to collect a palmately veined leaf at Alum Bluff that he thought was Ficus. He gave no mention to whether marginal characters were observed. Berry may have observed the Morphotype AB1 leaf instead.

Morphotype AB2. 4 specimens. Fig. 14a-d. Leaves simple. Lamina elongated ovate, symmetrical, unlobed microphylls, length to width ratio 7:1. Apex missing but likely acute-acuminate. Basal portion and petiole are missing in all specimens. Margin is serrate, 1 tooth order, 5 teeth/cm, tooth spacing regular, teeth are straight above and convex below, tooth apex simple, tooth

sinuses angular. Secondaries pinnate, weakly brochidodromous. Secondaries terminate in some but not all teeth. Spacing of secondaries increasing toward base, secondary angle relative to the primary vein decreasing toward base. Tertiaries alternate percurrent, vein course straight. Quaternary and higher order veins not well preserved.

Morphotype AB3. 3 specimens. [Fig. 15a-d](#). Leaves simple. Lamina ovate, symmetrical, unlobed microphylls, length to width ratio ca. 2:1. Apex is missing (straight?) as is basal portion and petiole in all specimens. Margin is entire. Secondaries pinnate, weakly brochidodromous. Spacing of secondaries increasing toward base, secondary angle relative to the primary vein smoothly decreasing toward base. Tertiaries random reticulate, vein course slightly exmedially ramified. Quaternary veins reticulate. Areolation appears to be well developed, freely ending ultimate veins appear absent.

Morphotype AB4. 1 specimen. [Fig. 16a, b](#). Leaves simple. Lamina ovate, symmetrical, unlobed microphyll, length to width ratio 2.75:1. Apex narrowly rounded, basal portion and petiole missing. Margin entire. Primary veins basal acrodromous. Secondaries basal acrodromous. Tertiary and higher order veins are not well preserved.

Morphotype AB5. 1 specimen. [Fig. 16c, d](#). Leaves presumably compound. Lamina asymmetrical, unlobed microphyll-notophyll (or leaflets from a compound leaf), length to width ratio ca. 2.33:1. Apex is missing (interpreted as acuminate/straight?), base cuneate. Petiole ca. 0.5 cm. Margin entire. Secondaries pinnate, craspedodromous, 1 basal vein. Spacing of secondaries

decreasing slightly toward base, vein angle relative to primary vein is uniform. Tertiary and higher order veins are not well preserved.

Morphotype AB6. 1 specimen. [Fig. 16e-g](#). Leaves simple. Lamina obovate, symmetrical, unlobed microphyll, length to width ratio 1.3:1. Apex obtuse, convex, base concave. Margin serrated, 1 tooth order, 2 teeth/cm, spacing regular, teeth flexuous or convex above and convex below. Secondary veins pinnate, craspedodromous, 1 basal vein. Secondary spacing and angle unclear due to poor preservation. Tertiary and higher order veins also obscure. This specimen is composed of fragmented segments of cuticle and no clear impression is evident.

Morphotype AB7. 1 specimen. [Fig. 16h, i](#). Leaves simple. Lamina ovate, symmetrical, unlobed microphyll, length to width ratio 1.14:1. Apex obtuse, acuminate, base obtuse, rounded. Margin entire. Secondaries pinnate, weak brochidodromous, 1 basal vein. Spacing and vein angle of secondaries uniform. Tertiary and higher order veins poorly preserved.

Morphotype AB8. 1 specimen. [Fig. 17a, b](#). Leaves simple. Lamina elliptic, symmetrical, unlobed microphyll, length to width ratio 1.65:1. Apex obtuse-rounded, base acute-convex. Margin entire. Secondary veins pinnate, weak brochidodromous, 1 basal vein. Spacing and angle of secondaries decreasing toward base. Tertiaries random reticulate or regular polygonal reticulate (preservation makes determination difficult). Higher order veins are not visible due to poor preservation.

Morphotype AB9. 1 specimen. [Fig. 17c-d](#). Leaves simple. Lamina elliptical, symmetrical, unlobed microphyll, length to width ratio 2.7:1. Apex acute-straight, base is missing (perhaps cuneate). Margins serrate, 1 tooth order, 3 teeth/cm, irregular spacing, angular sinus, tooth straight above and convex below. Only tertiary veins enervate the teeth. Secondary veins pinnate, semicraspedodromous, 1 basal vein. Spacing and angle of secondary veins decreasing slightly toward base. Tertiary veins regular polygonal. Quarternary veins regular polygonal reticulate. Higher order veins lacking or poorly preserved.

Morphotype AB10. 2 specimens. [Fig. 18a-b](#). Leaves simple. Lamina elliptic, symmetrical, unlobed notophyll, length to width ratio 2.6:1. Apex acute, convex, base acute, cuneate. Margin entire. Secondary veins pinnate, brochidodromous. 1 basal vein. Spacing and angle of secondaries decreasing toward base. Tertiaries and higher order veins not well preserved.

Morphotype AB11. 2 specimen. [Fig. 18c-e](#). Leaves simple. Lamina elliptic, symmetrical, unlobed notophyll, length to width ratio 2:1. Apex acute, straight, base obtuse, rounded. Margin entire. Secondary pinnate, veins brochidodromous. 1 basal vein. Spacing of secondaries decreasing toward base. Angle of secondaries increasing toward base. Tertiaries alternate percurrent. Higher order veins are not well preserved.

Morphotype AB12: 1 specimen. [Fig. 18f](#). Leaves simple. Lamina elliptical, symmetrical, unlobed microphyll, length to width ratio 4:1. Apex convex, base convex. Margin entire. Secondaries pinnate, weak

brochidodromous. Spacing of secondaries increasing toward the base, and vein angle of secondaries relative to the primary vein is smoothly increasing toward base. Tertiaries appear randomly reticulated, but are poorly preserved. Petiole ca. 0.3cm.

Fruits and Seeds

Carya (Juglandaceae). Fig. 19a-f. Fruits with thick, smooth husks (averaging ca. 2mm thick) (Fig. 19a, f), nut 13-15X20-30mm, endocarp 12-15X15-17mm. Husk appears to separate into four valves. Locule cast shows a pair of longitudinal grooves corresponding to primary and secondary septa with the the nut (Fig. 19d).

Paliurus (Rhamnaceae). Fig. 19g. Winged fruit, with the wing extending horizontally outward around the circumference of the fruit. Approximately 10X15mm, seed body 4X6mm. Persistent perianth disk scar present.

The evidence of a persistent perianth disk scar (raised rim below the wing), distinguishing it this taxa from Cyclocarya (Manchester 1999). Modern Paliurus occurs primarily in Asia, though some species do occur in southern Europe. The introduction of this Eurasian endemic group to the Alum Bluff flora significantly changes the interpretations of Berry (1916), as will be discussed later.

Scirpus (Cyperaceae). Fig. 19h. Three angled achene, approximately 0.4X1.29mm, apparently not subtended by hyaline scales. Specimen was unfortunately broken during preparation for SEM, but the three angled nature is still evident.

Unknown fruit. Fig. 19i. Globose fruit, 10X10mm. Several examples of this form exist at Alum Bluff, but none have yet revealed peduncle or perianth scars, etc. which would aid identification.

Spores and Pollen

Unlike the limited macrofloral assemblages, there are several Miocene localities in the eastern United States from which pollen is known (Table 2). Occurrence of palynomorphs at Alum Bluff has been compared with other known terrestrial Miocene localities in the eastern United States (Table 2). Approximately 30 palynomorphs have been identified at least to “type” (most similar systematic group) from Alum Bluff (Table 4). In addition, percentages of abundance of some of the pollen types identified at Alum Bluff are illustrated (Fig. 20). The most abundant pollen types, based on pollen counts of 1,072 grains, at Alum Bluff are Carya, Pinus, Ulmus, and an unknown monosulcate pollen (Magnoliid type). All other pollen types account for 2% or less of the total pollen abundance at the site. No attempt was made to identify pollen morphotypes to the species level.

Spores

Fern spores are relatively common in the Alum Bluff sediments, and as a group account for approximately 4-5% of the total palynomorph abundance. Despite this frequent occurrence in the palynomorph record, ferns are entirely lacking from the macrofossil assemblage. This is probably due in large part to the harsh, sandy preservation environment. Herbaceous fern remains likely decayed quickly in the highly oxic riverine deposits along the Apalachicola River.

Table 2. Terrestrial Miocene pollen localities from eastern North America used for comparison with Alum Bluff pollen. See [Table 3](#) for details of the occurrence of individual elements of several of these floras.

Formation or Locality	Geographic Location	Age	Reference
Ochoopee River Dune Field	Emanuel County, Georgia	Likely Middle Miocene	Rich et al. 2002
Catahoula Formation	Sicity Island, Louisiana	Early late Miocene	Wrenn et al. 2003
Brandywine Deposit	Brandywine, Maryland	Late Miocene	McCartan et al. 1990
Old Church Formation	Pamunkey River, Virginia	Middle Miocene	Frederiksen 1984
Calvert Formation	Kent County, Delaware	Late Oligocene-Miocene	Groot 1992
Legler Lignite (Cohansey Formation)	Legler, New Jersey	Late Miocene	Rachele 1976
Brandon Lignite	Near Brandon, Vermont	Early Miocene	Traverse 1955, 1994, Tiffney 1994, Tiffney and Traverse 1994

Adiantaceae. [Fig. 21a, b](#). Trilete spore, subtriangular., ca. 45X45 µm.

Laesural arms 17-20 µm long, straight, margo flange-like with irregularly sinuous ridges. Surface verrucate.

In the modern flora of Alum Bluff area, there is one species belonging to the Adiantaceae that occurs (*Adiantum capillus-veneris*). The spore closely resembles *Jamesonia*, a tropical member of the Adiantaceae. *Jamesonia* occurs from Mexico to Bolivia and Brazil at high altitudes. *Jamesonia* is not known from

Tertiary sites in North America, though it does have a fossil record from the Pleistocene within its native range (Hammen and Gonzalez 1960, Hafsten 1960). Graham and Jarzen also noted fossil Jamesonia from Puerto Rico (1969). The laesural ridges also resemble Anogramma of the Adiantaceae.

Botrychium (Ophioglossaceae). [Figure 21c](#). 1 specimen observed.

Trilete spore, subtriangular, ca. 35X35 μm . Laesura not evident in SEM. Surface rugulato-reticulate.

Extant Ophioglossaceae are subcosmopolitan. Fossil records from the Miocene of eastern North America are not known.

Cyathea (Cyatheaceae). [Figure 21d](#). Trilete spore, subtriangular, ca. 40X40 μm . Laesural arms ca. 12X1 μm long, straight, margo flange-like. Surface verrucate.

In North America, modern Cyatheaceae are widespread in tropical montane Mexico to Chile and in the Caribbean. In eastern North America, Cyathea has been reported from the Miocene in the Legler Lignite of New Jersey (Rachele 1976). Frederiksen (1984) also reported a Cyathea-like type in the Old Church Flora of Virginia.

Dryopteris (Dryopteridaceae). [Fig. 21e, f](#). Trilete spore, 30-40X40-55 μm . Laesural arms ca. 15X2 μm long, straight, margo line-like. Surface covered with large verrucate, almost bladder-like, processes.

Extant Dryopteris are cosmopolitan. Dryopteris ludoviciana occurs in the modern Alum Bluff area flora. Dryopteris is not known from other Miocene eastern North American sites.

Polypodiaceae. Fig. 21g-i. Bilateral monolete spore, 20-40X33-60 μm .. Laesurae 20-45 μm , simple commissure. Surface verrucate.

Modern Polypodiaceae are widespread with many species in temperate and tropical regions. Two species occur in the modern flora near Alum Bluff (Pleopeltis polypodioides and Phlebodium aureum). In the Cenozoic fossil record, Polypodiaceae is well known in North America. Polypodium fertile is known in the Miocene Weaverville Formation at Redding Creek, California (Kvaček et al. 2004). In eastern North America, members of the Polypodiaceae have been identified from the Brandon Lignite of Vermont (Traverse 1955, 1994, Tiffney 1994, Tiffney and Traverse 1994), Catahoula formation of Louisiana (Wrenn et al. 2003), Legler Lignite, New Jersey (Rachele 1976), and the Calvert Formation, Delaware (Groot 1992).

Pteris (Pteridaceae). Figure 21j. Trilete spores, rounded triangular, ca. 45X47 μm .. Laesurae not evident in SEM. Surface baculate to clavate. Equatorial ridge present, annulotrilete.

Extant Pteris is cosmopolitan, occurring in both warm and temperate regions. Three species occur today in the Alum Bluff area flora (Pteris cretica, P. multifida, and the introduced P. vittata).

Unknown Trilete Spores

Figure 21k, l. Trilete spores, rounded triangular, ca. 15-17X20-25 μm .. Laesural arms ca. 15 μm long, straight, margo lip-like. Surface slightly verrucate. Perhaps Momipites (an angiosperm pollen type)?

Figure 21m. Trilete spores, rounded triangular, ca. 17X20 μm .. Laesural arms ca. 10 μm long, straight, margo line-like. Surface psilate.

Figure 21n. 1 specimen observed. Trilete spore, subtriangular, 45X45 μm .. Laesural arms ca. 20 μm long, curved. A large gap (ca. 15 μm) extends between the laesurae. Margo may be line-like.

Figure 21o. 47X46 μm . Trilete spore, globose. Laesural arms ca 25 μm long, straight, margo line-like. Surface reticulate.

Figure 21p,q. ca. 45X60 μm . Trilete spore, ellipsoidal. Laesural arms ca 30 μm long, straight, margo line-like. Surface reticulate. May be a member of the Lycopodiaceae.

Pollen

Taxodium (Cupressaceae). Fig. 22a-c. Inaperturate pollen grains that split deeply and fold inwards along their equators, 18-25X15-22 μm . Very small gemmate ornamentation is evident in SEM (Fig. 22c).

Modern Taxodium is primarily restricted to the eastern North America, with one species occurring at higher elevations in Mexico. Both North American species of Taxodium occur near Alum Bluff in the modern flora. Taxodium is known from several other Miocene sites in eastern North America including the Brandywine Flora (McCartan et al. 1990), the Ochopee River dune field (Rich et al. 2002), the Calvert Formation, Delaware (Groot 1992), and the Legler Lignite (Rachele 1976). Traverse identified Glyptostrobus, a close relative of Taxodium, in the Brandon Lignite (1955).

At Alum Bluff, Taxodium is relatively uncommon, accounting for less than 2% of pollen abundance at the site. No macrofossils of Taxodium have been found at the site.

Pinus (Pinaceae). Fig. 22d-g. Vesiculate pollen grain with bladders broadly attached to the corpus. Overall-40-55X70-80 μm . Corpus 30-45X45-60 μm . Sacci 30-45X30-45 μm . Bladders reticulate under light microscopy (Fig. 22e, g), psilate under SEM (22d, f). Corpus reticulato-verrucate.

Pine is one of the most abundant and widespread genera in the palynological record, largely due to its copious pollen production and long-distance pollen dispersal (Traverse 1988). Seven species are native today in the Apalachicola River Valley. In the Miocene of the eastern United States, Pinus is known from the Ochopee River dune field (Rich et al. 2002), the Catahoula Formation (Wrenn et al. 2004), the Legler Lignite (Rachele 1976), the Brandywine Flora of Maryland (McCartan et al. 1990), and the Calvert Formation of Delaware (Groot 1992).

Despite the abundance of Pinus pollen in the Alum Bluff sediment (26.4% of the total pollen assemblage), no macrofossils of Pinus were discovered at Alum Bluff, indicating that Pinus was likely transported to the site from some distance away. The overabundance of pine pollen in the Alum Bluff sediment, however, suggests that Pinus was certainly present in the area immediately surrounding Alum Bluff.

Poaceae. Fig. 22h-k. Monoporate spheroidal-sub-spheroidal to prolate pollen grains, 40-45X40-65 μm . Surface psilate. Most examples exhibit a

prominent annulus (Fig. 22i-k), and one shows an operculum still in place (Fig. 22i).

Poaceus type pollen has also been identified from the eastern U.S. Miocene in the Legler Lignite (Rachele 1976), the Catahoula Formation (Wrenn et al. 2003), the Ochoopee River dune field (Rich et al. 2002), and the Brandon Lignite (Traverse 1955). In the Alum Bluff sediments, Poaceus type pollen was identified successfully only with SEM and was rare in the samples overall.

Liliales. Fig. 23a-d. Monosulcate pollen grains, 12-25X20-45 μm . Surface perforate to foveolate.

Liliaceous pollen has also been reported from the Miocene of the eastern U.S. at the Catahoula Formation (Wrenn et al. 2003), the Ochoopee River dune field (Rich et al. 2002), and the Piney Point Formation (Fredericksen 1984). At Alum Bluff, Liliaceous pollen is rare (>1% of total pollen assemblage).

Magnoliaceae. Fig 23e, f. Monosulcate pollen grains, 15-25X25-28 μm . Surface psilate.

These inconspicuous monosulcate grains constitute a large fraction of the pollen at Alum Bluff (13.0%), though this percentage doubtless includes a number of unknown taxa. Magnoliid type pollen is also known from the Miocene localities at the Ochoopee River dune field (Rich et al. 2002), and the Catahoula Formation (Wrenn 2003).

In the megafossil assemblage at Alum Bluff, there are several examples of entire margined, pinnately veined leaves that may belong to the Magnoliaceae,

however sufficient characters are lacking to confirm identification of the family among the megafossils.

Amaranthaceae. Fig. 23g-i. Periporate pollen grains, 15X15 μm . Surface scabrate to gemmate.

This pollen type is also known from the Calvert Formation (Groot 1992). Amaranthaceae/Chenopodiaceae type pollen is relatively rare at Alum Bluff and was probably transported to the site from the surrounding area.

Carya (Juglandaceae). Fig. 23j-m. Triporate pollen grains with the pores clearly shifted to one hemisphere, 45-50X45-60 μm . Annulus present, but not prominent. Surface sculpture scabrate.

Carya pollen is known from all the eastern U.S. Miocene localities except the Brandywine Flora. By far the most abundant pollen type at Alum Bluff, the presence of Carya pollen corroborates the identification of both leaf and seed macrofossils recovered from the site. The abundance of both macrofossil and palynological remains of Carya suggest that hickories were an important component of the Miocene Alum Bluff forest along with Ulmus and Sabalites.

Diospyros (Ebenaceae). Fig. 23n. Tricolpate pollen grains, ca. 30X30 μm . Surface sculpture psilate. Sculpturing is evident within the broad colpi, and appears to be baculate.

Diospyros is currently predominantly a tropical genus, with one species (Diospyros virginiana) occurring in the southeastern U.S. The Diospyros type is not known from any other Miocene eastern U.S. pollen localities. It is a rare component of the Alum Bluff flora (>0.5%).

This pollen type resembles some members of the Styracaceae as well, though it is distinctly different from this family due to the psilate surface (Styracaceae possess scabrate surface sculpturing.)

Gleditsia (Fabaceae). Fig. 25j-p. Tricolpate pollen grains, ca.30-40X30-40 μm . Sculpturing reticulate with horizontal striations across reticulum.

Comparison with modern reference material of Gleditsia supports this identification. Not only do both the fossil and modern material exhibit prominent reticulate sculpturing, but both exhibit horizontal striations on the reticulum. In addition, the length to width ratio (ca. 1.5:1) is the same for the modern and fossil material.

Berry (1916) reported observing fruits very similar to those of Gleditsia aquatica at Alum Bluff, though he was unsuccessful in collecting them. Gleditsia aquatica is a component of the modern floodplain forests near Alum Bluff today.

Ilex (Aquifoliaceae). Fig. 23o-u. Tricolpate pollen grains, 25-37X30-40 μm . Surface covered with very large pilate processes (Fig. 23u) with the stalks of the clubs being very narrow in relation to the head. Surface of club head covered with rugulate sculpturing.

Modern Ilex is a cosmopolitan genus, though most species are restricted to tropical and temperate Asia and America. There are 10 species native to the panhandle region of Florida. Ilex is known from all of the Miocene eastern U.S. palynofloras surveyed (Table 2). At Alum Bluff, it is a relatively infrequent occurrence.

Liquidambar (Altingiaceae). Fig. 23v-x. Periporate, spheroidal pollen grains, ca. 30-40X30-40 μm . Surface sculpturing foveolate. Pore membranes covered with bead-like sculpturing.

There are only a few extant species of Liquidambar that occur either in eastern North America (L. styraciflua) or Asia (L. acalycina and L. formosana in China, and L. orientalis in Asia Minor). Liquidambar styraciflua is a common component of floodplain habitats in the Apalachicola River Valley. Liquidambar is known from all of the Miocene eastern U.S. palynofloras (Table 2). At Alum Bluff, it comprises only 1% of the total palynofloral assemblage. Though Liquidambar was abundant in the modern environment at the Alum Bluff site, likelihood of contamination from modern sources is low since Liquidambar was found in samples processed with sterile techniques at the Canadian Geolabs, Inc (Liquidambar does not occur in Western Canada), and since grains exhibited no nucleus and were often corroded or deflated.

Myrica (Myricaceae). Fig. 23y, z. Triporate pollen grains, annulus present but not prominent, 30-35X30-35 μm . Surface sculpturing scabrate.

Myrica is a subcosmopolitan genus. There are several species native to the eastern U.S. (Myrica cerifera, M. inodora, and M. caroliniensis). Myrica pollen is known from the Catahoula Formation (Wrenn et al. 2003), the Ochoopee River dune field (Rich et al. 2002), and the Brandon Lignite (Traverse 1955). It is uncommon at Alum Bluff.

It is often difficult to discern the Betulaceous type pollen from the Myricaceous type pollen by light microscopy, and thus this palynomorph, which was not observed in SEM may represent Betulaceae.

Quercus (Fagaceae). Fig. 24a-f. Tricolpate pollen grains, ca. 20X30 μm . Surface sculpturing scabrato-verrucate.

Oaks occur primarily in northern temperate zones, with some species occurring at more tropical latitudes at high altitudes. In the panhandle of Florida, there are 24 native oak species (Clewell 1985, Wunderlin and Hansen 2003). Quercus is present in all of the Miocene eastern U.S. palynofloral localities. It is relatively rare at Alum Bluff, occurring at a frequency of about 1 per 1,000.

Ulmus (Ulmaceae). Fig. 24g-l. Stephanoporate, oblate pollen grains, ca. 30-45X30-45 μm . Distinct arci lacking (distinguishing it from Alnus). Surface sculpturing scabrate and rugulate. May occur with four (Fig. 24g-j), five (Fig. 24k), or six (Fig 24l) pores.

Modern elms are found primarily at northern temperate latitudes of North America and Eurasia. There are three species of Ulmus occurring in the Apalachicola River Valley (U. alata, U. americana, and U. rubra). Pollen occurring at Alum Bluff is more likely Ulmus than Planera, because according to Zavada, Planera possess little to no rugulae at the poles of the grain (1983). The specimens from Alum Bluff mostly show clear rugulae covering both the equatorial region as well as the poles (Fig. 24g-l). Present at all eastern U.S. Miocene localities, Ulmus is particularly abundant at Alum Bluff, comprising more than 10% of the pollen assemblage.

Asteraceae and Malvaceae. Fig. 25a-e. Two size classes: 18-25X30 μm , 30-45X32-47 μm . Smaller pollen grains tricolporate (Fig. 25a, b). Colpi and pores unclear in larger grains (Fig. 25c-e). All with echinate surface sculpturing.

Due to their clear tricolporate nature, it is suggested that the smaller grains (Fig. 25a, b) may be helianthid type pollen (Asteraceae). Similar helianthid type pollen recovered from the Catahoula Formation is age diagnostic for that area. Pollen of the helianthid type assigns an age of earliest late Miocene to the Catahoula Formation based on offshore pollen zonation markers in the Gulf of Mexico (Styzen 1996, Wrenn 1996, Wrenn et al. 2003). This reported age is slightly younger (ca. 3 million years) than that of Alum Bluff. Thus, the presence of the helianthid type pollen in the Alum Bluff assemblage may suggest a slightly younger age than reported by previous authors (Bryant et al. 1992, Webb et al. 2003). Until a firm diagnosis of the pollen at Alum Bluff being the helianthid type, this new assertion regarding age cannot be made with certainty.

The larger pollen grains (Fig. 25c-e) show some characteristics of the Malvaceae, particularly small "lines" or "bands" that innervate the echinate processes. These seem to be lacking in the small grains (Fig. 25a, b). Certain identification cannot be made, however, due to lack of resolution in determining present/absence and position of pores and/or colpi. Further examination via TEM or SEM may be warranted to gain the necessary resolution to distinguish these taxa.

Vitaceae type. Fig. 25u-x. Tricolporate pollen grain, ca. 18-30X18-30 μm . Surface sculpturing rugulate.

The sculpturing of this palynomorph closely resembles that of Vitis. The larger sized specimens (Fig. 25v, x) approach the typical size for Parthenocissus.

Uncertain Pollen Forms

Betulaceae type. Fig. 25f. Triporate pollen grain with a distinct annulus around the pores, 35X35 μm . Surface ornamentation appears scabrate.

Euphorbiaceae type. Fig. 25g, h. Pores and colpi not visible in SEM (may be inaperturate or have pores or colpi on one hemisphere), 30X35 μm . Sculpturing appears gemmate.

These morphotypes resemble sculpturing exhibited by some Euphorbiaceae.

Fabaceae type. Fig. 25i. Pores and colpi not visible in SEM (may be inaperturate or have pores or colpi on one hemisphere), 40X45 μm . Sculpturing dramatically reticulate.

This taxon resembles Vigna (Fabaceae) pollen.

Rubiaceae/Rhamnaceae type. Fig. 25q, r. Tricolporate, syncolpate, 15X15 μm . Surface sculpturing verrucate.

These pollen grain resemble some genera of Rubiaceae and Rhamnaceae.

Rosaceae type. Fig. 25s, t. 8X12 μm . Tricolpate pollen grain. Surface sculpturing striato-rugulate.

This specimen resembles some members of the Rosaceae due to its prominent striato-rugulate sculpturing.

Unknown Palynomorphs

Fig. 26a. 60X115 μm . Very large monosulcate pollen (?) grain. Surface psilate. Possibly an algal cyst.

Fig. 26b-d. Varying sizes. Tricolpate pollen grains. Sculpturing varies.

Fig. 26e, g-j. Varying sizes. Triporate pollen grains. Sculpturing varies.

Fig. 26f. ca. 17X17 μm . Tricolpate pollen grain. Surface verrucate.

Fig. 26k, l. 33X33 μm . Tricolpate pollen grain. Sculpturing perforate.

Fig. 26m, n. 30-45X40-45 μm . Periporate pollen grains. Sculpturing scabrate.

Fig. 26o, p. 30-45X65-75 μm . Apparently inaperturate, "boat shaped" pollen (?) grains. Surface psilate.

Dinoflagellate cyst

Fig. 26q. A marine dinoflagellate cyst.

Fungi

Several fungal types have been noted from Alum Bluff. Berry (1916) described a spot fungus known as Pestalozzites sabalana on leaves of Sabal from Alum Bluff. He compared it to modern species of Pestalozzites that occur on leaves of Serenoa and related groups, and his determination seems accurate. In examining sediment samples processed for pollen and spores at Alum Bluff, a number of fungal types were noted that occurred with frequency in the samples. Following are general descriptions of several fungal types, none of which were

identified taxonomically. Descriptions are tentative and were made following the terminology of AASP Workgroup on Fossil Fungal Palynomorphs (1983).

[Fig. 27a](#). Obovate, psilate, apparently diporate, dicellate fungal spore.

[Fig. 27b](#). Elliptic, psilate, inaperturate, tricellate fungal spore. Axis straight.

[Fig. 27c](#). Rounded rhombic, Slightly longitudinally striate, inaperturate, dicellate fungal spore. Axis straight, dividing spore into equal proportions.

[Fig. 27d](#). Elliptic, psilate, inaperturate, monocellate fungal spore.

[Fig. 27e, f](#). Rounded obdeltate, psilate, inaperturate, monocellate fungal spores.

[Fig. 27g](#). Partial scutate fruit body. Ostiole/pseudo-ostiole missing in these fragmented specimens.

[Fig. 27h](#). Circular, psilate, inaperturate, dicellate spore. Axis straight, dividing the spore into unequal proportions.

[Fig. 27i](#). Elliptic, reticulate, inaperturate, monocellate spore.

[Fig. 27j, k](#). Circular, slightly rugulate, inaperturate, monocellate spore cluster.

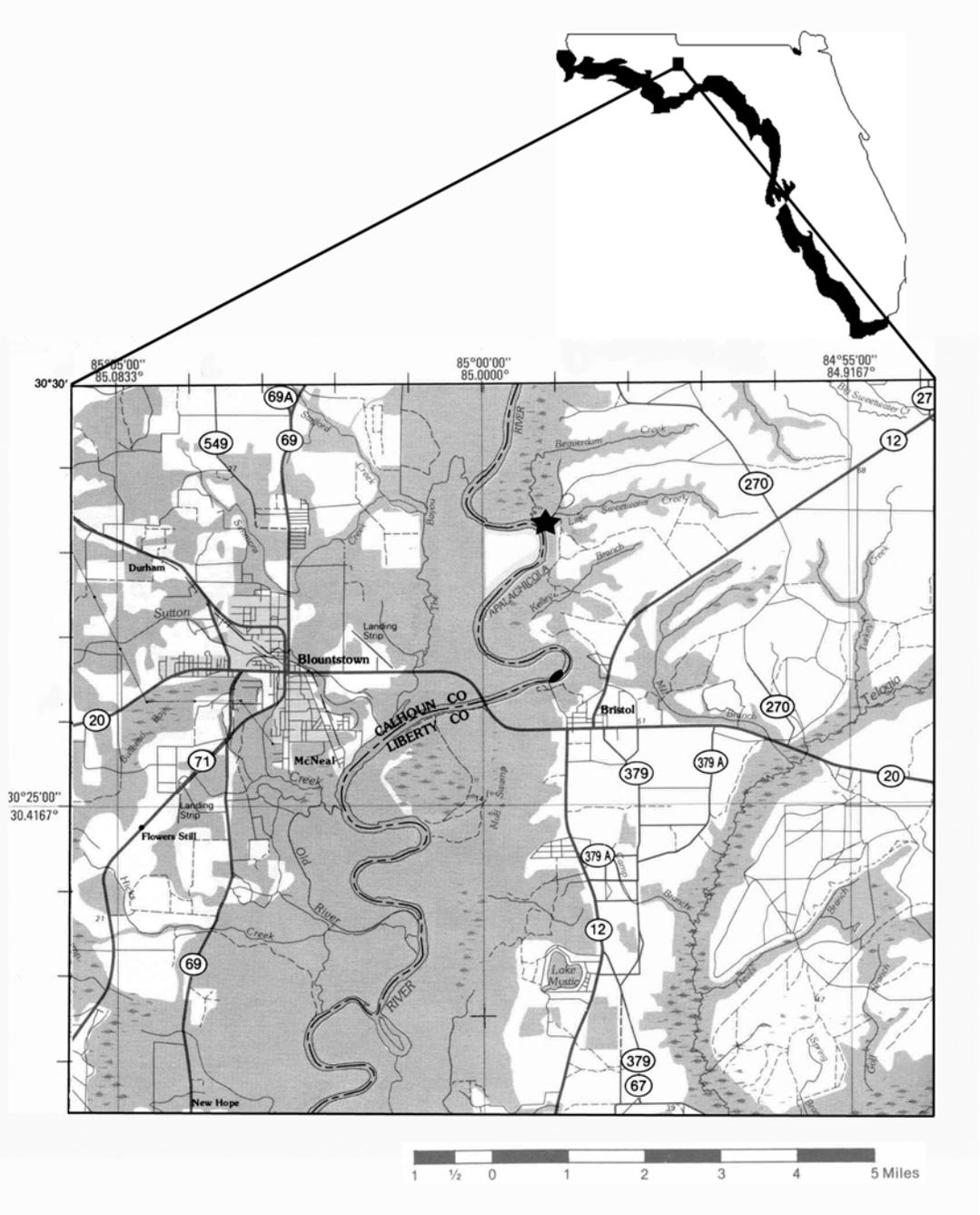


Figure 1. Map showing Alum Bluff and surrounding area. ★=Alum Bluff site. ● = Bristol boat landing.

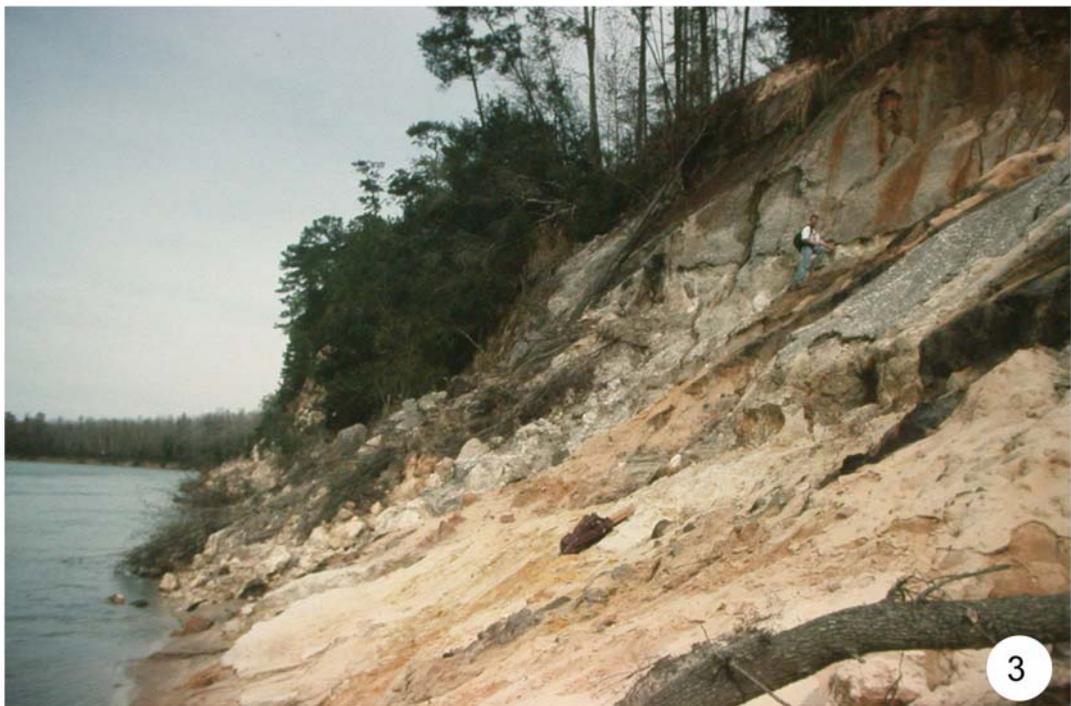


Figure 2. Apalachicola River and Alum Bluff exposure.

Figure 3. Alum Bluff exposures showing Early Miocene (lowermost portion at water level) to Pleistocene (uppermost portion) age sediments.

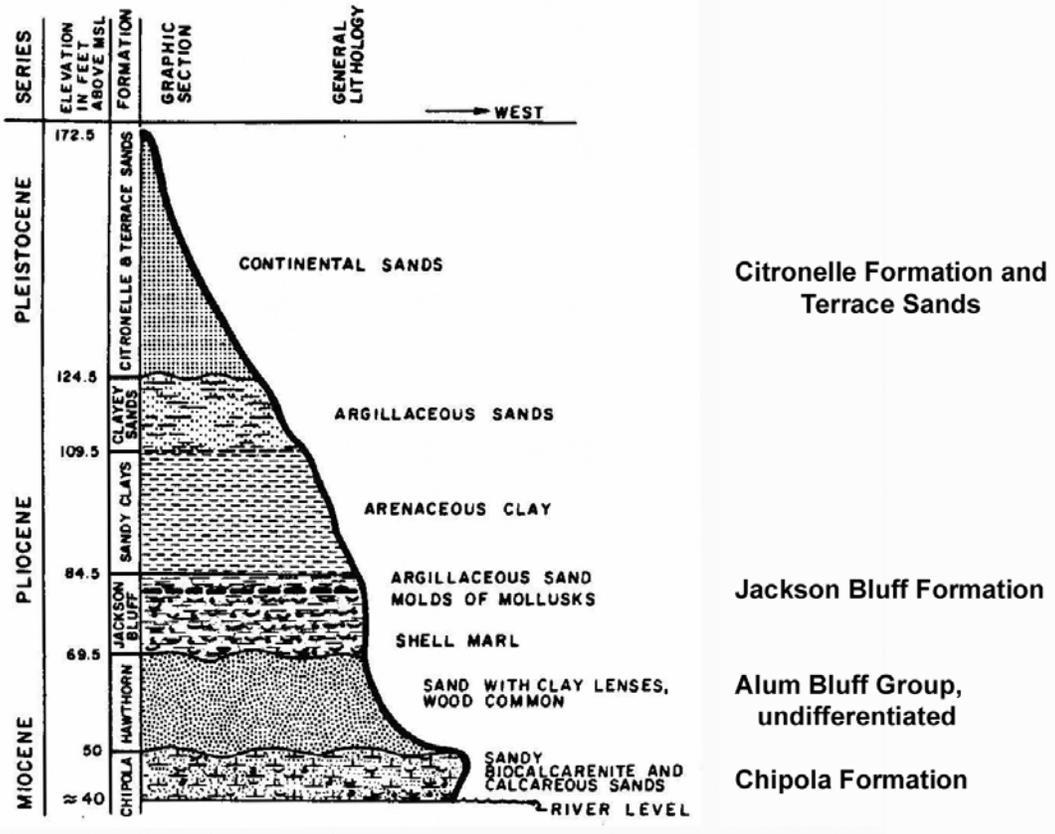


Figure 4. Lithostratigraphy of Alum Bluff. Modified from Schmidt 1986.

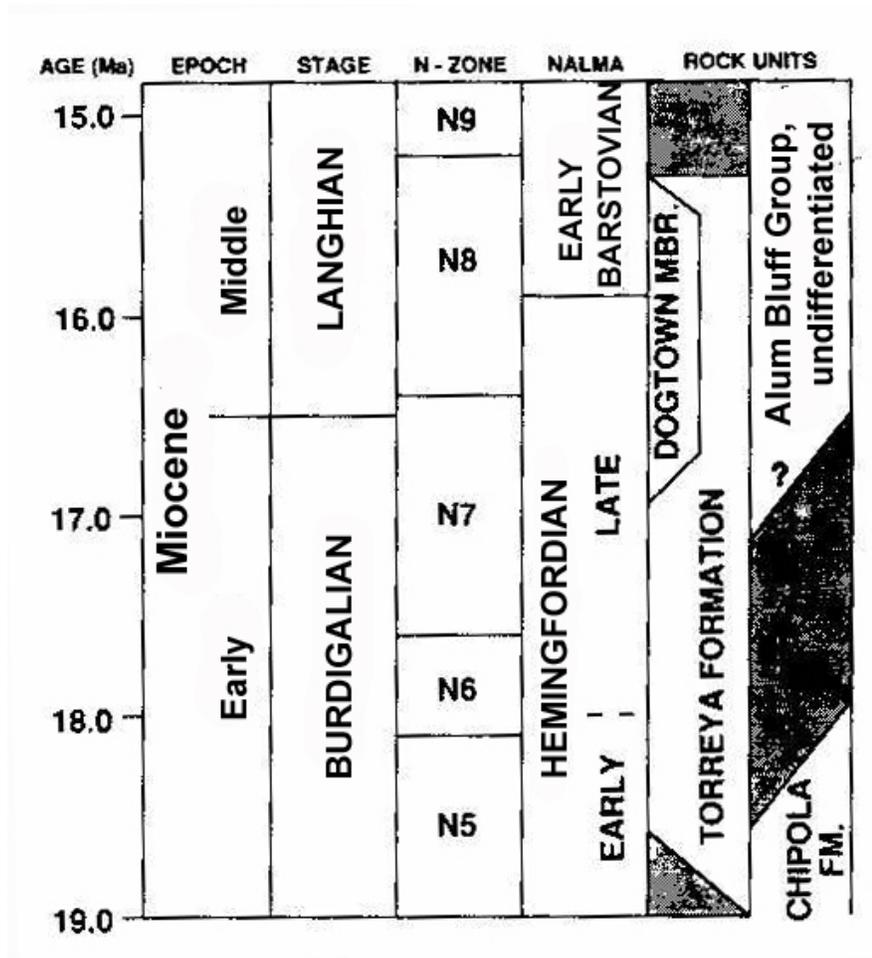


Figure 5. Summary of geochronology, showing temporal relationships between Torrey and Chipola Formations, and the Alum Bluff Group, undifferentiated. Stippled areas are unrepresented time intervals. Abbreviations: N-ZONE, planktonic foraminiferal zonation; NALMA, North American land-mammal age. Modified from Bryant et al. 1992.



Figure 6. Fossil plant strata at the Alum Bluff exposure. Arrows indicate fossil plant layers. One stratum lies slightly below where photo is cropped.

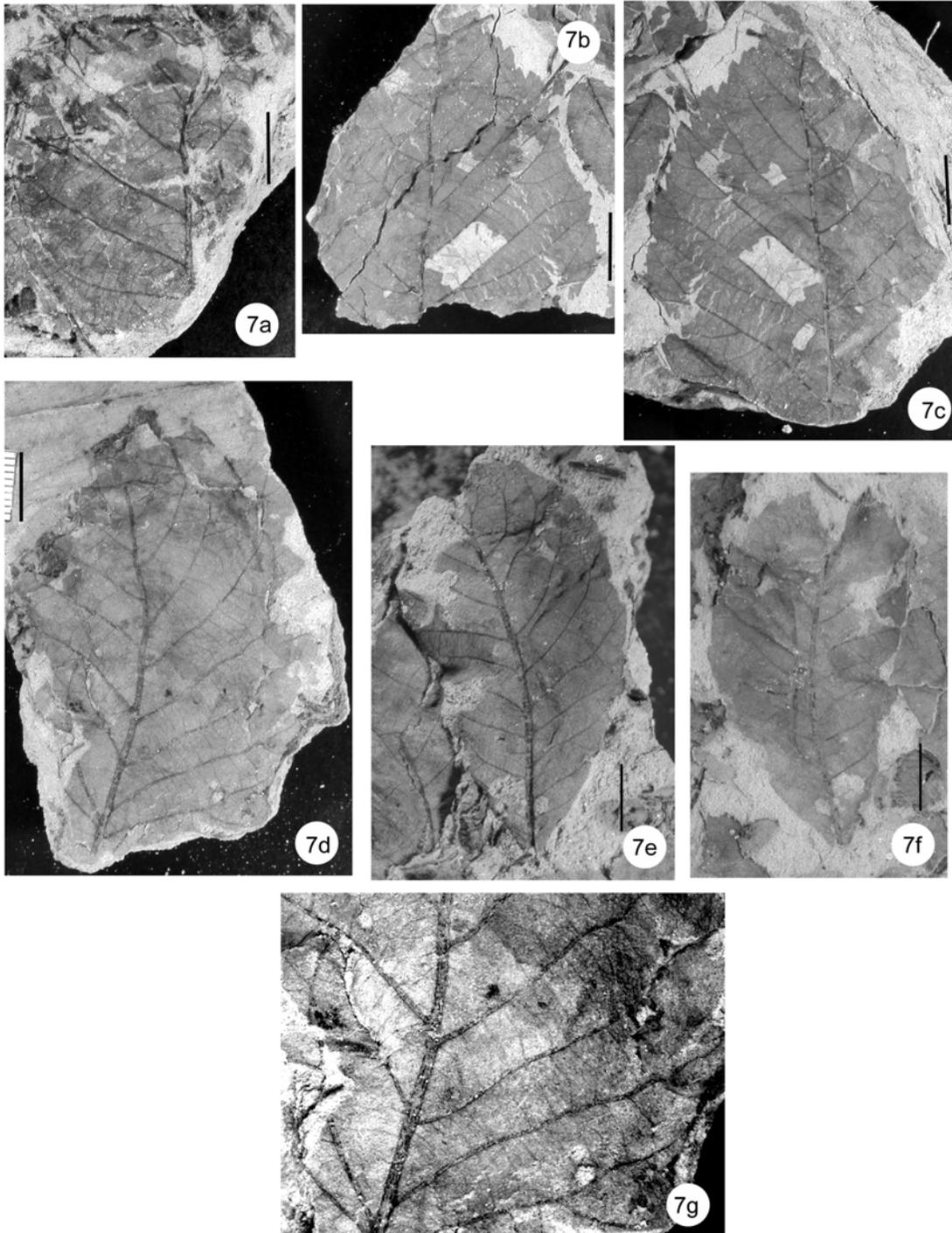


Figure 7. Leaflets of *Carya* (Juglandaceae). Scalebar=1cm. A) UF18049-043542, B) UF18049-043504, C) counterpart of "B," D) UF 18049-043502, E) UF18049-043588, F) counterpart of "E." G) UF18049-043502

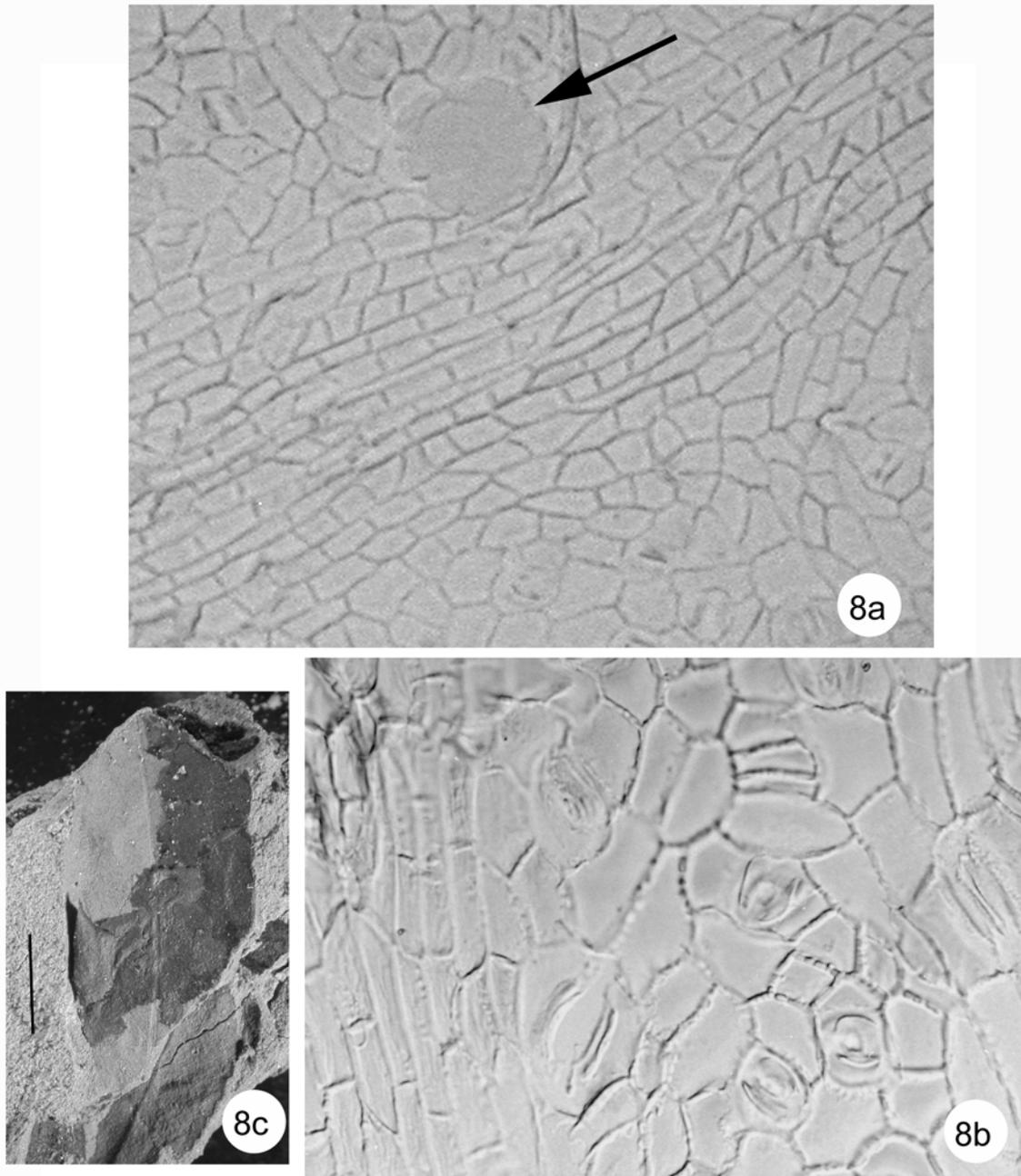


Figure 8. Lauraceous leaf. A) 200X, Abaxial cuticle at vein, arrow indicates oil cell from mesophyll, B) 400X, Abaxial cuticle near vein, note paracytic stomata, C) Specimen from which cuticle was obtained, UF 18049-043550. Note entire margin, weakly brochidodromous venation, and flaky, coriaceous cuticle.

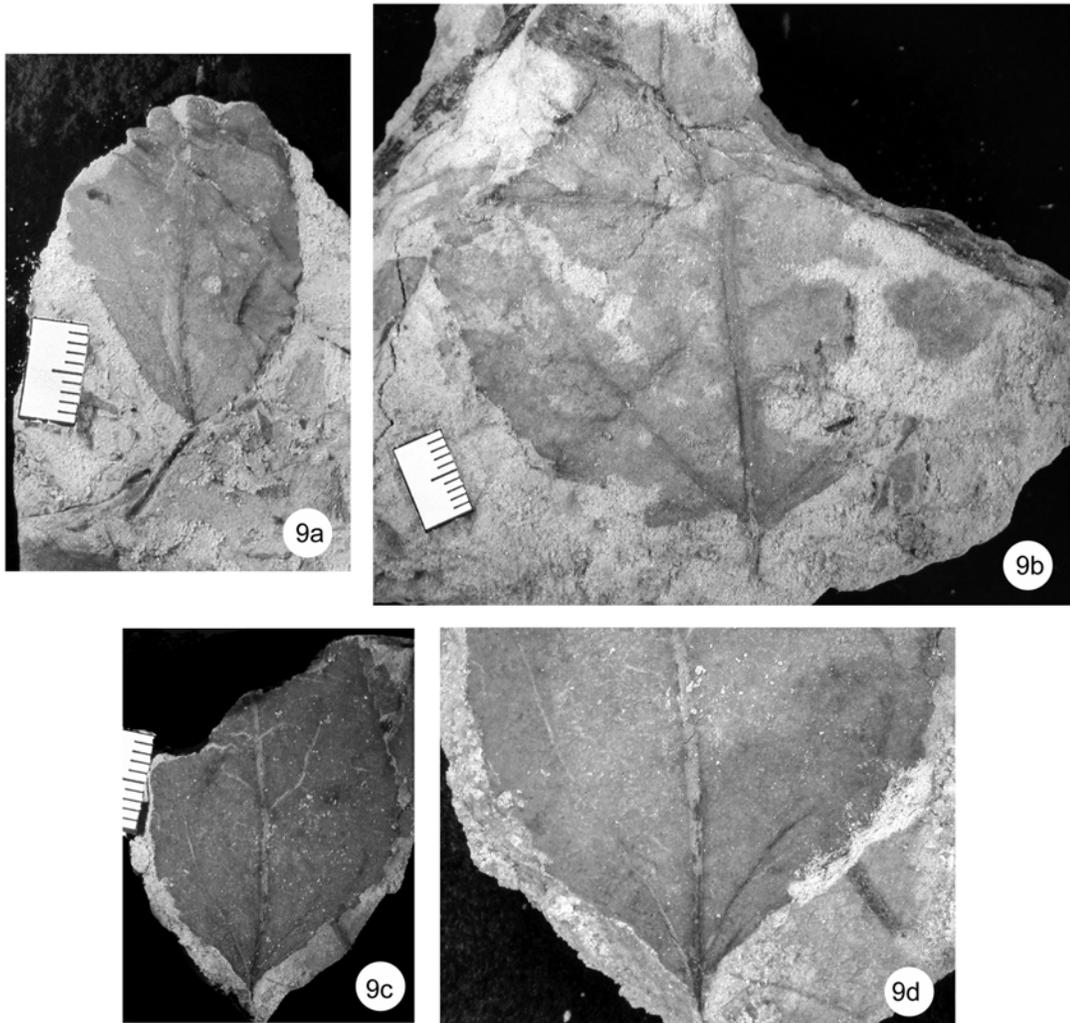


Figure 9. Leaves of *Paliurus* (Rhamnaceae). Scale bar=1cm. A) UF18049-043543, B) UF18049-043505, C) UF18049-043514, D) closeup of venation of C.

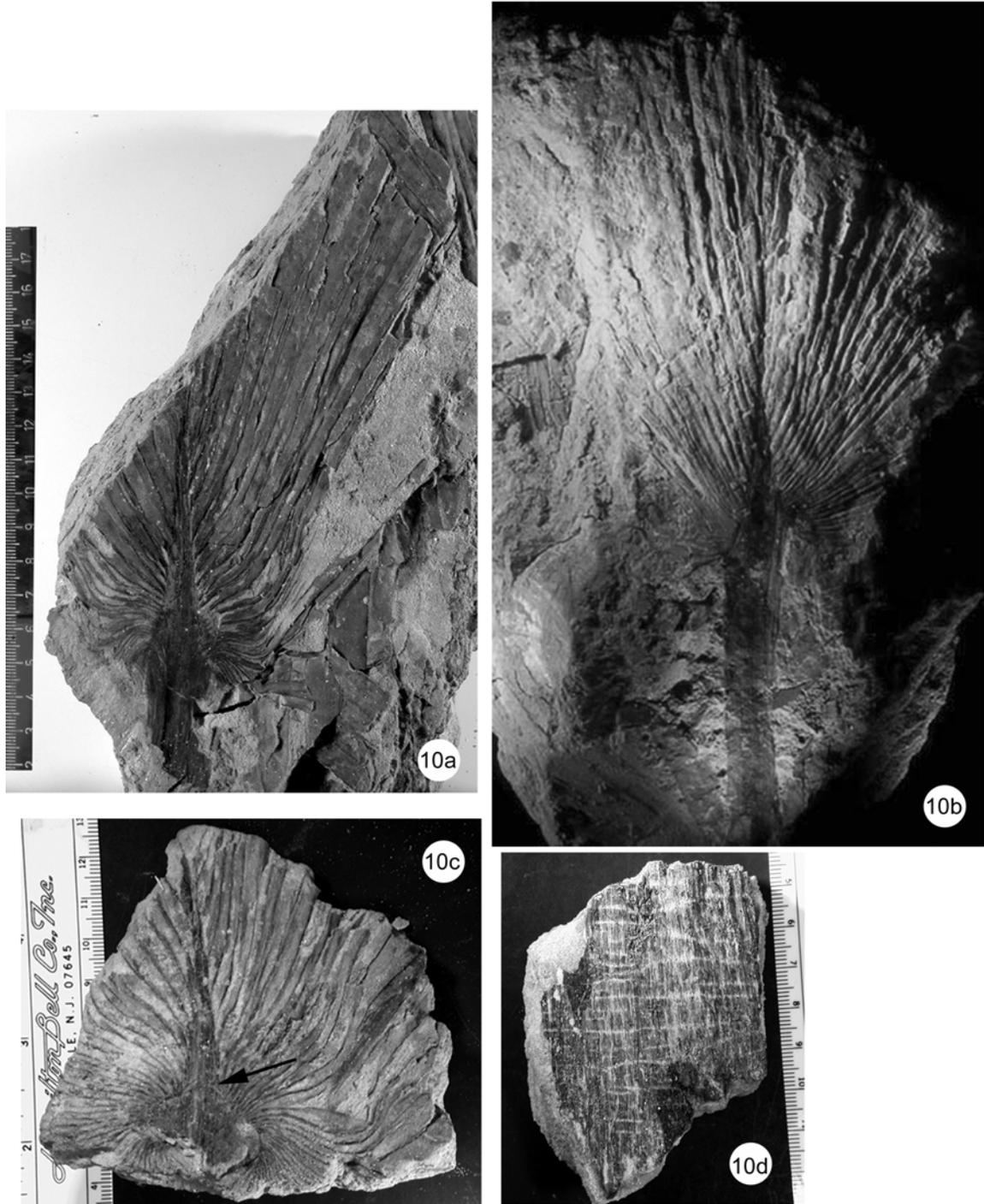


Figure 10. Leaves of Sabalites (Arecaceae). A) UF18049-029144, B) UF18049-?, C) UF18049-029143, D)UF18049-043552.



Figure 11. Graduate student Xin Wang with a very large example of a Sabalites leaf from Alum Bluff.

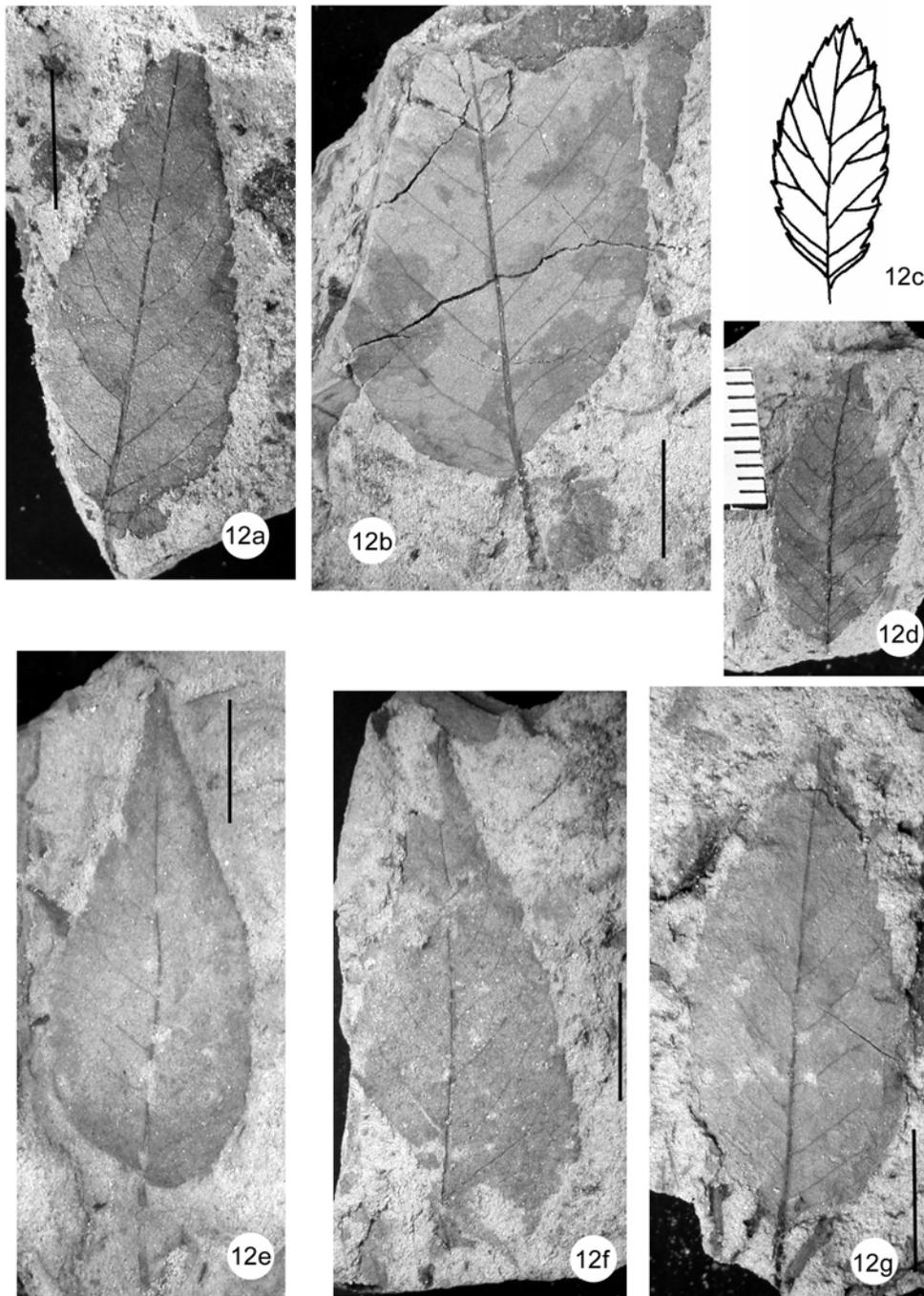


Figure 12. Leaves of *Ulmus* (Ulmaceae). Scale bar=1cm. A) UF18049-043513, B) UF18049-043531, C) Line drawing illustrating vein course, D) UF18049-043536, E) UF18049-043515, F) UF18049-029132, E) UF18049-043510.

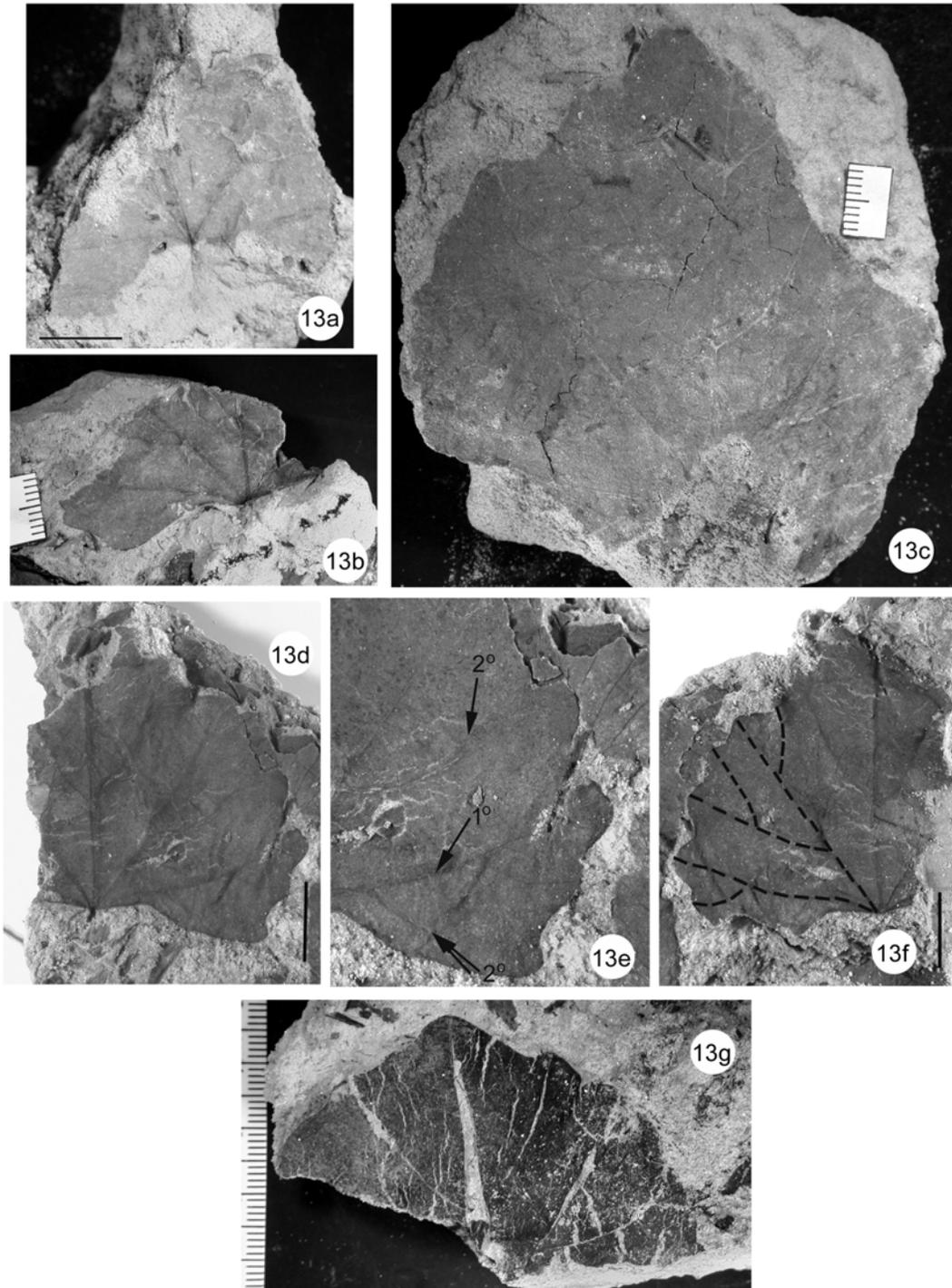


Figure 13. Alum Bluff leaf Morphotype AB1. Scale bar=1cm. A) UF18049-043566 (AB1.2), B) UF18049-043520, C) UF18049-043559, D) UF18049-043558 part, E) closeup of D, note arrows indicating primary and secondary veins, F) counterpart of D, note dotted line highlighting primary and secondary veins, G) leaf apex, UF18049-043522.

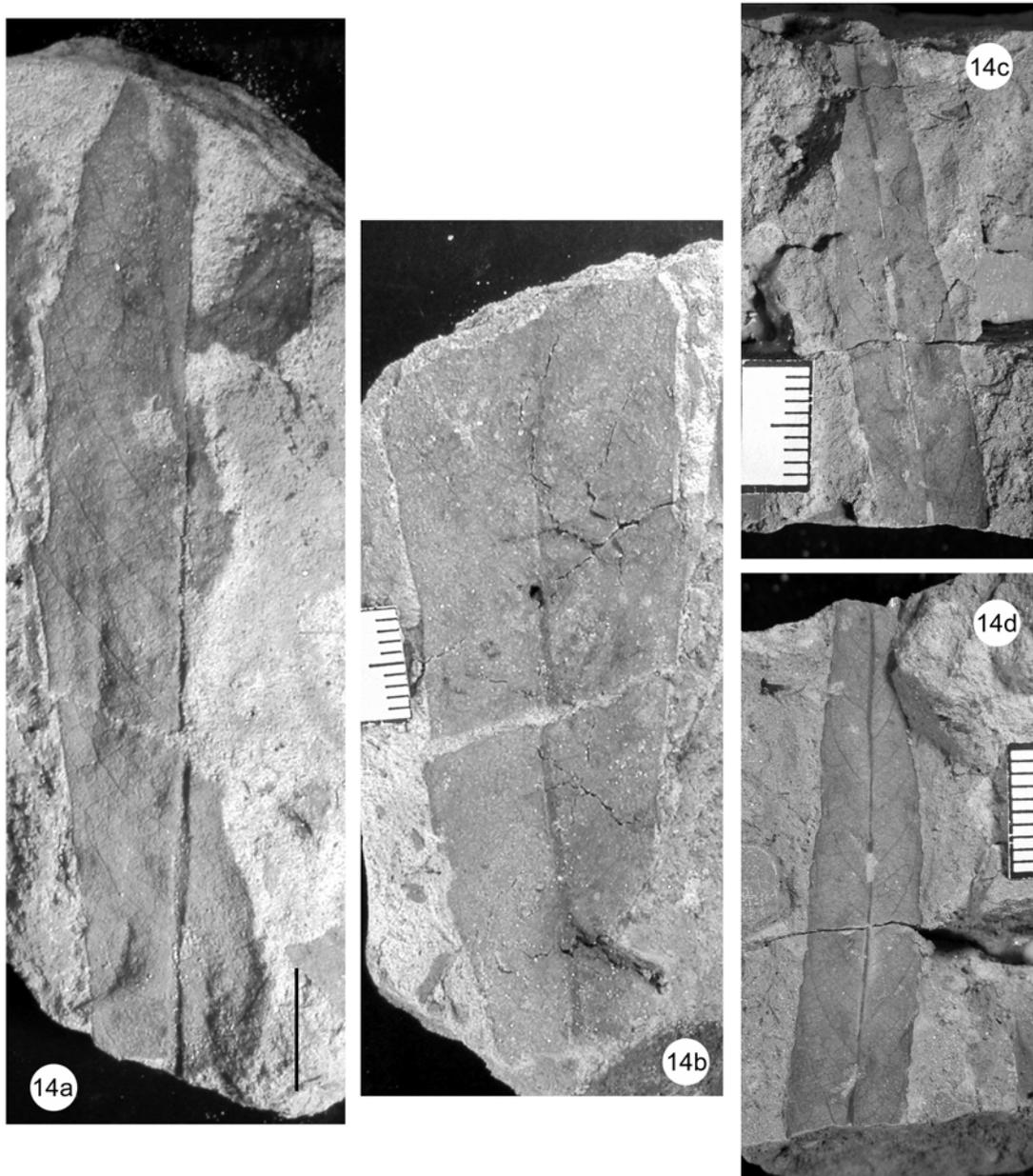


Figure 14. Alum Bluff leaf Morphotype AB2. Scale bar=1cm. A) UF18049-043557 part, B) counterpart of A, C) UF18049-043567 part, D) counterpart of "C."

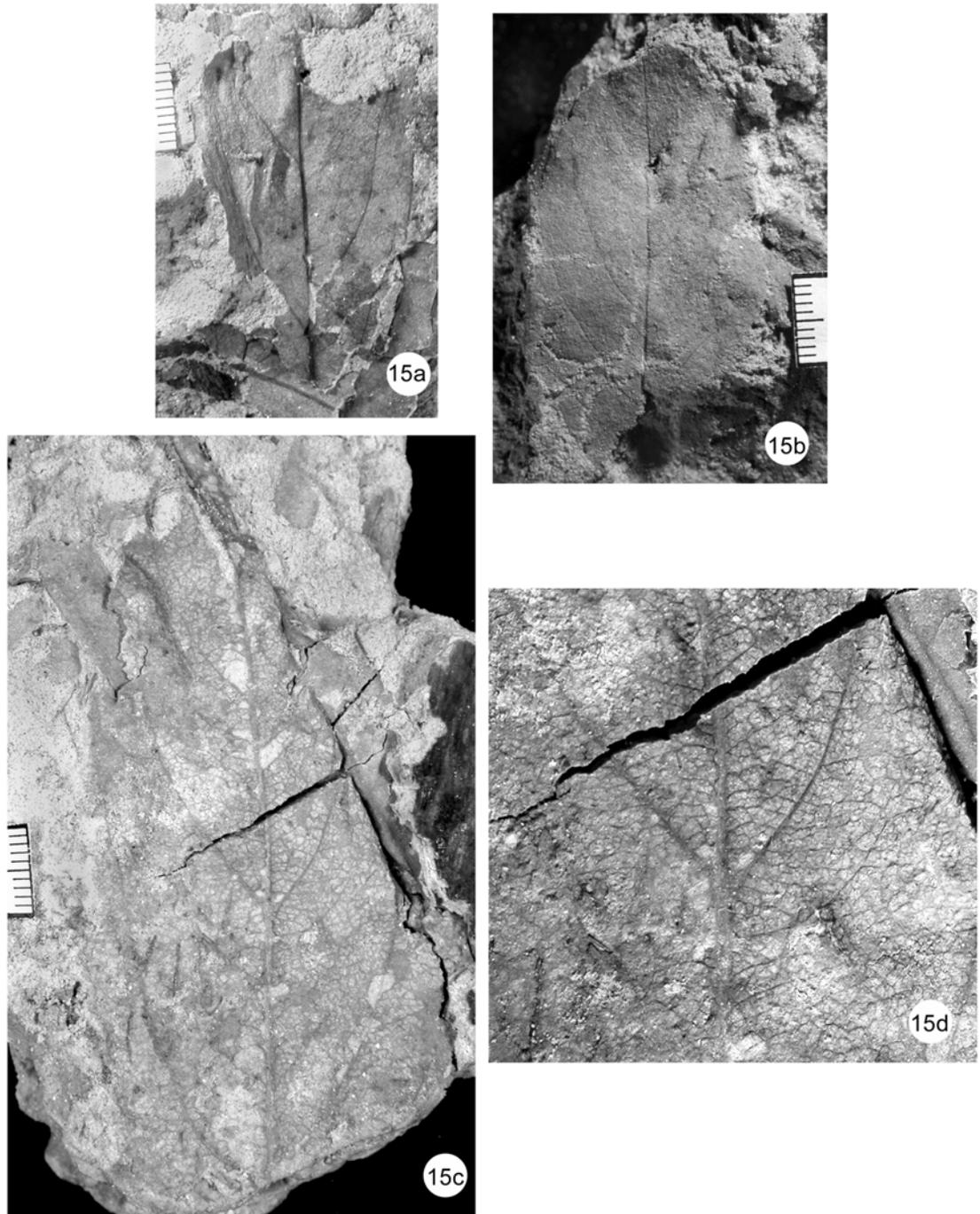
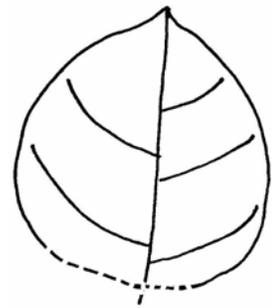
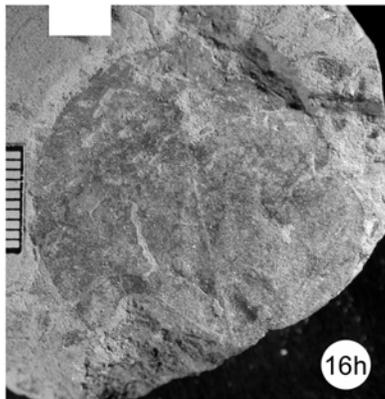
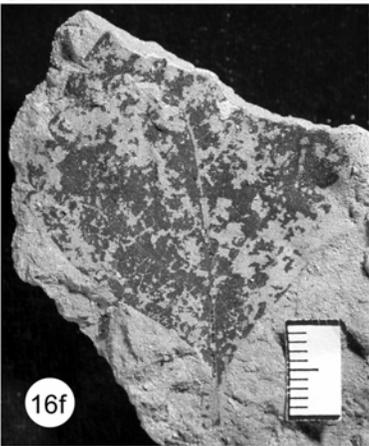
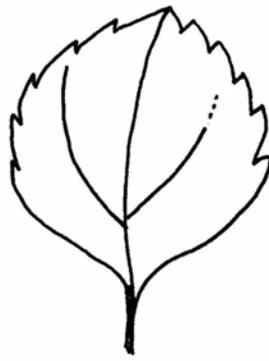
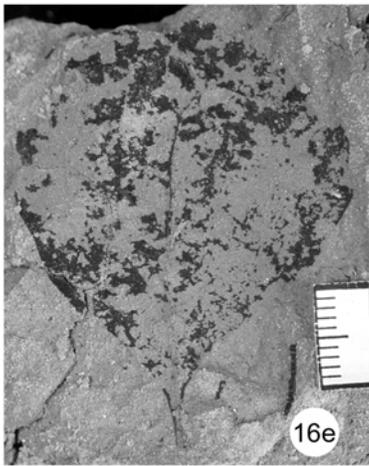
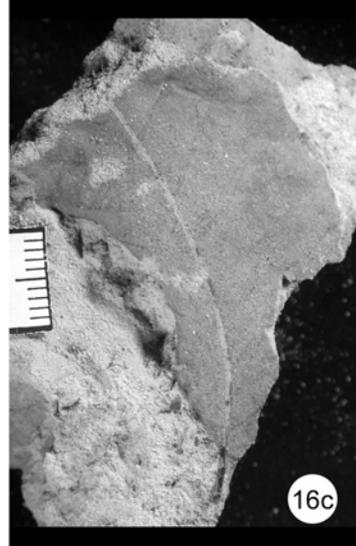
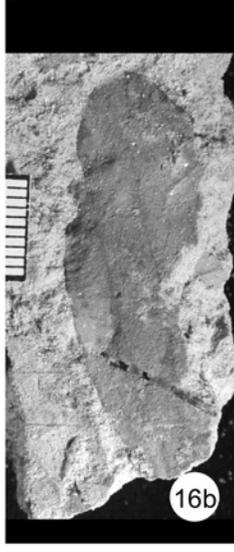


Figure 15. Alum Bluff leaf Morphotype AB3. Scale bar=1cm. A) UF18049-043523, B) UF18049-043587, C) UF18049-043557, D) closeup of C showing higher order venation.

Figure 16. Alum Bluff leaf Morphotypes AB4, 5, and 6. Scale bar=1cm. A) Morphotype AB4, UF18049-043575, B) counterpart of "A," C) Morphotype AB5, UF18049-043573, D) line drawing of C showing vein course, E) Morphotype AB6, UF18049-043553, F) counterpart of "E," G) line drawing of "E" showing vein course, H) Morphotype AB7, UF18049-043574), I) line drawing of "H" showing vein course.



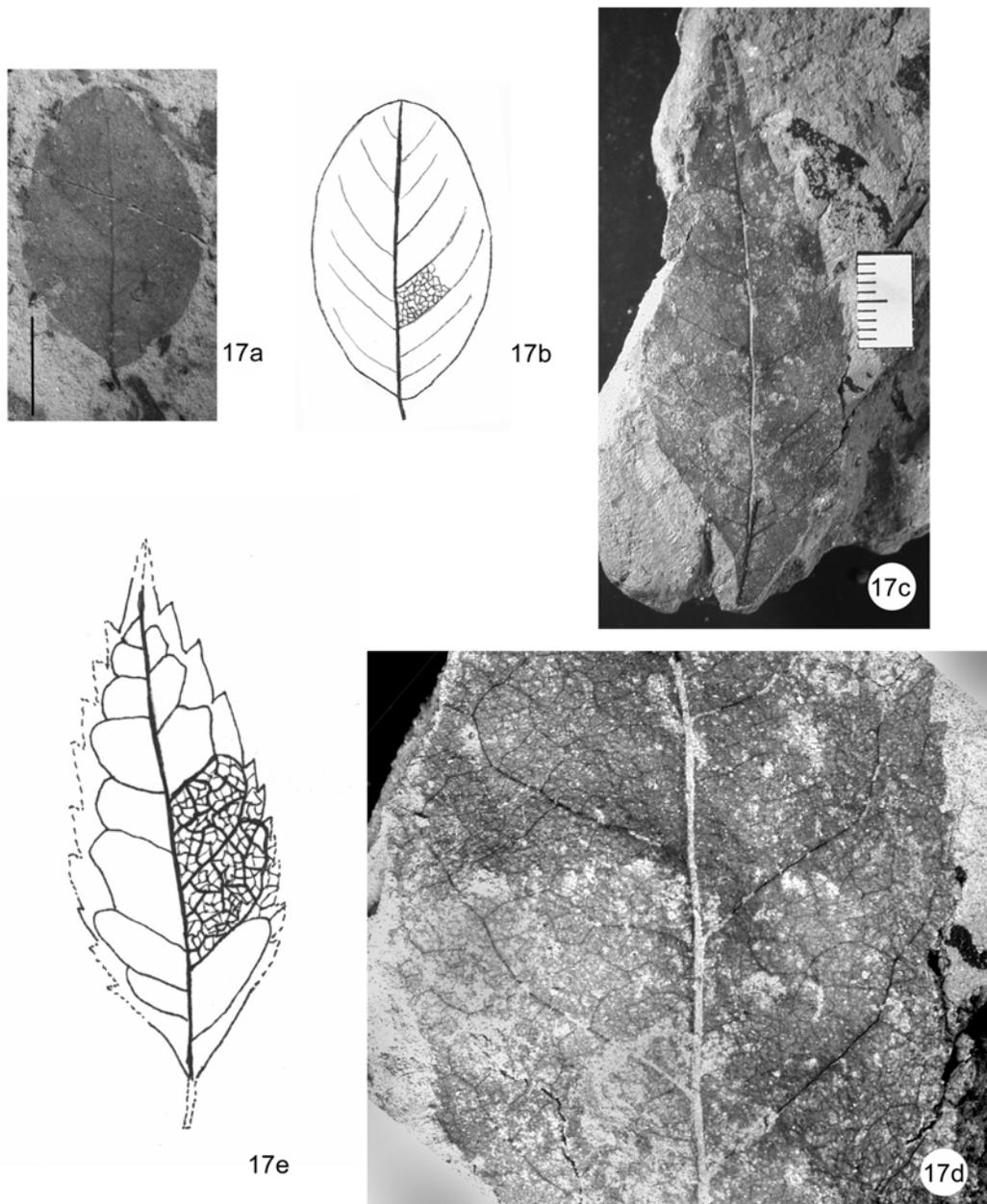


Figure 17. Alum Bluff leaf Morphotypes AB8 and 9. Scale bar=1cm. A) UF18049-043512, B) line drawing of A showing vein course and higher order venation, C) UF18049-043521, D) closeup of C showing higher order venation, E) line drawing of C showing venation.

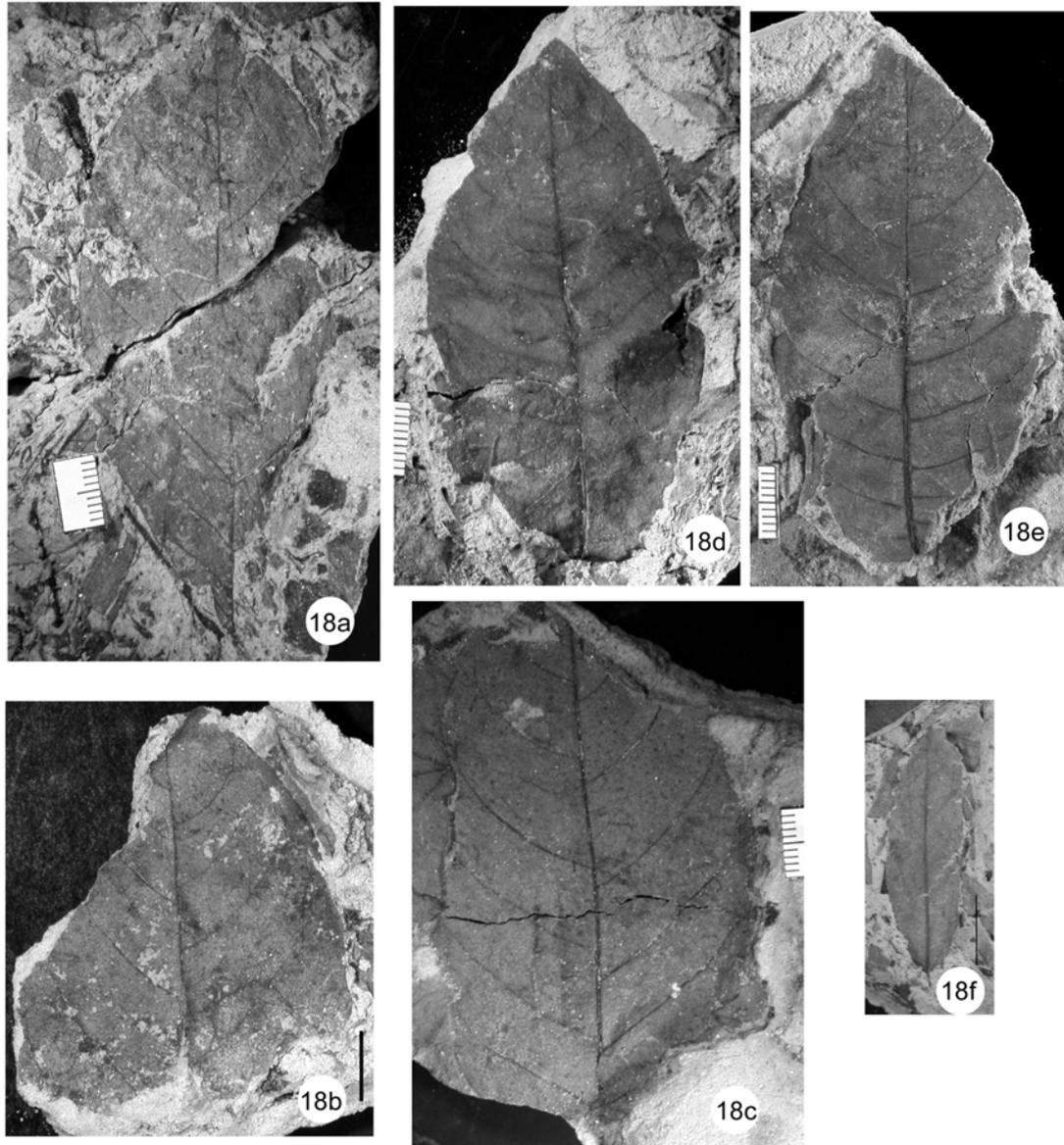


Figure 18. Alum Bluff leaf Morphotypes AB10, 11. Scale bar=1cm. A-B Morphotype AB10, A) UF18049-043527, B) UF18049-043503, C-E, Morphotype AB11, C) UF18049-029133, D) UF18049-043551, E) counterpart of D, F) Morphotype AB12, UF 18049-043589.

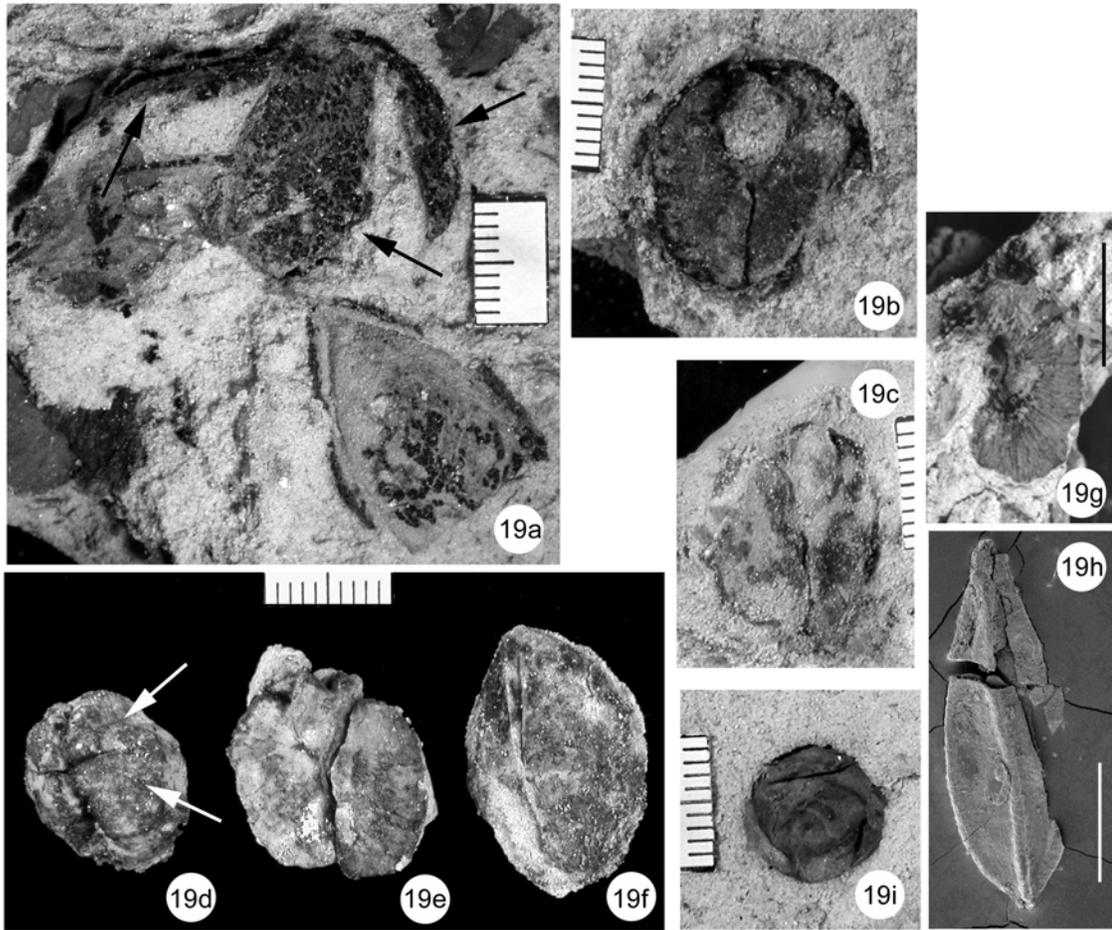


Figure 19. Fruits and Seeds from Alum Bluff. Scale bar=1cm. A-F, Carya. A) arrows indicate valves of dehiscent husk. Also note partial husk in lower right corner, UF18049-043528, B) endocarp, UF18049-043509, C) endocarp, UF18049-043500, D) endocarp, arrows indicate longitudinal grooves, UF18049-043525, E) endocarp, UF18049-043524, F) husk valve, UF18049-043526, G) Paliurus fruit, UF18049-026117, H) Scirpus achene, UF18049-043597, I) Unknown fruit, UF18049-043540.

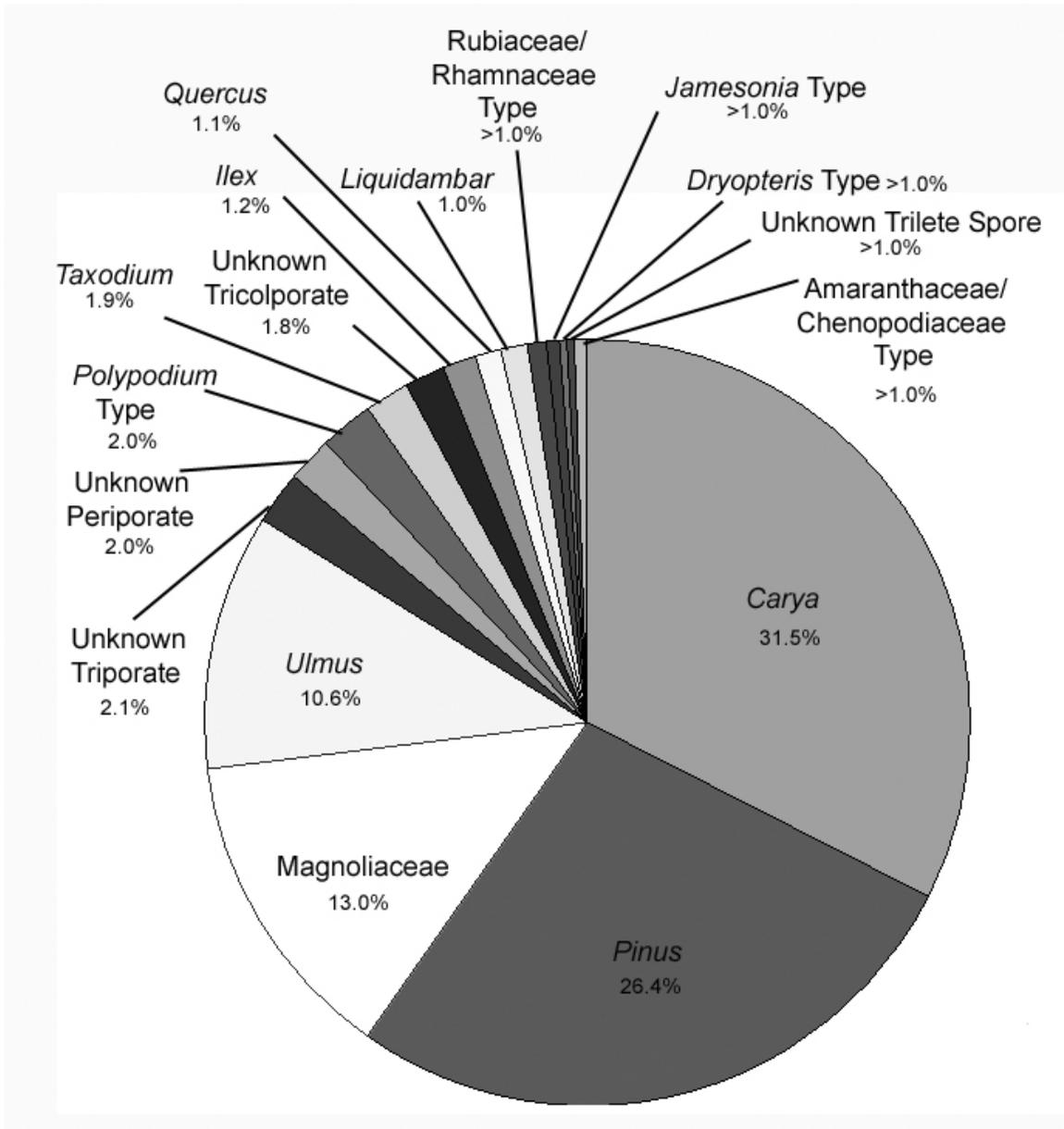


Figure 20. Pie chart showing pollen count summary for Alum Bluff.

Figure 21. Fern spores from Alum Bluff. Scale bar=15 μ . LM=Light micrograph, SEM=Scanning electron micrograph.

A-B. Adiantaceae. A) LM, UF18049-043592, PY02F, coordinates 29, 101.6, B) SEM, UF 18049-043594, PY01, SEM-A.

C. Botrychium, SEM UF18049-043591, PY01, SEM-B.

D. Cyathea, LM, UF18049-043592, PY02C, coordinates 50.1, 103.1.

E-F. Dryopteris, E) LM, UF18049-043592, PY02C, coordinates 36.9, 98.5, F) SEM UF18049-043591, PY01, SEM-B

G-I. Polypodiaceae. G) LM, UF18049-043593, PY01A, coordinates 37.1, 103.2, H) LM, UF18049-043596, PY01A, coordinates 41.9, 95, I) SEM, UF18049-043591, PY01, SEM-A.

J-L. Pteris, J) SEM UF18049-043593, PY01, SEM-B, K) LM, UF 18049-043595, PY01A, coordinates 24.6, 104, high focus showing trilete laesural arms, L) Low focus of "K" showing surface sculpturing.

M. Unknown trilete spore. LM, UF18049-043592, PY02C, coordinates 49.2, 111)

N. Unknown trilete spore, LM, UF18049-043592, PY02C, coordinates 40.4, 113.

O. Unknown trilete spore, LM, UF18049-043595, PY01A, coordinates 23, 107.3.

P. Unknown trilete spore, LM, UF18049-043592, PY02B, no coordinates available.

Q. Unknown trilete spore, LM, UF18049-043596, PY01A, coordinates 35.1, 98.

R-S. Unknown trilete spore, LM, UF18049-043592, PY02A, no coordinates available.

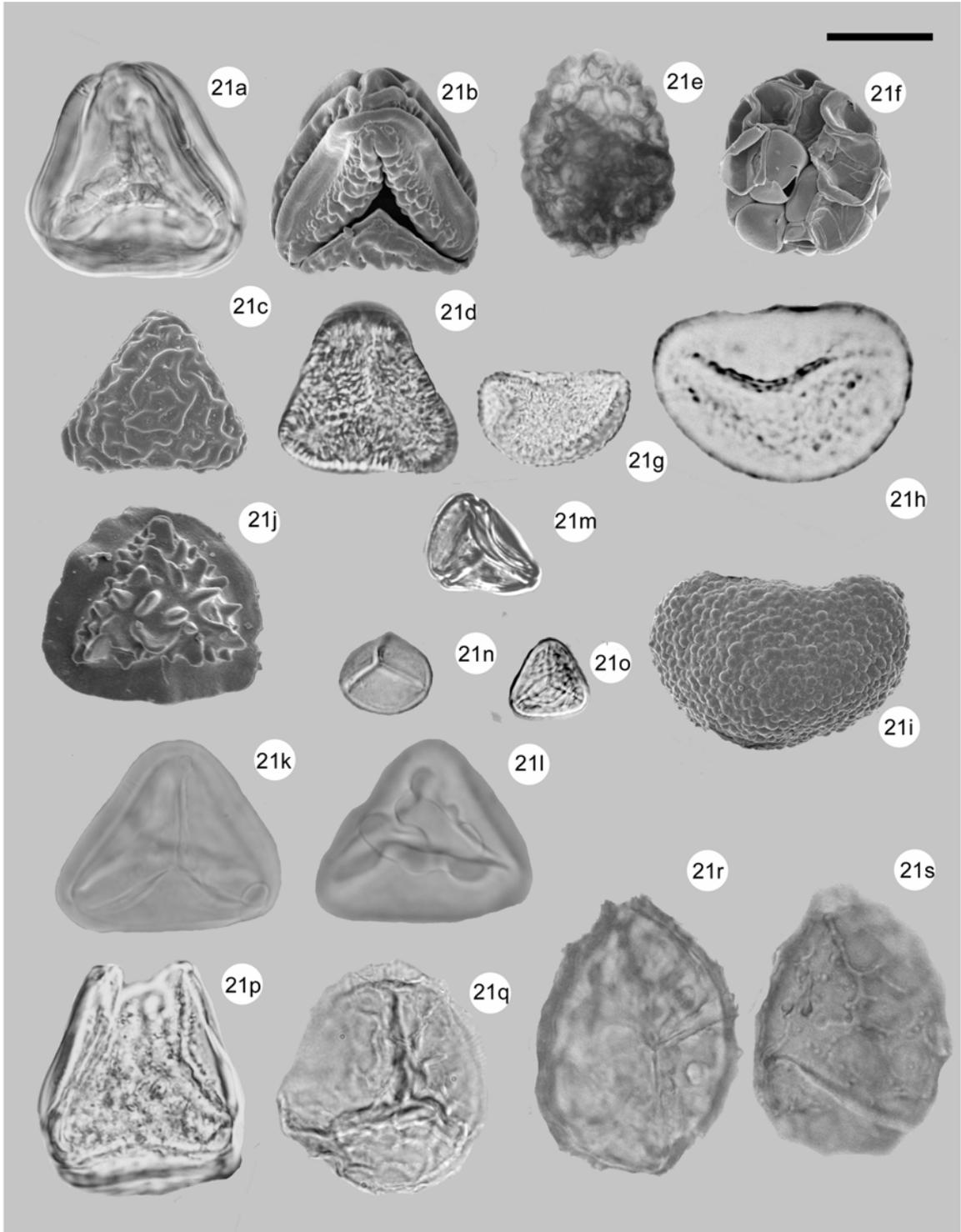


Figure 22. Gymnosperm and Poaceae type pollen from Alum Bluff. Scale bar=15 μ . LM=Light micrograph, SEM=Scanning electron micrograph.

A-C. Taxodium, A) LM, UF18049-043592, PY02C, coordinates 51.8, 96.3), B) LM, UF18049-043592, PY02A, no coordinates available, C) SEM, UF18049-043594, PY01, SEM-A.

D-G. Pinus, D) SEM UF18049-043591, PY01, SEM-A, E) LM, UF18049-043592, PY02A, no coordinates available, F) SEM, UF18049-043591, PY01, SEM-A, G) LM, UF18049-043592, PY02B, no coordinates available).

H-K. Poaceae, H) SEM, UF18049-043592, PY04, SEM-B, I) SEM, UF18049-043592, PY04, SEM-B), J) SEM, UF18049-043596, PY01, SEM-B, K) SEM, UF18049-043596, PY01, SEM-B.

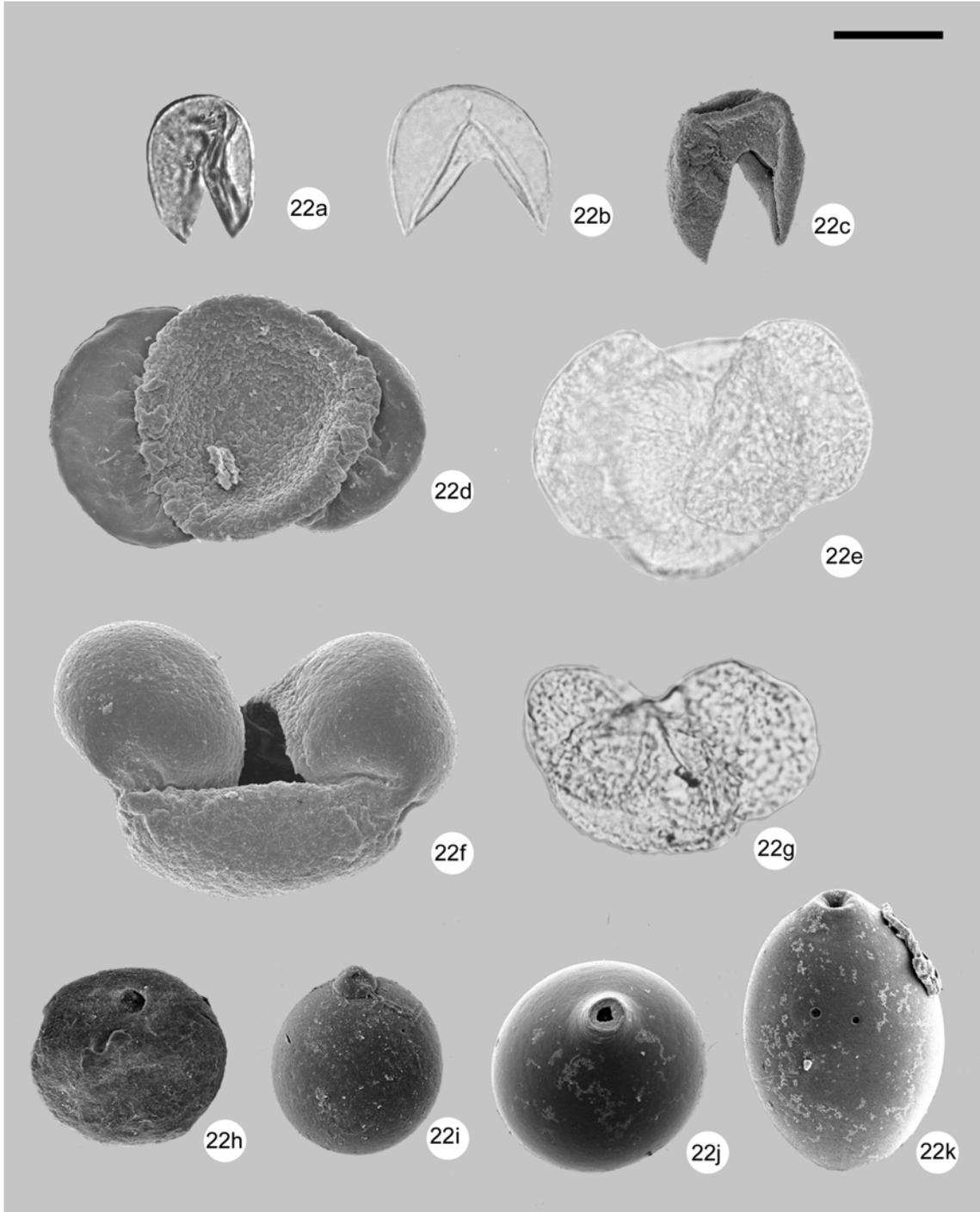


Figure 23. Liliaceae, Magnoliaceae type and miscellaneous dicotyledonous pollen from Alum Bluff. Scale bar=15 μ . LM=Light micrograph, SEM=Scanning electron micrograph.

A-D. Liliaceae type. A) SEM, UF18049-043595, PY01, SEM-B, B) LM, UF18049-043591, PY02B, no coordinates available, C) LM, UF18049-043596, PY01A, coordinates 41.5, 113.6, D) LM, UF18049-043592, PY02C, coordinates 45.1, 96.2.

E-F. Magnoliaceae type. E) LM, UF18049-043592, PY02B, no coordinates available, F) LM, UF18049-043592, no coordinates available.

G-I. Amaranthaceae type. G) LM, UF18049-043592, PY02C, coordinates 28.4, 100.1, H) LM, UF18049-043592, PY02C, coordinates 45.2, 106.9, I) SEM, UF18049-043593, PY01, SEM-D.

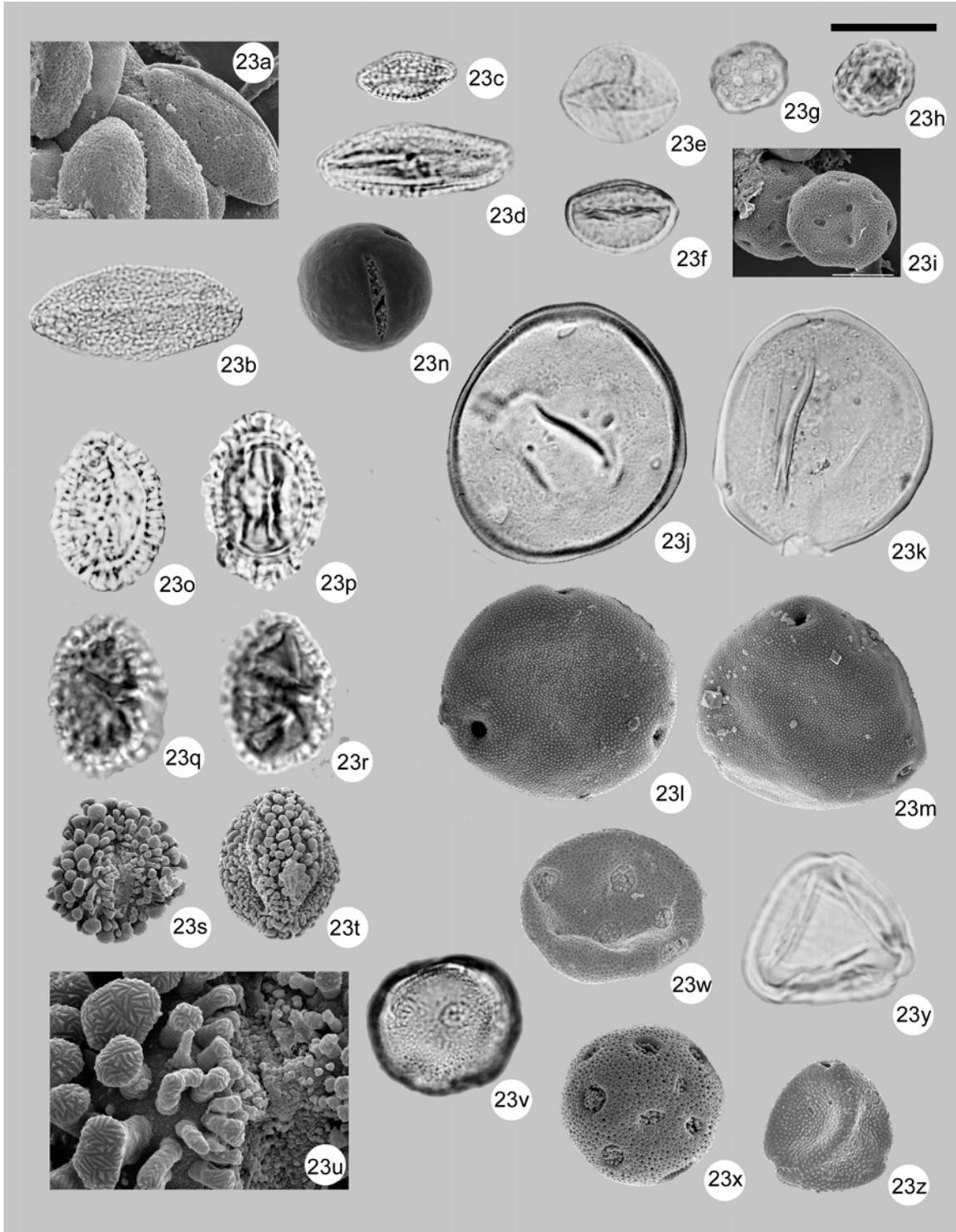
J-M. Carya. J) LM, UF18049-043591, PY02B, no coordinates available, K) LM, UF18049-043592, PY02C, coordinates 47.3, 113.6), L) SEM, UF18049-043594, PY01, SEM-A, M) SEM, UF18049-043593, PY01, SEM-B.

N. Diospyros, SEM, UF18049-043596, PY01, SEM-B.

O-U. Ilex. O) LM, high focus, UF18049-043593, PY01A, coordinates 43.3, 105.4, P) LM, mid-focus, UF18049-043596, PY01A, coordinates 45, 95), Q) LM, high focus, UF18049-043596, PY01A, coordinates 33.2, 99.8, R) same specimen as "Q" at mid-focus, S) SEM, UF18049-043596, PY01, SEM-B, T) SEM, UF18049-043596, PY01, SEM-B, U) closeup of "S" showing clavate sculpturing.

V-X. Liquidambar. V) LM, high focus, UF18049-043592, PY02C, coordinates 48.4, 103), W) SEM, UF18049-043591, PY01, SEM-B, X) SEM, UF18049-043594, PY01, SEM-B.

Y-Z. Myrica. Y) LM, UF18049-043596, PY01A, coordinates 43, 104.5, Z) SEM, UF18049-043591, PY01, SEM-C



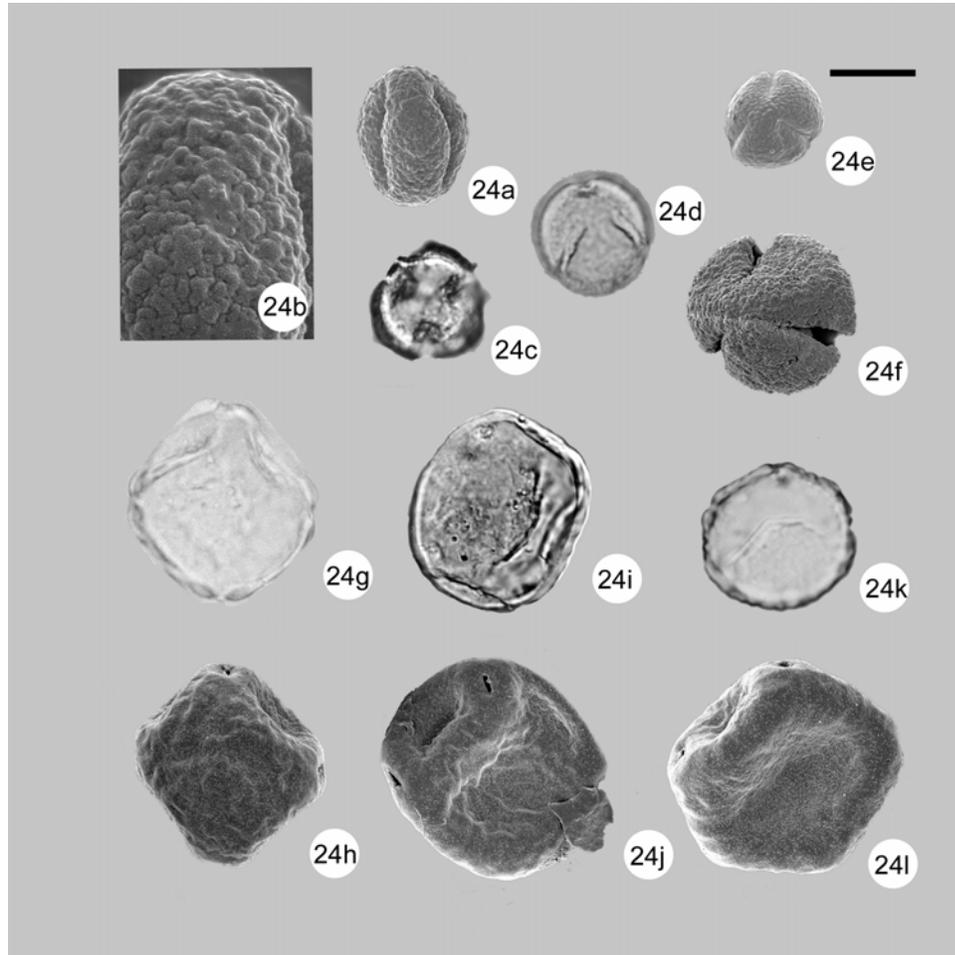


Figure 24. Fagaceae and Ulmaceae pollen from Alum Bluff. Scale bar=15 μ . LM=Light micrograph, SEM=Scanning electron micrograph.

A-F. Fagaceae. A) SEM, equatorial view, UF18049-043591, PY01, SEM-C, B) closeup of A showing sculpturing, C) LM, polar view, UF18049-043592, PY02C, coordinates 50.5, 97.5, D) LM, polar view, UF18049-043592, PY02B, no coordinates available), E) SEM, polar view, UF18049-043591, PY01, SEM-C, F) SEM, polar view, UF18049-043594, PY01, SEM-B.

G-L. Ulmaceae. G) LM, polar view, UF18049-043592, PY02A, no coordinates available, H) SEM, polar view, UF18049-043596, PY01, SEM-C, I) LM, oblique view, UF18049-043592, PY02C, coordinates 48.2, 113, J) SEM, oblique view, UF18049-043596, PY01, SEM-C, K) LM, polar view, UF18049-043592, PY02B, no coordinates available, L) SEM, oblique view, UF18049-043596, PY01, SEM-C.

Figure 25. Miscellaneous dicotyledonous pollen from Alum Bluff. Scale bar=15 μ . LM=Light micrograph, SEM=Scanning electron micrograph.

A-E. Asteraceae/Malvaceae type. A) possible helianthid type, LM, UF18049-043592, PY02B, no coordinates available, B) possible helianthid type, LM, UF18049-043592, PY02C, coordinates 40.99, C) Malvaceae?, SEM, UF18049-043592, PY04, SEM-B, D) Malvaceae?, LM, UF18049-043592, PY02C, coordinates 43.6, 112.9, E) Malvaceae?, LM, UF18049-043592, PY02F, coordinates 33.8, 94.8).

F. Betulaceae ? type, LM, UF18049-043596, PY01A, coordinates 43.4, 112.

G-H. Euphorbiaceae ? type. G) SEM, UF18049-043591, PY01, SEM-C, H) closeup showing sculpturing of "H."

I. Fabaceae ? type, possible Vigna ? type, SEM, UF18049-043594, PY01, SEM-B.

J-P. Gleditsia (Fabaceae), J) LM, UF18049-043596, PY01A, coordinates 34.4, 110.8), K) SEM, UF18049-043594, PY01, SEM-B, L) SEM, UF18049-043596, PY01, SEM-B, M) closeup of "L", N) SEM, UF18049-043596, PY01, SEM-A, O) closeup of "N," P) SEM, UF18049-043596, PY01, SEM-C.

Q-R. Rhamnaceae/Rubiaceae ? type. Q) LM, UF18049-043592, PY02C, coordinates 43.5, 111, R) LM, UF18049-043592, PY02C, coordinates 41.5, 113.1.

S-T. Rosaceae ? type. S) SEM, UF18049-043591, PY01, SEM-C (minor grain), T) closeup of "S."

U-X. Vitaceae. U) LM, polar view, UF18049-043592, PY02C, coordinates 47.1, 107.4, V) SEM, polar view, UF18049-043591, PY01, SEM-B, W) closeup of colpus and sculpturing of "W," X) SEM, equatorial view, UF18049-043591, PY01, SEM-B.

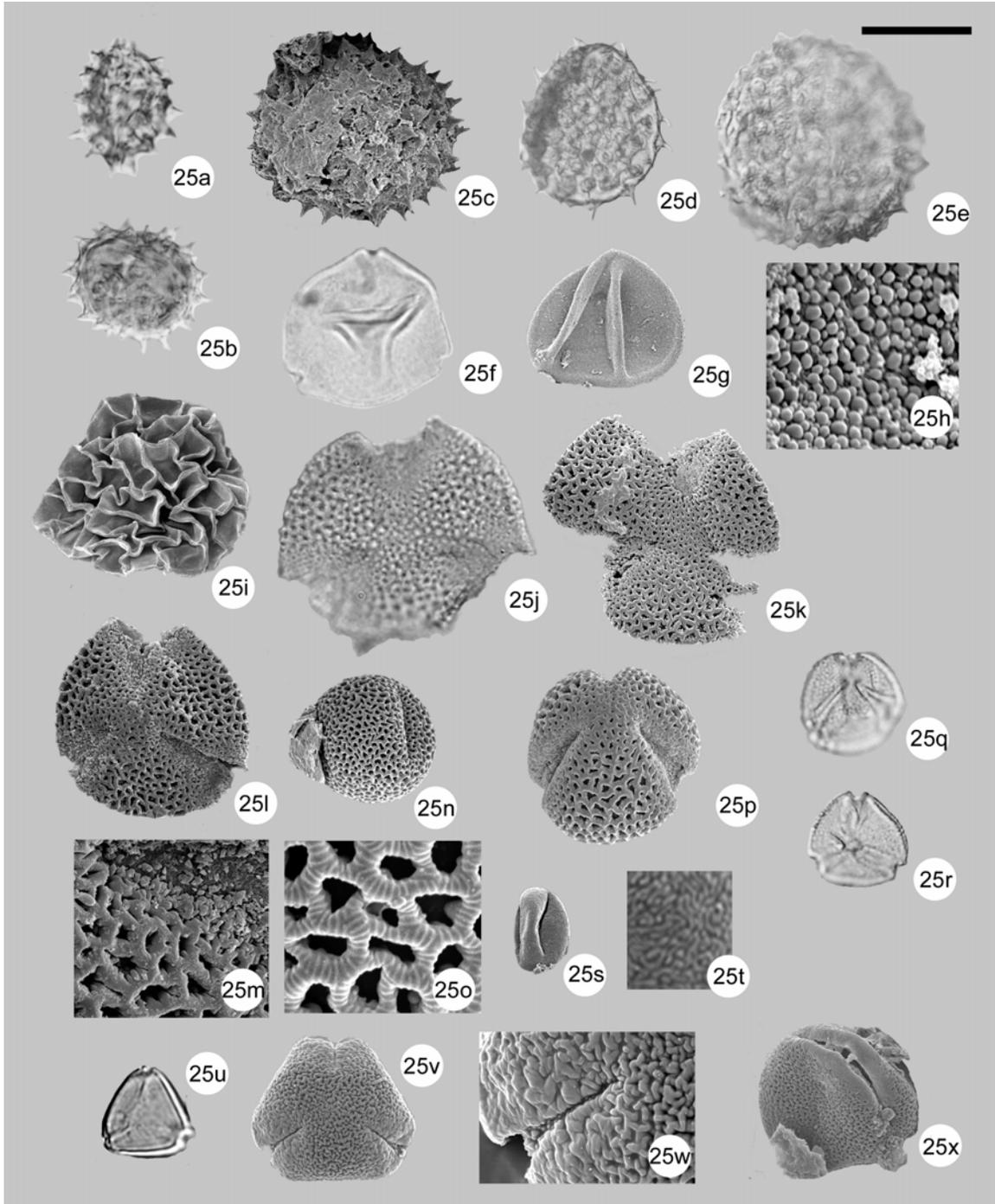


Figure 26. Unknown palynomorphs and dinoflagellate cyst from Alum Bluff. Scale bar=15 μ . LM=Light micrograph, SEM=Scanning electron micrograph.

A. Unknown large monosulcate pollen grain, LM, UF18049-043596, PY02A, coordinates 45.9, 106.

B-D. Unknown triporate pollen grains. B) LM, UF18049-043592, PY02C, coordinates 46, 107.1, C) LM, UF18049-043592, PY02B, no coordinates available, D) SEM, UF18049-043596, PY01, SEM-B.

E-I. Unknown Tricolporate pollen grains. E) LM, UF18049-043592, PY02B, no coordinates available, F) SEM UF18049-043591, PY01, SEM-B, G) LM, UF18049-043592, PY02B, no coordinates available, H) LM, UF18049-043592, no coordinates available, I) LM, UF18049-043592, PY02B, no coordinates available, J) SEM, UF18049-043591, PY01, SEM-A.

K-L. Unknown tricolpate pollen grain. K) SEM, UF18049-043594, PY01, SEM-A, L) closeup of sculpturing of "J."

M-N. Unknown periporate pollen grains. M) LM, UF18049-043592, PY02C coordinates 33, 107.5, N SEM, UF18049-043596, PY01, SEM-A.

O-P. Unknown apparently inaperturate pollen grains. O) SEM, UF18049-043591, PY01, SEM-A, P) SEM, UF18049-043591, PY01, SEM-B.

Q. Dinoflagellate cyst, LM, UF18049-043595, PY01A, coordinates 45.9, 106.

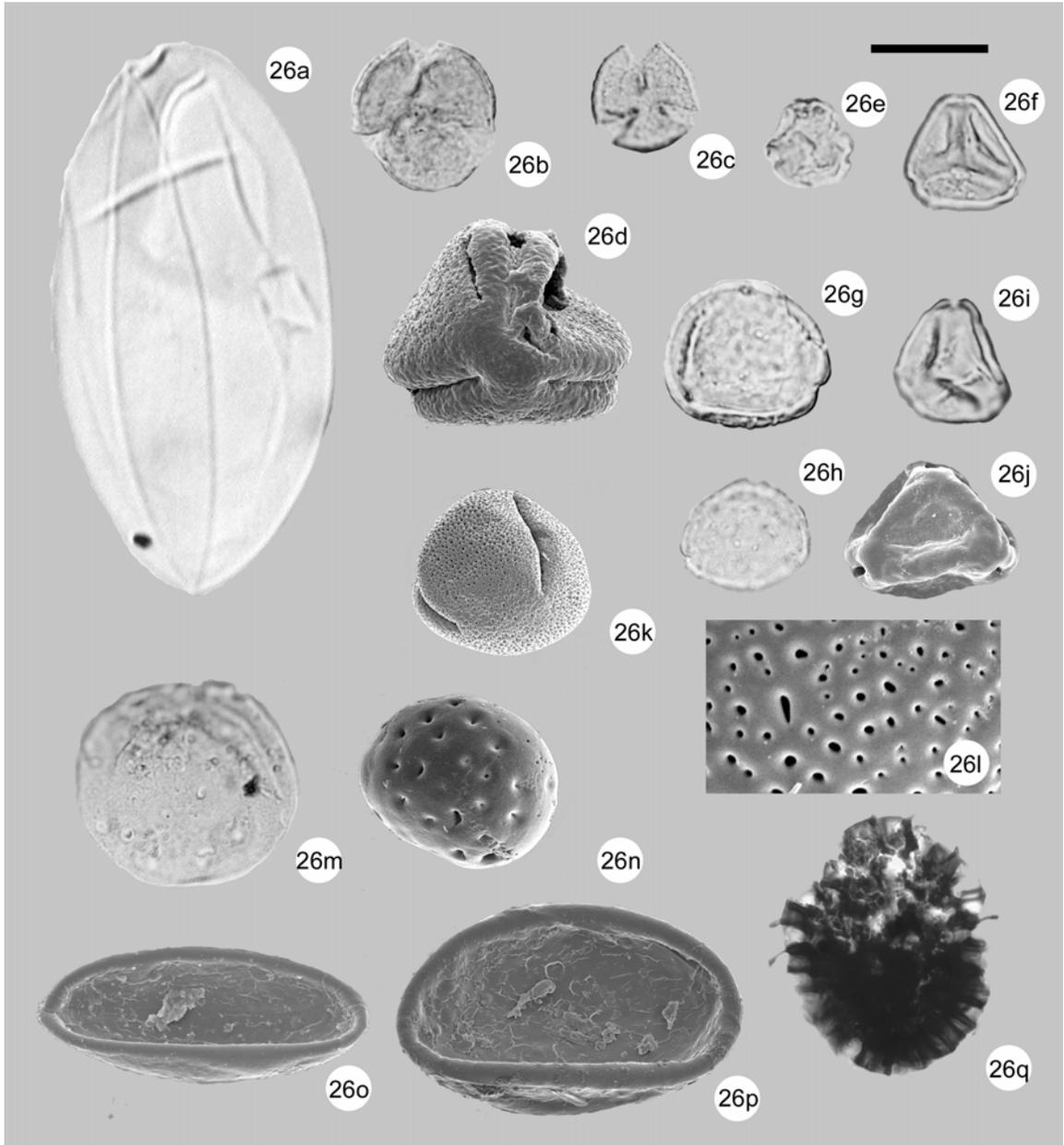


Figure 27. Fungal sporomorphs from Alum Bluff. Scale bar in A applies to all=15 μ .

A. Unknown obovate, dicellate fungal spore, SEM, UF18049-043596, PY01, SEM-B.

B. Unknown elliptic, tricellate fungal spore, SEM, UF18049-043596, PY01, SEM-C

C. Unknown rounded rhombic, dicellate fungal spore, SEM, UF18049-043592, PY04, SEM-B.

D. Unknown elliptic, monocellate fungal spore, LM, UF18049-043592, PY01A, no coordinates available

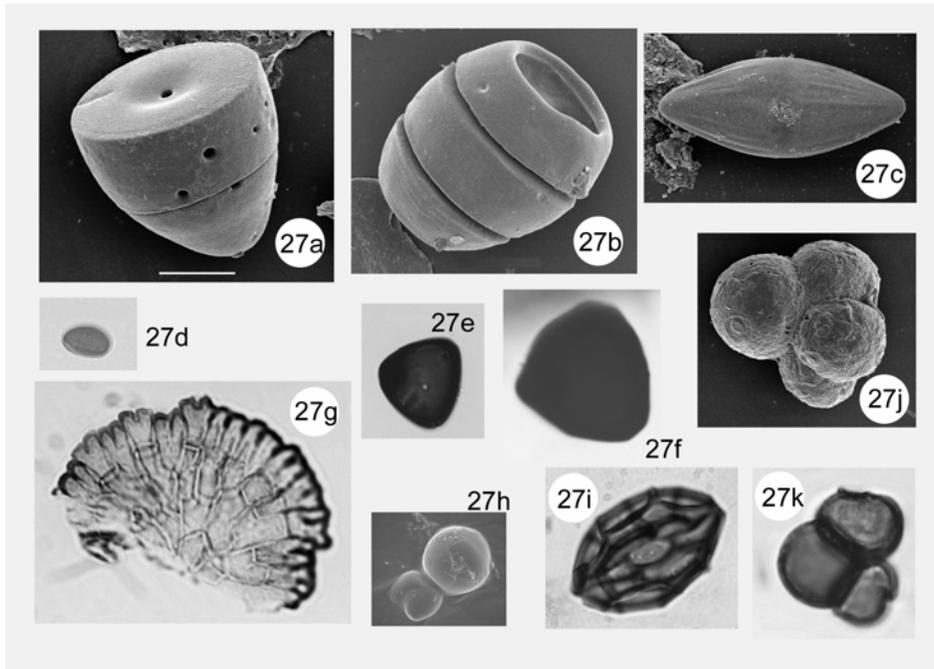
E-F. Unknown obdeltate, monocellate fungal spores. E) LM, UF18049-043592, PY02B, no coordinates available, F) LM, UF18049-043592, PY02C, coordinates 47.1, 43.8.

G. Unknown scutate fungal fruit body, LM, UF18049-043596, PY01A, coordinates 44.5, 101.

H. Unknown circular, dicellate fungal spore, SEM, UF18049-043594, PY01, SEM-B.

I. Unknown elliptic, monocellate fungal spore, LM, UF18049-043596, PY01A, coordinates 32.2, 99.

J-K. Unknown circular, monocellate fungal spore clusters. J) SEM, UF18049-043596, PY01, SEM-C, K) LM, UF18049-043592, PY02C, coordinates 49, 104.5.



DISCUSSION

Comparison with Other Miocene Floras

To place the paleocology of the Alum Bluff deposits in context, it may be useful to compare the flora to other known Miocene plant assemblages (Table 3). As mentioned earlier in the text, there are several southeastern U.S. Miocene pollen localities that are useful for comparison (Table 2, 3). In addition, Miocene pollen records are known from western localities such as the Clarkia flora of northern Idaho (Gray 1985). Leaf macrofossils have been identified from North American Miocene localities such as the Miocene Brandon Lignite, Vermont, (Tiffney 1993, 1994a, 1994b), the Brandywine deposits, Maryland (Late Miocene) (McCartan et al. 1990), the Clarkia flora, northern Idaho (Smiley et al. 1975, Smiley and Rember 1981, Rember 1991, Manchester et al. 1991, Kvaček and Rember 2000), and the Seldovia Point flora, Alaska (Miocene) (Wolfe 1972, Wolfe and Tanai 1980). Fruits and seeds have been identified from Miocene localities such as the Brandon Lignite, Vermont the Brandywine deposits of Maryland (Late Miocene) (McCartan et al. 1990), and the Clarkia Flora of Idaho (Smiley et al. 1975, Smiley and Rember 1981, Rember 1991, Manchester et al. 1991, Kvaček and Rember 2000).

Tiffney described the Early Miocene Brandon Lignite to be a mixed evergreen-deciduous forest with a climate similar to that of the U.S. Gulf coast (temperate to subtropical) (1994). The Middle Miocene Old Church flora of

Virginia was estimated to be similar to a modern temperate southern oak-hickory type forest (Fredericksen 1984). The late Miocene Brandywine flora of Maryland was thought to be deciduous with a warm-temperate climate (McCartan et al. 1990). The Ohoopsee River Dune Field paleoecology was interpreted as being a myriad of habitats all similar to those of the southern coastal plain today, including an oak-hickory forest, a shrub swamp dominated by Cyrilla, and a Sphagnum-bog (Rich et al. 2002). The flora of the Calvert Formation of Delaware was interpreted as being similar to the modern coastal plain flora of Delaware, typified by a temperate to warm-temperate flora (Groot 1992). The Legler Lignite of New Jersey was interpreted as being similar to that of the modern southern coastal plain floras (Rachele 1976). The Miocene Catahoula Formation in Louisiana was thought to be a subtropical to tropical mangrove type environment (Wrenn et al. 2003), though the large presence of temperate taxa shared with Alum Bluff (Table 3) may suggest other climatic conditions than described by Wrenn et al (2003).

Turning to Miocene floras from Western North America, the Clarkia Flora of northern Idaho, unlike most of the Miocene floras of eastern North America, exhibits a larger number of taxa with Asian distributions today, such as Cercidiphyllum, Trochodendron, and Paliurus among others. The Clarkia Flora has been described as being a mixed-mesophytic forest (Smiley et al. 1975, Smiley and Rember 1981, Rember 1991, Manchester et al. 1991, Kvaček and Rember 2000). Higher latitude floras such as the Seldovian Point flora of Alaska also share some elements with Alum Bluff. The Seldovian Point flora is also

described as a mixed-mesophytic to broad-leaved deciduous assemblage (Wolfe 1969, 1972, Wolfe and Tanai 1980). This flora also possesses more taxa now restricted to Asia, such as Zelkova and Cercidiphyllum, than the eastern North America Miocene floras. In this respect, Alum Bluff is more like some western North American floras than with its eastern counterparts due to the presence of Paliurus, which is restricted to the Eurasian landmass today.

The European Miocene fossil flora of Hambach, near Düren, Germany (which is also based on micro- and megafossils), was estimated to represent a floodplain forest with some upland elements being co-dominant with a sedge wetland (van der Burgh and Zetter 1998). The Miocene floras of Central Honshu, Japan illustrate some of the shared components of Alum Bluff with Asian Miocene localities (Ozaki 1991). These floras are thought to represent temperate environments.

Paleoecological Interpretations

Though paleoecological and paleoclimatological work has been done based on invertebrate assemblages from strata above and below the geological formation where plant fossil are found at Alum Bluff (DuBar and Taylor 1962), little such work has been done with the floristic assemblages of the region. Berry (1916) made some climatological and ecological inferences about the Alum Bluff flora in his original report. He inferred the significant presence of thermophillic elements that he identified indicated the climate of the Miocene Alum Bluff region was much warmer than the conditions occurring in that region of Florida today.

Table 3. Taxa shared between Alum Bluff and other Miocene localities.

	<u>Amaranthaceae</u>	<u>Asteraceae</u>	<u>Carya</u>	<u>Cyathea</u>	<u>Gleditsia</u>	<u>Ilex</u>	<u>Liquidambar</u>	<u>Liliaceae</u>	<u>Magnolaceae</u>	<u>Myrica</u>	<u>Paliurus</u>	<u>Pinus</u>	<u>Poaceae</u>	<u>Polypodaceae</u>	<u>Quercus</u>	<u>Taxodium</u>	<u>Ulmus</u>	<u>Vitis</u>
Alum Bluff, FL	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Brandon Lignite, VT			X			X						X					X	X
Brandywine flora, MD						X	X					X			X	X	X	X
Calvert Formation, DE	X		X			X	X							X	X		X	
Legler Lignite, NJ			X	X		X	X					X	X	X	X		X	
Old Church Formation, VA			X			X	X					X			X		X	
Ohoopsee River Dune Field, GA			X			X						X			X	X		
Catahoula Formation, LA			X			X	X	X	X	X		X	X		X	X	X	
Clarkia flora, ID						X	X				X	X			X	X	X	X
Seldovian Point flora, AK			X			X						X					X	
Hambach flora, Germany	X	X	X			X	X		X			X		X	X	X	X	X
Honshu floras, Japan				X	X	X	X				X				X	X	X	X

In other words, he interpreted the flora as being predominantly tropical and being gradually invaded by temperate elements, rather than the modern condition where the flora is predominantly temperate with some subtropical to tropical elements (Berry 1916). Berry identified tropical genera such as Artocarpus, Pisonia, Caesalpinia, Fagra (= Zanthoxylum), Rhamnus, Nectandra, and Bumelia (= Sideroxylon). According to Dilcher (1973a), at least 60% of the material Berry described for southeastern Eocene floras is incorrect. Though no attempt was made to revise Berry's original descriptions of the Alum Bluff flora, the statistics presented by Dilcher suggest that revision of Berry's 1916 Alum Bluff flora may be needed.

The description of the Alum Bluff flora presented here provides new data and a different interpretation regarding paleoclimate than that of Berry (1916). Of those morphotypes identified here, most are present in temperate areas. Taxa representative of tropical environments from the present study include Cyathea and Diospyros. Cyathea has been found in other Miocene temperate palynofloras (Table 3), and there is one species of Diospyros (Diospyros virginiana) in the extant flora of the region. The current author observed that the common serrated leaf forms and small leaf sizes at Alum Bluff are more typical of temperate floras. In addition, the presence of leaves identified as Carya, Ulmus, and Paliurus, as well as the large number of temperate taxa represented in the pollen, fruits, and seeds of Alum Bluff suggest that the climate of Alum Bluff was warm-temperate and more similar to the other North American, European, and eastern Asian Miocene communities discussed earlier. The community type

would have been similar to the modern northern Gulf Coast of Florida possessing an elm-hickory-cabbage palm forest occurring adjacent to or near an oak and pine dominated landscape. This differs somewhat from the modern flora at the immediate area surrounding Alum Bluff, which is today influenced by the unique environmental circumstances created by the Apalachicola River corridor.

Instead, the Miocene flora of Alum Bluff more closely resembles the area from the northern Gulf Coast of peninsular Florida through northern central Florida to the northern Atlantic coast of peninsular Florida extending up along the Georgia and South Carolina coasts. This difference between the modern and fossil floras of Alum Bluff is likely because the Apalachicola River Valley was in its infancy in the Middle Miocene (Clewell 1977) and had not yet developed the unique set of topographic (bluffs and ravines) and biogeographic (connection with Piedmont and Appalachia) characteristics that exists in the region today.

As mentioned earlier, based on taphonomy and lithology of the site, the undifferentiated beds of Alum Bluff Group are thought to represent deltaic or pro-deltaic sediments deposited in a high energy depositional environment (pers. comm. Dilcher 2004, Schmidt 1986). Thus, it can be interpreted that the warm-temperate flora of Alum Bluff occurred as floodplain and upland forests flanking a river.

The presence of dinoflagellate cysts suggest marine influence, though the infrequency of dinoflagellates (<0.1%) in the sediment indicates only a slight marine input. This reiterates the deltaic environment described previously, but it suggests that the coastline may have been near enough for some marine

sediments to reach from the Gulf up the pre-Apalachicola river delta to Alum Bluff. However, it is not uncommon for sediment from other more ancient strata to be re-worked with younger sediments (Traverse et al. 1988, Wrenn et al. 2003). This is especially common when the anomalous element is found with extremely low frequency (Traverse 1988). Thus, the presence of dinoflagellates at Alum Bluff may indicate re-working from older sediments rather than a marine influence at the site.

Because both the overlying Jackson Bluff Formation and the underlying Chipola Formation represent marine deposits (Schmidt 1986), it can further be inferred that the Alum Bluff flora represents a forest encroachment during an interval of sea level drop which was summarily displaced again as sea level rose.

Biogeographical Implications

Several important biogeographical conclusions are presented by this analysis of the Alum Bluff Flora. The presence of Paliurus suggests affinities with eastern Asian or southern European floras that are present in western North American Miocene assemblages, but conspicuously lacking from other eastern North American assemblages. This suggests that Paliurus at Alum Bluff was one of the last remnants of Eurasian taxa in eastern North America by the Miocene. The last record of Paliurus in North America was from the Miocene of Washington, USA (Berry 1928). It is unclear why Paliurus at Alum Bluff is disjunct from its contemporaneous western counterparts, or why Paliurus persisted at this more southern latitude while remaining absent in Miocene assemblages from the northeastern United States. Manchester (1999)

commented that the Paliurus likely made its way to the North American continent via a Beringial crossing in the Eocene. The genus disappears from North America after the Miocene (Manchester 1999). Thus, Paliurus may have arrived at Alum Bluff after being dispersed across the North American continental interior from the west. This cannot be confirmed, however, due to a lack of Miocene age deposits in the interior North America (Manchester pers. comm. 2004).

Alternatively, Paliurus may have arrived via a North Atlantic Land Bridge crossing. The genus is present in Europe and Asia today, and has an extensive fossil record on these continents, so it would be possible for Paliurus to arrive from Europe (in the Eocene?), however no Miocene fossil record of Paliurus is known from the northeastern U.S. (where it would have first arrived via an Atlantic crossing).

The floral assemblage described here supports the concept of a warm temperate climate existing in the region since the early Tertiary. Dilcher (1973a, 1973b) reported a warm temperate to cool subtropical climate for the Middle Eocene Claiborne Formation in Tennessee. Prior to the author's investigations, the Alum Bluff flora was thought to represent a Miocene tropical flora intermediate between an Eocene warm temperate to cool subtropical flora (Claiborne Formation) and a Pliocene temperate flora (Citronelle Formation) (Dilcher 1973a, 1973b, Graham 1964). However, new data presented here show that warm temperate conditions have continued in the southeastern United States Gulf Coastal Plain region since the Eocene.

CONCLUSIONS

Of the taxa at Alum Bluff, two are positively confirmed in both the leaf and pollen record (Carya, Ulmus), one is positively confirmed in the leaf, pollen, and fruit record (Carya), and one is tentatively confirmed in the leaf and pollen records while being positively confirmed in the fruit record (Paliurus). A summary of these and other taxa occurring at Alum Bluff is presented in [Table 4](#). Of the North American Miocene paleofloras, there are only a handful known from pollen, fruits, seeds, and leaves including the Clarkia flora of Idaho (Smiley et al. 1975, Smiley and Rember 1981, Rember 1991, Manchester et al. 1991, Kvaček and Rember 2000), and the Brandywine flora of Maryland (McCartan et al. 1990). A few sites are known to have fruits, seeds, and pollen such as the Brandon Lignite flora (Traverse 1951, Traverse 1955, Traverse 1994, Tiffney 1993, 1994a, 1994b). According to Graham (1964), the best circumstance for reconstructing paleoenvironments is a study of mega- and microfossils from a given locality. He also reported that very few Tertiary localities of this type in the southeastern United States were available. Review of the literature by the author also found occurrence of such sites in the Atlantic coastal plain to be rare. The compounding of data from both mega- and microfossils and the resulting increase in floristic diversity makes the current analysis of the Alum Bluff flora a paleobotanically important case. The examination of palynomorphs at Alum Bluff has greatly increased the number of taxa known from the site. Examination of

fruit and seed material has helped to confirm identification of pollen and leaves and increased the overall morphotype diversity at the site. The culmination of his study has been the determination that the Alum Bluff flora is more diverse than Berry originally described. Also, it was found that the Alum Bluff flora was likely warm-temperate, and that these conditions have persisted since the early Tertiary. In addition, the existence of Paliurus at Alum Bluff suggests biogeographical affinities with Eurasia, which further demonstrates that floristic elements limited to Eurasia today were once widely dispersed through both western and eastern North America.

Table 4. Summary of taxa identified at Alum Bluff.

Taxon	Pollen or spore?	Leaf?	Seed or Fruit?
Adiantaceae	Yes	No	No
Amaranthaceae/ Chenopodiaceae	Yes	No	No
Asteraceae/ Malvaceae	Yes	No	No
Betulaceae	Yes	No	No
Botrychium	Yes	No	No
<u>Carya</u>	Yes	Yes	Yes
<u>Cyathea</u>	Yes	No	No
Dinoflagellate cyst	Yes	N/A	N/A
<u>Diospyros</u>	Yes	?	No
<u>Dryopteris</u>	Yes	No	No
Euphorbiaceae	Yes	No	No
Fabaceae	Yes	No	No
<u>Gleditsia</u>	Yes	No	?
<u>Ilex</u>	Yes	No	No
Lauraceae	No	Yes (cuticle)	No
Liliales	Yes	No	No
<u>Liquidambar</u>	Yes	No	No
Magnoliaceae	Yes	No	No
<u>Myrica</u>	Yes	No	No
<u>Paliurus</u>	?	Yes	Yes
<u>Pinus</u>	Yes	No	No
Poaceae	Yes	No	No
Polypodiaceae	Yes	No	No
<u>Pteris</u>	Yes	No	No
<u>Quercus</u>	Yes	No	No
Rosaceae	Yes	No	No
<u>Sabalites</u>	?	Yes	No
<u>Scirpus</u>	No	No	Yes
<u>Taxodium</u>	Yes	No	No
<u>Ulmus</u>	Yes	Yes	No
Vitaceae	Yes	No	No

APPENDIX A
SELECTED WOODY TAXA OCCURRING
IN AND AROUND THE APALACHICOLA BLUFFS AND
RAVINES AREA AND THEIR TYPICAL HABITATS

Taxa marked with an asterisk (*) are either rare to Florida or endemic species. The list is compiled from taxa discussed for the region in Clewell (1977, 1985), Harper (1914), Ward (1979), Wolfe et al. (1988), and Wunderlin and Hansen (2003).

Species	Family	Habitat
Trees		
<u>Acer saccharum</u> subsp. <u>floridanum</u>	Sapindaceae	Bluffs, levees, hammocks
<u>Acer saccharum</u> subsp. <u>leucoderme</u>	Sapindaceae	Bluffs, levees, hammocks
<u>Acer saccharinum</u>	Sapindaceae	Riverbanks
<u>Betula nigra</u>	Betulaceae	Riverbanks, floodplains
<u>Carpinus caroliniana</u>	Betulaceae	Floodplains, bluffs
<u>Carya aquatica</u>	Juglandaceae	Floodplains
<u>Carya glabra</u>	Juglandaceae	Pine-oak-hickory woods
<u>Carya tomentosa</u>	Juglandaceae	Pine-oak-hickory woods, calcareous hammocks
<u>Cornus florida</u>	Cornaceae	Hammocks, pine-oak-hickory woods
<u>Fagus grandifolia</u>	Fagaceae	Bluffs, hammocks
<u>Ilex opaca</u>	Aquifoliaceae	Hammocks, bluffs
<u>Liquidambar styraciflua</u>	Altingiaceae	Floodplains, bluffs, hammocks, secondary woods
<u>Liriodendron tulipifera</u>	Magnoliaceae	Creek swamps, bluffs near seepages
* <u>Magnolia ashei</u>	Magnoliaceae	Bluffs, hammocks, bayheads (Endemic)
<u>Magnolia grandiflora</u>	Magnoliaceae	Bluffs, floodplains, hammocks, secondary woods
<u>Ostrya virginiana</u>	Betulaceae	Hammocks, bluffs
<u>Oxydendron arboreum</u>	Ericaceae	Hammocks, bluffs, bayheads
<u>Planera aquatica</u>	Ulmaceae	Floodplains, riverbanks
<u>Pinus glabra</u>	Pinaceae	Hammocks, bluffs, well-drained floodplains
<u>Pinus echinata</u>	Pinaceae	Pine-oak-hickory woods

Species	Family	Habitat
Trees (continued)		
<u>Pinus serotina</u>	Pinaceae	Pinelands
<u>Prunus caroliniana</u>	Rosaceae	Bluffs, calcareous hammocks, scrub
<u>Quercus alba</u>	Fagaceae	Bluffs, hammocks, pine-oak-hickory woods, sinks
<u>Quercus laevis</u>	Fagaceae	Sandhills, scrub, pine-oak-hickory woods
<u>Quercus michauxii</u>	Fagaceae	Moist hammocks, floodplains, sinks
<u>Quercus muhlenbergii</u>	Fagaceae	Bluffs
<u>Quercus nigra</u>	Fagaceae	Floodplains, hammocks, secondary woods
<u>Quercus shumardii</u>	Fagaceae	Bluffs, calcareous hammocks
<u>Taxodium ascendens</u>	Cupressaceae	Swamps, ravines
<u>Taxodium distichum</u>	Cupressaceae	Swamps, ravines
<u>Tilia americana</u> var. <u>caroliniana</u>	Malvaceae	Bluffs, hammocks, riverbanks
* <u>Taxus floridana</u>	Taxaceae	Hammocks and cedar swamps (Endemic)
* <u>Torreya taxifolia</u>	Taxaceae	Hammocks (Endemic)
<u>Ulmus alata</u>	Ulmaceae	Bluffs, floodplains, calcareous river swamps
<u>Ulmus americana</u>	Ulmaceae	Bluffs, floodplains, hammocks
<u>Ulmus rubra</u>	Ulmaceae	Bluffs, floodplains, hammocks
Woody Vines		
<u>Bignonia capreolata</u>	Bignoniaceae	Floodplains, hammocks
<u>Campsis radicans</u>	Bignoniaceae	Floodplains, ruderal
<u>Decumaria barbara</u>	Hydrangeaceae	Calcareous hammocks, margins of gum swamps
<u>Gelsemium sempervirens</u>	Gelsemiaceae	Various habitats
* <u>Schisandra coccinea</u>	Schisandraceae	Bluffs
<u>Smilax smallii</u>	Smilacaceae	Hammocks, bluffs, dunes, secondary woods
<u>Vitis aestivalis</u>	Vitaceae	Hammocks, riverbanks
<u>Vitis rotundifolia</u>	Vitaceae	Various habitats
Shrubs		
<u>Alnus serrulata</u>	Betulaceae	Along creeks and branches
<u>Aralia spinosa</u>	Araliaceae	Hammocks, secondary woods
<u>Callicarpa americana</u>	Verbenaceae	Flatwoods, scrub, bluffs, secondary woods
* <u>Cornus alternifolia</u>	Cornaceae	Moist woodlands
* <u>Dirca palustris</u>	Thymelaeaceae	Bluffs, riverbanks
<u>Euonymus americanus</u>	Celastraceae	Hammocks, bluffs

Species	Family	Habitat
Shrubs (continued)		
<u>Gleditsia aquatica</u>	Fabaceae	Floodplains
<u>Gleditsia triacanthos</u>	Fabaceae	Floodplains
<u>Hamamelis virginiana</u>	Hamamelidaceae	Bluff, hammocks, floodplains, creek swamps
<u>Halesia carolinia</u>	Styracaceae	Bluffs, calcareous hammocks, floodplains
<u>Halesia diptera</u>	Styracaceae	Bluffs, hammocks, floodplains
<u>Hydrangea quercifolia</u>	Hydrangeaceae	Bluffs, stream banks
* <u>Hydrangea arborescens</u>	Hydrangeaceae	Bluffs
<u>Hypericum frondosum</u>	Clusiaceae	Floodplains
* <u>Kalmia latifolia</u>	Ericaceae	Bluffs, creek swamps
<u>Ilex coriacea</u>	Aquifoliaceae	Wet ravines, bogs
<u>Illicium floridanum</u>	Illiciaceae	Creek swamps, seepages on bluffs
<u>Leucothoe axillaris</u>	Ericaceae	Creek swamps
<u>Lyonia ferruginia</u>	Ericaceae	Flatwoods, bogs, acid swamps, creek swamps
<u>Lyonia lucida</u>	Ericaceae	Flatwoods, bogs, acid swamps, creek swamps
<u>Myrica cerifera</u>	Myricaceae	Flatwoods, bogs, hammocks
<u>Osmanthus americana</u>	Oleaceae	Floodplains, bluffs, flatwoods, swamps
<u>Ptelea trifoliata</u>	Rutaceae	Bluffs, hammocks
* <u>Rhapidophyllum hystrix</u>	Arecaceae	Bluffs, calcareous hammocks
* <u>Rhododendron austrinum</u>	Ericaceae	Bluffs, hammocks, floodplains
* <u>Sideroxylon lycioides</u>	Sapotaceae	
* <u>Stewartia malacodendron</u>	Theaceae	Bluffs, steepheads, bayheads
<u>Symplocos tinctoria</u>	Symplocaceae	Hammocks, bluffs, floodplains, sandhills, flatwoods
<u>Styrax americana</u>	Styracaceae	Hammocks and swamps, flatwoods, riverbanks
<u>Styrax grandifolia</u>	Styracaceae	Dry bluffs, calcareous hammocks, floodplains
<u>Rhus copallina</u>	Anacardiaceae	Sandhills, flatwoods, floodplains, secondary woods, ruderal
<u>Vaccinium arboreum</u>	Ericaceae	Uplands
<u>Viburnum dentatum</u>	Adoxaceae	Floodplains, bluffs, titi swamps, secondary woods
<u>Viburnum obovatum</u>	Adoxaceae	Floodplains, riverbanks

APPENDIX B EXPLANATION OF PALYNOMORPH TERMINOLOGY

The following is a brief description of terminology used to describe spores and pollen grains from Alum Bluff. Not all of the terms below are used in the thesis, but are provided as background and comparison for the palynomorph terminology that was used.

The basic structure of a pollen grain consists of an outer **exine**. The exine is made up of the **sexine** (which is composed of a **tectum**, **column** and **foot layer**) and the **nexine**. An **intine**, a **plasmalemma** and the **protoplast** are the innermost layers. In fossilized pollen, typically only the outer layers remain (intine and exine). Some pollen grains belonging to conifers possess **vesiculate** pollen, or pollen with attached bladders (as in Pinus). The **sacci** (=“vesicles” or “bladders”) attach to the **corpus**, or body of the pollen grain. There are typically two sacci present, however in some groups there is only one.

Pollen is described based on (1) the shape of the grain, (2) the ornamentation of the exine, and (3) the number and arrangement of pores or apertures over the surface of the grain.

(1) Grain Shape: The shape of a pollen grain is determined based on a ratio of the polar and equatorial diameters of the grain. The pole of a grain is the location of a single pore or the midpoint of a furrow of the grain OR where the end of the grain where furrows converge (in tricolpate or tricolporate grains).

Grain shape, however, often varies between polar and equatorial views. Thus, grain shape terminology is often omitted from descriptions unless both polar and equatorial views are identified. The following terms describe the shape of a grain based on the P/E ratio.

>2.0=**perprolate** (very elongated)

1.3-2.0=**prolate** (slightly elongated)

0.75-1.3=**subspheroidal**

0.50-0.75=**oblate** (slightly flattened)

<0.5=**peroblate** (very flattened).

(2) Ornamentation of the exine: The following terms describe the ornamentation of the exine. These features are often helpful in determining generic or specific divisions.

Psilate-surface smooth

Perforate-surface with small holes

Foveolate-with holes or depressions

Fossulate-sideways elongate holes

Scabrate-rough or flecked

Verrucate-warty or bumpy

Papillate-hollow, finger-like projections, longer than broad and >1 μm

Baculate-having rod-shaped sculptural elements

Gemmate-having "door knob" shaped elements less than 1 μm in height.

Clavate-having club-shaped sculptural elements

Pilate-similar to gemmate, but knob-shaped elements taller than $1\mu\text{m}$.

Echinate- spiny

Rugulate-irregular

Striate-roughly parallel ridges

Reticulate-net like (ridges and gaps)

(3) Number and Arrangement of pores and apertures: Pollen with pores is referred to as **porate**. Pollen may be **mono-**, **di-**, **tri-**, or **periporate**. When a grain has more than four pores oriented along the equator of a grain, it is referred to as **stephanoporate**. In addition to pores, furrows also known as **colpi** may be present. Grains with furrows are referred to as **colpate**. Colpi range from being very long and stretching the length of the grain to being short and unapparent. When the colpi of a pollen grain fuse or meet (typically at the apex of the grain), it is referred to as being **syncolpate**. When a pollen grain possesses both pore and colpi, it is referred to as **colporate**. The pores in these grains are located within the furrows. Sometimes, the exine around the pore is modified. When the pore possesses a cap or plug, it is referred to as an **operculum**. The **aspis** is the thickening of the exine around the pore. The **annulus** may be a ring around the pore and may be a thickened or thinned area of the exine. The **oncus** is a thickening of the intine that may occur under a pore, and the **arcus** may be a band which arcs between pores and is actually thickened sexine.

The terminology for pteridophyte and lycopod spore morphology differs somewhat from that of pollen. Spores that form **tetrads** during development may or may not split apart upon maturity. When they do split apart, they form

monads with tetrad scars remaining on the surface where the spore once made contact with the tetrad. There are two basic forms: a **radiosymmetrical trilete** form and a **bilaterally symmetrical monolete** form. **Monolete** and **trilete** refers to the number of dehiscence fissures present, also known as **laesura**. A spore is called **anisopolar** when there is a prominent tetrad scar on the proximal end (the end that was connected to the tetrad). A spore is **apolar** when the two poles are identical (occurs in globose and alete spores). When a swollen protrusion is present surrounding the laesura, this is referred to as a **margo**. The margo may be lip-like, flange-like, or line-like. When a margo is absent, the palynomorph is said to have a laesura with a simple commissure. When present, the laesural ridges may be ornamented. In addition, **proximal ridges** may be present near the equator of the spore. These proximal ridges may assume several different forms.

Regarding the surface ornamentation of spores, the same terminology that was used for pollen in part II above may be used (as was done in this thesis).

Shape of spores is also an important characteristic. Spores may be **ellipsoidal** (ratio of long axis/short axis falling between 1.25 to 2), **subellipsoidal** (ratio of long axis/short axis above 2), **globose** (ratio of long axis to short axis below 1.25), **rounded triangular** (convex sides), **subtriangular** (sides straight and angle rounded), **deltoid triangular** (sides straight and angles acute), **triquete** (sides slightly concave), or **trilobate** (sides deeply concave). In some fern species, an **equatorial ridge** is evident. When the equatorial ridge is the same width all the way around the spore, it is referred to as **annulate**. When

the equatorial ridge is wider on the interradial side than at the radial angles, it is referred to as **annulotrilete**.

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BIOGRAPHICAL SKETCH

Sarah Lynn Corbett grew up in rural Echols County, Georgia. Her early rural experiences later inspired her career decision to become a botanist. She received her undergraduate degree in biology from Valdosta State University in Valdosta, Georgia. While a student at VSU, she worked as an assistant in the VSU herbarium for three years. Also while attending VSU, she spent a summer abroad studying Spanish in Guadalajara, Mexico, and another summer studying the anatomy of spathes of the genus Commelina at the Smithsonian Institution's National Museum of Natural History. After college, she spent a year in Philadelphia, Pennsylvania, at the Morris Arboretum of the University of Pennsylvania as the Flora of Pennsylvania Intern. While there, she conducted a floristic inventory of an area adjacent to the Pine Swamp Natural Area in French Creek State Park. She also worked in the herbarium of the Academy of Natural Sciences Museum in Philadelphia during this time. Upon leaving Pennsylvania and before beginning her graduate studies at the University of Florida, she spent three months as an intern at the University of Georgia Marine Institute on Sapelo Island, Georgia, where she studied distribution and feeding habits of the marsh grasshopper (Orchelimum fedicinum) on Sapelo and Cumberland Islands. She currently has a paper in press co-authored by Dr. Steven R. Manchester in the International Journal of Plant Sciences entitled "Phytogeography and fossil

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