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WALTER K. BUECHLER[1], MICHAEL T. DUNN[2], AND WILLIAM C. REMBER[3]

Abstract—A rich leaf and seed flora, diatoms, and palynomorphs have been recovered from late Miocene lacustrine sediments at Pickett Creek, Idaho. The sediments are part of the lower Chalk Hills Formation of the Idaho Group. Chemical analysis of two ash samples suggests an age range of 8.5-10.5 m.y.. While southwestern Idaho and southeastern Oregon are rich in middle Miocene floras, major late Miocene assemblages are rare and Pickett Creek is the youngest in this area. The examined fossil beds consist of 3 m of lacustrine sediments, overlaid by 3 cm of volcanic ash, 3.7 m of pure diatomite, and 15 m of lacustrine and fluvial sediments. They contain a diverse leaf flora of more than 45 leaf species in addition to fruits, including those of *Acer*, *Ostrya*, *Salix*, *Fraxinus*, *Quercus*, *Pterocarya* and Fabaceae species. In addition to random collections, a stratigraphic megafossil count was done on a surface of 60 x 100 cm, through a total depth of 293 cm below the diatomite. Pollen samples were taken every 30 cm. The most abundant megafossil taxa are *Quercus prelobata* (50%), *Q. columbiana* (9%), five *Salix* species (8%) and five Fabaceae species (5.7%). Based on the predominance of white oaks, the presence of several live oaks and dryland species of *Pinus* (pollen), small leafed Fabaceae (leaves and fruits), Amaranthaceae, and Chenopodiaceae (pollen), the ecologically and climatologically most similar modern forest type is the broad-leaved forest of the Californian foothill woodlands. A high proportion of xeric leaf forms (*Quercus simulata*, *Quercus hannibali*, *Quercus oberlii*, *Robinia* species) indicates drier habitats, possibly on slopes above the lake. Evergreen species (*Quercus hannibali*, *Q. simulata*, *Mahonia macginitiei*, *Lyonothamnus* cf. *parvifolius*, possibly *Quercus oberlii* and some unassignable specimens) amount to about 6.5% of the collection. Two new species (*Populus douglasae* and *Quercus oberlii*) are described.

Pollen analysis corresponds with most of the leaf families and suggests additional taxa from higher elevation and dry sites (*Abies*, *Pinus*, Amaranthaceae, Chenopodiaceae). The sediments contain a rich and variable diatom flora of more than 47 species, including four new *Cymbella* species.

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Based on megafossil plant remains and palynomorphs, the present study gives a detailed account of a fossil flora dominated by white oaks and growing under summer-dry conditions. It establishes well documented estimates for early late Miocene climate parameters and provides the earliest evidence for a Neogene Snake River Plain lake-system. Its position in the poorly known stratigraphy between the Chalk Hills and Poison Creek Formations makes Pickett Creek an interesting area for future geological and stratigraphic exploration.

INTRODUCTION

Geographic, Climatic and Temporal Significance of the Flora

The middle Miocene is generally characterized by a relative maximum of mean annual temperature (MAT), followed by a rapid decline. On the west coast of North America, MAT decreased from about 16.5°C at 13 million years ago (m.y.a.) to about 10°C at 9 m.y.a. (Wolfe, 1995). In the late middle Miocene (12 m.y.a.), the uplift of the Cascade Range increased significantly (Reiners et al., 2002). The combined influence of the Cascade Range uplift and general cooling of world climate resulted in increasingly drier and colder conditions in the Western Interior (Smiley and Rember, 1985). As a consequence, vegetation changed from dense, mixed broad-leafed deciduous forests to more open, partially savanna-like associations similar to those found today in the foothills of the Central Valley of California. Pickett Creek represents an important stage in the course of this development. While southwestern Idaho and southeastern Oregon are rich in middle Miocene floras, no major late Miocene or younger flora was known from this area before investigation of the Pickett Creek assemblage. Based on megafossil plant remains and palynomorphs, the present study gives a detailed account of a fossil flora dominated by white oaks and growing under summer-dry conditions. It establishes well documented estimates for early late Miocene climate parameters and provides the earliest evidence for a Neogene Snake River Plain lake-system. Findings of the study extend our knowledge about floral and climatological developments in the Pacific Northwest from the middle Miocene into the late Miocene. Its position in the poorly known stratigraphy between the Chalk Hills and Poison Creek formations makes Pickett Creek an interesting area for future geological and stratigraphic exploration.

Our interpretation of the Pickett Creek flora and our systematic treatment of species are based on a large number of previous publications. Recent major revisions of Miocene floras and species of southeastern Oregon and southwestern Idaho include Chaney and Axelrod (1959), Axelrod (1964), and Fields (1983, 1996).

Early paleobotanical publications were based on random collections without detailed reference to stratigraphic horizons. Nineteenth century and early twentieth century investigations rarely reported numbers of specimens per species, nor the total number of specimens on which they were based. High-resolution stratigraphic investigations of paleobotanical megafossil deposits were not carried out until recently. Lack of such data precludes quantitative statements on taphonomic mechanisms and habitat evolution during the time of deposition. While not all sites are suited for high-resolution, layer-by-layer exploration, Pickett Creek meets requirements such as good preservation, abundance of specimens, and preservation of major paleotopographic features. Quantitative investigation of megafossil remains was pioneered by one of the present authors at the middle Miocene Clarkia site in northern Idaho (Rember, 1991). Rember cut out a stratigraphic column measuring $762 \times 30 \times 45$ cm, transported it to the laboratory, and examined it for macrofossils at intervals of 0.5 to 1.0 cm. The number of specimens per species was added up for sections of 30 cm. Biostratigraphic data suggested a riparian floodplain flora in the lower third, a slope-species dominated flora in the middle third, and a swamp floodplain flora in the upper third of the section (Rember, 1991).

From the beginning of the present project, it was our intent to repeat and refine this working procedure, and to provide evidence of its consistency, independent of its direct benefit for the present project.

Previous Work

Leaf remains, similar in matrix and floral composition to those from Pickett Creek, were found in Charles J. Smiley's collection at the University of Idaho, Moscow. He collected the specimens at a site discovered by L. R. Hoxie. Excellent preservation of the specimens and uncertainty regarding the location and age of the fossil layers prompted our search for the site, which we re-discovered in the spring of 1996. The Pickett Creek diatomite, which is on top of the lower fossil layers, has been investigated for mining purposes by Powers (1947) and Mayerle (1991), but no reference to leaf remains or other megafossils was made by these authors. Several diatomite mining claims still exist in the area.

Regional Geology

The Pickett Creek fossil beds are on the southern margin of the western Snake River Plain. The western SRP was likely formed as a complex graben (Wood, 1994, Bonnichsen et al., 2004) along the track of the Yellowstone hot spot (Bonnichsen and Godchaux, 2002; Shervais et al., 2002; Wood and Clemens, 2002). Basement rocks of the Pickett Creek fossil beds are Silver City granites that are generally considered to be part of the Idaho Batholith (Taubeneck, 1971; Bonnichsen and Godchaux, 2002). These granites were emplaced as a deep pluton during the Cretaceous but they are not likely to have been exposed until the Tertiary (Warner, 1985). They crop out in two places in the Pickett Creek lake basin.

Rhyolite ridges dissected by a number of ephemeral creeks surround the Pickett Creek fossil beds and form the Pickett Creek lake basin. These rhyolites have not been examined, but are presumably part of the Owyhee Front Rhyolite (Bonnichsen and Godchaux, 2002; Godchaux and Bonnichsen, 2002, Bonnichsen et al., 2004) that occurs discontinuously from southwest of Homedale to southwest of Murphy, Idaho. Owyhee Front Rhyolite units southeast of Murphy and southwest of Grand View are usually included in the Browns Creek group (Bonnichsen and Godchaux, 2002) and have been dated as between 11.0-11.2 m.y. (Ekren et al., 1981, 1984; Bonnichsen et al., 1988; Wood and Clemens, 2002).

Recent studies suggest that lacustrine deposition in the western SRP occurred between 12 and 2 m.y.a. (Godchaux and Bonnichsen, 2002), but the depositional history prior to 6 m.y.a. is still poorly understood (Wood and Clements, 2002; B. Bonnichsen, pers. comm., 1997). The strata generally dip toward the center of the plain (Mabey, 1982), and these rocks are commonly divided into the Poison Creek, Chalk Hills, and Glenns Ferry formations of the Idaho Group (Bonnichsen et al., 2004, and references therein; see also Fig. 1).

We place the Pickett Creek fossil beds in the Chalk Hills Formation as mapped by Ekren et al. (1981), but realize that these strata may be older than anything yet reported as Chalk Hills. The Chalk Hills Formation consists of fluvial sands, lacustrine sands and silts, and numerous basalt units (Malde and Powers, 1962; Smith et al., 1982), however, the entire formation has yet to be systematically mapped. Generalizing the entire formation, Wood and Clemens (2002) described the basal sediments as usually coarse sand and gravel with an increasing number of interbedded mudstones higher up in the section. Higher still, sediments grade into tuffaceous muds and clays with silicic ash, lapilli, and some basaltic ash beds. Fission track dates suggest the basal ashes are approximately 8 m.y. old and the upper Chalk Hills sediments 5–6 m.y. old (Kimmel, 1982). Sometime during a 4 to 6 m.y. interval, the lake that deposited the Chalk Hills Formation drained, either partially or completely, for unknown reasons (Wood and Clemens, 2002). The
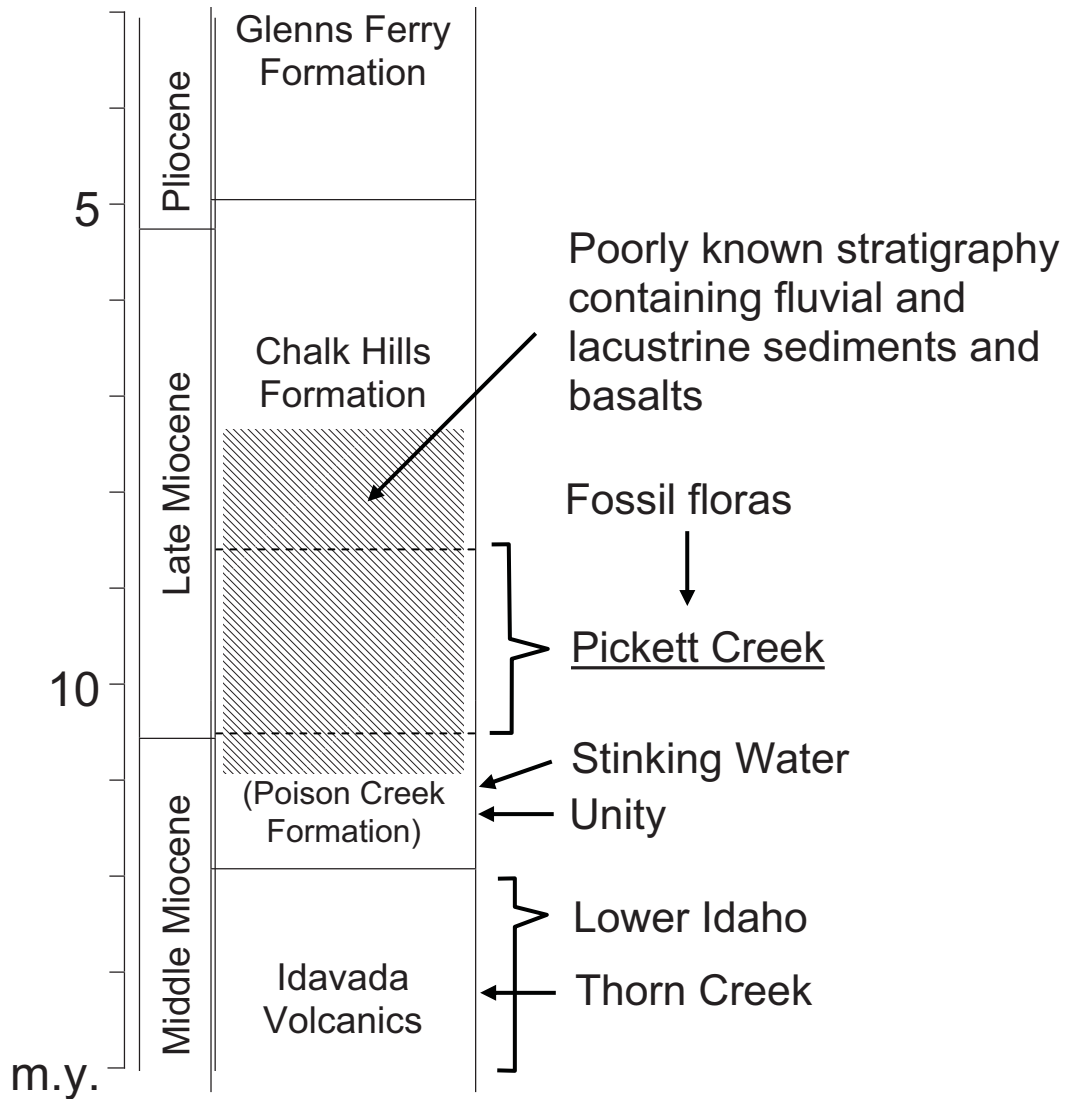
FIG. 1 — Stratigraphy of the western Snake River Plain (modified from Swirydcuk et al. 1982). Note that Pickett Creek is the youngest of a group of plant holding fossil sites in the Western Snake River Plain. Its position within the poorly known stratigraphy between Chalk Hills and Poison Creek Formations (hatched area) makes it an interesting area for future stratigraphic explorations.

Chalk Hills strata were then deformed by tilting and faulting (Wood, 2004). However the Pickett Creek beds are not dipping, presumably because of their proximity to the Silver City Granites as noted above.

Location of Fossil Beds

The Pickett Creek fossil beds are 13.3 miles south of Murphy and 6 miles west of Oreana, Owyhee County, Idaho, at 1359 m elevation, 43° 00.351' N / 116° 33.215' W. The outcrops are

☆ I   Fossil site I (II)

⊕   Water affected basalt

○   Unconsolidated sandy
       outcrops

●   Diatomite outcrops

Estimated current area of
diatomite, based on
Powers (1947) and
explorations by claim
owners.

Speculative current
distribution of diatomite

Supposed Miocene
shoreline based on
shore line features

Current 1280 m
elevation contour
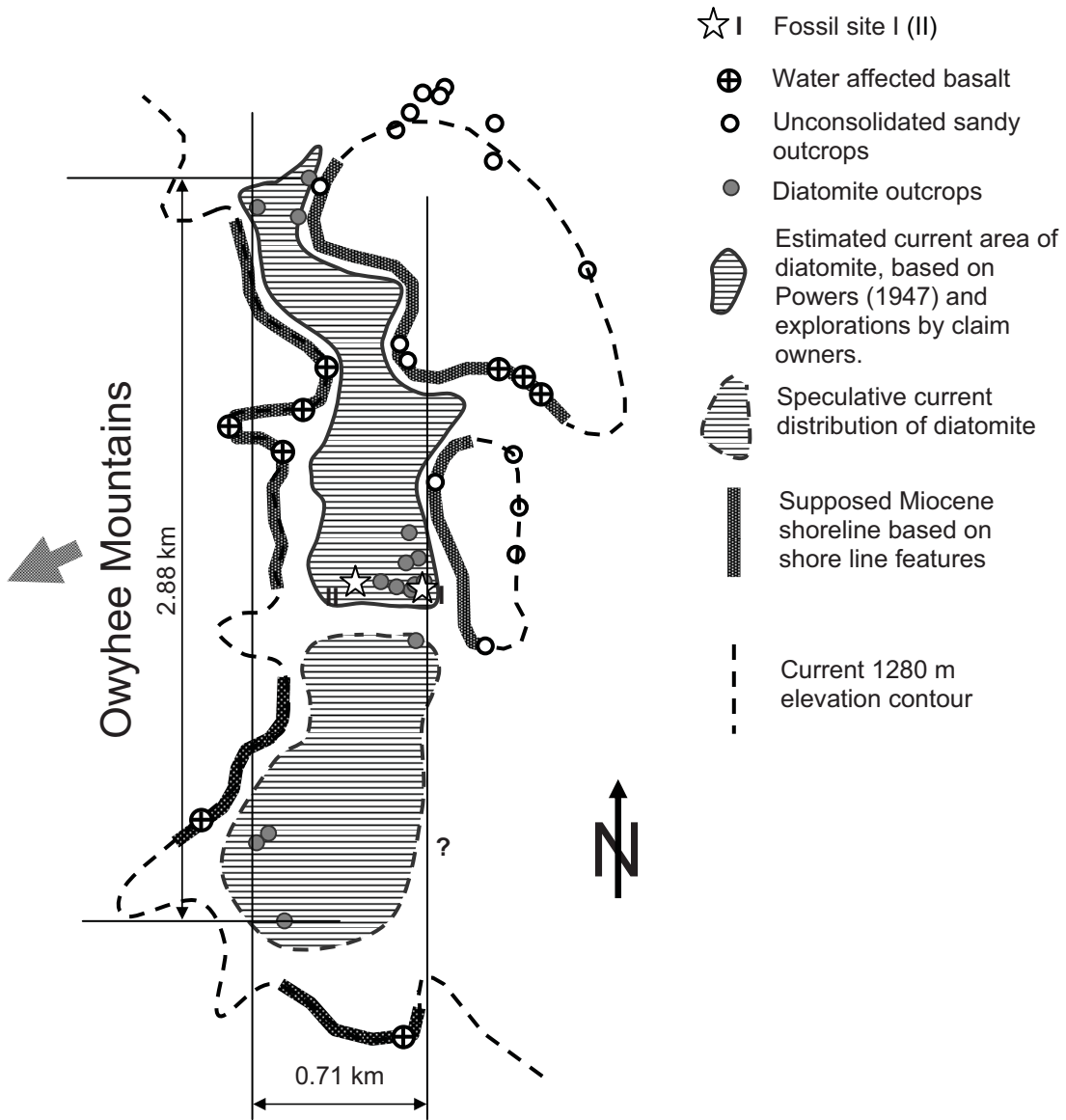
Owyhee Mountains

2.88 km

0.71 km

?

N

FIG. 2 — Estimated shoreline and diatomite deposits of Late Miocene Pickett Creek lake. Note that the northern part of the current diatomite distribution (encircled with a solid line) represents part of the Late Miocene lake bed in size and shape. The northern end and the middle part were more recently eroded by creeks from the Owyhee Mountains. Near the southern end the lake may have extended further eastward.

between Bates and Pickett Creeks in a depression that probably corresponds with the late Miocene lake bed. The known part of the Pickett Creek diatomite extends over an area measuring about

275 × 305 m, with a typical thickness of 3.7 m (Powers, 1947). It may be connected with another outcrop about 800 m away, in the Pickett Creek stream bed (Fig. 2).

METHODS

Ash Dating

Two samples of volcanic ash, one from Site I (0 to -3 cm) and one from Site II (+500 cm, see Table 1); (PKT-I and PKT-II at the Department of Geology and Geophysics, University of Utah), were electron-probe analyzed and their chemical composition compared to middle to late Miocene Ar/Ar-dated fallout tuffs (Perkins et al., 1998). The Pickett Creek samples have compositions typical of tuffs from the Twin Falls region, which suggests an age range between 10.5-8.5 m.y.a. (F. Brown, University of Utah, written communication).

Paleotropography

The mountain slopes in the vicinity of the fossil sites were searched for features of the ancient shoreline (Fig. 2). Basalt flows were examined for abrupt changes in surface weathering. Sections with increased weathering and decay into smaller pieces were interpreted as "water-affected basalt" (Jenks and Bonnichsen, 1989). Sand samples were collected from unconsolidated outcrops and their grain size spectrum qualitatively compared under the microscope with sand from the fossil beds. A sieve analysis was performed with sand from the most massive sand deposit. The results (mean grain size = 2.55 phi, standard deviation = 0.68 phi, skewness ~ 0) classify the sample as between beach sand and river sand (Friedman, 1961). A final interpretation of the supposed shoreline features will require future work.

Megafossil Remains

High-resolution stratigraphic and random collections were made at two sites 230 m apart (Site I and Site II). In stratigraphic collections, all specimens from a 60 × 100 cm plot were registered as a function of depth. In random collections, only well preserved specimens showing taxonomically useful characters were collected. Because of their non-representative quality, these data were not used for statistical purposes. For these specimens only site number (I or II), but not depth of deposition, was registered. Investigated total depth at Site I was 293 cm (Pit 1); specimens were registered in 21 naturally occuring units, I-B … I-U, each of 10-20 cm thickness. At Site II, only one fossil unit (II-B) was examined. Designations I-A and II-A (fossil units) refer to random collections from Site I and Site II respectively.

Rock was removed with a chain saw and chipped down with a hammer and knife to an average thickness of < 1 cm. Undeterminable leaf debris was counted separately. Loss of material through cutting, transportation, and handling was estimated to be < 5% by volume.

A second pit (Pit 2) of the same dimensions as Pit 1 was excavated at Site I (3 m from Pit 1); two units of layers N and O ($I-N_2$ and $I-O_2$) were reexamined to test variability of deposition and representativeness of the sampling method.

Megafossil specimens (Figs. 3-12) were scanned directly with a high-resolution flatbed scanner. Software contrast-enhancement was used as necessary. Tracing of margins and veins was done rarely, and such tracing is noted in the legend.

TABLE 1 — Physical stratigraphy of Pickett Creek Site I and Site II (see Methods).

Depth in cm	Fossil units	Lithology and state of preservation
Site II:		
+1500 to +550	—	Upper boundary identical with natural surface; lower part of unit fine silt and diatoms, seasonally laminated, with well preserved leaf fossils; sediments gradually coarsening toward upper boundary, with fewer and less well-preserved leaf fossils, finally turning into river gravel.
+550 to +528	II-B[1]	Contains best-preserved specimens at this site; matrix of very fine silt and diatoms, finely seasonally laminated; yearly deposits about 2 - 6 mm.
+528 to +370	—	Mixture of silt, fine sand and diatoms; proportion of diatoms gradually decreasing from pure diatomite at bottom to layers of fine silt and diatoms at top.
Site I:		
+370 to 0	—	Mostly unlaminated, massive, white diatomite; no pollen, spores or other organic remains preserved; in some locations the lowest few cm of diatomite are as regularly laminated as sediments of unit II-B.
0 to -3	—	Grey volcanic ash; no fossil specimens preserved.
-3 to -12	I-B[2]	Crystals just below ash layer; preservation of fossils relatively poor; most leaf impressions uncolored.
-12 to -20	I-C	Preservation relatively poor; most leaf impressions uncolored.
-20 to -35	I-D	Preservation relatively poor; most leaf impressions uncolored.
-35 to -55	I-E	Preservation relatively poor; most leaf impressions uncolored.
-55 to -66	I-F	Preservation relatively poor; most leaf impressions uncolored.
-66 to -69		Brittle ash-sediment mixture; no fossil specimens preserved.
-69 to -80	I-G	Preservation very poor; most leaf impressions uncolored, and material brittle; crystals in lowest 0.5 - 1 cm.
-80 to -90	I-H	Preservation relatively poor; most leaf impressions uncolored.
-90 to -97	I-I	Preservation relatively poor; most leaf impressions uncolored; crystals at lower boundary.
-97 to -116	I-K	Matrix almost unlayered (turbulent sedimentation?); uncountable small wooden debris; most leaves colored, many fragmented; upper boundary uneven, and no distinct lower boundary.
-116 to -128	I-L	Matrix almost unlayered (turbulent sedimentation?); uncountable small wooden debris; leaves fragmented.
-128 to -148	I-M	Matrix partially layered, containing many small, wooden debris; many leaves torn into several pieces; lower boundary distinct.
-148 to -164	I-N I-N$_2$	Matrix well layered; preservation good; specimens usually darker colored, with more organic material than in units B - M; lower boundary not distinct.
-164 to -184	I-O I-O$_2$	Matrix well layered; preservation good; specimens usually darker colored, with more organic material than in units B - M; lower boundary distinct.
-184 to -205	I-P	Matrix well layered; preservation good; specimens usually darker colored, with more organic material than in units B - M; lower boundary distinct.

TABLE 1 (continued)

Depth in cm	Fossil units	Lithology and state of preservation
-205 to - 222	I-Q	Matrix well layered; preservation good; specimens usually darker colored, with more organic material than in units B - M. Lower boundary distinct.
-222 to - 239	I-R	Preservation slightly poorer than in units N, O, P, Q; partially turbulent sedimentation (in layer of 2 - 4 cm thickness); lower boundary distinct but uneven (variation within 6 cm).
-239 to - 257	I-S	Leaf preservation relatively good (imprints stained, with some organic material), but leaves are often fragmented; mostly turbulent sedimentation; lower boundary not distinct.
-257 to - 275	I-T	Leaf preservation relatively good, but leaves never flat; sedimentation lamina up to about 5 mm thick; lower boundary not distinct.
-275 to - 293	I-U	Preservation poorer than in unit T; leaves never flat; sedimentation lamina up to about 5 mm thick; lower boundary not distinct.

[1] Stratigraphic collection at Site II (see Methods)

[2] Stratigraphic collection in Pit 1 at Site I

Palynomorphs

Sediment samples were taken at Site I (nine samples: diatomite, -40, -70, -100, -130, -160, -190, -220 and -270 cm) and Site II (one sample). Samples were decalcified in 10% HCl, demineralized in 50% HF, and mounted in silicon oil.

Diatoms

Samples were taken at Site I at +10 cm, -300 cm, and -500 cm (see physical stratigraphy in Table 1). They were decalcified in 10% HCl, soaked in H_2O, loosened up by repeated freezing and thawing, and mounted in Meltmount 1.662. Most identification was done using a light microscope and modern diatom forms as references. A second set of samples was examined by K. Krammer, Meerbusch, Germany, and four *Cymbella* forms were described as new species (Krammer, 2002).

Varves

Sediment slabs were cut out, air dried, ground fine, and impregnated with epoxy resin for differential staining of clastic deposits and chemical precipitates (calcium carbonate?). Peels were made with clear Scotch tape from unimpregnated sediment slabs, which were examined for easily recognizable diatom species. Sediments were considered varved (seasonally deposited) if deposition was flat (not rippled) within an area of at least one square foot and if occurrence of diatom-rich layers was consistently intercalated with clastic deposits and chemical precipitates (fossil units II-B and lowest part of diatomite at Site I; Table 1).

SYSTEMATICS OF PLANT REMAINS

It is beyond the scope of this study to give a complete taxonomic revision of Pickett Creek species. Citations at the beginning of some of the following paragraphs give the main sources on which we relied in our assignments. No complete list of synonyms was attempted. For general descriptive terminology, we followed Dilcher (1974), and for special *Acer*-related terms we followed Wolfe and Tanai (1987). Taxonomic confidence levels and the number of specimens collected are given in Table 2.

We follow the practice of using "fossil" names for Miocene species even if they seem to be identical with extant species. Our main reason is that many fewer characters can be used to define fossil species than extant ones. The classification of modern *Salix*, for example, is to a large extent based on floral characteristics and traits of the leaf surface. Out of 176 morphological characters (G. Argus, pers. communication) only 19 can be found on well preserved fossil specimens. Plant organs like stems, leaves, flowers, and fruits are usually isolated in the fossil record and should only be combined for description with great caution. Accordance in the few available characteristics does not mean that the non-available characteristics correspond as well. Wolfe (1964) discussed the issue and promoted the use of modern names for fossil species if no difference between extant and fossil species can be found. His suggestion may have advantages for evolution research, but only after the issue has been addressed on a much larger scale, including revisions of major floras and critical Miocene and Pliocene species. A change to extant names at the present time would, in our opinion, only introduce ambiguities between old and new literature.

The Pickett Creek collection of 2000 specimens contains two new species, *Populus douglasae* and *Quercus oberlii*. Both species have very distinctive features that separate them from other taxa. Taxonomic confidence levels for family and genus are rated "good" (Table 2).

Fish, gastropod and insect fossils are not considered here. They may be subjects of future work and publication.

Family EQUISETACEAE
Equisetum sp.
Fig. 3A, B

Equisetum is represented by stems with one to several nodes. The stems are ~ 3-7 mm wide and show 12-14 longitudinal ridges on each side of the flattened stem. No sheaths or leaves have been preserved, but in some specimens up to 9 leaf scars are visible. Internodes are 28-65 mm long. The Pickett Creek material is similar to fossil *E. haguei* Knowlton and *E. wyomingense* Lesquereux in stem diameter and number of longitudinal ridges, but the few preserved characteristics do not allow an assignment to a fossil species. In fragmentary specimens without typical nodes, the assignment to *Equisetum* was based on a distinct thickness of the stem, not present in leaves of *Typha*, and on the widths of ridges, which are at least 2-3 times broader than cellular bands in *Typha* and most Poaceae species.

Family PINACEAE
Pinaceae remains
Fig. 3I

A well-preserved cone bract, 20 mm wide and 15 mm long, with a 7 mm long spike, shows characteristics that are common in *Abies. Pinus, Picea, Larix,* and probably also *Pseudotsuga* can be excluded. A needle-like structure, with 105 mm of its length preserved, 1.0 mm wide, with

TABLE 2 — List of megafossils from sites I and II. The two fossil sites are 230 m apart. Site I (the older deposit) and Site II are separated by 3.7 m of massive diatomite and 5.28 m of lacustrine sediments. Taxonomic confidence levels are subjective statements, indicating confidence in our taxonomic conclusions.

Species	Organs	Taxonomic confidence[1] Family/Genus/Species	Site I			Site II		
			Random collection: no. of specimens	Stratigraphic collection: no. of specimens	Stratigraphic collection: % of total specimens	Random collection: no. of specimens	Stratigraphic collection: no. of specimens	Stratigraphic collection: % of total specimens
Equisetum sp.	Stems	Excel./Excel./N.A.	8	78	4.8	1	—	—
Pinaceae remains	Fruit Leaves	Good/N.A./N.A.	1	2	0.12	—	—	6.98
Typha sp.	Leaves	Good/Good/ N.A.	1	5	0.31	—	—	—
Poaceae sp.	Stems Leaves	Good/N.A./N.A.	5	9	0.55	—	—	—
Populus bonhamii	Leaves	Excel./ Excel./Good	10	11	0.68	—	1	2.33
cf. *Populus crassa*	Leaves	Excel./ Doubt./Doubt.	—	—	—	2	3	6.98
Populus douglasae	Leaves	Good/Good/N.A.	6	15	0.92	2	—	—
Populus eotremuloides	Leaves	Excel./Excel./Good	2	2	0.12	—	3	6.98
Populus lindgreni	Leaves	Excel./Excel./Doubt.	—	—	—	1	1	2.33
Populus washoensis	Leaves	Excel./Excel./Excel.	1	4	0.25	1	—	—
Salix churchillensis	Leaves	Excel./Excel./Excel.	4	4	0.25	—	—	—
Salix desatoyana	Leaves	Excel./Excel./Excel.	—	7	0.43	—	—	—
Salix inquirenda	Leaves	Excel./Excel./Excel.	9	25	1.5	1	5	11.63
Salix succorensis	Leaves	Excel./Excel./Excel.	17	47	2.9	3	3	6.98
Salix wildcatensis	Leaves	Excel./Excel./Excel.	1	8	0.49	—	—	—
Salix sp. ?²	Leaves	Excel./Good/N.A.	6	36	2.2	2	6	13.95
Salix sp.	Catkins	Excel./Excel./N.A.	1	1	0.06	—	—	—
Salix sp.	Stipule	Excel./Excel./N.A.	—	1	—	—	—	—

Table 2 (continued)

Taxon	Organ	Preservation						
Betula sp.?	Leaves	Good/Doubt./N.A.	1	2	0.12	—	—	—
Ostrya oregoniana	Leaves	Excel./Excel./Excel.	17	31	1.90	—	—	—
Ostrya oregoniana	Fruits	Excel./Excel./Excel.	4	9	0.55	2	1	2.33
Juglandaceae sp.	Fruits	Excel./N.A./N.A.	2	2	0.12	—	—	—
Juglans browniana	Leaves	Excel./Excel./Excel.	1	—	—	—	—	—
Pterocarya mixta	Leaves	Excel./Excel./Good	7	11	0.68	—	—	—
Pterocarya sp.	Fruit	Excel./Excel./N.A.	1	—	—	—	—	—
Carya sp. ?	Leaf	Good/Doubt./N.A.	—	1	0.06	1	—	—
Quercus bockéei	Leaves	Good/Good/Good	2	1	0.06	2	—	—
Quercus columbiana	Leaves	Excel./Excel./Excel.	24	150	9.2	—	5	11.63
Quercus hannibali	Leaves	Excel./Excel./Excel.	11	28	1.7	3	1	2.33
Quercus oberlii	Leaves	Good/Good/N.A.	4	10	0.61	1	—	—
Quercus prelobata	Leaves	Excel./Excel./Excel.	21	811	49.8	—	2	4.65
Quercus sp.	Fruits Catkins	Excel./N.A./N.A.	3	1	0.06	2	—	—
Quercus simulata	Leaves	Excel./Good/Good	20	70	4.3	—	1	2.33
Ulmaceae sp.	Leaves	Excel./Good/N.A.	6	8	0.49	1	—	—
Zelkova brownii	Leaves	Excel./Good/Good	—	3	0.18	—	—	—
Ceratophyllum sp..	Plants	Excel./Excel./Good	—	—	—	1	—	—
Mahonia macginitiei	Leaves	Excel./Excel./Excel.	4	—	—	—	—	—
Lyonothamnus cf. parvifolius	Leaves	Good/Good/Good	1	4	0.25	—	—	—
Amelanchier magnifolia	Leaves	Excel./Excel./Excel.	9	11	0.68	—	1	2.33
cf. Apios americana	Leaf	Excel./Good/N.A.	1	—	—	—	—	—
Cladrastis sp.?	Leaves	Excel./Good/N.A.	7	14	0.86	—	1	2.33
Robinia sp.?	Leaves	Excel./Good/N.A.	13	41	2.5	—	—	—

TABLE 2 (continued) — List of megafossils from sites I and II. The two fossil sites are 230 m apart. Site I (the older deposit) and Site II are separated by 3.7 m of massive diatomite and 5.28 m of lacustrine sediments. Taxonomic confidence levels are subjective statements, indicating confidence in our taxonomic conclusions.

Species	Organs	Taxonomic confidence[1] Family/Genus/Species	Site I			Site II		
			Random collection: no. of specimens	Stratigraphic collection: no. of specimens	Stratigraphic collection: % of total specimens	Random collection: no. of specimens	Stratigraphic collection: no. of specimens	Stratigraphic collection: % of total specimens
Sophoreae sp.? (Form A)	Leaves	Excel./Doubt./N.A.	3	5	0.31	—	—	—
Sophoreae sp.? (Form B)	Leaves	Excel./Doubt./N.A.	2	3	0.18	—	—	—
Sophora sp.? (Form C)	Leaves	Excel./Doubt./N.A.	3	3	0.18	1	—	—
Fabaceae sp. [2]	Leaves	Good/N.A./N.A.	2	28	1.7	—	1	2.33
Fabaceae sp.	Fruits	Excel./N.A./N.A.	2	—	—	—	—	—
Acer busamarum	Leaves	Excel./Excel./Good	1	1	0.06	—	—	—
Acer chaneyi	Leaves	Excel./Excel./Good	3	8	0.49	—	—	—
Acer chaneyi	Fruit	Excel./Excel./Good	—	—	—	—	1	2.33
Acer latahense	Leaves	Excel./Excel./Excel.	10	16	0.98	—	—	—
Acer latahense	Fruits	Excel./Excel./Good	3	3	0.18	—	—	—
Acer cf. macrophyllum	Leaves	Excel./Excel./Excel.	5	44	2.7	2	2	4.65
Acer cf. macrophyllum	Fruits	Excel./Excel./Excel.	1	3	0.18	—	—	—
Acer scottiae	Leaves	Excel./Excel./Excel.	5	10	0.61	—	—	—
Acer scottiae	Fruits	Excel./Excel./Good	1	2	0.12	—	—	—
Acer remains	Leaves Fruits	Excel./Excel./N.A.	1	11	0.68	—	—	—
Fraxinus coulteri	Fruits	Excel./Excel./Good	1	2	0.12	—	—	—
Fraxinus dayana	Fruits	Excel./Excel./Excel.	1	4	0.25	—	—	—
Parthenocissus sp.	Leaf	Good/Good/N.A.	1	—	—	—	—	—

Table 2 (continued)

Tilia sp. (seed bracts)	Excel./Excel./N.A.	1	—	—	—	—	—
Unassigned, but potentially assignable leaf remains, approx. 11 forms	N.A./N.A./N.A.	3	16	0.98	1	5	11.63
Fish: [3]							
Centrarchidae, Archoplites near *clarki*		1	1	0.06	—	—	—
Cyprinidae sp.		2	—	—	—	—	—
Catostomus (*Pantosteus ?*) sp.		1	—	—	—	—	—
Undet. fish specimens		1	—	—	—	—	—
Undet. fish bones and scales		—	3	0.18	—	—	—
Gastropods:							
Operculae (various species ?)		3	1	0.06	—	—	—
Shells ?		1	—	—	—	—	—
Insects:							
Species 1 (not assigned)		1	—	—	—	—	—
Species 2 (not assigned)		—	1	0.06	—	—	—
Species 3 (not assigned)		1	—	—	—	—	—
Species 4 (not assigned)		—	—	—	1	—	—
Total:							
Potentially determinable megafossils		291	1628	100%	30	43	100%
Undeterminable debris			1141			36	

[1] For definition see introductory text to Flora and Faunal List – Megafossils

[2] Collective categories of potentially several undetermined species
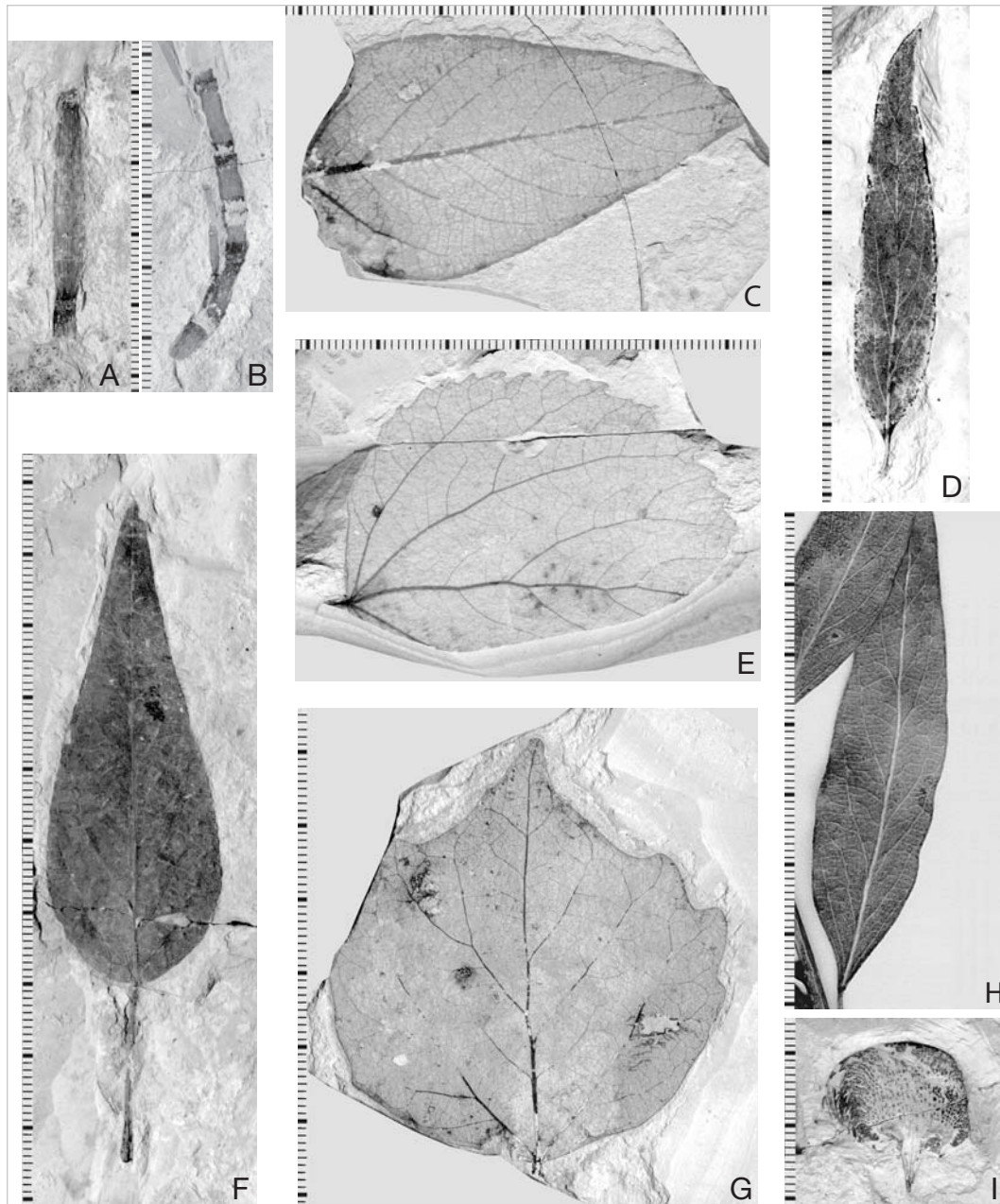
[3] Fish remains may be treated independently

FIG. 3 — A, *Equisetum* sp. (UM 73712, I-A114). B, *Equisetum* sp. (UM 73713, I-S5). C, *Populus eotremuloides* Knowlton (UM 73721, II-B26). D, *Populus douglasae*, new species (UM 73720, I-A322, holotype). E, *Populus lindgreni* Knowlton (UM 73715, II-A9). F, *Populus bonhami* Axelrod (UM 73717, I-A192). G, *Populus washoensis* Brown (UM 73718, II-A28). H, *Populus euphratica* Oliv. (herbarium specimen). I, Pinaceae cone bract (UM 73719, I-U5). Scales are in cm (subdivided into mm). All images approximately natural size.

an entire margin, stomatal lines not clearly recognizable, may represent a *Pinus* needle. A loose bunch of needles, 1.5 mm wide, up to 20 mm long, with a distinct keel, is clearly conifer, possibly belonging to an *Abies* species.

Family TYPHACEAE
Typha sp.

Assignment to this genus is mainly based on a thin leaf-like structure and absence of a midrib (if both margins are preserved). Distinction from genera of the Poaceae was sometimes difficult or impossible.

Family POACEAE

This category includes both stems and leaves. In one specimen, the typical sequence of stem, node, sheath, and broadened base of the lamina is preserved. Distincion from *Typha* is sometimes doubtful and is mainly based on the smaller width of Poaceae leaves. This group of specimens probably contains several genera.

Family SALICACEAE
Populus bonhamii Axelrod
Fig. 3F

Populus bonhamii Axelrod, 1985, p. 127: pl. 5, figs. 4-6; pl. 6, fig. 1; pl. 20, figs. 1, 4, 7.

Leaf blades are 4.4-10.5 cm long and 1.4-5.0 cm wide, with a mean length-to-width ratio of 2.3. Five to 12 pairs of secondary veins diverge at about 45º from the midrib. Well-preserved specimens show a margin with closely-spaced, small, crenate teeth. In the few complete specimens, the length of the petiole is ~ 50% of the length of the leaf blade, or ~ 2-5 cm. The Pickett Creek material corresponds well with Axelrod's description and his illustations (Axelrod, 1985). Fields (1996) pointed out that *Populus payettensis* (Knowlton) Axelrod and *P. bonhamii* are difficult to distinguish and need a thorough revision. We assigned our specimens to *P. bonhamii* because in Knowlton's specimens (for *Rhus payettensis*, in Knowlton, 1898), the leaf base is less rounded, and the proximal pair of secondaries is weaker and shorter than in our collection.

Cf. *Populus crassa* (Lesquereux) Cockerell
Fig. 4A, C

Populus crassa MacGinitie, 1953, p. 93, pl. 22, fig. 3; pl.23, Fig.4.

Populus crassa was originally based on calyces from Eocene Florissant beds and was first described as *Macreightia crassa* Lesquereux (1883, p. 175). Cockerell (1908, p. 83) assigned calyces to *Populus* , noting that "they should doubtless be associated with some of the fossil leaves, but until they are found connected, such association with any particular species can hardly be made". MacGinitie (1953) synonymized leaves of several Florissant species under the name *P. crassa* (Lesquereux) Cockerell and gave a detailed description of leaves, and two images, which, at first sight, correspond with the Pickett Creek specimens. We hesitate, however, to assign our leaves formally to *P. crassa* for the following reasons: (1) *Populus crassa* has, as far as we know, only twice been reported from other localities and geological periods than Eocene Florissant. Both
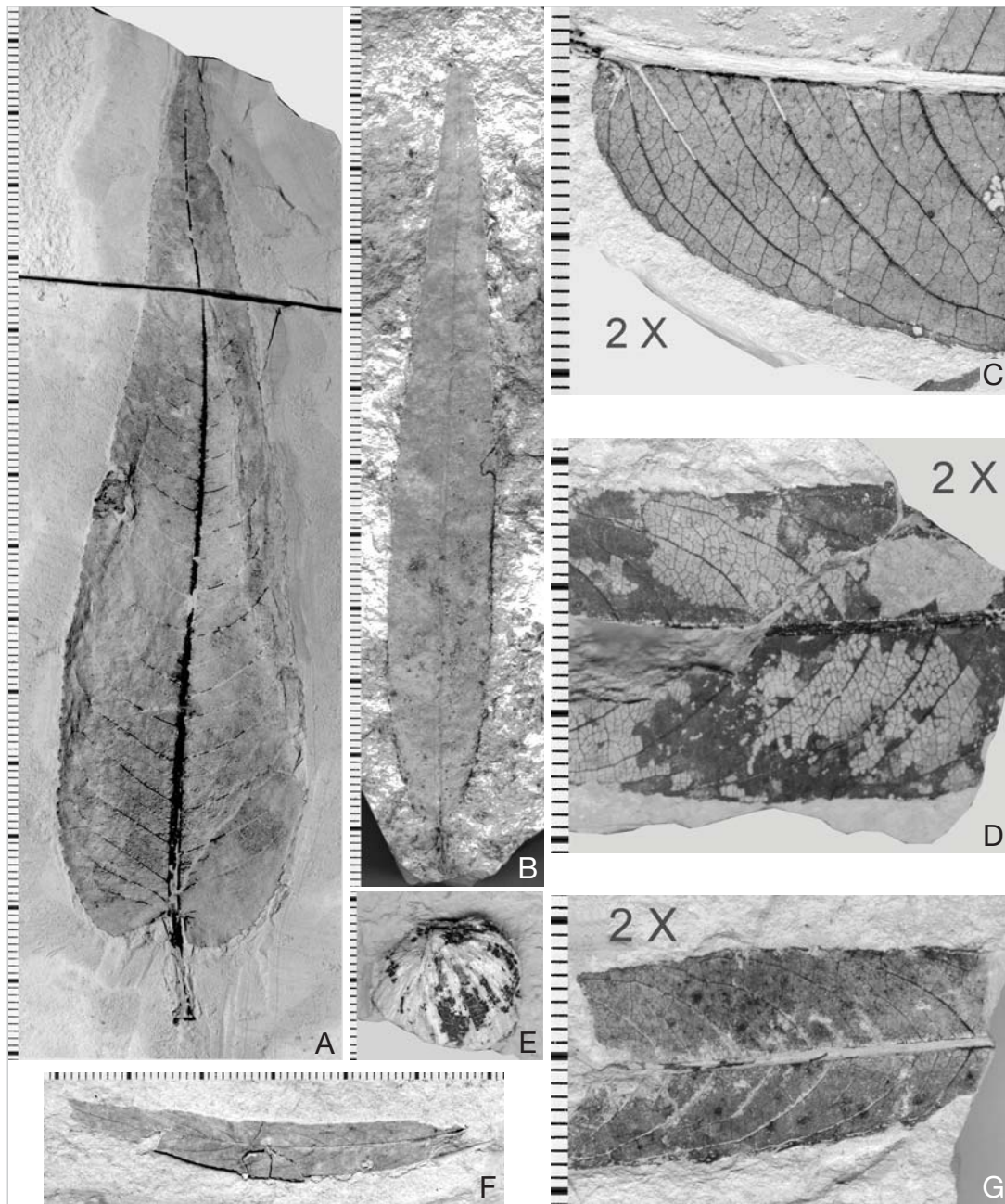
FIG. 4 — A, cf. *Populus crassa* (Lesquereux) Cockerell (UM 73716, II-B19). B, *Salix succorensis* Chaney and Axelrd (UM 73722, I-A131a). C, cf. *Populus crassa* (Lesquereux) Cockerell (UM 73714, II-B30). D, *Salix inquirenda* Knowlton (UM 73725, I-A296). E, Juglandaceae nut (UM 73730, I-P19). F, *Salix churchillensis* Axelrod (UM 73726, I-A128). G, *Salix succorensis* Chaney and Axelrod (UM 73727, I-A133a). Scales are in cm (subdivided into mm). Unless otherwise indicated images are approximately natural size.

publications, one concerning the late Miocene Kilgore Flora (MacGinitie, 1962), and the other concerning the Pliocene Creede Flora (Knowlton, 1923), do not convincingly confirm the similarity of their specimens with the Eocene fossils. A close relationship of the Florissant specimens with our leaves seems therefore unlikely. (2) The absence of an elongated first pair of secondaries in our material makes an assignment to *Populus crassa* less evident.

The Pickett Creek specimens do, however, also have the following characteristics indicative of *Populus* (counter-indicative of *Salix*): (1) auriculate leaf bases are more common in *Populus*, although they may occur on replacing shoots of mechanically injured willows; and (2) ovate-lanceolate leaves with the widest part in the proximal quarter of the leaf blade are more common in *Populus* than in *Salix*. In the fragmentary specimens the demarcation between *Salix inquirenda* and cf. *Populus crassa* was mainly based on the distinctly larger width of the latter. To facilitate future revisions of this taxon, we give a full description for the Pickett Creek specimens, based on one complete leaf and four fragmentary specimens from Site II.

Description.—Leaf ovate-lanceolate, length 12.7 cm, width 3.5-4.0 cm; widest part at 0.2 of the full length from base; margin regularly crenate-serrate over whole length of leaf; apex attenuate; petiole 2 mm wide (base 3 mm), 1.5 cm long; base rounded to cordate or auriculate; midrib 1.3 mm wide near base; about 23 pairs of opposite to alternate secondaries, originating at varying angles between 50° and 90°; curving upward, branching, and looping near margin; in leaves with cordate to auriculate bases the lowest 2-3 pairs of secondaries originate at a common point, forming a palmate arrangement; numerous intersecondaries; tertiary venation reticulate, connecting between secondaries and intersecondaries; areolation a fine, polygonal mesh; texture coriaceous; leaf remains usually well stained.

Populus douglasae, new species
Fig. 3D, H

Holotype.—UM 73720, I-A322, University of Michigan Museum of Paleontology, Ann Arbor.

Diagnosis.—Leaves of this species are characterized by an usually lanceolate form combined with a decurrent transition into the petiole and low departure angles of the secondary veins.

Description.—Leaves lanceolate to very narrow elliptic; 2.8-8.5 cm long and 0.6-1.4 cm wide; apex acute to attenuate, base acute (normal), the lower part decurrent into petiole; midrib stout; petiole about 10% of leaf blade; venation camptodromous, with about 10 secondaries on each side of midvein, diverging at close to 0°, then bending outward and continuing irregularly at angles between 10-30°, branching occasionally and connecting to higher and lower secondaries; tertiary mesh irregularly polygonal, not well preserved; margin entire; texture chartaceous, but leaf blade usually well stained.

Discussion.—Similar leaves are found on juvenile, shrub-like growing plants and on root suckers of modern *Populus euphratica* Oliv. (subgenus *Turanga* Dode, Ascherson and Graebner, 1913). Unlike *P. douglasae*, older, tree-like growing individuals of that species exhibit a wide spectrum of forms from lanceolate-untoothed to wide obovate and coarsely toothed. Some wider leaves distantly resemble fossil *P. washoensis* Brown and modern *P. grandidentata* Michaux. In *P. euphratica* as well as in *P. washoensis* and *P. grandidentata*, tips of the lobe-like teeth carry no distinctive glands. Because many modern *Populus* species are highly heterophyllous, it is possible that *P. douglasae* is a lancelolate leaf form of *P. washoensis*, a species also present at Miocene Pickett Creek.

Fossil *Populus payettensis* (Knowlton) Axelrod differs from *P. douglasae* in a toothed margin and in usually much wider leaves. McGinitie (1933) published a leaf under the name *Phyllitis oregonianus* Knowlton with a secondary venation similar to *P. douglasae*, but the leaf is elliptical and the margin is distinctly toothed. The type of *P. oregonianus* (Knowlton, 1902) has an entire margin, but its secondary venation resembles that of a *Cornus* leaf (Knowlton, 1902).

Other genera like *Salix* (section *Longifoliae*), *Ligustrum* and *Forestiera* (Oleaceae), *Myrica* (Ericaceae) may have similarly acute decurrent leaf bases, but they do not exhibit low diverging angles of secondary veins.

This species is named for the first author's spouse Dorothy A. Douglas, botanist and professor at Boise State University, honoring her great support during this project.

Populus eotremuloides Knowlton (sensu lato)
Fig. 3C

Populus eotremuloides Knowlton, 1898, p. 725: pl. 100, figs. 1, 2; pl. 101, figs. 1, 2.
Populus alexanderi Dorf, 1930, p. 75: pl. 6, figs. 10, 11; pl. 7, figs 2, 3.
Populus trichocarpa Torrey and Gray. Wolfe, 1964, p. N18: pl. 8, figs 3, 11, 12.

This group includes specimens with a wide range of sizes and shapes that best match those of modern *P. trichocarpa.* We follow Wolfe (1964) and unite *P. eotremuloides* Knowlton with most of *P. alexanderi* Dorf*,* but prefer, for reasons mentioned earlier, not to use the name of an extant species (*P. trichocarpa*). *Populus trichocarpa* may be separated from *P. bonhamii* by the shape of the apex. While leaves of *P. eotremuloides* have an acute apex (see Fig. 3C), those of *P. bonhamii* are acuminate.

Populus lindgreni Knowlton (?)
Fig. 3E

Populus lindgreni Knowlton, 1898, p. 725: pl. 100, fig. 3.
Populus lindgreni, Chaney and Axelrod, 1959, p. 151: pl. 17, fig. 1-3.
Populus voyana Chaney and Axelrod, 1959, p. 152: pl. 18, fig. 1, 3, 4.

Only two partially preserved specimens of this species have been found at site II. Knowlton's specimens from the Payette Formation (Knowlton, 1898) were later split into *P. lindgreni* and the new species *P. voyana* by Chaney and Axelrod (1959) on the basis of differences in petiole and midrib thickness, and minor deviations in leaf shape and tooth size. These differences may, in our opinion, potentially be explained by natural variability and differences in preservation. Our scarce material does not allow us to clearly distinguish between the two species. We tentatively assigned our specimens to *P. lindgreni* because the name would have priority if the validity of the name *P. voyana* was challenged. A thorough revision of *P. lindgreni* is outside the scope of this publication.

Populus washoensis Brown
Fig. 3G

Populus washoensis Brown, 1937b, p. 516.
Populus washoensis Wolfe, 1964, p. N18: pl. 7, fig. 6, 7.

Some large-toothed *Populus* leaves resemble extant *P. grandidentata* Michaux. Similar to *P. grandidentata*, the tips of the teeth are rounded (like the lobes in *Quercus columbiana*) and carry no glands. Despite some variation in shape and number of teeth, they best match specimens of fossil *Populus washoensis* Brown shown in Wolfe (1964).

Salix churchillensis Axelrod
Fig. 4F

Salix churchillensis Axelrod, 1991, p. 42: pl. 6, fig. 4-7.

Complete specimens are 4.5-6.5 cm long and 0.6-1.0 cm wide. All specimens have, as far as preserved, an entire margin.

Salix desatoyana Axelrod
Fig. 5D

Salix desatoyana Axelrod, 1985, p. 133: pl. 22, fig. 2, 6, 7.

The specimen in Fig. 5D is 9.5 cm long and 0.75 cm wide. At least some marginal teeth are preserved in every specimen. Some of the more poorly-preserved and fractured leaves may not be distinguished from *Salix truckeana* Chaney.

Salix inquirenda Knowlton
Figs. 4D, 5C

Salix inquirenda Knowlton, 1926, p. 32: pl. 11, fig. 1, 2.

Leaves of *Salix inquirenda* Knowlton are characterized by their comparatively large size, a rounded leaf base and, most of all, their venation. Secondary veins leave the midvein at 70-80°, then bend continuously upward and run along the margin for a distance equal to at least half the greatest width of the leaf. Such a combination is rare in modern *Salix*. *Salix inquirenda* has long been confused with *S. hesperia* (Knowlton) Condit. Axelrod (1992) noted that leaves of *Salix hesperia* (first described as *Juglans hesperia* Knowlton, 1898) are broader than those of *S. inquirenda*. They have a cordate base, not an acute or rounded one. The apex is acute, not acuminate as in *S. inquirenda,* and secondaries diverge at a higher angle in *S. hesperia*. The Pickett Creek leaves have a length-to-width ratio between 4.0 and 6.25. They are therefore narrower than Knowlton's *Juglans hesperia* (l:w = 2.8) and Condit's *S. hesperia* (l:w = 2.3), and closer to Knowlton's *S. inquirenda* (l:w = 5.8). Some leaves of *S. hesperia* are indistinguishable from leaves of modern *S. floridana* Chapman, a species growing in *Taxodium* and *Chamaecyparis* swamp forests of Florida and Georgia. *Salix inquirenda* was probably a riparian species similar to modern *S. bonplandiana* Kunth, *S. laevigata* Bebb, and *S. carolinensis* Michaux of section Humboldtianae. Literature and specimens of the *S. hesperia - inquirenda* complex should be reviewed and the two species more clearly separated.

The large number of specimens found (Table 2) indicates that *S. inquirenda* must have been a common tree along the lake shoreline and the riverbanks. In specimens where both base and tip of the leaf are missing, the demarcation between *S. inquirenda* and *S. succorensis* is mainly based on leaf width. This may have led to a miscount of ~ 5 % of the combined specimens of both species.

Salix succorensis Chaney and Axelrod
Fig. 4B, G

Salix inquirenda Smith, 1939, p. 111: pl. 6, fig. 3.
Salix succorensis Chaney and Axelrod, 1959, p. 154: pl. 16, fig. 8.

The well-preserved complete leaves are 80-135 mm long, 11-19 mm wide, with a length to width ratio of 7-8.5. The widest part is in the basal third or half of the lamina. Most specimen margins show fine, regular serrations. The leaf base is cuneate and the apex slenderly acuminate (more so than in *S. inquirenda*). Some of the incomplete or poorly-preserved specimens may belong to other *Salix* species and may have been wrongly summarized here as *S. succorensis*. The problem of demarcation between *S. succorensis* and *S. inquirenda* is addressed under the latter species. Leaves of this type comprise 2.8% of all leaves in the stratigraphic collection of Site I. They are the most abundant form among the willows of Pickett Creek.
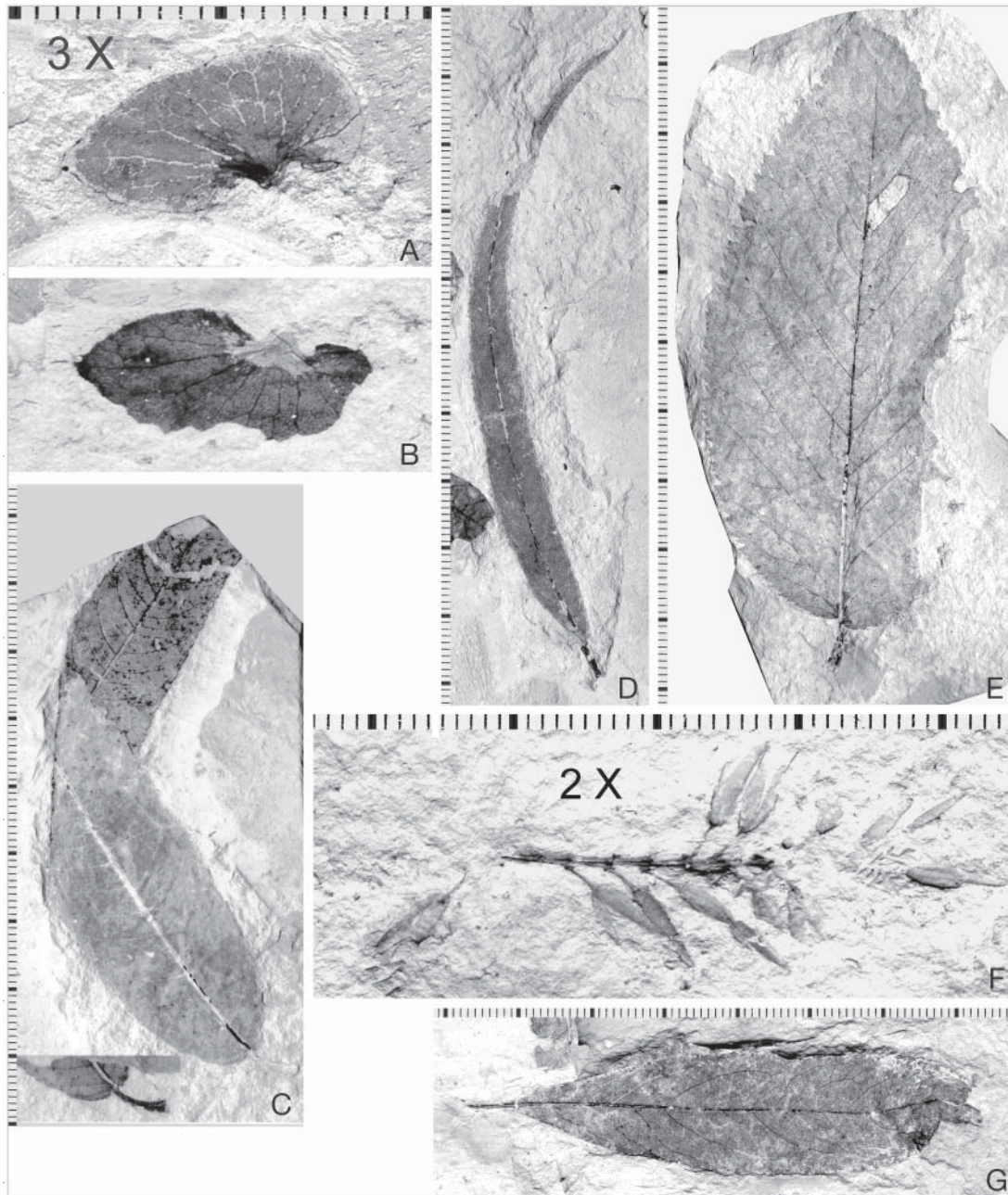
FIG. 5 — A, *Salix* sp. stipule (UM 73731, I-NO2-1a). B, *Salix* sp. stipule (UM 73732, I-NO2-1b, counterpart). C, S*alix inquirenda* Knowlton (UM 73724, I-A46, insert shows mirrored counterpart of leaf base). D, *Salix desatoyana* Axelrod (UM 73723, I-O3). E, *Ostrya oregoniana* Chaney (UM 73735, I-N2-32). F, *Salix* sp. female catkin (UM 73728, I-A186a). G, *Salix wildcatensis* Axelrod (UM 73729, I-A52a). Scales are in cm (subdivided into mm). Unless otherwise indicated images are approximately natural size.

Salix wildcatensis Axelrod
Fig. 5G

Salix coalingensis Dorf, 1930, p. 78: pl. 7, fig. 5 only.
Salix coalingensis Axelrod, 1938, p. 170, 171; pl. 4, fig. 8.
Salix wildcatensis Axelrod, 1944, p. 132.

Leaves of this type were first described by Dorf (1930, p. 78-79) under the name *S. coalingensis*. Axelrod (1944, p. 132) showed that all except one of Dorf's specimens belonged either to *Persea* or *Salix hesperia*. The remaining specimen was, without a formal description, given the new name *Salix wildcatensis*. As Axelrod (1944) noted, these leaves are similar to those of modern *Salix lasiolepis* Bentham.

Salix sp. (?)

In this category we summarized predominantly poorly-preserved parts of small, "willow-like" leaves in which identifying traits (e.g., status of the margin and of secondary veins) were missing.

Salix sp.
Fig. 5F

Parts of two female *Salix* catkins and a single *Salix* capsule were found at Site I. In specimen UM 73728 (I-A186a), the preserved part of the axis is 55 mm long. The pedicels are thin, about 2 mm long. The carpels are 5-6 mm long, open, only slightly bent, with no seeds present. At the base of some pedicels two nectaries are visible, with the longer one on the adaxial side about 0.3 mm long and the abaxial nectary significantly shorter. In the modern genus *Salix,* few species have female catkins with two nectaries per capsule. Skvortsov (1999) and others consider modern species with two or more nectaries per flower, or with a lobed discus, as phylogenetically old or retarded. Extant species with two nectaries in female plants are *S. fragilis* from Europe (subgenus *Salix,* section *Salix*) and *S. pentandra* L. from Europe and, in some plants, *S. lucida* Muhlenberg from North America (both subgenus *Salix*, section *Salicaster*; Neumann, 1981, p. 51, and Argus, 1997, p. 55). Some high mountain or arctic members of subgenus *Chamaetia* also have two nectaries, but they are not considered here. Among the *Salix* species from Pickett Creek, S. *succorensis* and *S. inquirenda* are the most likely to have produced these catkins.

Salix sp.
Fig. 5A, B

A very large, single *Salix* stipule was found at Site I. Its dimensions (5 × 13 mm) suggest that it belongs to a large-leafed species, most likely *S. inquirenda*. Modern *S. lasiandra* Bentham, as an example, may produce stipules of that form and size on fast-growing, long shoots.

Family BETULACEAE
Betula sp.?

Three poorly-preserved, incomplete leaves from Site I differ sufficiently from *Ostrya* leaves to be put in a separate category. They are more widely ovate, with an almost truncate base. They

have larger, irregularly-sized teeth, and, where preserved, they have a more acuminate apex. Assignment to an established fossil species was not possible.

Ostrya oregoniana Chaney
Figs. 5E, 6D

Ostrya oregoniana Chaney, 1927, p. 106: pl. 9, fig. 12; pl. 10, fig. 1-4.
Ostrya oregoniana Chaney and Axelrod, 1959, p. 162: pl. 22, fig. 8-10; pl. 24, fig. 10-12.

Ostrya leaves and involucres were found in comparatively large numbers (Table 2). The better-preserved leaves resemble modern *Ostrya virginiana* (Miller) Koch very closely in size, shape, and serration of the margin. The Pickett Creek leaves average about 80 mm in length. This is consistent with the size of *O. virginiana*, but not with *O. knowltonii* Coville, which is generally distinctly smaller. Some of the involucres show the imprint of a nutlet with an ovate outline and an acute and apparently hairy tip. They correspond well with the shape and size of *Ostrya virginiana* fruits. Nutlets from herbarium specimens of *O. knowltonii* were wide elliptic in shape and seemed to be characteristicly different from those of *O. virginiana* and *O. oregoniana*. Contradictory statements about the shape of nutlets in two modern species (Sargent, 1965; Krüssmann, 1977, p. 356, 357), however, seem to diminish the diagnostic value of the nutlet shape.

Family JUGLANDACEAE
Fruits
Fig. 4E

Four specimens are most likely parts of juglandoid (*Carya* or *Juglans*) exocarps and nuts. The exocarps are strongly deformed; parts may have already been missing before fossilization. Specimen UM 73730 (see Fig. 4E) is a cast of a nut with a diameter of about 2.1 cm. The nut is missing in the other three specimens; nut diameter was estimated to be 2.5 cm for two of them, and 3.5 cm for the third.

Juglans browniana Chaney and Axelrod
Fig. 6A

Juglans browniana Chaney and Axelrod, 1959, p. 156: pl. 20.

Our single specimen corresponds well with the original description and some distal leaflets of the holotype of Chaney and Axelrod (1959). Our leaflet is 12.0 cm long and 3.0 cm wide. The widest part is at the basal third of the lamina. The petiolule is not preserved; the margin is sharply serrate.

Pterocarya mixta (Knowlton) Brown
Fig. 7A

Salix mixta Knowlton, 1902, p. 32: pl. 2, fig. 11, fig. 12 (leaflet on right only).
Pterocarya mixta Brown, 1937a, p. 170: pl. 47, fig. 2, 3.

Complete leaflets are 4.1-10.5 cm in length (average 7.3 cm) and 1.4-4.0 cm in width (average 2.5 cm). Comparison with herbarium material of several Asian *Pterocarya* species showed a good similarity in shape and size range of the Pickett Creek fossils with modern *Pterocarya stenoptera* DeCandolle from China. The fossil specimens did, however, have a distinctively higher density of secondary veins than most modern leaflets.
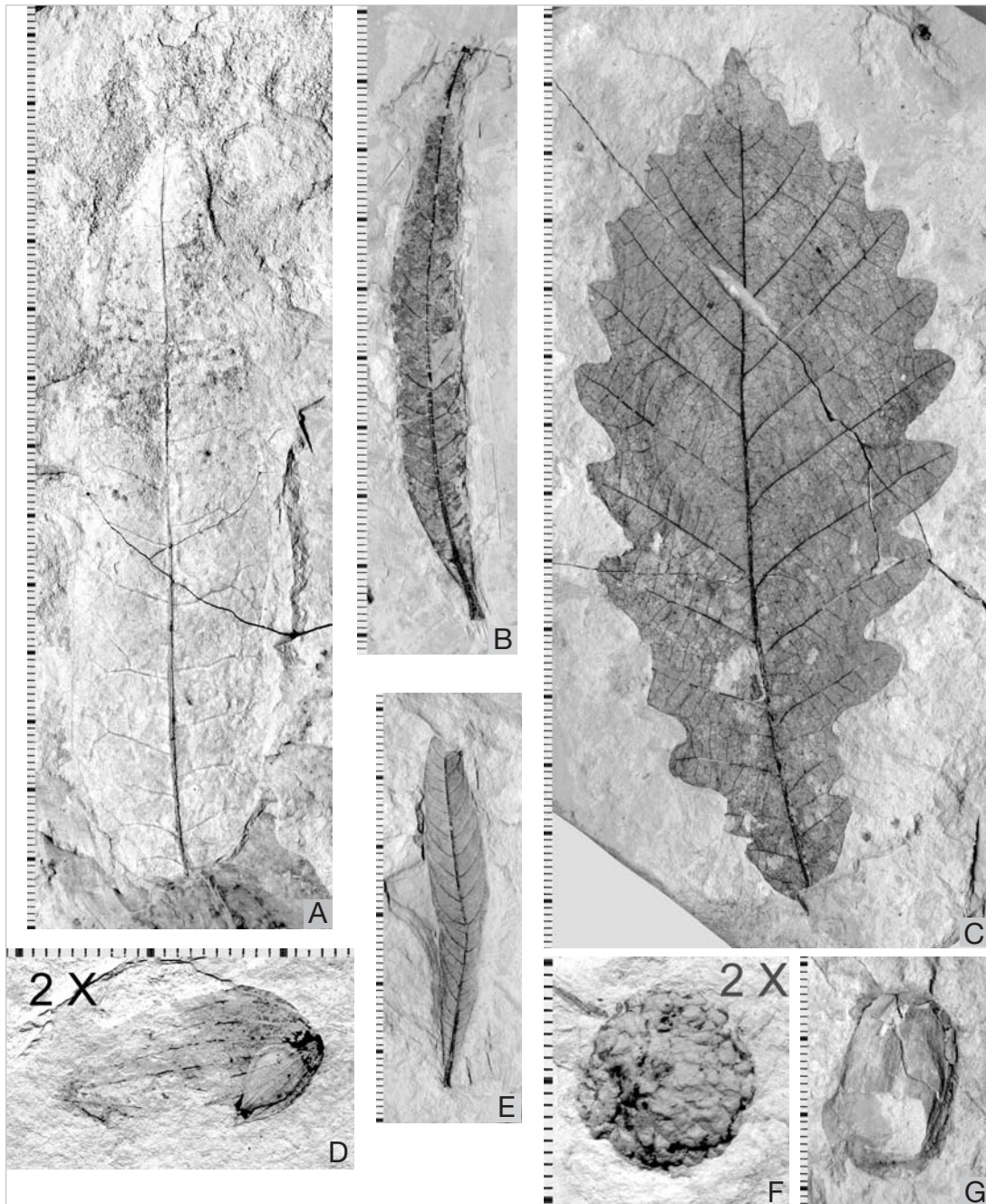
FIG. 6 — A, *Juglans browniana* Chaney and Axelrod (UM 73733, I-A108b). B, *Quercus oberlii*, new species (UM 73737, I-A227, holotype). C, *Quercus columbiana* Chaney (UM 73739, I-A62b). D, *Ostrya oregoniana* Chaney involucre (UM 7734, II-A24). E, *Quercus oberlii*, new species (UM 73738, I-A216a). F, *Quercus* cupule (UM 73742, I-A321). G, *Quercus* nut (UM 73741, I-A64). Scales are in cm (subdivided into mm). Unless otherwise indicated images are approximately natural size.

Pterocarya sp.
Fig. 7F

A single mold of a *Pterocarya* nutlet, with parts of the two wings attached to it, was found at Site I. The nutlet diameter was ~ 7.5 mm. Although it seems likely that this fruit belongs to the same species as the leaf specimens, we do not formally assign it to *Pterocarya mixta* because of the mold's insufficient details.

Carya sp. (?)

A single leaflet of average preservation, with the apex missing, seems to represent the terminal leaflet of a *Carya* leaf. It is elliptic, 2.8 cm wide, and about 8 cm long, with a cuneate base. It is regularly-toothed from the base up, with distinctly sharper teeth than those of *Pterocarya mixta*.

Family FAGACEAE
Quercus bockéei Dorf

Quercus bockéei Dorf, 1930, p. 84-86: pl. 8, fig. 8-11.

Four partially-preserved leaves correspond well with Dorf's description and specimens. Three of them clearly exceed the size range of *Quercus simulata* leaves from Pickett Creek and the range given in the original description (Knowlton, 1898). The largest is 4.6 cm wide and probably about 13 cm long. The leaves are narrowly obovate to oblanceolate and have an acute to obtuse base. No apex is preserved. The margin is entire in the proximal half of the blade and bears comparatively small, widely-spaced teeth in the distal half. Each tooth is fed by a secondary vein.

Quercus columbiana Chaney (sensu lato)
Fig. 6C

Quercus columbiana Chaney, 1920, p. 170: pl. 13, fig. 1, 2.
Quercus winstanleyi Chaney,1944, p. 342: pl. 60, fig. 1, 3-5; pl. 61, fig. 1, 2, 4; pl. 62, fig. 2.

Chaney (1944) noted that differences in shape and margin are not sufficiently constant to separate *Q. columbiana* from *Q. winstanleyi*, and that the two species can only be distinguished by their average length per location. An important part of these leaves can therefore not be assigned on the basis of individual measurements. Because the Pickett Creek specimens, with an average length of about 9 cm, come closer to *Q. columbiana* (8 cm) in this respect, and because the name *Q. columbiana* has priority in case of a unification, we synonymize the two species under the name *Q. columbiana* sensu lato. Similar extant species are *Q. prinus* L. of eastern U.S.A., and *Q. aliena* Blume, and *Q. fabri* Hance of eastern Asia (Chaney 1944). *Quercus columbiana* is the second most abundant species after *Q. prelobata*, comprising 9% of the stratigraphic collection of Site I. Its distinction from *Q. prelobata* is considered under the latter species. Most leaves in this category would also fit the description of Pliocene *Q. winstanleyi* Chaney.

Quercus hannibali Dorf
Fig. 8H

Quercus hannibali Dorf, 1930, p. 86: plate 8, fig. 8-11.
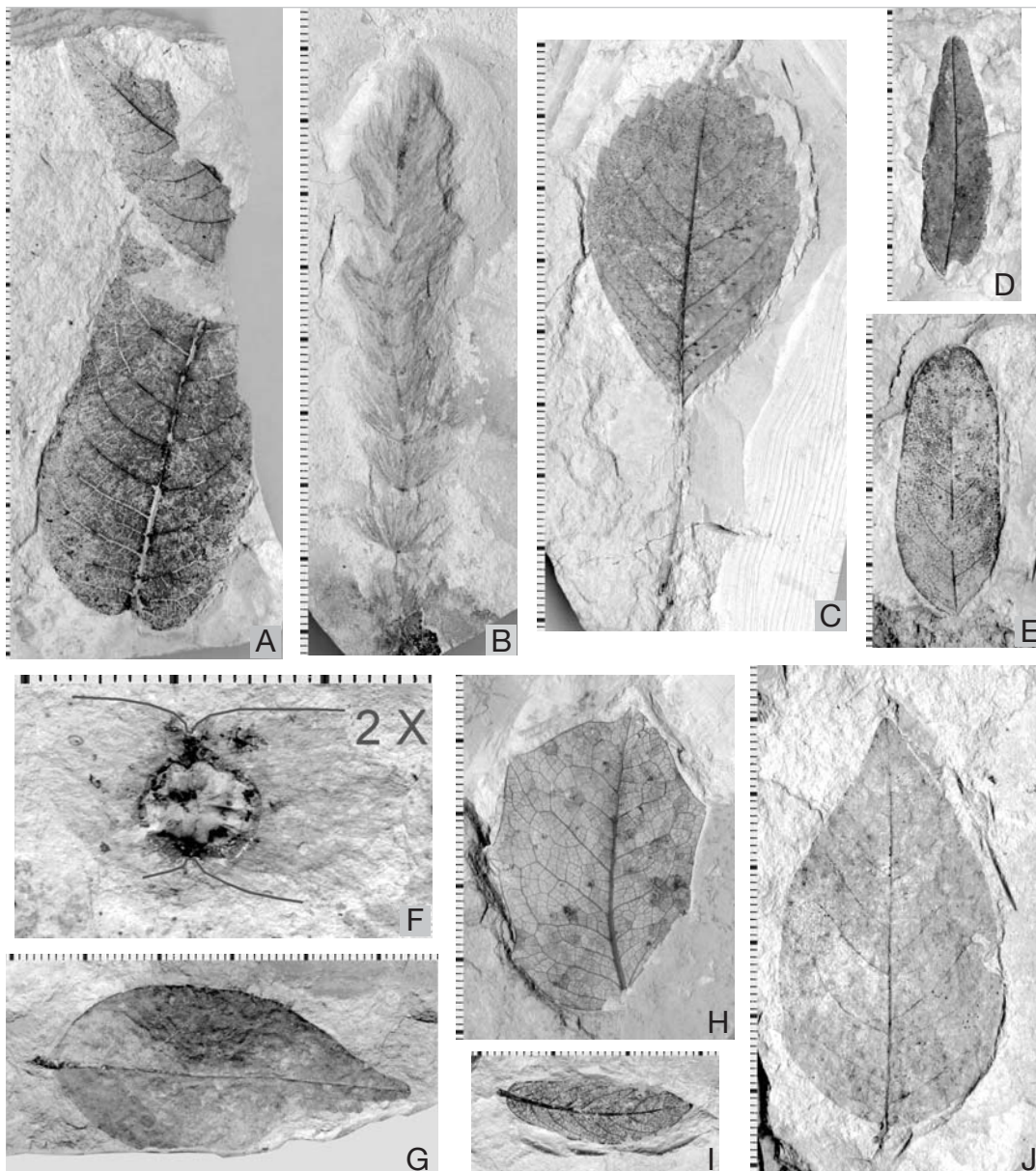*Quercus dayana* (in part) Knowlton, 1902, p. 51: plate VI, fig. 1.

FIG. 7 — A, *Pterocarya mixta* (Knowlton) Brown (UM 73745, I-N13a). B, *Ceratophyllum* cf. *demersum* L (UM 73750, II-A27). C, *Amelanchier magnifolia* Arnold, (UM 73753, I-A281). D, Sophoreae sp.? Form B (UM 73761, IA135). E, *Robinia* sp.? (UM 73756, I-A231a). F, *Pterocarya* sp. nutlet (UM 73746, I-A266, outline of wings traced). G, Sophoreae sp.? Form C (UM 73758, I-A120). H, *Mahonia macginitiei* Axelrod (UM 73751, I-A141). I, unassigned specimen (UM 73772, I-P11). J, *Cladrastis* sp. (UM 73755, I-A309). Scales are in cm (subdivided into mm). Unless otherwise indicated images are approximately natural size.
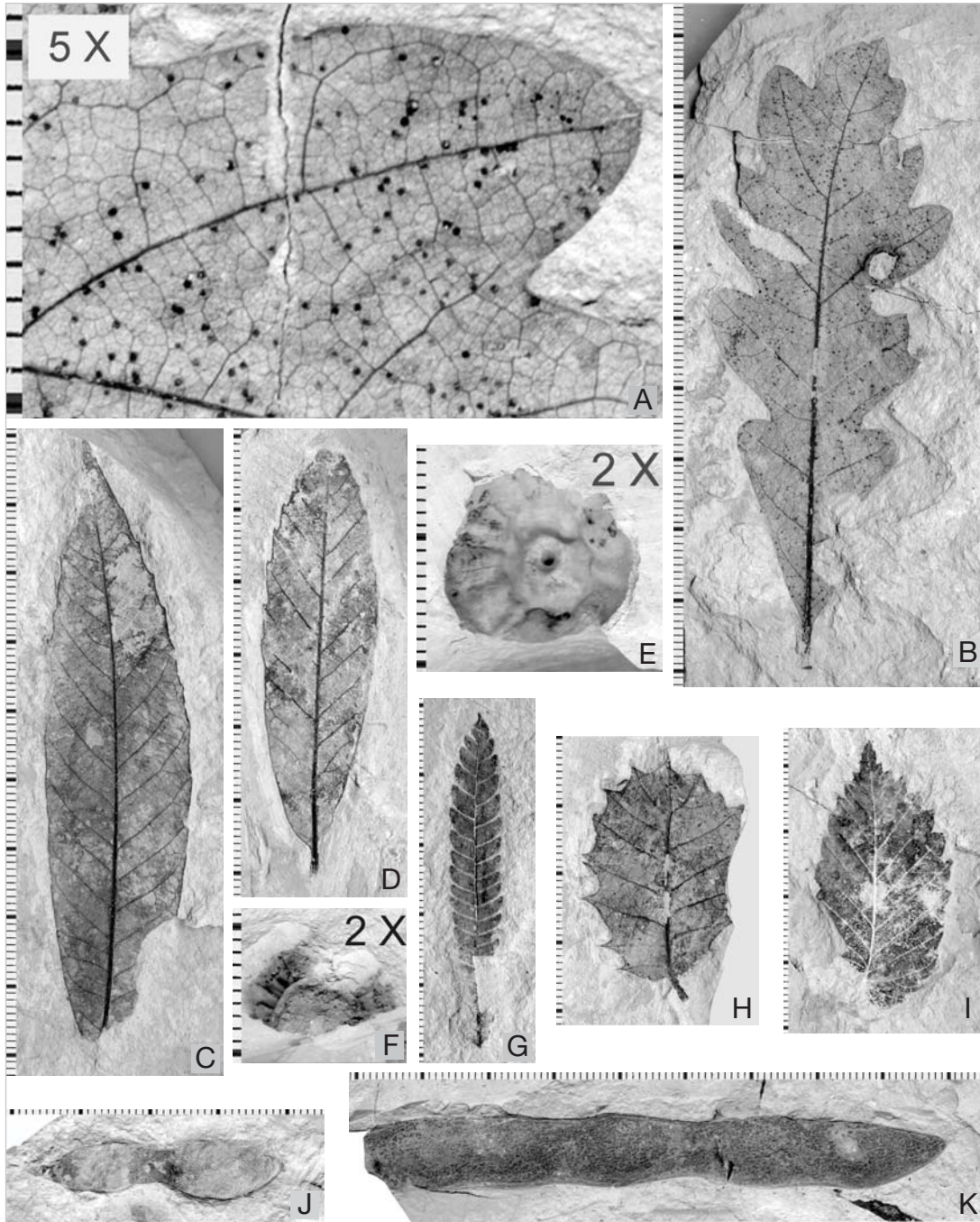
FIG. 8 — A, *Quercus prelobata* Condit, fungal spots (I-A61). B, *Quercus prelobata* Condit (I-A61). C, *Quercus simulata* Knowlton (UM 73743, I-NO2-3). D, *Quercus simulata* Knowlton (UM 73744, I-NO2-2). E, *Quercus* (*Lithocarpus*?) nut, mold of distal end (UM 73747, I-A320a). F, *Quercus* (*Lithocarpus*?) nut, mold of proximal end (UM 73748, I-A320b). G, *Lyonothamnus* cf. *parvifolius* (Axelrod) Wolfe

The Pickett Creek specimens cannot be distinguished from extant *Quercus crysolepis* Liebmann of California and southern Oregon. Both the fossil and the extant material show about the same broad range of forms and sizes. *Q. chrysolepis* often has leaves with entire margins and leaves with toothed margins on the same twig. We therefore put the Pickett Creek specimens, which include both forms in about equal numbers, into one species. Throughout the literature of North American paleobotany there has been confusion about evergreen oaks of the *Q. chrysolepis* type. It is beyond the scope of this paper to revisit the entire issue in detail. However, a brief recapitulation is necessary: Knowlton (1902, p. 51, 52) described *Q. dayana* as a new species with entire margins on the basis of one specimen. He separated it from *Q. convexa* Lesquereux, another closely-related species with entire margins. Dorf (1930, p. 86-88) described *Q. hannibali*, on the basis of many specimens, as a species with both, entire and toothed margins. He compared *Q. hannibali* to extant *Q. chrysolepis*, *Q. tomentella* Engelm., and *Q. agrifolia* Née. Axelrod (1950) included *Q. hannibali* and *Q. browni* Brooks in *Q. dayana,* and stated that his *Q. dayana* includes a range of forms (that is, also toothed leaves) similar to that of modern *Q. chrysolepis*. Chaney and Axelrod (1959, p. 166, 167) reversed this treatment and separated the species again, admitting that "Since there are many resemblances between these species, it seems likely that if a collection included only two or three entire-margined leaves it might not be possible to determine with any degree of certainty whether the material represented *Q. dayana* or *Q. hannibali*, particularly if the finer details of venation were obscure." We use the name *Q. hannibali* for the Pickett Creek collection because we cannot group our specimens in more than one species and because *Q. hannibali* has, in our opinion, priority as a taxon that includes entire-margined and toothed leaves.

Axelrod (1995) formally synonymized *Q. hannibali* under the name *Q. pollardiana* (Knowlton) Axelrod. Fields (1996) recapitulated the taxonomic history and gave an extensive synonomy of the whole complex, confirming Axelrod`s treatment. We do not follow these authors because Axelrod has given no explanation for his treatment and Fields' thesis has not been published.

Quercus oberlii, new species
Fig. 6B, E

Holotype.—UM 73737 (I-A227), University of Michigan Museum of Paleontology, Ann Arbor.

Diagnosis.—Distinguishing characteristics that classify these leaves as *Quercus* are the high divertion angle of secondaries, the coriaceous texture of the leaf, and the thickened margin.

Description.—Leaves very narrow elliptic to linear; 2.8-9.8 cm long and 0.35-0.9 cm wide; apex long attenuate, base acute cuneate, the lowest part decurrent into petiole; midrib stout to massive; petiole 5-8% of leaf length; midvein and secondary veins protruding on lower side and impressed on upper side of leaf; venation camptodromous, with up to 30 secondaries of varying length on each side of midvein, diverging at close to 90°, bending slightly upward, some branching into higher-order veins halfway to margin, most branching and connecting to higher and lower secondary within the last quarter before the margin; tertiary mesh not clearly visible, seemingly irregularly polygonal; margin entire, apparently thickened, in large leaves slightly, in small leaves strongly revolute, texture coriaceous.

Discussion.—Evergreen, East-Asian *Quercus salicina* Blume is living evidence that oak leaves may assume such an uncommon, xeromorphic form. A direct evolutionary relationship between the two species is unlikely however, because members of subgenus *Cyclobalanopsis* have apparently never grown in North America (Rember, 1991). Among extant North American species, leaves of *Q. phellos* L. and *Q. laurifolia* Michx. come close to *Q. oberlii*, but their leaf bases are

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(UM 73752, I-O15). H, *Quercus hannibali* Dorf (UM 73740, I-O34). I, *Zelkova brownii* Tanai and Wolfe (UM 73749, I-O14). J, Fabaceae sp., pod (UM 73760, I-A147). K, Fabaceae sp., pod (UM 73763, I-A248a). Scales are in cm (subdivided into mm). Unless otherwise indicated images are approximately natural size

not as acutely cuneate as in the Pickett Creek specimens. During the search for living equivalents of *Q. oberlii*, the following extant taxa were also considered. Some members of the *Salix exigua* group come close to our leaves in general leaf form, including the characteristic form of the leaf base, but they do not have the strong marginal thickening, and secondaries do not connect directly to lower and higher neighbors. Some *Myrica* species, e.g., the South African *M. integra* (A. Chev.) Killik, also have similarly shaped leaves, but their secondary and tertiary venation pattern is distinctly different. Axelrod (1939) assigned some long-linear to lanceolate leaves from the Miocene of the western Mohave Desert to *Dodonaea californica* and compared them to living *D. viscosa* L. A comparison with similar herbarium specimens of 14 mainly Australian *Dodonaea* species (including *D. viscosa*) showed that the leaves are not as coriaceous as in *Q. oberlii*, the petioles are longer compared to blade length, the blade tapers more gradually into the petiole, the secondary veins typically diverge at a lower angle, and veins are only barely protruding on the leaf's lower surface. In all these respects, Axelrod's specimens come closer to *Dodonaea viscosa* than to our specimens.

The first author names this species for Heinz Oberli (1913-1983), district forest engineer at Wattwil, Switzerland, and an outstanding botanist and paleobotanist.

<div align="center">

Quercus prelobata Condit
Fig. 8A, B

</div>

Quercus prelobata Condit, 1944, p. 43: plate 7, fig. 3, 4.

Most leaves of this group correspond well with the original description by Condit, although the size range, 45-145 mm, is considerably larger at Pickett Creek. In about 5% of all *Q. prelobata* and *Q. columbiana* leaves, number of lobes and their length are intermediate between the two species, so that assignment to one or the other was subjective. Similar extant species are *Q. lobata* Née of California and *Q. garryana* Douglas of Pacific North America (Condit 1944). *Quercus prelobata* leaves comprise ca. 50% of the determinable remains in the stratigraphic collection of Site I.

Several specimens of *Q. prelobata* exhibit numerous, apparently randomly-distributed, fungal fruiting bodies (Fig. 8A). These fruiting bodies are 80-120 μm in diameter, circular to subcircular in shape, and appear to be embedded in the surface of the leaf.

<div align="center">

Quercus simulata Knowlton
Fig. 8C, D

</div>

Quercus simulata Knowlton, 1898, p. 30; plate 101, fig. 3.
Lithocarpus simulata Rember, 1991, p. 81: plate 9, fig. 5.
Lithocarpus nevadensis Axelrod, 1992, p. 38: pl. 9, figs. 4, 5.

Quercus simulata is a controversial species. It is not clear whether it belongs to *Quercus, Lithocarpus*, or *Castanopsis* (for a comprehensive review see Fields, 1996, p. 363-379).

Knowlton (1898) assigned some leaves from the Payette Formation to the new species *Quercus simulata* and compared it to extant *Q. imbricaria* Michx. (subgenus *Erythrobalanus*, sec. *Phellos*) of the eastern U.S.A. Knowlton's description included entire-margined as well as shallowly toothed specimens. Chaney and Axelrod (1959, p.171) saw a closer relationship with *Q. myrsinaefolia* Blume and *Q. stenophylla* Makino (subgen. *Cyclobalanopsis*) from China and Japan. Rember (1991, p. 81, 82) questioned this relationship based on paleochemical evidence established by Giannasi and Niklas (1985) on leaves from Clarkia, northern Idaho. He also stated that no fossil involucres of subgenus *Cyclobalanus* are known from North America. The Clarkia collection contains, along with a large number of *Quercus simulata* leaves, several *Lithocarpus*-like involucres and staminate aments, and a large amount of tricolporate pollen that can not be distinguished from pollen of modern *Lithocarpus densiflora*. Rember (1991) therefore suggested that *Q. simulata* represents multiple species of the genus *Lithocarpus* and proposed the new com-

bination *Lithocarpus simulata*. A few years earlier, Axelrod (1985, p. 145) had already transferred a part of the earlier findings of *Q. simulata* to the new species *Lithocarpus nevadensis*, which he described as being similar to extant *Lithocarpus densiflora*. He maintained *Q. simulata* as a separate species because of a finer venation and the shape of the leaf tip. Later Axelrod (1992, p. 38; 1995, p. 49) listed both species as separate taxa for the Pyramid Flora and the Purple Mountain Flora of western Nevada. Though 4.3% of the Pickett Creek collection was comprised of *Q. simulata* leaves, no tricolporate (*Lithocarpus*) pollen was found in the fossil sediments (see footnote to Table 6 concerning tricolporoidate pollen).

We decided therefore, to leave the Pickett Creek remains in the genus *Quercus*, and admit that *Q. simulata* from one location may not be the same species or even genus as *Q. simulata* from another location.

The Pickett Creek collection contains slightly more toothed then entire-margined specimens.

<div align="center">

Quercus (*Lithocarpus*?) sp.
Figs. 6F,G; 7E,F

</div>

Fruits of the *Quercus*/*Lithocarpus* group are rare in the Pickett Creek flora as compared to leaves. Only four remains from Site I and two from Site II may be assigned to these two genera. A cupule (specimen UM 73742, I-A321), about 1.3 cm in diameter, with apparently individual, non-fused scales, most likely belongs to *Quercus*. Two nuts (specimen UM 73741, I-A64), both about 2.5 cm long and 1.5 cm wide (flattened during fossilization) also belong to this genus. Specimen UM 73747(48), I-A320a(b) is a mold of a *Quercus* or *Lithocarpus* nut. It may have measured about 1.5 cm in diameter and was probably shorter than wide. Proximal and distal ends of this nut have radially-arranged dents as they are seen in some herbarium specimens of *Lithocarpus densiflora*. A poorly-preserved and fractured specimen from Site II may represent an oak nut or a fruit remain of another genus or family. A partially-preserved male catkin from Site II shows some characteristics common in the *Castanea*/*Quercus*/*Lithocarpus* group. A large number of stamens per flower are arranged in distinctive whorls, 2-3 mm apart from each other.

<div align="center">

Family ULMACEAE
Ulmaceae sp.

</div>

Some poorly-preserved leaves from Pickett Creek belong to the Ulmaceae, most of them to the genus *Ulmus*. Classification on the species level is difficult, because marginal characteristics and details of tertiary venation are at best poorly preserved. Most specimens show at least some subsidiary teeth and may therefore be excluded from *Zelkova brownii* Tanai and Wolfe. Affiliation with Ulmaceae is suggested by a usually strong asymmetry of the leaf base.

<div align="center">

Zelkova brownii Tanai and Wolfe
Fig. 8I

</div>

Zelkova browni Tanai and Wolfe, 1977, p. 8: pl. 4A, fig. C-G.

Three leaves from Site I are an estimated 3.5-8.5 cm long and 2.0-4.0 cm wide. The bases are asymmetrical. The margin has large, blunt teeth, with no subsidiary teeth present. Occasionally an additional (large) tooth is fed by a major tertiary vein.

<div align="center">

Family CERATOPHYLLACEAE
Ceratophyllum sp.
Fig. 7B

</div>

Two specimens of *Ceratophyllum* sp. were found at Site II. They show a strong resemblance to extant *Ceratophyllum demersum* L., an aquatic plant growing in slow-moving water in the north-

western U.S.A. Herendeen, Les, and Dilcher (1990) described several species of *Ceratophyllum* from the Tertiary of North America, mainly on the basis of fossil fruits. Because we found no fruits and our specimens are lacking clarity in some details, we cannot assign our specimens to an established fossil species.

<div align="center">

Family BERBERIDACEAE
Mahonia macginitiei Axelrod
Fig. 7H

</div>

Mahonia macginitiei Axelrod, 1985, p.150: pl.11, fig. 2, 4, 9; pl. 27, fig. 7.

The leaflets are an estimated 3.5-5.5 cm long and 2.2-2.7 cm wide; venation is pinnate; the margin has 3-4 shallow sinuses between sharp and only partially preserved, aristate teeth.

<div align="center">

Family ROSACEAE
Lyonothamnus cf. *parvifolius* (Axelrod) Wolfe
Fig. 8G

</div>

Lyonothamnus parvifolius Wolfe, 1964, p. N26: pl. 10, fig. 1, 14, 15; pl. 11, fig. 1, 3-6.
Lyonothamnus parvifolius Erwin and Schorn, 2000, p. 179-193: fig. 7.

Primary leaf segments and fragments of *Lyonothamnus* were found at Pickett Creek. They best match specimens of *L. parvifolius* as described by Wolfe (1964) and Erwin and Schorn (2000). Because the venation of the secondary segments is not preserved in the Pickett Creek collection, our assignment is entirely based on the shape of the secondary segments, which is more rectangular than in *L. wolfei* Erwin et Schorn or in *L. mohavensis* Axelrod (see Axelrod, 1939, pl. 8, fig. 6, 9). *Lyonothamnus parvifolius* has previously been found in three middle Miocene locations in Nevada: Purple Mountain, Stewart Valley, and Aldrich Station (Erwin and Schorn, 2000). Pickett Creek is the youngest and most northern location of the species.

<div align="center">

Amelanchier magnifolia Arnold
Fig. 7C

</div>

Amelanchier couleeana (Berry) Brown, Chaney and Axelrod, 1959, p. 183: pl. 36, fig. 1 only.
Amelanchier magnifolia (var. *magnifolia)* Schorn and Gooch,1994, p. 8: pl. 1, fig. 12.

Leaves closely resemble those of modern *Amelanchier alnifolia* Nutt. in size, venation and tooth form. They are 3.0-7.0 cm in length and 2.1-4.5 cm in width. In the only fully-preserved leaf, the petiole measures 60% of the leaf blade length. The leaf base in *Amelanchier magnifolia* from Pickett Creek is usually acute to obtuse, while *A. alnifolia* has a rounded to sometimes slightly cordate base.

<div align="center">

Family FABACEAE

</div>

Most pea family leaflets from Pickett Creek cannot be classified to genus or species because of lack of detail and because some leaf forms occur in many different genera. The following assignments are to leaf-form categories rather than to genera or species. Affiliation to the pea family is based on the presence of the typical transverse wrinkles on petiolules (if preserved) that develop during the fossilization of the pulvinus on most Fabaceae leaflets, and on general leaflet forms (e.g., in *Robinia*).

Cf. Apios americana Medic.
Fig. 9A

A single, almost complete and well preserved specimen shows similarities to modern climbing or trailing genera of the Fabaceae. Affiliation to the pea family is suggested by the typical transverse wrinkles on the petiolule (only preserved on the counterpart of specimen UM 73754, I-A106a). Our specimen is distinct from the *Cladrastis*-type specimens in a more ovate form and an almost straight course of the first two or three pairs of secondaries. Comparisons with herbarium material from North America show a striking resemblance with *Apios americana* Medic. of northeastern U.S.A. Weaker similarities were found with *Desmodium pauciflorum* (Nutt.) DC. and *Falcata comosa* (L.) Kuntze. However, considering the huge number of genera and species in the pea family, it seems very unlikely that we really found the right genus with our limited search.

Cladrastis sp.
Fig. 7J

Leaflets of this group are 5.0-8.5 cm in length and 3.0-4.0 cm in width. For the smaller leaflets the delimitation to *Sophora*-type leaflets and various forms summarized under the general category of Fabaceae-leaflets is somewhat arbitrary. All leaflets of the present category may belong to the same species. An assignment to *Cladrastis* seems reasonable but more details would be necessary to exclude other genera (P. Herendeen, pers. communication). Among fossil species *Cladrastis lariversii* Axelrod is most similar to our specimens.

Robinia sp. ?
Fig. 7E

Leaflets are 2.5-4.8 cm long and 1.2-1.9 cm wide. Typical dimensions are 3.5 × 1.4 cm. Most specimens have at least a slightly retuse apex, some of them with a small, protruding extension of the midrib. Fossil leaflets of this type are usually assigned to the genus *Robinia*, most frequently to *R. californica* Axelrod. There are, however, several other genera with similar leaflets that cannot be excluded without cuticular examination (P. Herendeen, pers. communication). We assume that leaflets summarized under this category may belong to more than one species or even to more than one genus.

Sophoreae sp.? (Form A)
Fig. 9G

Leaflets are narrow-oblong and on average 3.5 cm long and 1.0 cm wide. A fossil species with similarly shaped but somewhat smaller leaflets is *Amphora oblongifolia* Axelrod. Leaflets of this type are, however, not restricted to the genus *Amphora*. We tentatively assign these leaflets to the tribe Sophoreae, though we know other tribes of the subfamily Papilionoideae cannot be excluded with certainty (P. Herendeen, pers. communication).

Sophoreae sp.? (Form B)
Fig. 7D

Leaflets are ovate-lanceolate, 1.8-3.1 cm long and 0.6-0.9 cm wide. A similarly shaped fossil species is *Amorpha stenophylla* Axelrod. We place our specimens only in the tribe Sophoreae because of poorly preserved venation and lack of other details.
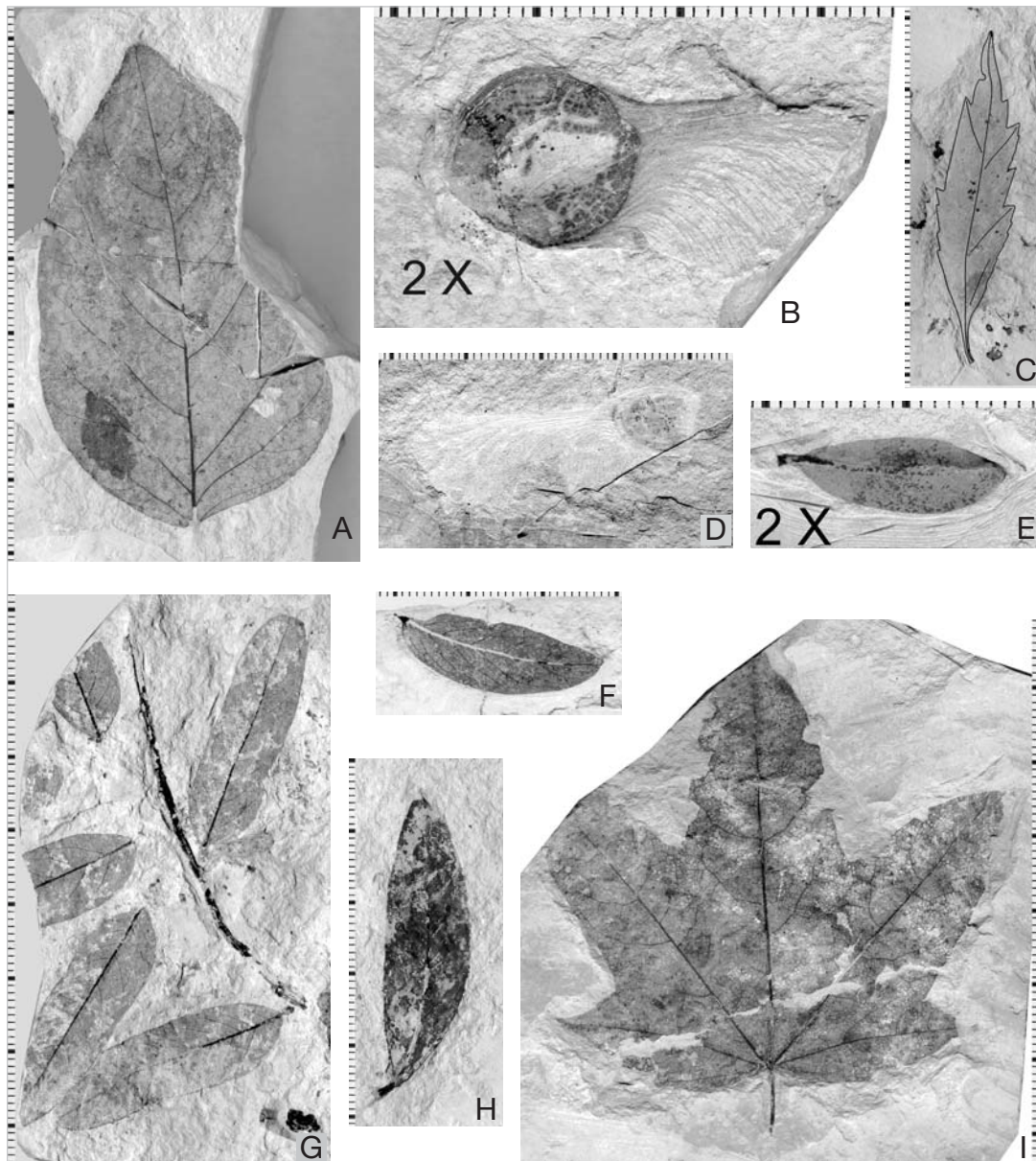
FIG. 9 — A, cf. *Apios americana* Medic (UM 73754, I-A106a). B, *Acer* sp., samara (UM 73759, I-Q2). C, *Parthenocissus* sp., margin and veins traced for better visibility (UM 73777, I-A233). D, *Acer scottiae* McGinitie, samara (UM 73762, I-A202b). E, unassigned specimen (UM 73773, II-B13). F, unassigned specimen (UM 73775, I-O2-33). G, Sophoreae sp.? Form A (UM 73757, I-A49). H, unassigned specimen (UM 73776, I-R39). (I) *Acer scottiae* McGinitie (UM 73764, I-A66). Scales are in cm (subdivided into mm). Unless otherwise indicated images are approximately natural size.

Sophoreae sp.? (Form C)
Fig. 7G

Leaflets are characterized by a narrow-ovate form and an acute apex with a sometimes rounded tip. They are 3.8-5.8 cm long and 1.6-2.4 cm wide. The venation is poorly preserved. Similar shapes can be found in genera such as *Cladrastis*, *Sophora*, *Zenia* and many others. Axelrod (1992, p. 42) showed a specimen under the name *Sophora spokanensis* Knowlton which is similar in shape to our specimen UM 73758, I-A120.

Fabaceae sp.

Most leaves in this category are either incomplete or poorly preserved. They may belong to one of the Fabaceae taxa treated above or to other pea family species. For most specimens, affiliation with the family is supported either by a typical leaflet shape or by the transverse striae on the petiolules.

Fabaceae fruits
Fig. 8J, K

Two pea pods were found at Site I. Specimen UM 73760, I-A147 is complete. It is 3.7 cm long and 8.5 mm wide (max. width). It probably contained two seeds. The restriction between the seeds is about 5 mm wide. The suture was apparently open before fossilization and the fruit probably empty. Specimen UM 73763, I-A248 is almost complete. It is 8.7 cm long and 10 mm wide (max. width) and contained probably five seeds. The fruit is barely restricted between seeds and the suture apparently closed. The fruit is about 3.0-3.5 mm thick (max. thickness where the seeds are). In both specimens the seeds were obviously oriented parallel to the fruit margin, distinctive for the genus *Cladrastis* (Herendeen, Crepet and Dilcher, 1992, p. 306).

Family ACERACEAE
Acer busamarum Wolfe and Tanai
Fig. 10A

Acer busamarum Wolfe and Tanai, 1987, p. 150: pl. 50, fig. 1, 4.

Leaves of this species may be confused with *Acer* cf. *macrophyllum*. In contrast to the latter, the most apical lateral lobes in *A. busamarum* are almost as long as the medial lobe. *Acer busamarum* has fewer teeth than *A.* cf. *macrophyllum*, they are less pointed, and no secondary teeth are present.

Acer chaneyi Knowlton
Fig. 11A, C

Acer chaneyi Knowlton, 1926, p. 45: pl. 27, fig. 2.
Acer chaneyi Wolfe and Tanai, 1987, p. 89-91: pl. 32, fig. 3, 4; pl. 42, fig. 1-4; pl. 44, fig. 1; pl. 48, fig. 3.

These leaves correspond well with Knowlton's type specimen of *Acer chaneyi* and with the description and figures given for that species in Wolfe and Tanai (1987). All leaves have five primary veins, but basal lobes are either very small or absent. One samara from Site II very likely belongs to the same species. The nutlet is 3 cm long and 0.8 cm wide; approximately 20 veins extend from the attachment scar into the wing; no ridge is visible on the nutlet. Departing from

the diagnosis in Wolfe and Tanai, the wing extends almost halfway into the distal margin of the nutlet, and no sulcus is present.

Acer latahense Wolfe and Tanai
Fig. 10D

Acer latahense Wolfe and Tanai, 1987, p. 80, 81; pl. 35, fig. 2, 4, 5.

Wolfe and Tanai (1987) give a distribution of this species from late early to middle Miocene of northeastern Washington and eastern Oregon. Pickett Creek therefore may be one of the last occurences of this species and its most eastern outpost. All our leaves have three lobes and three primary veins. Lateral primary veins depart from the middle primary vein at an angle of 30º-45º and curve outward, finally reaching a 40°-50° angle. This unusual characteristic, although not mentioned in the original description, is consistent with Wolfe and Tanai's figures. Oligocene *A. glabroides*, which has an otherwise very similar leaf form, has lateral primary veins that are straight or bend slightly upward.

Acer latahense Wolfe and Tanai
Figs. 10F,11D

Acer glabroides Brown, 1937a, p. 180: pl. 58, fig. 14, 15 only.
Acer glabroides Chaney and Axelrod, 1959, p. 193: pl. 40, fig. 8 only.

Acer latahense is defined only by its leaves. Before Wolfe and Tanai (1987) described their new species, however, several authors had published leaves and samaras from the Miocene under the name *Acer glabroides* Brown. Some of these specimens should now be transferred to *A. latahense*. The Pickett Creek collection contains six samaras that correspond with Miocene specimens published by Brown (1937a) and Chaney and Axelrod (1959), as well as with samaras of *A. rufinerve* S. et Z., an extant species similar to *A. latahense* (Wolfe and Tanai, 1987). The Pickett Creek samaras are ~2.5 cm long, with nutlets measuring 0.8 cm. Six veins originate along the attachment scar and converge beyond the nutlet apex. The attachment angle is ~35°; the wing extends 1/3 along the distal margin of the nutlet, forming a slight sulcus. We propose that samaras of this type be tentatively assigned to *A. latahense*.

Acer cf. *macrophyllum* Pursh
Fig. 12A, C, D

Acer bendirei Lesquereux (in part), 1888, p. 14: pl. 8, fig. 1 only.
Acer macrophyllum Wolfe, 1964, p. N24 and N29: pl. 5, fig. 4-6 (samaras). Wolfe and Tanai, 1987, p.158: pl. 49, fig. 9, pl. 53, fig. 1.
Acer oregonianum Knowlton, Axelrod, 1991, p. 62: pl. 19, fig. 1-3 (samaras only).

A fossil leaf of this species was first described under the name *Acer bendirei* Lesquereux. Lesquereux (1888) showed four leaves; three were later identified as *Platanus dissecta* Lesquereux by Chaney and Axelrod (1959, p. 191). The remaining leaf was compared to extant *A. saccarinum* L (Chaney and Axelrod, 1959, p. 191) or *A. macrophyllum* Pursh (Brown, 1937a, p. 179; and Wolfe, 1964). Wolfe (1964) renamed Lesquereux's three sycamore leaves as *Platanus bendirei* and proposed the name of extant *A. macrophyllum* Pursh for the fourth one. As explained above, we refrain from using names of extant species and instead use the term "cf." to refer to the similarity with *A. macrophyllum*. With 53 specimens, *Acer* cf. *macrophyllum* was the most abundant maple leaf at Pickett Creek.

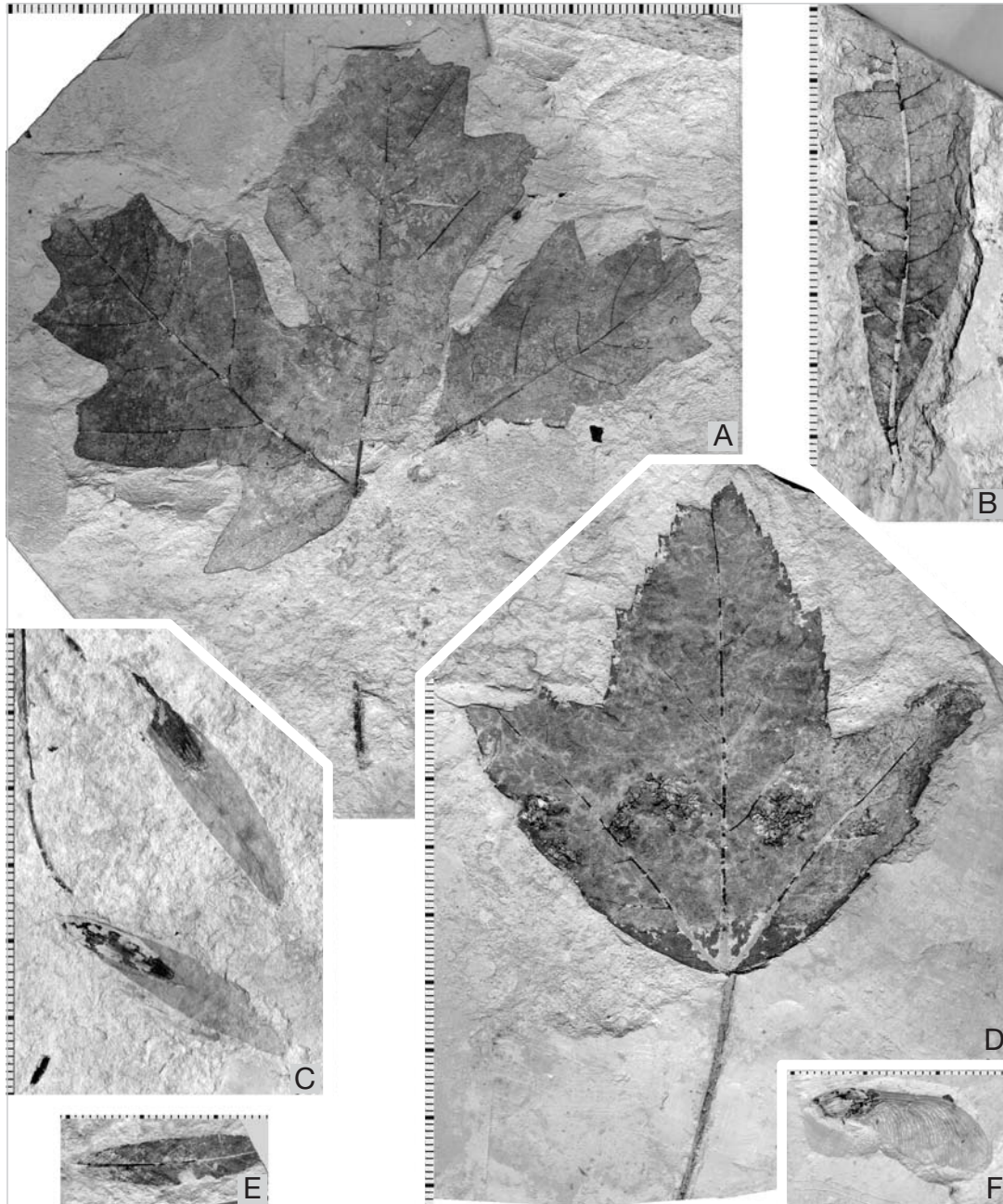FIG. 10 — A, *Acer busamarum* Wolfe and Tanai (UM 73765, I-O32a). B, unassigned specimen (UM 73771, I-A209). C, *Fraxinus dayana* Chaney and Axelrod, samaras (UM 73766, I-P36). D, *Acer latahense* Wolfe and Tanai (UM 73767, I-A252b). E, unassigned specimen (UM 73782, I-P7). F, *Acer latahense* Wolfe and Tanai, samara (UM 73768, I-A145). Scales are in cm (subdivided into mm). All images are approximately natural size.
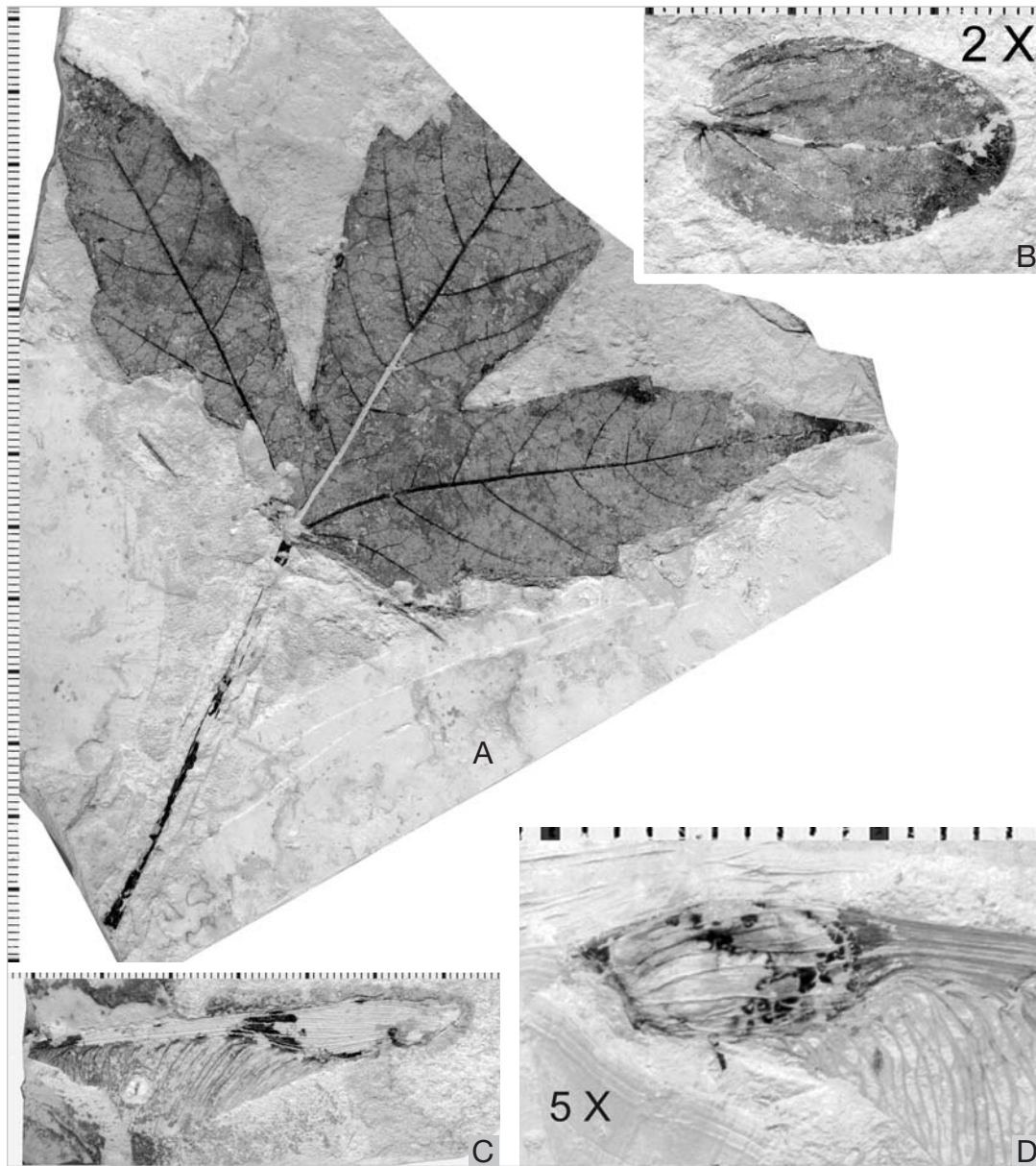
FIG. 11—A, *Acer chaneyi* Knowlton (UM 73769, I-N2-18). B, unassigned specimen (UM 73774, I-A153). C, *Acer chaneyi* Knowlton, samara (UM 73770, II-B5). D, *Acer latahense* Wolfe and Tanai, samara, detail of image F, Fig.10 (UM 73768, I-A145). Scales are in cm (subdivided into mm). Unless otherwise indicated images are approximately natural size

Four samaras of the *A. macrophyllum* type were found at Site I. They match modern material, the specimens published by Wolfe (1964) and Wolfe and Tanai (1987) under the name *A. macrophyllum* Pursh, and those published by other authors including Axelrod (1991, p. 62, 63) under the name *A. oregonianum* Knowlton. Although the latter name should have priority, we list our specimens here under the same name as the leaves.

Acer scottiae MacGinitie
Fig. 9D, I

Acer scottiae MacGinitie, 1933, p. 62: pl. 11, fig. 8 only; pl. 12, fig. 4.
Acer scottiae Wolfe and Tanai 1987, p. 202, 204, 206: pl. 57, fig. 1-8; pl. 58, fig. 5-7; pl. 59, fig. 8.

Leaves have 5 – 7 lobes and usually seven primary veins. MacGinitie (1933) and Chaney and Axelrod (1959, p. 196) have published both leaves and samaras under the name *A. scottiae*. The general form and especially the attachment angle of their samaras, however, vary so much that it seems unlikely they all belong to the same species. Three samaras from Site I correspond well with the specimens shown by Wolfe and Tanai

Acer remains
Fig. 9B

In this category we summarize 12 mostly incomplete specimens (ten leaves and two samaras) that clearly belong to Acer, but could not be assigned to any established fossil species. The two samaras are incomplete, but the unusual shape and size of their nutlets (almost circular in outline with a diameter of ~ 1.4 cm) suggests that they belong to the same species.

Family OLEACEAE
Fraxinus coulteri Dorf

Fraxinus coulteri Dorf, 1936, p. 123: pl. 3, fig. 3, 4.

Three relatively poorly-preserved samaras are about 3.0 cm long and 0.4-0.5 cm wide. They have a narrow-lanceolate seed body.

Fraxinus dayana Chaney and Axelrod
Fig. 10C

Fraxinus dayana Chaney and Axelrod, 1959, p. 201: pl. 44, fig. 1-3.

Five specimens including six samaras were found at Site I. They average about 3.6 cm in length and 0.8 cm in width, thus a little shorter and narrower than those described by Chaney and Axelrod (4.0 cm, 1.2 cm).

Family VITACEAE
Parthenocissus sp.
Fig. 9C

The *Parthenocissus* leaflet is similar to narrow-leafed, horticultural clones of *Parthenocissus quinquefolia* (L) Planch. and *P. heptaphylla* (Buckl.) Brit. and Small (Kruessmann, 1977).
Description.—Leaflet narrow-elliptic; 4.2 cm long and 1.0 cm wide; apex attenuate; base cunate, the lowest part decurrent into petiolule; midrib and secondary veins barely visible; margin irregularly toothed with two series of teeth, one very large, the other small, only visible under the microscope; texture membranaceous.
Judging from its axial asymmetry, our specimen was probably one of the narrow, lateral leaflets. Because of insufficient morphological details we did not assign this specimen to an established fossil species.
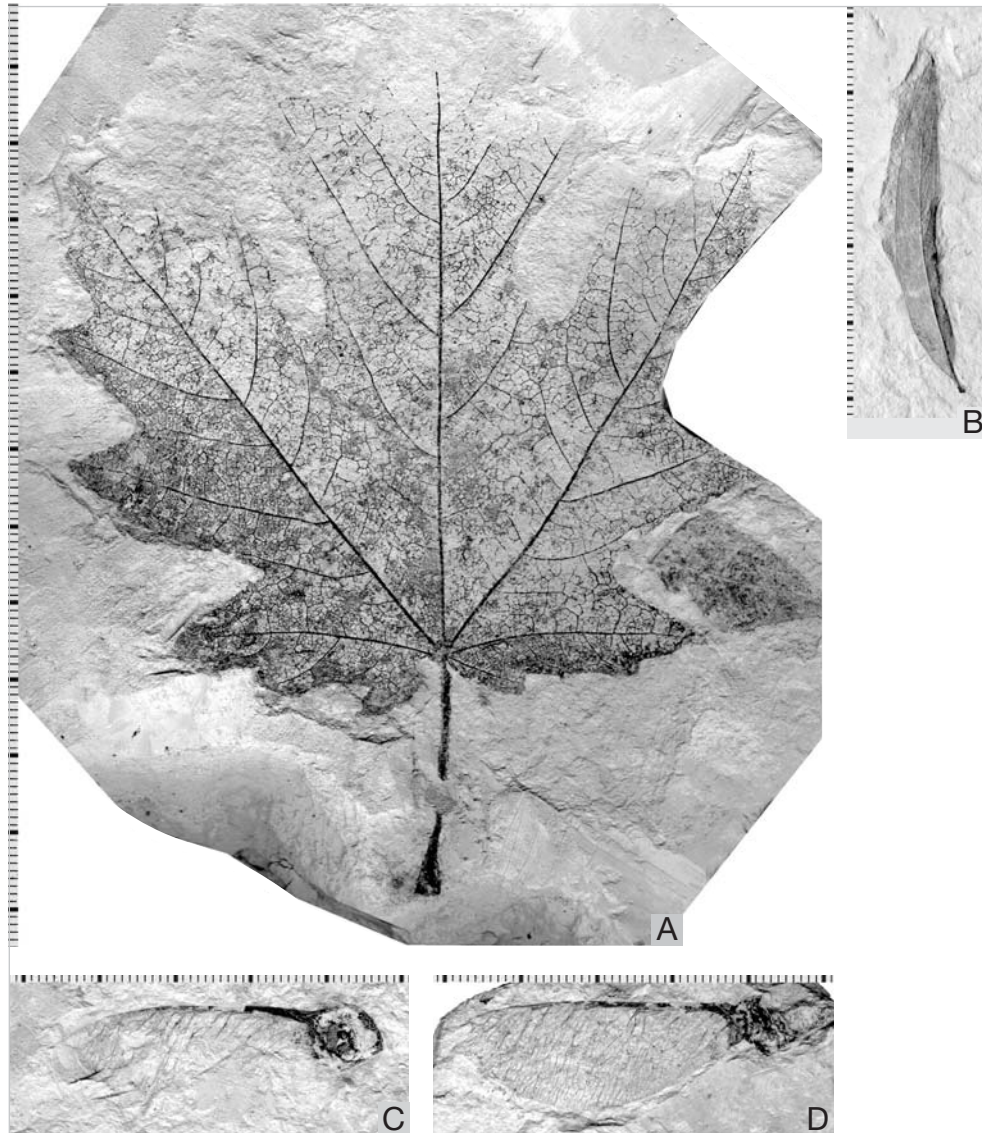
FIG. 12— A, *Acer* cf. *macrophyllum* Pursh (UM 73778, I-A278a). B, unassigned specimen (UM 73781, I-A222). C, *Acer* cf. *macrophyllum* Pursh, samara (UM 73779, I-N2-31). D, *Acer* cf. *macrophyllum* Pursh, samara (UM 73780, I-A126). Scales are in cm (subdivided into mm). All images are approximately natural size.

UNASSIGNED SPECIMENS

Table 3 lists specimens that could not be assign to an established fossil or modern taxon below the suborder level. To facilitate future revisions and additions we give specimen numbers and,

in some cases, a short description and a picture. Assignment suggestions are at the "doubtful" confidence level or below.

RESULTS AND DISCUSSION

Paleotopography

The position of diatomite deposits, fossil layers, and some of the basalt flows relative to the current surface suggest that the local topography at the time of deposition may have been similar to the current situation. Sandy outcrops and water-affected basalt flows near the Pickett Creek fossil sites suggest an ancient lake shoreline at an elevation of 1250-1280 m (1: 24 000 Sinker Canyon Quadrangle map, edition 1990). The two fossil sites were situated in a 500-700 m wide north-south oriented channel (Fig. 2). Site I was situated about 500 m off the western shore, only 100 m away from the eastern coast, at a depth of about 20 m. Site II lay, when its fossils were deposited, about 200 m offshore, close to a small river mouth, at a depth of 10-15 m. During diatomite deposition, a period of 1000 to 3000 years, the location of the fossil beds was isolated from major sediment influx but still supplied with fresh water. Based on the distribution of diatomite outcrops with similar species composition, we estimate that this more isolated area covered 1-2 km². This suggests a lake size of at least 2-4 km². It is likely that Pickett Creek Lake was part of a Snake River Plain lake-system. Jenks and Bonnichsen (1989) found the highest stand of Pliocene Lake Idaho around the present 3800-ft elevation contour. This is about 300-400 ft. lower than the Pickett Creek shoreline.

Taphonomy

Most deposited leaves, flower parts, fruits, and pollen may have come from the western coast of Pickett Creek Lake, transported by water from a river mouth and by prevailing winds. Steepness of the landward terrain suggests that the bottomland association occupied only a narrow strip of land where groundwater from the lake was available. The megafossil and pollen assemblage of Site I may come from five different vegetation zones: (1) the lake-beach, where wave action created a constantly changing environment; (2) the groundwater-rich area between lake-beach and mountain slope; (3) the potentially dryer mountain slope; (4) the river floodplain; and (5) a mountain conifer association, as implied by the combination of abundant *Pinus* pollen and scarce Pinaceae megafossils. The majority of leaves most likely came from trees growing close to the lakeshore and near to riverbanks. The composition of the flora at Site II, with more *Salix* and *Populus* species (Table 2), suggests a riparian origin. The difference in floral composition between Site I and Site II may have been caused in part by environmental changes related to basalt flows (topographical changes and forest fires), and in part because Site II was closer to the river mouth. The relative closeness of both fossil sites to mountains explains the abundance of *Pinus* pollen and the presence of pollen from typical dryland plants of the Amaranthaceae/ Chenopodiaceae group.

Density and preservation of fossils varied considerably with time (Table 1). Deposition of volcanic ash resulted in layers of brittle sediments, making recovery of the few remains difficult. It may have also contributed to a faster decay of pollen and megafossils in layers just below the ash. In lower units at Site I, sedimentation was often turbulent, as indicated by uneven layering, fragmented leaves, and uncountable wood debris. As the basin filled up with sediments, deposition became more evenly layered and preservation of the megafossils improved. The thickness of some varved layers at Site II and of varved diatomite at Site I (2-6 mm per year; Table 1: units

TABLE 3 — Unassigned specimens.

Specimen no.	Dimensions of leaf blade (l/w)[1]	Figure no.	Remarks
UM 73774 (I-A153)	2.1 x 1.4 cm	Fig. 11B	Leaf base cordate; basal pair of secondaries very strong, reaching up into the distal quarter of the blade; margine finely serrate. *Ceanothus* sp.? (but probably not a known fossil species)
UM 73781 (I-A222)	4.2 x 0.7 cm	Fig. 12B	Leaf very narrow elliptic; base asymmetric; margin entire; secondaries departing at about 30°. Thymelaeaceae sp.? (see MacGinitie, 1953, p. 152).
UM 73776 (I-R39) I-F13, I-F4, I-G7	4.0 x 1.2 cm	Fig. 9H	Leaf narrow elliptic; base cuneate; apex acute; margin entire; up to 14 pairs of secondaries. *Vaccinium* sp.?, cf. *V. sophoroides* (Knowlton) Brown?
I-A247, I-P2, I-E8, I-F2	8 (?) x 1.8 cm	—	Leaf petiole 1.7 cm long, 2 - 3 mm thick, margin coarsely toothed. *Arbutus* sp.? *Gordonia* sp.?
I-F10	3.5 x 0.7 cm	—	Leaf (or leaflet?) lanceolate; base slightly cordate; apex acute; widest part of leaf at about 1/4 of the full length from base; probably no petiole (leaf sitting?); margin entire; numerous fine secondaries departing at 50°.
UM 73772 (I-P11) I-O$_2$-11, I-N10	2.5 x 0.85 cm	Fig. 7I	Leaf (or leaflet?) narrow elliptic; base rounded; apex acute; margin possibly finely serrate in the upper part; nine pairs of secondaries.
UM 73775 (I-O$_2$-33) I-P37, I-O11	2.7 x 1.1 cm	Fig. 9F	Leaf elliptic; base rounded; apex acute; margin entire; eight pairs of secondaries, departing at about 30°.
UM 73782 (I-P7)	2.8 (?) x 0.65 cm	Fig. 10E	Leaf narrow elliptic; base acute; apex not preserved; margin entire (?); about 14 pairs of secondaries. Narrow leafed *Salix* sp.? Cf. *Salix repens* L?
UM 73771 (I-A209)	6.0 x 2.0 cm	Fig. 10B	Specimen partially preserved. Base cunate; midrib stout; secondaries weak compared to midrib, irregularly diverging at angles between 60° and 90°, irregular in their course to the marginal region where they branch and connect with venation of the lower and higher secondaries. *Tilia* seed bract?
I-R43	4.2 x 0.6 cm	—	Leaf lanceolate; base obtuse; apex attenuate; margin toothed; numerous secondaries. Small and narrow leafed *Salix* sp.?

TABLE 3 (continued)

II-B16	3.2 x 1.1 cm	—	Leaf elliptic; base obtuse (rounded?); apex acute; petiole 3 mm; margin entire; about 14 pairs of sec- ondaries.
UM 73773 (II-B13) II-B40, II-B27 II-A31 II-B10	1.4 x 0.5 cm 1.9 x 0.7 cm 3.3 x 0.9 cm	Fig. 9E	Leaf elliptic; base acute; apex acute; margin entire; secondaries fine and weakly preserved, departing at low angles; texture coriaceous. Prophyll?

[1] Dimensions refer to the first specimen in the column on the left.

II-B and diatomite) suggests that the examined part of the Pickett Creek sediments may represent a time interval between 1000 and 3000 years.

Physical Stratigraphy

Diatomite and fossiliferous siltstones crop out in steep-walled, usually waterless dry washes (arroyos) up to 3 m deep (Site I), and on poorly consolidated slopes of a Pickett Creek tributary (Site II). At Site I, accessible fossil beds consist of 3 m lacustrine sediments, overlaid by 3 cm of volcanic ash and 3.7 m of massive diatomite. At Site I fossil recovery was stopped because of dif- ficult access and problems with chainsaw exhaust gases at about 1.2 m below the dry wash bottom (corresponding to fossil unit I-O). Site II includes the massive diatomite layer, overlaid by 15 m of lacustrine and fluvial sediments. Site I and Site II lay 230 m apart. Table 1 lists the thickness of fossil units, their numbering system, and lithology, as well as the state of fossil preservation. Reference level (0 cm) is the lower boundary of the massive diatomite.

Flora and Faunal List - Megafossils

Taxonomic confidence levels given in Table 2 are subjective statements, indicating confidence in our taxonomic conclusions. The following definitions were used: **excellent**, other taxa may be excluded with certainty (implying that all potential candidates have been considered); **good**, the given taxon fits best, but other taxa may not be absolutely excluded (because of imperfect preser- vation or other reasons); **doubtful**, the given taxon fits, but other taxa may be in the same rank or have not all been sufficiently investigated. The taxonomic confidence levels apply to relatively well-preserved specimens of the collection.

The use of our numerically-representative sampling method, in which we attempted to include as many specimens as possible, resulted in a relatively high number of poorly-preserved or frag- mented specimens that were difficult to assign to the species level. We tried to overcome this problem by introducing collective categories for several undetermined species.

Test of Sampling Method (Stratigraphic Collection)

Table 4 shows the five most abundant taxonomic groups in units N and O in Site I, Pit 1 and in Site I, Pit 2. A multinomial Chi-Square test suggests no significant difference in the composition of the flora between units N_1 and N_2: $\chi^2 = 4.96$ ($< \chi^2_{0.05[4]} = 9.48$), but does suggest a significant difference between units O_1 and O_2: $\chi^2 = 11.48$ ($> \chi^2_{0.05[4]} = 9.48$). However, if the data for *Salix*

TABLE 4 — Consistency of sampling method for the stratigraphic collection based on dominant taxa.

Group	Overall Frequency (N, N_2, O, O_2)	Number of Specimens in Units			
		N_1	N_2	O_1	O_2
Quercus prelobata	49.8%	57	66	85	85
Quercus columbiana	10.2%	17	10	19	14
Equisetum sp.	4.9%	8	6	5	10
Acer cf. macrophyllum	3.7%	4	4	6	8
Salix succorensis	3.4%	6	7	2	5
	$\chi^2_{p = 0.05, 4df} = 9.48$	$\chi^2_{4df} = 4.96$		$\chi^2_{4df} = 11.48$	

succorensis are omitted because the expected frequency is less than five (Sokal and Rohlf, 1981), no significant difference in the composition of the flora is suggested between units O_1 and O_2: $\chi^2 = 6.98$ ($< \chi^2_{0.05[3]} = 7.81$). Therefore, assuming no significant change in the lateral composition of the flora, or of the depositional environment over the three meters between the pits, the sampling methodology is consistent.

Frequency of Specimens in Sedimentary Layers

The total number of remains (determinable and undeterminable) per cm depth varied between 4.2 (units I-B and I-K) and 16 (unit I-R, Table 5). Total numbers per dm³ were 0.7 and 2.7 respectively. Units with turbulent or poorly layered sediments, containing predominantly uncolored specimens, had lower numbers of specimens than did well-layered units with good preservation (coloration) of remains. This may be in part because uncolored specimens were more likely to be missed than colored ones. The same may be true for a poorly layered matrix that is more difficult to split.

The percentage of determinable remains was higher in well-layered units (maximum 71%) and lower in units with turbulent sedimentation (minimum 16%).

The percentage of the most abundant species, *Quercus prelobata* (Table 2), ranged from 27% of all specimens in unit I-L, to 65% of all specimens in unit I-T (percentage over all units = 49.8%). This species had the highest representation in all units except in I-L, where the low share of determinable remains (16%) makes representative statements impossible. Unit-specific statements about species with low overall frequencies are critical; variations may result from small sample sizes and changes in taphonomic mechanisms, rather than from floral changes. Table 2 therefore only shows the combined frequency of species over all fossil units at Site I.

Composition of the Palynoflora

Samples from -130 cm and below (see Methods) yielded sufficient pollen for a combined, non-quantitative survey (Table 6). Other layers contained only few and poorly-preserved pollen, likely because of their proximity to the surface and the related influx of surface water and oxygen.

Pollen taxa (Table 6) correspond with most of the megafossil families and suggest additional taxa from higher elevation and dry sites (*Abies*, *Pinus*, Amaranthaceae, Chenopodiaceae). Leopold and Wright (1985) described a similar pollen assemblage from the Salt Lake Formation near Trapper Creek (11-12 m.y.). Their samples were dominated by *Pinus*, contained up to 10% *Ulmus*

TABLE 5 — Occurrence of determinable and undeterminable remains in relation to depth, sedimentation, and preservation in units B - U at Site I. See Table 1 for details of sedimentation. Total remains per cm includes determinable and undeterminable remains per cm depth (within the 60 x 100 cm plot).

| | Preservation poor (uncolored) | | | | | | | | | | | Preservation good (colored) | | | | | | | |
| | Layered | | | | | | | | Turbulent | | | Well layered | | | | | Part. turbulent | | |
Sediment unit	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U
Thickness of unit (cm)	9	8	15	20	11	11	10	7	19	12	20	16	20	21	17	17	18	18	18
Total determinable remains	22	42	49	61	38	26	44	20	16	11	30	116	166	161	144	183	59	71	71
Undeterminable remains	16	26	34	26	31	23	31	28	64	56	65	47	86	67	80	81	75	58	79
Total remains per cm	4.2	8.5	5.5	4.4	6.3	4.5	7.5	6.9	4.2	5.6	4.8	10	13	11	13	16	7.4	7.2	8.3
Determinable remains %	57	62	59	70	55	53	59	42	20	16	32	71	66	71	64	69	44	55	47

– *Zelkova* and had small amounts of *Quercus*, *Juniperus*-type, *Abies*, *Pterocarya*, *Carya*, *Juglans*, *Sarcobatus,* and *Ephedra.* Together with evidence from leaf remains, Leopold and Wright suggested a mixed conifer – hardwood forest or woodland on the Snake River Plain during Mio-Pliocene time.

Composition of the Diatom Flora

Preliminary data concerning the Pickett Creek diatom flora from three fossil layers of Site I are presented in Table 7. Both SEM studies and comparisons with Miocene diatom literature are necessary before more definitive statements can be made. Dominant and abundant species of layer +10 cm (diatomite) were also present in all diatomite outcrops within an area measuring 2.9 ×0.7 km near the Pickett Creek fossil sites. This preliminary work suggests that the Pickett Creek collection may contain several new species.

Paleoclimatology

Data on dicot leaf characters of a fossil flora, such as percentage of woody species with entire margins, can be used to estimate climatic parameters. Wolfe (1993) summarizes the development of such methods and specifically describes the use of the Climate-Leaf Analysis Multivariate Program (CLAMP). A CLAMP analysis was performed using 31 leaf characters of 41 Pickett Creek species from Site I.. Estimates for climatic parameters are given in Table 8. CLAMP scoresheet is reproduced in Table 9.

The Pickett Creek CLAMP estimate of mean annual temperature (MAT; 13.4°C) is within the climatic range of the modern Californian foothill woodlands to which we will compare the Pickett Creek flora (see Paleoecology). MAT of the Central Valley of California is 16-17°C near the valley bottom, 11°C at 1000 m in the north and up to 15.5°C at 1000 m in the south (Wolfe, 1992). The late Miocene Pickett Creek MAT estimate is also close to the estimate for the Snake River Plain (14°C) based on late Miocene fish distributions (Smith and Patterson, 1994).

The mean annual range of temperature (MART; 21.2°C) is lower than the present value in the Pickett Creek area (24.6°C). Modern MART values for the Californian Central Valley vary between 16.6°C (Sacramento) and 19.9°C (Red Bluff and Bakersfield, data from NOAA website at http://www.wrcc.dri.edu/htmlfiles/ca/ca.avg.html, accessed 2/18/2003).

Length of growing season (6.8–8.8 months) corresponds well with values from the foothill woodlands (6–10 months, Munz and Keck, 1968). CLAMP precipitation estimates have very large standard errors and are therefore difficult to compare with modern data (for California foothill woodlands precipitation see Paleoecology).

The mean annual relative humidity (67%) is distinctly higher than the estimated value of <50% for modern Pickett Creek. However, it is not much lower than present values for the west coast of North America (82% at Astoria, 77% at Eugene, and 74% at Portland, Oregon; Ruffner, 1980). This can be explained by the presence of a lake and by a higher precipitation during the Miocene.

Paleoecology

Comparing fossil assemblages to modern forest types with morphologically similar species may give valuable indications on ecology and climatic parameters of the paleoflora. The presence or absence of species is, however, as much the result of a floras biogeographic and climatic prehis-

TABLE 6 — List of palynomorphs from layers -130 to - 270 cm at Site I.

Pollen/spore type.	Max dim. (μm)	Frequency	Plant taxon	Possibly related Pickett Creek megafossil
Bisaccate, body length	50	Abundant	*Pinus*	*Pinus* needle?
Bisaccate	90	Rare	*Picea*	Not represented
Inaperturate	7-13	Rare	Basidiomycetes	Not represented
Inaperturate	30-40	Rare	Taxodiaceae/ Cupressaceae/ Taxaceae	Not represented
Inaperturate	50-80	Rare	*Equisetum* ?	*Equisetum* sp.
Monoporate	63	Rare	Cyperaceae ?	Poaceae?
Tricolpate	18-23 (34?)	Rare	*Salix*	Various *Salix* sp.
Tricolpate (tricolporoidate?)[1]	15-30	Dominant	Several taxa?	?
Tricolpate	30-36	Abundant	*Quercus*	Various *Quercus* sp.
Tricolpate	35	Rare	*Acer* ?	Various *Acer* sp.?
Stephanocolpate (4)	25	Rare	*Fraxinus* ?	*Fraxinus* samara?
Triporate	25-28	Rare	*Ostrya*/*Carpinus*	*Ostrya oregoniana* (leaves and involucres)
Triporate?	20-30	Rare	Asteraceae	Not represented
Triporate	23	Rare	*Betula*	*Betula* sp.?
Triporate	55 and 25	Rare	Onagraceae	Not represented
Triporate	55	Rare	*Carya*	Juglandoid fruit?
Stephanoporate (5,6)	28-30	Rare	*Alnus*	Not represented
Stephanoporate (6)	40-43	Rare	*Ulmus, Zelkova*	*Ulmaceae* sp. and *Zelkova brownii*
Stephanoporate (5)	40-43	Rare	*Planera*/*Pterocarya*	*Pterocarya mixta*
Periporate (10)	40-45	Rare	*Juglans*	*Juglans browniana*
Periporate (14-24)	23-33	Rare	Amaranthaceae/ Chenopodiaceae	Not represented

[1] Tricolpate pollen of probably several taxa with a clear exine and no other obvious characteristics. This pollen type, as a group, is the most abundant at Pickett Creek. Some of this pollen may in fact be tricolporoidate, i. e. tricolporate without a well-defined equatorial pore (Traverse, 1988, p. 82).

TABLE 7 — Composition of diatom flora. Layer at +10 cm is diatomite layer. Abbreviations: D = dominant; A = abundant; R = rare; V = very rare; X = very rare and found only in a preparation with combined material from all 3 layers. Statements on ecology refer to comparable modern species.

Genus and species (Round et al., 1990)	Abundance in layer (approx. depth)			Remarks
	+10 cm	-300 cm	-500 cm	
Melosira juergensii C.A. Agardh. (or related to it)	R	–	–	
Ellerbeckia arenaria var. *teres* (Brun.) Crawford	A	–	–	Littoral on flat, sandy beaches
Aulacoseira ambigua (Grunow) O. Müller	X	X	X	Planktic
Aulacoseira cf. *canadensis* Hustedt?	A	D	–	Genus is planktic, indicates deep lakes with abundant nutrients, esp. Si.
Aulacoseira cf. *crenulata* Thwaites?	R	–	–	Lives in shallow, marshy systems.
Aulacoseira sp., *A. distans* group? *A. solida* (Eulenstein) K. Krammer?	D	–	–	
Aulacoseira sp., *A. "praedistans"*? *A. "praeislandica"*?	R	A	D	Genus is planktic, indicates deep lakes with abundant nutrients, esp. Si.
Actinocyclus sp., related to *A. gorbunovii* Bradbury & Krebs*?*	–	–	R	
Fragilaria leptostauron (Ehrenb.) Hust. ?	V	–	–	
cf. *Fragilaria pinnata v. trigona* (Brun & Heribaud) Hustedt?	V	V	–	Potential new species
Fragilaria neoproducta Lange-Bertalot?	X	X	X	
Fragilaria sp., *F. lapponica* Grunow?	–	–	V	
Fragilaria capucina var. *lanceolata* Grunow	X	X	X	
Fragilaria virescens Ralfs	–	–	R	
Fragilaria sp.?	–	–	V	
Fragilaria sp.?	X	X	X	
Martyana martyi (Heribaud) Round?	–	–	R	
Synedra capitata Ehrenb.	V	V	–	Mainly littoral
Ceratoneis arcus (Ehrh.) Kützing? *Synedra rumpens* Kützing?	R	–	–	Potential new species
Tabellaria fenestrata (Lyngbye) Kützing	–	V	R	

TABLE 7 (continued)

Tetracyclus cruciformis Andrews	A	–	–	
Tetracyclus lacustris Ralfs?	X	X	X	Littoral in nordic and mountain lakes.
Tetracyclus ellipticus (Ehrenb.) Grunow	–	–	V	
Tetracyclus emarginatus (Ehrenb.) Wm. Smith	X	X	X	Littoral
Eunotia sp. , *E. exigua* ?	–	V	V	
Eunotia flexuosa (Brebisson) Kützing?, *E. bilunaris* complex?	–	–	V	
Eunotia pectinalis (Kützing) Rabenhorst	X	X	X	
Eunotia sp.*? E. sylvahercynia* ?	–	–	V	
Cymbella elizabethana Krammer et Buechler	X	X	X	New species from Pickett Creek (Krammer, 2002)
Cymbella robertii Krammer et Buechler	X	X	X	New species from Pickett Creek (Krammer, 2002)
Cymbella buechleri Krammer	X	X	X	New species from Pickett Creek (Krammer, 2002)
Cymbella duplopunctata Krammer	X	X	X	New species from Pickett Creek (Krammer, 2002)
Gomphonema parvulum Cleve	–	–	R	
Gomphonema grovei Schmidt *et al*.?	–	–	V	
Achnanthes sp., *A. lanceolata* Cleve?	–	–	V	
Cocconeis placentula Ehrenberg	X	X	X	
Pinnularia sp.	–	–	R	
Caloneis schumanniana var. *biconstricta* (Grunow) Reichelt ?	–	–	V	
Navicula bacillum Ehrenberg	–	–	V	
Diploneis finnica (Ehrenberg) Cleve?	X	X	X	Potential new species
Navicula pseudoscutiformis Hustedt	–	–	R	
Navicula sp.	–	V	R	
Stauroneis phoenicentron (Nitzsch) Ehrenberg?	–	–	V	
Hantzschia spectabilis (Ehrenberg) Hustedt?	–	–	V	
Nitzschia sp. , *N. fonticola* Grunow?	–	–	V	
Surirella sp., *S. tenera* Gregory?	–	V	R	Genus of shore habitats
Various forms of sponge spicules	A	–	–	Littoral, shallow water

TABLE 8 — Estimates from CLAMP analysis of climatic parameters at late Miocene Pickett Creek.

	Late Miocene Pickett Creek		Contemporary Pickett Creek Area
	Mean	Standard error	Mean
Mean annual temperature	13.4°C	1.9°C	8.6°C [1]
Warm-month mean temperature	24.0°C	2.9°C	23.0 °C [2]
Cold-month mean temperature	2.8°C		-1.6°C [2]
Mean annual range of temperature	21.2°C	>2.9°C	24.6°C [2]
Length of growing season (months with 10ºC or higher mean temperature)	7.8 months	1 month	6.8 months [2]
Precipitation during growing season	69 cm	55 cm	17.4 cm [2]
Mean monthly growing season precipitation	10 cm	6.1 cm	2.0 cm [2]
Total precipitation of three consecutive wettest months during growing season	21 cm	21 cm	7.5 cm [2]
Total precipitation of three consecutive driest months during growing season	15 cm	14.8 cm	3.2 cm [2]
Mean annual relative humidity[3]	67%	12 %	< 50 %
Enthalpy[4]	30.5 kJ kg^{-1}	5.9 kJ kg^{-1}	< 19 kJ kg $^{-1}$

[1] Pickett Creek value calculated from Wolfe (1992)

[2] Pickett Creek mean value between the two closest climatological stations, Anderson Dam, Idaho (50 mi NE of Pickett Creek, 3882 ft) and Deer Flat Dam, Idaho (45 mi NW of Pickett Creek, 2510 ft) (Ruffner, 1980)

[3] Pickett Creek, estimated; the Pickett Creek area likely has a lower relative humidity than Boise Air Terminal (51.8 %) (Ruffner, 1980)

[4] Total thermodynamic heat content of the air

tory as of its current conditions. The modern flora with the highest number of similar species is therefore not necessarily the most similar with respect to ecology and climatic parameters. The most dominant canopy members of a plant community determine much of the general ecology of a flora, while species living on the edge of their climatic range provide more specific information on climate parameters.

Miocene floras have often been compared to various species-rich forest types in eastern United States and eastern China (e.g. Chaney, 1959; Axelrod, 1964). Pickett Creek does indeed have many genera and similar species in common with forests of both areas. In addition, its CLAMP-derived temperature parameters correspond well with conditions in the Appalachian mixed broad-leafed deciduous forest of eastern Tennessee and western North Carolina. But the absence of evergreen oaks and other drought resistant species in this modern forest type indicates an important difference in precipitation regime. Based on the predominance of white oaks, the presence of several live oaks and dry-land species of *Pinus*, small leafed Fabaceae, Amaranthaceae and Chenopodiaceae, the ecologically and climatologically most similar modern forest type is the broad-leaved forest of the Californian foothill woodlands with wet winters and dry summers. This plant community extends along the foothills and valley borders of the Central Valley between 120 and 915 m, occasionally reaching 1500 m. Average rainfall is 38-102 cm (almost entirely in winter). Length of growing season is 6 to 10 month (Munz and Keck, 1968).

Temperature parameters correspond well with CLAMP-derived Pickett Creek values (see Paleoclimatology). Indicator species (dominant or characteristic for the plant community) of the Californian foothill woodlands are *Pinus sabiniana, P. coulteri* at higher altitudes, *Quercus douglasii* and *Q. lobata* (white oaks), *Q. chrysolepis, Q. agrifolia and Q. wislizenii* (evergreen oaks), *Umbellularia californica, Rhamnus californica, Ceanothus cuneatus, Cercis occidentalis* (Munz and Keck, 1968). The following Pickett Creek taxa are represented by morphologically similar taxa in the foothill woodlands: *Juglans sp., Ceratophyllum demersum, Mahonia sp., Amelanchier alnifolia, Robinia pseudoacacia* (introduced), *Acer macrophyllum* and several other *Acer* sp. Absent from California are all species of *Pterocarya, Ostrya, and Zelkova*. They left the western United States during the late Miocene or Pliocene when summer precipitation was reduced (Axelrod, 1991, 1992).

The following ecological interpretations of the Pickett Creek forest are based on the frequency of leaves found, on characteristics of morphologically similar extant species, and on general ecological characteristics of modern genera.

The most common canopy members of the bottomland forest were *Quercus prelobata and Acer cf. macrophyllum*. Their modern counterparts, *Quercus lobata* Née, *Q. garryana* Douglas and *Acer macrophyllum* Pursh, may grow to 24-30 m in height and are the largest species of their genera on the North American Pacific Slope (Sudworth, 1908). The role of *Quercus prelobata* as an important canopy tree is supported by its abundance in the stratigraphic collection. In old stands of white oak, stems are usually far apart (Sudworth, 1908), leaving a wide, well-lighted area for subcanopy trees between them. *Quercus columbiana, Acer chaneyi, A. scottiae* and species of *Ostrya, Ulmus,* and *Zelkova* were minor constituents of the canopy and subcanopy.

The lakeshore and streamside vegetation (upstream from Pickett Creek Lake) included alluvial pioneer species like *Salix inquirenda, S. succorensis* and several *Populus* species. Narrow leafed *Salix churchillensis* is indistinguishable from extant *S. exigua Nutt*. (subgenus *Longifoliae*). *Salix exigua* now grows on riverbanks, gravel bars, but also in smaller, seasonally dry-running creeks. Of all willows, species of subgenus *Longifoliae* are best adapted to dry air conditions. *Salix wildcatensis*, possibly the predecessor of extant *S. lasiolepis* Bentham, grew probably in small creeks with little competition from large trees. All Pickett Creek Salix species are of the alluvial type with a preference for well aerated, relatively fast flowing water and with a high light demand (Skvortsov, 1999). Small-leafed Fabaceae species may have grown in dry locations, on slopes above the lake or river. *Equisetum, Ceratophyllum*, and *Typha* species indicate the presence of wetlands with year-round moisture.

Quercus hannibali, Q. simulata, Mahonia macginitiei, Lyonothamnus cf. parvifolius, possibly *Quercus oberlii*, and some of the unassignable specimens were evergreen shrubs or small trees. Evergreens amount to about 6.5 % of the stratigraphic collection at Site I. They were clearly more abundant than in the Appalachian mixed broad-leaf deciduous forest, where broad-leaf evergreens are a minor component (Wolfe, 1979) and live oaks are missing.

The wide ecological range of the modern affinities of the Pickett Creek leaf assemblage suggests that leaves came from several distinct vegetation zones (see also Taphonomy).

Pickett Creek Flora in relation to other Miocene and Pliocene Floras of the Northwest

We compared the Pickett Creek flora with 24 well documented middle to early Miocene floras of Washington, Oregon, Idaho, northern California and northern Nevada, and with seven late Miocene or Pliocene floras of the same area. Except for the two new species, all 27 well-defined Pickett Creek species (confidence level good or excellent) had their first appearance in the middle Miocene or earlier. Only 10 species were represented in late Miocene or Pliocene assemblages. We found no references to the following 19 species in late Miocene or Pliocene floras: *Populus bonhamii, P. lindgreni, P. douglasae, Salix churchillensis, S. desatoyana, S. succorensis, Ostrya oregoniana, Juglans browniana, Quercus columbiana, Q. oberlii, Pterocarya mixta, Zelkova brownii, Mahonia macginitiei, Amelanchier magnifolia, Acer busamarum, A. chaneyi, A. latahense, Fraxinus coulteri, F. dayana* (reference data from Axelrod, 1944, 1991, 1992, 1995; Chaney, 1944, 1959; Chaney and Axelrod, 1959; Condit, 1944; Dorf, 1936; Fields, 1996; Smith, 1941; Smiley, 1963;

Table 9 — Score sheet for CLAMP analysis. A CLAMP analysis was performed on taxa from Site I in March 1998 at the University of Arizona in Tucson using the CLAMP 3B database. The following changes of systematic assignments have since been made (compare to Table 2): "*Ulmus* sp." was added to "Ulmaceae sp.", and "*Umbellularia* sp." united with "*Quercus simulata*". Two leaves of "*Acer* cf. *macrophylum*"

Species	Form	Teeth						Size								
	Lobed	None	Regular	Close	Round	Acute	Cmpd	Nano	Lepto 1	Lepto 2	Micro 1	Micro 2	Micro 3	Meso 1	Meso 2	Meso 3
Mahonia macginitiei Axelrod	0	1	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0
Parthenocissus sp.	0	1	0	0	0	1	1	0	0	0	1	0	0	0	0	0
cf. *Apios americana*	0	1	0	0	0	1	1	0	0	0	0	0	1	0	0	0
Cladrastis sp.?	0	1	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0
Robinia sp.?	0	1	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0
Sophoreae sp.? (Form A)	0	1	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0
Sophoreae sp.? (Form B)	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Sophoreae sp.? (Form C)	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Fabaceae sp.?	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Ostrya oregoniana Chaney	0	0	0.5	1	0.5	0.5	1	0	0	0	0	0.33	0.33	0.33	0	0
Quercus columbiana Chaney sensu	0	0	0.5	0.5	1	0	0.5	0	0	0	0	0.25	0.25	0.25	0.25	0
Quercus hannibali Dorf	0	1	0	0	0	0	0	0	0	0	0.33	0.33	0.33	0	0	0
Quercus oberlii Buechler	0	1	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0
Quercus prelobata Condit	1	0.5	0	0.5	0.5	0	0.5	0	0	0	0	0.25	0.25	0.25	0.25	0
Quercus simulata Knowlton	0	0.5	0	0	0	0.5	0	0	0	0	0	0.5	0.5	0	0	0
"*Umbellularia* sp."	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Juglans browniana Chaney and Ax.	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0
Pterocarya mixta (Knowlton) Brown	0	0	0.5	1	1	0	0	0	0	0	0	0.5	0.5	0	0	0
Populus bonhamii Axelrod	0	0	0.5	0	1	0	0	0	0	0	0	0.5	0.5	0	0	0
Populus douglasae Buechler	0	1	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0
Populus eotremuloides Knowlton	0	0.5	0.25	0.25	0.25	0.25	0	0	0	0	0	0.33	0.33	0	0	0.33
Populus washoensis Brown	0	0	0.5	1	0.5	0.5	0	0	0	0	0	0	1	0	0	0
Salix churchillensis Axelrod	0	1	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0
Salix desatoyana Axelrod	0	1	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0
Salix inquirenda Knowlton	0	0	1	1	1	0	0	0	0	0	0	0.33	0.33	0.33	0	0
Salix succorensis Chaney & Axelrod	0	0	0.5	1	1	0	0	0	0	0	0.5	0.5	0	0	0	0
Salix wildcatensis Axelrod	0	1	0	0	0	0	0	0	0	0	1	1	0.5	0	0	0
Lyonothamnus cf. *parvifolius*	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Amelanchier macnifolia Arnold var.	0	0	0.5	0.5	0	1	0	0	0	0	0	0.33	0.33	0.33	0	0
Ulmaceae sp.	0	0	0.5	1	0	1	1	0	0	0	0.33	0.33	0.25	0	0	0
Zelkova brownii Tanai et Wolfe	1	0	0.5	0.5	0	1	0.5	0	0	0	0.25	0.25	0.5	0.25	0.5	0.5
Acer chaneyi Knowlton	1	0	0.5	0	0	1	0.5	0	0	0	0	0.25	0.25	0	0.25	0.25
Acer latahense Wolfe et Tanai	1	0	0	0	0	1	0.5	0	0	0	0	0.25	0.25	0	0.25	0.25
Acer cf. *macrophyllum* Pursh	1	0	0	0	0	1	0.5	0	0	0	0	0.25	0.25	0	0.25	0.25
Acer scottiae MacGinitie	1	0	0	0	0	0	0	0	0	0	0	0.25	0.25	0	0.25	0.25
Unassigned leaf type 2	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Unassigned leaf type 3	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Unassigned leaf type 5	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Unassigned leaf type 6	0	0.5	0.25	0	0	0.25	0	0	0	0	1	0	0	0	0	0
Unassigned leaf type 7	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
No. of species	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
Total per character	6	22	7.5	6.75	7.75	11	7.5	0	0	1.5	11.91	11.31	9.81	3.07	1.75	1.58
Percentage (rounded)	15	54	18	16	19	27	18	0	0	4	29	28	24	7	4	4
	Lobed	None	Regular	Close	Round	Acute	Cmpd	Nano	Lepto 1	Lepto 2	Micro 1	Micro 2	Micro 3	Meso 1	Meso 2	Meso 3

Table 9 (continued) — were taken out of that category and are now listed as "*Acer busamarum*". Through these changes the percentage of leaves with entire margins has been reduced from 53.7% (CLAMP analysis) to 52.5% (Table 2). For "unassigned leaf types" refer to Table 3.

Species	Apex				Base			L:W					Shape		
	Emargin.	Round	Acute	Atten.	Cordate	Round	Acute	<1:1	1-2:1	2-3:1	3-4:1	>4:1	Obovate	Elliptic	Ovate
Mahonia macginitiei Axelrod	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0
Parthenocissus sp.	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0
cf. *Apios americana*	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0
Cladrastis sp.?	0	1	0	0	0	1	0	0.5	0.5	0.5	0	0	0	1	0
Robinia sp.?	1	1	0	0	0	1	0	0	0	1	0	0	0	0.5	0.5
Sophoreae sp.? (Form A)	0	1	0	0	0	1	0	0	0	0.5	0.5	0	0	1	0
Sophoreae sp.? (Form B)	0	1	0	0	0	-	-	0	0	0	1	0	0	0	1
Sophoreae sp.? (Form C)	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
Fabaceae sp.?	0	0	0	1	0	1	0	0	0	1	0	0	0	0	1
Ostrya oregoniana Chaney	0	0	0.5	0.5	0.5	0.5	0	0.5	0.5	0.5	0	0	0	1	0
Quercus columbiana Chaney	0	1	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	0.5	0
Quercus hannibali Dorf	0	1	0	0	0.5	0.5	0	0.5	0.5	0.5	0	0	0.5	0.5	0
Quercus oberlii Buechler	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0
Quercus prelobata Condit	0	0	0	0	0	0.5	0.5	0.33	0.33	0.33	0.33	0	0.5	0.5	0
Quercus simulata Knowlton	0	0	0.5	0.5	0	1	0	0	0	0.5	0.5	0	0	1	0
"*Umbellularia* sp."	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0
Juglans browniana Chaney and	0	0	0	1	0.5	0.5	0	0	0	0	1	0	0	1	0
Pterocarya mixta (Knowlton)	0	1	0	0	0.5	0.5	0	0	0	0.5	0.5	0	0	0.5	0.5
Populus bonhamii Axelrod	0	0	0.5	0.5	0	0.5	0	0.33	0.33	0.33	0.33	0	0	0	1
Populus douglasae Buechler	0	0.5	0.5	0	0.33	0.33	0.33	0	1	0	0	0	0	0.5	0.5
Populus eotremuloides	0	0.5	0.5	0	0	1	0.5	0	1	0	0	0	0	0.5	0.5
Populus washoensis Brown	0	0.5	0.5	0	0	0.5	0.5	1	0	0	0	0	0	1	0
Salix churchillensis Axelrod	0	0	1	0	0	0.5	0.5	0	0	0	0	0	0	1	0
Salix desatoyana Axelrod	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1
Salix inquirenda Knowlton	0	0	1	0	0	1	0	0	0	0	0.5	0.5	0	0.5	0.5
Salix succorensis Chaney &	0	0	0.5	0.5	0	1	0	0	0	0	0	1	0	0.5	0.5
Salix wildcatensis Axelrod	0	1	0	0	0	0.5	0.5	0	0	0	0.5	0.5	0	1	0
Lyonothamnus cf. *parvifolius*	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0
Amelanchier magnifolia Arnold	0	0.5	0.5	0	0.5	0.5	0	0	1	0	0	0	0	1	0
Ulmaceae sp.	0	0	0	1	0	1	0	0	1	1	0	0	0	1	0
Ulmus sp.	0	0	0.5	0.5	0.5	0.5	0.5	0	0.5	0.5	0	0	0	0.5	0.5
Zelkova brownii Tanai et Wolfe	0	0.5	0.5	0	1	0	0	0.5	1	0	0	0	0	0.5	0
Acer chaneyi Knowlton	0	0	1	0	0.5	0.5	0	1	0	0	0	0	0	0.5	0.5
Acer latahense Wolfe et Tanai	0	0	1	0	0	1	0	0.5	0.5	0	0	0	0	0.5	0.5
Acer cf. *macrophyllum* Pursh	0	0.5	0.5	0	1	0	0	1	0	0	0	0	0.5	0.5	0
Acer scottiae MacGinitie	0	0	1	0	0	1	0	1	0	0	0	0	0.5	0.5	0
Unassigned leaf type 2	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
Unassigned leaf type 3	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0
Unassigned leaf type 5	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1
Unassigned leaf type 6	0	1	0	0	0	1	0	1	0	0	0	1	0	1	0
Unassigned leaf type 7	0	0.5	0.5	0	0	1	0	0	0.5	0.5	0	0	0	1	0
No. of species	41	41	41	41	41	40	40	41	41	41	41	41	41	41	41
Total per character	1	15.5	21	4.5	7.33	27.83	4.83	4.5	10.16	8.16	7.16	11	2.5	29	9.5
Percentage (rounded)	2	38	51	11	18	70	12	11	25	20	17	27	6	71	23
	Emargin.	Round	Acute	Atten.	Cordate	Round	Acute	<1:1	1-2:1	2-3:1	3-4:1	>4:1	Obovate	Elliptic	Ovate

Wolfe, 1964). Pickett Creek shares its three most abundant species, *Quercus prelobata, Q. columbiana,* and *Q. simulata* with only two other floras: Thorn Creek (13.2 m.y., Fields, 1996) and Cove Creek (Lower Idaho, 12–14 m.y., Fields, 1996). In both floras they are, however, far less abundant than in Pickett Creek. Besides Pickett Creek, only Thorn Creek has a similarly high percentage of white oaks (*Q. eoprinus* Smith with 43%). The Unity flora of Oregon (11.3 m.y., Retallack, 2004) is dominated by *Quercus pollardiana* (syn. *Q. hannibali*) but has also *Q. prelobata* and *Q. simulata*. The mean annual temperature of the Unity assemblage is estimated to be 12.9°C (7.7 – 17.7°C, Retallack, 2004). The flora is compared to the contemporary grassy live oak woodland and savanna on the western slopes of the Sierra Nevada, northern California (Retallack, 2004). The Stinking Water flora (11 m.y., Graham, 1999, p. 264) is dominated by *Quercus pseudolyrata* Lesquereux (33%), and evergreen oaks: *Q. hannibali* (8%), *Q. dayana* (7%), *Q. simulata* (6%), and *Q. prelobata* (4%) (Chaney, 1959). Of all these oak-dominated floras Pickett Creek is the youngest and the most eastern. Three species usually abundant in middle Miocene floras of the Northwest are missing at Pickett Creek. *Taxodium dubium* and *Glyptostrobus oregonensis* had their last apperance in the floras of the lower Idaho Formation (12–14 m.y.). The presence of swamp-dwelling taxa like *Equisetum* sp., *Typha* sp., and *Ceratophyllum* cf. *demersum* suggests that Pickett Creek probably had the habitat to support growth of *Taxodium* and *Glyptostrobus*, had they not already disappeared from the northwest because of decreasing temperatures. The northern range limit of modern *Taxodium distichum* is near Washington, D.C., at 14.1°C mean annual temperature (Little, 1971). The third species, *Liquidambar pachyphyllum*, survived in the more humid and equable climate of the northern west coast (Troutdale flora) until early Pliocene. In early late Miocene the intermountain west may have been already too dry for that species. The composition of the Pickett Creek flora and its relation to older and younger floras suggests an age close to the middle Miocene - late Miocene transition (10.4 m.y.a.). This agrees with the older age bracket given by ash dating (10.5 m.y.a.) and the earliest evidence of lacustrine deposition at about 10 m.y.a.

PALEOALTITUDE

Paleoaltitude for a fossil assemblage can be estimated by comparing its CLAMP-derived mean annual temperature with the mean annual temperature of an isochronous coastal assemblage, via an assumed lapse rate (Wolfe, 1992). The practical use of this method can, however, be limited by several uncertainties. The age estimates for the two assemblages may not be sufficiently reliable, and the paleo lapse rate may differ from the present-day value because of topographic changes (uplift of the Cascade Range) and changes in large-scale weather patterns (freezing of the Arctic Ocean). Paleoaltitudes are especially prone to large errors in intermountain plateaus of the Pacific Northwest, where lapse rates are low, and small differences in mean annual temperature translate into major changes of altitude. West Coast reference temperatures of 8.5–10.5 m.y.a. are between 10.7°C and 13.5°C (Wolfe, 1995: fig. 11, corrected for latitude). We estimated paleoaltitude for Pickett Creek using minimum and maximum tolerances for mean annual temperatures and a modern lapse rate of 1.65°C/km (mean value between Anderson Dam and Deer Flat Dam, Idaho; Wolfe, 1992). Altitude varied between – 2790 m and +1210 m, depending on the data combination used. The results demonstrate the method-related problems for sites leeward of the Cascades. The most reasonable result (+1210 m) was obtained by using a low estimate for Pickett Creek (13.4ºC minus standard error) and a high estimate for the West Coast (13.5°C). This suggests that CLAMP-derived annual mean temperature may be 1 –2°C too high. A slightly lower value would still be compatible with the temperature regime in the Californian foothill woodlands. Pierce and Morgan (1992) showed that the Yellowstone hotspot created at least a temporary uplift along its path through the Snake River Plain. This suggests that Pickett Creek paleoaltitude was probably not lower than it is today (1359 m).

SUMMARY

The high frequency and generally good preservation of Pickett Creek megafossils allowed a high-resolution stratigraphic examination on a statistical basis. A similarly detailed study had previously only been done at the middle Miocene Clarkia site in northern Idaho (Rember, 1991). Although no significant change in floral composition was found within the investigated sediments, the data may provide a valuable basis for quantitative comparisons with future stratigraphic investigations in the Pickett Creek area and other fossil sites. A statistical test of sampling data revealed the consistency of the method.

While southwestern Idaho and southeastern Oregon are rich in middle Miocene floras, no major late Miocene or younger flora was known from this area before the investigation of the Pickett Creek assemblage. Findings of this study may contribute to a better understanding of the early history of Neogene Snake River Plain lake-systems, and the floral and climatic changes after the middle Miocene temperature maximum. Pickett Creek continues the series of oak dominated floras of the northwest from the middle Miocene into late Miocene.

Local stratigraphy, floral composition of local diatomite outcrops, and shoreline features (water-affected basalt and possibly beach sand) revealed a minimum size of the lake of $2-4$ km^2, and a sequence of events under which fossil remains were deposited. The partial preservation of the ancient topography, together with megafossil and pollen data, suggests five distinct vegetation zones: lake-beach, bottomland, mountain slope, river floodplain, and a mountain conifer association.

Floral composition suggests an oak-dominated broad-leaved forest similar to the foothill woodlands of the Central Valley in California. A CLAMP (Climate – Leaf Analysis Multivariate Program) analysis of leaf characteristics revealed a mean annual temperature of 13.4°C ± 1.9°C (standard error) and a mean annual range of temperature of 21.2°C. These values are within the climatic range of the modern foothill woodlands plant communities. Pollen analysis corresponds with most of the megafossil families and suggests additional taxa from higher elevation and dry sites. It is consistent with findings of other authors (Leopold and Wright, 1985) and supports the concept of an oak-dominated, summer-dry, and predominantly broad-leafed forest.

In comparison with other northwestern floras, Pickett Creek has more species in common with early and middle Miocene assemblages than with Late Miocene and Pliocene floras, suggesting an age close to the middle Miocene – late Miocene transition (10.4 m.y.a.). This agrees with the older age bracket given by ash dating (8.5–10.5 m.y.a.).

Paleoaltitude estimates vary greatly, depending on whether high or low temperature estimates are used. This reflects the method-related problems for sites with low lapse rates leeward of the Cascades. The highest estimate, 1210 m, is close to the present altitude of the fossil site.

OTHER PICKETT CREEK RELATED RESEARCH

Material from Pickett Creek has prompted research and publications by other authors: Gerald R. Smith, University of Michigan, Ann Arbor, studied fossil fish. A publication including the description of a new *Catostomus* species is in preparation. Kurt Krammer, Institut für Oberflächenanalyse e. V., Meerbusch, Germany studied diatom samples from Site I and described four new *Cymbella* species (Krammer, 2002). Michael T. Dunn, Dept. of Biological Sciences, Cameron University, Lawton, Oklahoma, worked on epiphyllous fungi on *Quercus* leaves from Pickett Creek (preliminary results in: Fossil epiphyllous fungi on *Quercus prelobata* from the Miocene Pickett Creek fossil beds, Owyhee County, Idaho, USA, unpublished report at the Department of Geosciences, Boise State University, Idaho). Walter K. Buechler, Boise, Idaho, established a correlation between petiole epidermal cell size and polyploidy level in modern *Salix* leaves and applied it to fossil material from Pickett Creek (Buechler, 2000).

FUTURE TASKS

Results from the present study answer many questions but pose an array of new ones. Future work should focus on the following issues: (1) Direct Ar/Ar dating of fallout tuffs may narrow the age range of the sediments. (2) Floral data from Site II are based on only 73 specimens. A quantitatively more thorough investigation may reveal interesting differences to Site I. (3) Except for the lowest few cm, the diatomite deposit (+370 to 0 cm) was disturbed by bioturbation soon after deposition. Of the varved bottom part, only a few square feet have been unsuccessfully searched for leaf imprints. A more thorough examination of these layers may reveal more clues to the aftermath of the ash deposit at 0–3 cm, which may also have triggered the massive diatom bloom. (4) Our data suggest a minimum size of 2– 4 km² for Pickett Creek Lake. A geographically extended search for shore line features and sediments with similar diatom floras could lead to a better-founded estimate and, potentially, to a better understanding of early SRP lake-systems.

Some of the suggested new tasks exceed the possibility of a privately funded and performed project. They require the use of heavier equipment, more manpower and more detailed arrangements with the Bureau of Land Management and diatomite claim-owners than are currently available.

ACKNOWLEDGMENTS

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