Late Tertiary floral assemblage from upland gravel deposits of the southern Maryland Coastal Plain

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ABSTRACT

A diverse flora has been discovered in a dark clay lens in upland gravel in southern Maryland near Brandywine. More than 49 taxa have been identified in the assemblage, which includes leaves, seeds, fruits, pollen, and a *Taxodium* (bald cypress) trunk. The vegetation is dominated by deciduous trees and vines. Four taxa are now absent from North America but survive elsewhere; one is extinct. A late Miocene age and warm-temperate climate are inferred from the flora. The clay lens probably represents a cutoff distributary in the extensive braided stream system that covered the area and is unique in Maryland. Similar dark clays have been described from Miocene sands and gravels in New Jersey. The Brandywine flora is the first direct evidence of the Miocene age of part of the fluvial upland deposits of Maryland. On the basis of the age inferred from the flora, the Brandywine deposit is correlated with the St. Marys Formation or the Eastover Formation, which are upper Miocene shelly marine units south and southeast of Brandywine.

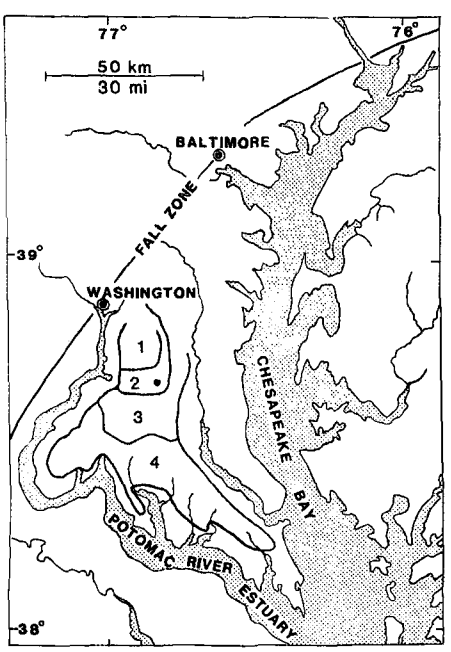

Figure 1. Map showing location of deposit at Brandywine, Maryland (solid circle in lobe 2), in western part of Salisbury embayment, U.S. Atlantic Coastal Plain. Fall zone marks approximate inner edge of Coastal Plain. Numbered lobes show where sand and gravel accumulated in subaerial alluvial plain during early to middle Miocene (1), late Miocene (2), and Pliocene (3, 4).

INTRODUCTION

The Brandywine deposit, located 20 km southeast of Washington, D.C. (Fig. 1), is geologically significant. The deposit is contained in a channel filled with clay that is part of a system of thin surficial sand and gravel sheets that bevel marine units of Cretaceous through late Miocene age. Before the discovery of the Brandywine fossils in 1986, little direct evidence was available with which to date these upland deposits, which compose the most extensive nonglacial gravel sheets in the emerged Atlantic Coastal Plain. The clay lens contains the most diverse late Cenozoic terrestrial flora currently known from the Atlantic Coastal Plain, and the flora provides good evidence for the age and climatic conditions during deposition of the second oldest upland deposit of the Maryland Coastal Plain (lobe 2 in Fig. 1).

The age and origin of the upland deposits throughout the Salisbury embayment of the Atlantic Coastal Plain have been debated for more than 100 years. Some workers have considered the surficial sand and gravel sheets to be Quaternary glacial outwash (McGee, 1888; Jordan, 1967) or interglacial marginal marine deposits (Cooke, 1958; Shattuck, 1906). Hack (1955), following the lead of Flint (1940), argued against a marine origin for any surficial deposits above 30 m and conclusively demonstrated the fluvial nature of the upland deposits at Brandywine. Hack (1955) and Glaser (1971) established the stratigraphic age of the upland deposits near Brandywine as post–middle Miocene because they bevel the middle Miocene Choptank Formation and probably pre-Pleistocene because of the deep weathering and their physical separation from dated Pleistocene units in the lowlands of southern Maryland. Lithologic evidence suggests a nonglacial climate during deposition. The few published reports of late Tertiary floral assemblages (Hollick, 1906; Berry and Hawkins, 1935; Berry, 1937; Leopold, 1969) were based on sparse and poorly preserved material and, in most cases, controversial lithostratigraphy. In contrast, the Brandywine flora is diverse and well preserved, and it

has aided significantly in establishing the correct stratigraphic interpretation of the host deposit.

GEOLOGY OF THE BRANDYWINE DEPOSIT

The Brandywine clay lens was probably about 30 m wide, 90 m long, and 6 m thick. It occupies an irregular channel remnant in a southward-accumulating alluvial plain (Fig. 1) composed largely of quartzose sand and gravel (Fig. 2). The clay occurs in the deepest part of the channel, which is lined by steeply dipping sand and gravel cross beds. The surface elevation is 64 m.

Such channels are unusual features in the upland deposits of southern Maryland; most channels in this plain do not exceed 1–2 m in depth and are filled with coarse sediment. The upland deposits are mainly composed of interbedded and poorly sorted coarse sand and fine to medium gravel, massive to subhorizontally bedded medium gravel, and sparse lenses of trough-cross-bedded to planar-bedded coarse sand. These features are characteristic of braided stream deposits in alluvial plains (Rust, 1978).

The homogeneous fine-grained texture of the clay that fills the channel suggests that the cutoff remained connected to the main channel, at least during floods, throughout the filling process. The channel probably filled rapidly, because pollen data do not suggest the ecological changes expected of a slow transition from a pond surrounded by sparse vegetation to a swamp or pond in dense forest.

The top of the clay is at the same elevation in the excavated pit and in two drill holes located about 12 m and 25 m to the southeast; this uniform elevation suggests that the top of the clay lens is level. No evidence of deformation caused by surface loading was observed in the clay, so it had time to dewater and become consolidated before the overlying 7.5 m of gravel was deposited. Gravel above and below the clay lens is similar, about 85% monocrystalline quartz, 10% chert, and 5% polycrystalline quartz.

BRANDYWINE FLORA

The floral assemblage thus far identified from this site includes 49 taxa identified mainly at the generic level and at least 10 other taxa of pollen, 7 of fruits and seeds, and several of leaves. Of the identified taxa, all but one (*Mneme*) represent living genera. Four (*Alangium*, *Pterocarya*, *Zelkova*, and *Trapa*) are not found in North America today but survive elsewhere in temperate climates. Of the 44 genera still occurring in North America, only 2 do not grow in Maryland today. *Sophora* occurs west of the Appalachians, and *Larix* grows only as far south as New Jersey. The assemblage is dominated by trees (54%) and some shrubs (18%) and vines (8%). The scarcity of terrestrial herbs (6% of the flora) and the absence of grass pollen suggest a lack of open space adjacent to the depositional site. Aquatic plants (14%) round out the flora. Several taxa are represented by multiple organs (Table 1, Fig. 3).

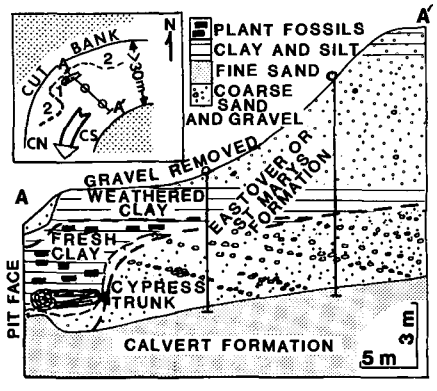

Figure 2. Diagrammatic map of channel that contained cutoff channel, and lithologic cross section reconstructed from outcrops and two drill holes (open circles); *Taxodium* (cypress) trunk not to scale. All material above Calvert Formation is inferred to be upper Miocene on basis of flora. No major lithostratigraphic breaks were found in section beyond edges of channel. Fresh clay was dark gray to black where wet, pale to medium gray where dry; weathered clay was gold. Inset: Dot pattern indicates coeval gravel surrounding channel fill; A-A′ is cross-section line; circles indicate drill holes; CN and CS are northern and southern edges of abandoned channel. 1—Fallen trunk of *Taxodium*, not to scale; 2—sediment removed by erosion or quarrying operations. Large arrow denotes direction of water movement inferred from sedimentary structures.

TABLE 1. FLORA FROM THE BRANDYWINE, MARYLAND, SITE

		Organ			Life environment*				Status†
Family	Genus	Leaf	Fruit, seed	Pollen	Aquatic	Swamp	Transitional	Upland	
Trapaceae	*Trapa*	..	x	..	x	..	..	..	E
Nymphaeaceae	*Nuphar*	..	..	x	x	..		..	N
Isoetaceae	*Isoetes*	..	..	x	x	..	..	..	N
Typhaceae	*Typha*	..	x	..	x	..	..	..	N
Potomogetonaceae	*Potomogeton*	x	..	..	x	..	..	..	N
Lythraceae	*Mneme*	..	x	..	x	..	..	..	O
Ceratophyllaceae	*Ceratophyllum*	x	..	..	x	..	..	..	N
Taxodiaceae	*Taxodium*	x§	x	x	..	x	..	..	N
Hamamelidaceae	*Liquidambar*	..	..	x	..	x	x	..	N
	Hamamelis?	..	x	..	..	x	x	..	N
Betulaceae	*Alnus*	..	..	x	..	x	..	..	N
	Betula	..	..	x	..	x	x	..	N
	Carpinus/Ostrya		..	..	x	..	x	x	N
Nyssaceae	*Nyssa*	x	..	x	..	x	x	..	N
Vitaceae	*Vitis*	x	x	..	..	x	x	..	N
	Parthenocissus?		x	..	..	x	x	..	N
Smilacaceae	*Smilax*	x	..	..	..	x	x	..	N
Rutaceae	*Ptelea*	x	..	..	..	..	x	..	N
Salicaceae	*Salix*	x	..	..	..	x	x	..	N
	Populus sp. 1	x**	..	..	..	..	x	x	N
	Populus sp. 2	x††	..	..	..	..	x	x	N
Aceraceae	*Acer*	..	x	..	..	..	x	x	N
Celastraceae	*Celastrus*	x	..	..	..	..	x	x	N
	Euonymus	..	..	x	..	..	x	x	N
Aquifoliaceae	*Ilex*	x§§	x	x	..	..	x	x	N
Platanaceae	*Platanus*	x***	x	..	..	..	x	x	N
Anacardiaceae	*Toxicodendron*	x†††	..	?	..	..	x	x	N
Fagaceae	*Fagus*	..	..	x	..	..	x	x	N
	Quercus sp. 1	x	x	x	..	..	?	x	N
	Quercus sp. 2	x	?	?	..	..	?	x	N
	Quercus sp. 3	x	?	?	..	..	?	x	N
Alangiaceae	*Alangium*	x	..	..	..	..	x	x	E
Magnoliaceae	*Liriodendron*	..	..	x	..	..	x	x	N
Selaginellaceae	*Selaginella*	..	..	x	..	..	x	x	N
Cornaceae	*Cornus*	..	x	..	..	..	x	x	N
Caprifoliaceae	*Sambucus*?	..	x	..	..	x	x	x	N
Compositae	*Ambrosia*	..	x	x	..	..	x	x	N
	Artemisia	..	..	x	..	..	x	x	N
Juglandaceae	*Carya*	x	x	x	..	..	..	x	N
	Juglans	..	..	x	..	..	..	x	N
	Pterocarya	x	x	x	..	..	x	x	E
Leguminosae	*Gleditsia*	x§§§	..	..	..	..	..	x	N
	Sophora	x	..	..	..	..	..	x	N
Ulmaceae	*Ulmus*	x	..	x	..	..	..	x	N
	Zelkova-type	..	..	x	..	..	..	x	E
Pinaceae	*Pinus*	..	..	x	..	..	..	x	N
	Larix	..	..	x	..	x	x	x	N
Rosaceae	*Prunus*	..	..	x	..	..	..	x	N

Note: Leaves identified by Wolfe; seeds and fruits by Tiffney and Wing; pollen by Ager. Symbols, except last column: x=present; ..=absent; ?=uncertain.

*Environment inferred from similar modern taxa: aquatic plants live in or on water; swamp plants tolerate root submersion for long periods; transitional plants need damp environment, do not tolerate root submersion for long periods; upland plants tolerate well-drained soils.

†E=absent from the extant North American flora but living elsewhere; O=extinct; N=taxon still lives in area.

§*T.* cf. *T. distichum.*

**P. aff. *P. balsamifera.*

††P. aff. *P. heterophylla.*

§§*T.* aff. *I. cornuta.*

***P. cf. *P. occidentalis.*

†††*T.* aff. *T. radicans.*

§§§*G.* aff. *G. triacanthos.*

PALEOCLIMATE

The flora reflects a temperate climate. Deciduous taxa (74%) dominate the assemblage. Only five taxa (10%) represent evergreen plants. Of these, *Pinus* (pine), *Smilax* (greenbriar), and *Myrica* (wax myrtle) or *Comptonia* (sweet fern) tolerate winter temperatures colder than those now occurring in Maryland. Modern evergreen oaks (*Quercus*) occur as close as southeastern Virginia (Fernald, 1970). The presence of a large bald cypress trunk (1 m across, 4 m long) and absence of drought-tolerant taxa indicate a high ground-water table and adequate rainfall at the site for an extended period. Late Miocene shallow-marine temperatures in the Maryland area were mild temperate to warm temperate, except during earliest Eastover and earliest Yorktown time, when they were cool temperate (Fig. 4). During the late Miocene, the western Salisbury embayment probably had hot summers, mild winters with limited frost, and an even seasonal distribution of rain, as does the coast of North and South Carolina today.

AGE OF THE FLORA

The scarcity of published fossil floras in northeastern North America makes a biostratigraphic age assignment difficult; however, a late Miocene age is likely for the Brandywine. The inference is based on probable climatic tolerances of plant taxa during the late Cenozoic as well as on subtle evolutionary differences in the organs.

The floristic evidence suggests a Brandywine-time climate little different in its extremes from today's climate. The Old World exotic flora (*Alangium*, *Pterocarya*, *Zelkova*, and *Trapa*) are all known from other Neogene records of eastern North America, and they probably became extinct during Pleistocene extremes. All would grow in the area if transplanted today. This evidence supports a pre-Pleistocene age for the Brandywine flora. Early Tertiary floras of eastern North America (Tiffney, 1985; Wolfe, 1985) are diverse and rich in taxa now found mostly in more equable climates. Many of these taxa died out in North America as the global climate cooled, restricting the flora to its modern composition. The many living, temperate genera in the Brandywine assemblage suggest a late Tertiary age.

Supporting evidence for the inferred late Miocene age is provided by climatic patterns derived from marine data and by comparisons with pollen floras from elsewhere. Comparison of pollen in middle Miocene marine units in Maryland and New Jersey with those of Pliocene units in Virginia and Maryland suggests that the Brandywine flora is late Miocene and is correlated with either the St. Marys Formation or the upper Eastover Formation (Fig. 4).

Molluscan faunas of the late Miocene St. Marys and Eastover Formations suggest mild to warm-temperate marine conditions during most of the late Miocene (Ward, 1984; Ward and Strickland, 1985; Ward and Powars, 1989) and subtropical marine temperatures in the late Pliocene when all but the lowermost Yorktown Formation was deposited (Ward and Strickland, 1985; Ward and Huddlestun, 1988; Ward et al., 1989). Lithologic and floral data (L. McCartan and L. A. Sirkin, unpub. data) suggest that other, stratigraphically younger, gravel beds in Maryland are Pliocene and were deposited under temperate conditions similar to those of the modern terrestrial climate.

The flora of the Legler lignite bed of the dominantly marine Cohansey Sand of New Jersey (Rachele, 1976; Greller and Rachele, 1983) was presumed to be late Miocene by Frederiksen (1984b). New palynological evidence from core ACGS-4 in the New Jersey Coastal Plain (Owens et al., 1988) indicates a middle Miocene age close to the well-dated middle Miocene marine Kirkwood Formation of New Jersey (Owens et al., 1988). The Legler lignite flora is generally similar to the Brandywine flora, although the Legler contains some thermophilic (warm-adapted, excluded by extended cool periods) taxa missing from the Brandywine (such as *Cyathea*, *Podocarpus*, *Engelhardia/Momipites*, *Cyrilla*, and *Gordonia*). The St. Marys Formation also shares some wide-ranging pollen genera with the Brandywine flora, but it contains *Momipites* and *Symplocos*, thermophilic taxa absent at Brandywine. Both floras contain *Taxodium* but have a low representation of other conifers. This suggests that the Brandy-

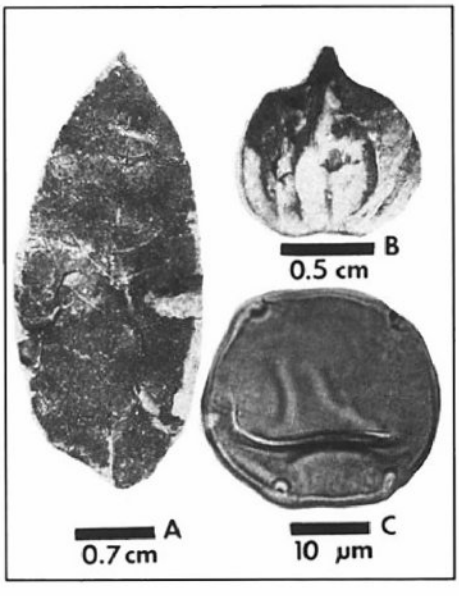

Figure 3. *Pterocarya*, member of walnut-hickory group, absent from extant North American floral assemblages but still living in China. A—leaflet; B—endocarp (seed); C—pollen.

Age	Formation		Marine climate of Maryland and Virginia
	New Jersey	Maryland	
late Pliocene	——	Bacons Castle	Warm temperate—ST common
early Pliocene	——	Yorktown	Warm temperate—ST common Cool to mild temperate
late Miocene	Pensauken	Eastover **BRANDYWINE DEPOSIT**	Warm temperate—ST present Mild temperate Cool temperate
	Bridgeton	St. Marys	Warm temperate—ST present Warm temperate
middle Miocene	Cohansey Sand **LEGLER LIGNITE**	Choptank	Mild temperate
early Miocene	Kirkwood	Calvert	Warm temperate—ST common Warm temperate—ST present
late Oligocene	Old Church	Old Church	Warm temperate—ST present

Figure 4. Age and climate of Miocene and Pliocene units in Maryland and New Jersey. Sources for stratigraphic units are as follows: Bacons Castle, Eastover, St. Marys—Sirkin and Owens (1976), L. A. Sirkin *in* Owens and Denny (1979), and L. A. Sirkin (unpub. data); Yorktown, Brandywine site, Choptank, Calvert, Cohansey Sand—Owens et al. (1988) and Ager (unpub. data); Pensauken, Bridgeton, Cohansey Sand, Legler lignite, Calvert—Rachele (1976) and Greller and Rachele (1983); Old Church—Frederiksen (1984a) and Edwards (1984). Marine climate information is from Ward (1984), Ward and Strickland (1985), Ward and Huddlestun (1988), Ward et al. (1989), and Ward and Powars (1989); average climate is based on benthic mollusks within Salisbury embayment; multiple entries reflect members. ST = subtropical benthic mollusks.

wine is no older than the St. Marys or the Legler lignite and is possibly younger. Recycling of these thermophyllic taxa is possible but unlikely; outcrops that may contain them are at least 17 km to the west or are deeply buried.

The lower part of the upper Miocene Eastover Formation, and its Delmarva Peninsula correlative the Pensauken Formation (Sirkin and Owens, 1976; L. A. Sirkin *in* Owens and Denny, 1979), contain pollen of conifers adapted to cool climates, such as *Picea* (spruce) and *Tsuga* (hemlock), indicating a cooler climate than that of Brandywine. Marine evidence, however, suggests that the upper part of the Eastover Formation was deposited under warmer conditions that were possibly similar to the paleoclimate of late St. Marys time. The lower and upper parts of the Eastover Formation occur in the same geographic area, excluding the possibility that they were influenced by source areas of different elevations and thus different vegetation types. The Pliocene Yorktown flora is modern in aspect and contains several pollen taxa that resemble modern species. The Brandywine appears a bit less modern than the Yorktown and has fewer pollen taxa directly comparable to modern species.

In summary, pollen relations within the Salisbury embayment indicate that the Brandywine flora is probably late Miocene in age, possibly coeval with the St. Marys Formation, or perhaps a bit younger and coeval with the upper Eastover Formation. A hiatus of about 2.5 m.y. separates the Yorktown (late Pliocene) from the Eastover. This suggests a window of about 4 m.y. for deposition of the Brandywine, from about 6 to 10 Ma.

This conclusion is reinforced by data from Massachusetts, where Frederiksen (1984b) has described both middle Miocene and Pliocene pollen assemblages, independently dated by vertebrate and invertebrate fossils. The Pliocene assemblage, which lacks the broad-leaved element that dominates the Brandywine, appears to reflect a cool-temperate climate. The middle Miocene flora, represented in the Legler lignite, has a strong deciduous component but contains some taxa, such as *Cyrilla*, *Gordonia*, *Podocarpus*, and *Symplocos*, that indicate a humid, subtropical, terrestrial climate and that are absent from the Brandywine deposit. These floristic differences could simply reflect different site ecologies, but the general pattern suggests that the Brandywine flora indicates an age and a climate intermediate between those of the two Massachusetts floras.

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