SOME ASPECTS OF TERTIARY VEGETATIONAL HISTORY IN THE GULF/CARIBBEAN REGION (1)

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ABSTRACT

Early studies on tropical American Tertiary vegetation and paleoenvironments were hindered by a lack of a tectonic model accurately depicting land-sea relationships during the Cenozoic, improper identification of the specimens, errors in the age of the floras, imprecise correlations, and incomplete or misleading data on the range and ecological characteristics of the modern analogs. Consequently, the impression was created that paleobotanical data was inconsistent with and, therefore, mostly irrelevant to emerging concepts based on isotope-derived paleo-temperature curves, Tertiary mammalian faunas and marine invertebrates. New data on palynofloras from eight formations in the Gulf/Caribbean region have demonstrated a general consistency with evidence derived from other lines of inquiry. In particular, these studies have clarified the history of the northern temperate element in the Latin American biota and the time of origin of floristic and faunal relationships between eastern United States and eastern Mexico; corrected misconceptions about the antiquity of the existing version of the neotropical rain forest and stability of neotropical Cenozoic paleoenvironments, demonstrating support for certain aspects of the refugium model of biological diversification; and have established a general consistency between the new paleobotanical data and results from other independent approaches. As part of the review, a catalog is presented of plant megafossils and microfossils reported from the Gulf/Caribbean Tertiary.

Study of the Tertiary history of vegetation in northern Latin America, based on plant megafossils (leaves, wood, seeds and fruits), was active in the decade between 1918 and 1928 (e.g., Berry, 1918, 1921, 1923; Hollick, 1928). During the past 60–70 years, however, not a single new megafossil flora has been studied, and none of the older ones revised. The investigations of Dilcher and co-workers on tropical Eocene floras of the Mississippi Embayment region (e.g., Dilcher & Dolph, 1970; Dilcher & Mehrotra, 1969; Jones & Dilcher, 1980), have shown that many identifications made or accepted by Berry (1916, 1930) were incorrect: (*Aralia* now *Dendropanax*; *Knightiophyllum* not related to modern *Knightia* nor Proteaceae; *Rhamnus* now referred to extinct genus *Berhamniphyllum* in a different tribe of the Rhamnaceae). Examination of the Berry and Hollick specimens at the Smithsonian Institution and New York Botanical Garden suggests that many generic determinations of the Latin American material are also questionable. In order to better evaluate the paleobotanical data, a compilation was made of Tertiary megafossils reported for northern Latin America (Mexico, Central America, and the Antilles; Table 1). Excluded were unpublished theses, dissertations and technical reports, abstracts, mimeographed material, casual mention of plant material, and artificial generic names with little or no reference to biological affinities. The results show that concepts about vegetational history for the 60 million years of Tertiary time for the entire Gulf/Caribbean region were based on about 90 plants assigned to modern genera, and experience has shown that many of these are probably incorrectly determined. Furthermore Berry was the principal North American paleobotanical spokesman arguing for permanence of continents and ocean basins in the anti-Wegener debates of the early 1900's. In a symposium at the American Association of Petroleum Geologists meetings (van Waterschoot van der Grach et al., 1928), the fiercest attack was that of Edward W. Berry, Professor of paleontology at John (sic) Hopkins University. Wegener's method, he said, "is not scientific, but takes the familiar course of an initial idea, a selective search through the literature for corroborative evidence, ignoring most of the facts that are opposed to the idea, and ending in a state of auto-intoxication in which the subjective idea comes to be considered as an objective fact" (quoted from Sullivan, 1974, p. 12). It is not surprising, therefore, that the paleobotanical data has led to many misconceptions about Gulf/Caribbean Tertiary vegetational history, and generally has proved inconsistent with new concepts derived from ^{18}O isotope studies of DSDP cores, fossil mammalian faunas, and land-sea

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relationships based on Caribbean plate tectonics.

More recently, data have been obtained from the study of plant microfossils (pollen and spores) preserved in lignites of Tertiary age in northern Latin America (Graham, 1976a, 1985, 1987a; Graham & Jarzen, 1969). Lignites commonly contain well-preserved palynomorphs, and are important in many Latin American countries as a low-cost source of fuel. Consequently, their age and location are frequently better known than for economically less-important deposits. In our studies, about 400 samples have been collected and ca. 75% have yielded researchable material. Samples were also collected from associated terrestrial to near-shore, fine-grained sediments (shales, clay — and siltsones) to minimize lithologic control of the assemblages. A total of eight microfossil floras are presently included in the project (Fig 1), and study of four of these has been completed and the results published (stippled in Fig.1).

		PANAMA	MEXICO	PUERTO RICO	COSTA RICA
PLIOCENE					
MIOCENE	U	GATUN	PARAJE SOLO		
	M	LA BOCA			
	L	CUCARACHA CULEBRA			USCARI
OLIGOCENE	U				
	M			SAN SEBASTIAN	
	L				
EOCENE	U	GATUNCILLO			
	M				
	L				
PALEOCENE					

Fig. 1. Age and distribution of fossil palynofloras included in the project, Studies in Neotropical Paleobotany. Stippled formation names mean study of the material is complete and the results published.

A compilation of genera represented by pollen and spores in Tertiary deposits in northern Latin America is given in Table 2. A total of 135 palynomorphs have been identified, and although revision in some identifications may be necessary as studies continue, the palynological data presently available provide a more accurate picture of Tertiary paleoenvironments and paleocommunities than the existing megafossil evidence collected earlier in the century. It is unfortunate that both mega — and microfossils cannot be used to investigate these complex tropical communities, because up to one-third of the fossils may be represented in only one or the other assemblage (based, for example, on pollen and spore vs. leaf floras preserved in the upper Miocene Sucker Creek flora of southeastern Oregon; Graham, 1965). Herbaceous plants with leaves that remain attached and wither on the stem (grasses, sedges, many composites), plants of upland environments removed from the basin of deposition, and those with thin, delicate leaves are often poorly represented in the megafossil record, while the pollen may be quite abundant (see Chaney, 1959 for a discussion of factors that influence numerical representation in the megafossil record). In contrast, the large and important tropical family Lauraceae is not represented as microfossils because the pollen does not survive fossilization or extraction processes. Thus, the most reliable basis for reconstructing Tertiary paleocommunities and paleoenvironments in northern Latin America at present is the microfossil record, and although limited, the approach has provided new insight into three aspects of vegetational history.

The Temperate Element in the Northern Latin American Biota, and History of the Floristic

Relationship between Eastern United States and Eastern Mexico: Along the eastern escarpment of the Mexican Plateau, in a zone between about 1000 and 2000 m, is a temperate community known as the bosque caducifolio (deciduous forest, oak-*Liquidambar* forest). Represented are some 50 genera of plants that also occur in the deciduous forests of eastern United States, their range disrupted by the deserts of southern Texas and northern Mexico (see list in Graham, 1973). The presence of these temperate elements of northern affinity in eastern Mexico has long intrigued biogeographers, and their occurrence was initially attributed to climatic changes and vegetational response during the Pleistocene (e.g., Deevey, 1949). A study of the palynomorphs preserved in the Paraje Solo formation near Coatzacoalcos, state of Veracruz, Mexico (Graham, 1976a) demonstrated that these temperate elements were already established in eastern Mexico by the end of the Miocene. None were recovered from the Oligo-Miocene Simojovel group of Chiapas, Mexico (Langenheim et al., 1967). Furthermore, the paleotemperature curve of Savin (1977; see later section) shows a sharp drop at the end of the Miocene, with temperatures increasing further back into earlier Miocene times. Thus the late Miocene was not only a favorable time for the introduction of northern temperate elements into eastern Mexico, but earlier times were less favorable because of warmer, more tropical conditions. Recent palynological studies, therefore, have clarified the time of origin of biotic affinities between eastern United States and eastern Mexico, and reveal a pattern of climatic change and plant migrations consistent with evidence from global paleotemperature curves and Caribbean tectonics.

Rain Forest Stability and the Refugium Concept: Prior to 1970 the biogeographic literature was consistent in presenting a picture of great antiquity for the tropical rain forest, and stability in terrestrial equatorial environments through Cenozoic time. A search for the paleobotanical evidence upon which this impression was based revealed only the few scattered studies done in the early 1900's. The identifications in these older treatments tended to reflect the common tropical plants with which temperate-trained paleobotanists were familiar (*Ficus*, palms, '*Piperites*', '*Melastomites*') which in turn reinforced an impression of modern tropical forest extending uninterruptedly through Cenozoic time.

One Tertiary palynological study from an area where neotropical rain forest is the present climax vegetation was on the upper Miocene Paraje Solo assemblage of Veracruz, Mexico (Graham, 1976a). Several modern communities were well represented, including the manglar (mangrove), bosque caducifolio (deciduous forest), bosque de pino y encino (pine-oak for... oyamel (high-altitude fir forest). However, the selva alta perennifolia (tropical rain forest), which would have grown immediately adjacent to the coastal basin of deposition for the lignites, was absent or poorly developed. It appears that at times during the Cenozoic the tropical rain forest in southeastern Mexico was restricted to more local habitats, concomitant with expansion of upland adjacent communities. Subsequent studies by Leyden (1984) showed that the dynamic and changing nature of the community continued into the Pleistocene. Thus the modern version of the rain forest in the region may be very recent, its present range and composition dating from late Cenozoic, possibly post-glacial times. The tropical rain forest is now generally regarded as a delicately balanced, ephemeral community that has undergone considerable alteration in range and composition throughout the Cenozoic (Graham, 1976b).

A consequence of this new view of rain forest dynamics is support for the Haffer model of diversification, or the refugium concept. Haffer (1969, 1970, 1974, 1981, 1982) noted that the distribution of toucan and jacamar species in Amazonia was not uniform, but clustered in certain localities surrounded by regions of lower species diversity. The data of van der Hammen & González (1960) on Quaternary vegetation from the adjacent high plain of Bogota demonstrated that climatic changes during the Pleistocene affected equatorial biotas at elevations of about 2500 m. Haffer extrapolated these changes into the Amazon lowlands, although direct evidence from the basin itself was lacking. According to the model, during glacial times climates were cooler and drier, and water tables lower because of lowering sea-levels associated with expansion of the continental ice sheets. As a result, the tropical rain forest was confined to climatically favourable areas (refugia) that perpetuated moist conditions during periods of drier climates (e.g., at the confluency of major river systems, base of mountain slopes, or low areas underlain by impervious hard-pan sediments). The intervening regions were occupied by drier caatingas-cerrado (savannah-type) vegetation. During the interglacials climates were warmer and more moist, water tables rose, and the rain forest expanded from the refugia and coalesced into the widespread community now occupying the basin; the drier vegetation again occupied the adjacent slopes, as at present. The repeated isolation and expansion of the rain forest during the late Cenozoic was considered important in accounting for the high species diversity characterizing the tropics, while the zones of present-day high species concentration were viewed as marking the location of former refugia. Subsequently, Brown (1975; Brown et al., 1974) and Prance (1979) found that the Heliconiini butterflies and certain plant families showed patterns similar to those revealed by the toucans and jacamars (see papers in Prance,

Obviously, critical to the model is paleontological documentation that Cenozoic changes in climate significantly affected lowland neotropical biotas. As noted earlier, the prevailing view prior to about 1970 was that the tropical rain forest was an ancient, unchanging community that had existed under stable conditions since the Cretaceous. For this reason the data from Veracruz, Mexico were important because they demonstrated for the first time that, in an area where rain forest is presently the climax vegetation, this community was absent or poorly developed during late Cenozoic times. Evidence is still meager from the critical area of the Amazon Basin, and recent evidence suggests some modification in the initial version of the model may be necessary. For example, Liu & Colinvaux (1985) have found that at least one area of the basin outside the proposed refugia was not occupied by drier, savannah-like vegetation during the last glacial period, but rather by elements of the adjacent lower montane forest. It seems likely that the vegetation of the Amazon Basin during glacial times was a more complex moasic than implied by the original Haffer model. Nonetheless, it has been established that the tropical rain forest has undergone considerable change in range and composition during the late Cenozoic, and this discovery has been one of the significant results of recent studies on neotropical vegetational history.

Emerging Consistency between the New Vegetational History Data and Results from Other Lines of Inquiry: Prior to the initiation of palynological studies on the Gulf/Caribbean Tertiary, the only available information on terrestrial plant communities came from megafossil floras investigated in the early 1900's. In the meantime, now evidence on paleoenvironments, paleophysiography and historical biogeography was emerging, based on ^{18}O-derived paleotemperature curves and fossil mammalian and marine invertebrate faunas. The new models were considered within the context of radiometrically controlled biostratigraphy and land-sea relationships derived from plate tectonic reconstructions. Thus, attempts to incorporate information on plant paleocommunities involved comparing the new data to paleobotanical results 50 years out of date. It is not surprising that these results were inconsistent with, and therefore, generally regarded as irrelevant to concepts based on other lines of inquiry.

Recently, attempts have been made to compare the paleoclimatic picture of the Gulf/Caribbean Tertiary based on terrestrial vegetation (Graham, 1987b) with the global paleotemperature curve resulting from ^{18}O analyses of DSDP cores (Savin, 1977; Savin & Douglas, 1985; Savin et al., 1975). These comparisons are preliminary because the palynological analyses presently include only four of the eight floras of the project, and refinements in the paleotemperature curve are also ... way. One core located off the eastern coast of Mexico will be particularly important, but it has not yet been analyzed for its ^{18}O content (Savin, pers. comm., 1986). Nonetheless, some useful information is now emerging.

The paleotemperature curve reveals a sharp drop in ocean bottom and surface water temperatures at the end of the Miocene in the higher latitudes of both the northern and southern hemispheres. Studies by Wolfe (1978; Wolfe & Hopkins, 1967) in North America, Hubbard & Boulter (1983) in Europe, and Tanai & Huzioka (1967) in Japan show the temperature decline is also reflected by terrestrial floras of the northern hemisphere. Towards the end of the Miocene, however, there is a decoupling of the histories of the high and lower (equatorial) temperatures, with those of the equatorial regions showing little or no change, and perhaps even becoming somewhat warmer (Savin, pers. comm., 1986). The difference apparently involved (1) the final separation of Antarctica from Australia and South America, resulting in cold waters continually circulating around Antarctica, (2) late Cenozoic initiation of the arctic continental ice sheet, and (3) the freer circulation of warmer equatorial waters. Since northern terrestrial floras reflect the late Miocene drop in temperature, and analyses of the DSDP cores show equatorial waters no colder than at present, the question arises as to how far south the temperature decline affected terrestrial vegetation. In this connection, results from the late Miocene Paraie Solo microflora of Veracruz, Mexico (lat. 18° N) become relevant.

It was noted earlier that the tropical rain forest was absent, or poorly represented in the assemblage, suggesting lower temperatures. This interpretation is supported by the presence of pollen from plants growing removed, altitudinally, from the coastal basin of deposition. The bosque caducifolio (mid-altitude deciduous forest), bosque de pino y encino (higher-altitude pine-oak forest), and bosque de oyamel (high-altitude fir forest) were all represented, suggesting a lowering of ecotones, bringing these upland forests into closer proximity to the depositional basin. Finally, *Picea* (spruce) was present in the assemblage. Spruce grows in Mexico today only at high elevations in the northern mountains, removed some 1000 km from the Veracruz site. Collectively, these results suggest cooler temperatures, and are consistent with the paleotemperature curve independently derived from ^{18}O analysis of Tertiary marine invertebrates.

Another point of agreement involves the migratory history of temperate elements across the isthmian region. Because of the misidentification of

ical literature, biogeographic patterns and geographic affinities of the vegetation were obscured. For example, the fossil genus *Knightiophyllum*, recognized by Berry from the Claiborne (middle Eocene) formation of Tennessee, was supposedly related to the modern genus *Knightia* (Proteaceae), presently restricted to New Zealand and New Caledonia. Reinvestigation of the material by Dilcher & Mehrotra (1969) demonstrated the specimens are not related to *Knightia* and do not even belong to the family Proteaceae.

In contrast, geographic patterns derived from genera recently identified in the palynofloras are consistent with those based on terrestrial mammalian faunas (e.g., Marshall, 1985; Marshall et al., 1976, 1981, 1982; Webb, 1976, 1978, 1985), marine invertebrate (Woodring, 1966; Jones & Hasson, 1985), and land-sea relationships reconstructed from plate tectonic models (Smith, 1985; Donnelly, 1985; Gose, 1985). Collectively, these studies reveal that the final segment in the isthmian region, connecting the North and South American continents, was uplifted about 3.8 Ma. At that time there began an interchange of large terrestrial mammals, as well as provincialization of marine invertebrate faunas into Pacific and Caribbean communities. It is now known that the plants had a similar history. Genera such as *Alnus*, *Ilex*, *Myrica*, and *Quercus* are known from Tertiary deposits north of about the present Panama Canal region (Graham, 1973), but do not appear in northern South America until Plio-Pleistocene times (van der Hammen, in Livingstone & van der Hammen, 1978). Conversely, *Weinmannia* (family Cunoniaceae), presently distributed from South America (Chile) into Mexico, is common in late Cenozoic deposits from South America, but has not been reported from the Tertiary to the north. Thus, a hallmark of the new paleobotanical data from northern Latin America is a general consistency with results from a variety of other independent approaches, including paleotemperature patterns and the migratory history of other groups of terrestrial organisms.

TABLE 1.

Plant megafossils reported from the Gulf/Caribbean Tertiary. Many of the identifications made in the early 1900's are likely incorrect, and none of the floras have been revised. Spelling of generic names and family assignments follow that in the original citations listed in parentheses. Asterix (*) designates genera of exclusively fossil plants

Arranged by Age/Country

Tertiary undifferentiated (most mid-to late Tertiary probably Oligo-Miocene to Miocene)

Mexico

Palmoxylon, **Acacioxylon* (Felix & Nathorst, 1893)

Juglans (Mullerried, 1938)

Costa Rica

*Anona, Buttneria?, Ficus, Goeppertia, Heliconia, Hieronymia, Inga, Nectandra, *Phyllites, *Piperites* (Berry, 1921a)

Palmacites (Gomez-P., 1971)

**Karatophyllum* (Gomez-P., 1972)

Panama

*Banisteria, Calyptranthes, Cassia, Diospyros, Ficus, Guatteria, Hieronymia, Hiraea, Inga, *Melastomites, Mespilodaphne, *Myristicophyllum, *Palmoxylon, Rondeletia, *Rubiacites, Schmidelia, *Taenioxylon* (Berry, 1918)

Antigua

**Palmoxylon* (Stenzel, 1897)

Dominican Republic

*Bucida, Bumelia, Calyptranthes, Guettarda, Inga, *Melastomites, Pisonia, Pithecolobium, *Poacites, Sapindus, Sophora* (Berry, 1921c)

Haiti

Chara, Gymnogramme, Bumelia, Chrysophyllum, Guettarda, Mespilodaphne, Mimusops, Pisonia, Simaruba (Berry, 1923a)

Miocene

Mexico

*Acrostichum, Gymnogramme, Allamanda, *Anacardites, Anona, *Apocynophyllum, *Bignonoides, Cedrela, Connarus, Coussapoa, Crescentia, Dioclea?, Drypetes, Fagara, Ficus?, Goeppertia, Gouania, Guettarda, Gymnocladus, Inga, *Lecythidophyllum, Leguminosites, Liquidambar, *Melastomites, Mespilodaphne, Moquillea, Myrcia, Nectandra, Rondeletia?, Simaruba* (Berry, 1923b)

Panama

**Iriartites* (Berry, 1921b), **Palmocarpon* (Berry, 1928)

Antigua

Phytelephas (Kaul, 1943)

Cuba

*Gleichenia, *Antholithus, Bignonia, Bumelia, Caesalpinia, *Caesalpinites, Calophyllum, Capparis, Cassia, Celastrus, Dalbergia, Dodonaea, Drypetes, Eugenia, Exostema, Fagara, Heliconia, Inga, Laguncularia, Metopium, Mimusops, Myrcia, Pisonia, Pithecolobium, Pseudolmedia, Reynosia, Rheedia, Sapindus, Simaruba, Sophora, Swietenia, Trichilia, Zizyphus* (Berry, 1939)

Oligo-Miocene

Mexico

Acacia, Tapirira (Miranda, 1963)

Costa Rica

**Mixoneura?, *Pecopteris?, Thelypteris?* (Gomez-P., 1970; tentative identifications, especially for first two compared to genera of Paleozoic ferns; material from private collection)

Oligocene

Dominican Republic

Grammitis (Gomez-P., 1982)

Puerto Rico

*Isoetes?, Hemitelia, Zamia, Acrodiclidium, Aniba, Annona, *Apocynophyllum, Aspidosperma, Bactris, Cassia, *Chondrites, Chrysophyllum, Combretum, Copaiva, Cynometra, Dipholis, Echites, Echitonium?, Eugenia, Ficus, Guarea, Guettarda, Hancornia, Hufelandia, Icacorea, Inga, Iriartea, Lonchocarpus, *Malvocarpon, Manicaria, Melicocca, Misanteca, *Mussophyllum, Myrcia, Myrsine, Oreodaphne, *Palmocarpon, *Palmacites, *Palmophyllum, Pithecellobium, Plumiera, Psidium, *Ramulus, Rhizophora?, Sapota, Sapindus, Sideroxylon, Sophora?, Trichilia, Zizyphus* (Hollick, 1928)

Arranged Taxonomically

Incertae Sedis

**Antholithus* (Miocene, Cuba, Berry 1939)

**Chondrites* (Oligocene, Puerto Rico, Hollick 1928)

**Phyllites* (Tertiary undifferentiated, Costa Rica, Berry 1921a)

**Ramulus* (Oligocene, Puerto Rico, Hollick 1928)

Algae

Chara (Characeae; Tertiary undifferentiated, Haiti, Berry 1923a)

Lycopsida

Isoetes? (Isoetaceae; Oligocene, Puerto Rico, Hollick 1928)

Filicinease (Ferns)

Acrostichum (Pteridaceae; Miocene, Mexico, Berry 1923b)

Gleichenia (Gleicheniaceae; Miocene, Cuba, Berry 1939)

TABLE 1. *(Continued)*

Gymnogramme (Gymnogrammaceae; Tertiary undifferentiated, Haiti, Berry 1923a; Miocene, Mexico, Berry 1923b)

Grammitis (Polypodiaceae; Oligocene, Dominican Republic, Gomez-P. 1982)

Hemitelia (Cyatheaceae; Oligocene, Puerto Rico, Hollick 1928)

**Mixoneura?* (tentative identification of specimen in private collection, compared to genus of Paleozoic ferns; Oligo-Miocene(?), Costa Rica, Gomez-P. 1970)

**Pecopteris?* (tentative identification of specimen in private collection, compared to genus of Paleozoic ferns; Oligo-Miocene(?), Costa Rica, Gomez-P. 1970)

Thelypteris? (Thelypteridaceae; tentative identification of specimen in private collection; Oligo-Miocene(?), Costa Rica, Gomez-P. 1970)

Gymnospermae

Zamia (Cycadaceae; Oligocene, Puerto Rico, Hollick 1928)

Angiospermae

Acacia (Leguminosae, Subfam. Mimosoideae; Oligo-Miocene, Mexico, Miranda 1963)

**Acacioxylon* (Leguminosae, Subfam. Mimosoideae; Tertiary undifferentiated, Mexico, Felix & Nathorst 1893)

Acrodiclidium (Lauraceae; Oligocene, Puerto Rico, Hollick 1928)

Allamanda (Apocynaceae; Miocene, Mexico, Berry 1923b)

**Anacardites* (Anacardiaceae; Miocene, Mexico, Berry 1923b)

Aniba (Lauraceae; Oligocene, Puerto Rico, Hollick 1928)

Annona/Anona (Annonaceae; Tertiary undifferentiated, Costa Rica, Berry 1921a; Miocene, Mexico, Berry 1923b; Oligocene, Puerto Rico, Hollick 1928)

**Apocynophyllum* (Apocynaceae; Miocene, Mexico, Berry 1923b; Oligocene, Puerto Rico, Hollick 1928)

Aspidosperma (Apocynaceae; Oligocene, Puerto Rico, Hollick 1928)

Bactris (Palmae; Oligocene, Puerto Rico, Hollick 1928)

Banisteria (Malpighiaceae; Tertiary undifferentiated, Panama, Berry 1918)

Bignonia (Bignoniaceae; Miocene, Cuba, Berry 1939)

**Bignonoides* (Bignoniaceae; Miocene, Mexico, Berry 1923b)

Bucida (Combretaceae; Tertiary undifferentiated, Dominican Republic, Berry 1921c)

Bumelia (Sapotaceae; Tertiary undifferentiated, Dominican Republic, Berry 1921c; Tertiary undifferentiated, Haiti, Berry 1923a; Miocene, Cuba, Berry 1939)

Buttneria? (Sterculiaceae; Tertiary undifferentiated, Costa Rica, Berry 1921a)

Caesalpinia (Leguminosae, Subfam. Caesalpinioideae; Miocene, Cuba, Berry 1939)

Caesalpinites (Leguminosae, Subfam. Caesalpinioideae; Miocene, Cuba, Berry 1939)

Calophyllum (Guttiferae; Miocene, Cuba, Berry 1939)

Calyptranthes (Myrtaceae; Tertiary undifferentiated, Panama, Betty 1918; Tertiary undifferentiated, Dominican Republic, Berry 1921c)

Capparis (Capparidaceae; Miocene, Cuba, Berry 1939)

Cassia (Leguminosae, Subfam. Caesalpinioideae; Tertiary undifferentiated, Panama, Berry 1918; Miocene, Cuba, Berry 1939; Oligocene, Puerto Rico, Hollick 1928)

Cedrela (Meliaceae; Miocene, Mexico, Berry 1923b)

Celastrus (Celastraceae; Miocene, Cuba, Berry 1939)

Chrysophyllum (Sapotaceae; Tertiary undifferentiated, Haiti, Berry 1923a; Oligocene, Puerto Rico, Hollick 1928)

Combretum (Combretaceae; Oligocene, Puerto Rico, Hollick 1928)

Connarus (Connaraceae; Miocene, Mexico, Berry 1923b)

Copaiva (= *Copaifera;* Leguminosae, Subfam. Caesalpinioideae; Oligocene, Puerto Rico, Hollick 1928)

Coussapoa (Urticaceae; Miocene, Mexico, Berry 1923b)

Crescentia (Bignoniaceae; Miocene, Mexico, Berry 1923b)

Cynometra (Leguminosae, Subfam. Caesalpinioideae; Oligocene, Puerto Rico, Hollick 1928)

Dalbergia (Leguminosae, Subfam. Palionoideae. Miocene, Cuba, Berry 1939)

Dioclea? (Leguminosae, Subfam. Papilionoideae. Miocene, Mexico, Berry 1923b)

Diospyros (Ebenaceae; Tertiary undifferentiated, Panama, Berry 1918)

Dipholis (Sapotaceae; Oligocene, Puerto Rico, Hollick 1928)

Dodonaea (Sapindaceae; Miocene, Cuba, Berry 1939)

Drypetes (Euphorbiaceae; Miocene, Mexico, Berry 1923b; Miocene, Cuba, Berry 1939)

Echites (Apocynaceae; Oligocene, Puerto Rico, Hollick 1928)

Echitonium? (Apocynaceae; Oligocene, Puerto Rico, Hollick 1928)

Eugenia (Myrtaceae; Miocene, Cuba, Berry 1939; Oligocene, Puerto Rico, Hollick 1928)

Exostema (Rubiaceae; Miocene, Cuba, Berry 1939)

TABLE 1. *(Continued)*

Fagara (fossils subsequently referred to *Xanthoxylum* = *Zanthoxylum*, Rutaceae; Miocene, Mexico, Berry 1923b; Miocene, Cuba, Berry 1939)

Ficus (Moraceae; Tertiary undifferentiated, Costa Rica, Berry 1921a; Tertiary undifferentiated, Panama, Berry 1918; Oligocene, Puerto Rico, Hollick 1928; *Ficus?*, Miocene, Mexico, Berry 1923b)

Geoppertia (Lauraceae; Tertiary undifferentiated, Costa Rica, Berry 1921a; Miocene, Mexico, Berry 1923b)

Gouania (Rhamnaceae; Miocene, Mexico, Berry 1923b)

Guarea (Meliaceae; Oligocene, Puerto Rico, Hollick 1928)

Guatteria (Annonaceae; Tertiary undifferentiated, Panama, Berry 1918)

Guettarda (Rubiaceae; Tertiary undifferentiated, Dominican Republic, Berry 1921c; Tertiary undifferentiated, Haiti, Berry 1923a; Miocene, Mexico, Berry 1923b; Oligocene, Puerto Rico, Hollick 1928)

Gymnocladus (Leguminosae, Subfam. Caesalpinioideae; Miocene, Mexico, Berry 1923b)

Hancornia (Apocynaceae; Oligocene, Puerto Rico, Hollick 1928)

Heliconia (Mussaceae; Tertiary undifferentiated, Costa Rica, Berry 1921a; Miocene, Cuba, Berry 1939)

Hieronymia (Euphorbiaceae; Tertiary undifferentiated, Costa Rica, Berry 1921a)

Hiraea (Malpighiaceae; Tertiary undifferentiated, Panama, Berry 1918)

Hufelandia (Lauraceae; Oligocene, Puerto Rico, Hollick 1928)

Icacorea (Myrsinaceae; Oligocene, Puerto Rico, Hollick 1928)

Inga (Leguminosae, Subfam. Mimosoideae; Tertiary undifferentiated, Costa Rica, Berry 1921a; Tertiary undifferentiated Panama, Berry, 1918; Tertiary undifferentiated, Dominican Republic, Berry 1921c; Miocene, Mexico, Berry 1923b; Miocene, Cuba, Berry 1939; Oligocene, Puerto Rico, Hollick 1928)

Iriartea (Palmae; Oligocene, Puerto Rico, Hollick 1928)

**Iriarites* (Palmae; Miocene, Panama, Berry 1921b)

**Juglans* (Juglandaceae; Tertiary undifferentiated, Mexico, Mullerried 1938)

Karatophyllum (Bromeliaceae; Tertiary undifferentiated, Costa Rica, Gomez-P. 1972)

Laguncularia (Combretaceae; Miocene, Cuba, Berry 1939)

**Lecythidophyllum* (Lecythidaceae; Miocene, Mexico, Berry 1923b)

**Leguminosites* (Leguminosae; Miocene, Mexico, Berry 1923b)

Liquidambar (Hamamelidacea; Miocene, Mexico, Berry 1923b)

Lonchocarpus (Leguminosae, Subfam. Papilionoideae; Oligocene, Puerto Rico, Hollick 1928)

**Malvocarpon* (Malvaceae; Oligocene, Puerto Rico, Hollick 1928)

Manicaria (Palmae; Oligocene, Puerto Rico, Hollick 1928)

**Melastomites* (Melastomataceae; Tertiary undifferentiated, Panama, Berry 1918; Tertiary undifferentiated, Dominican Republic, Berry 1921c; Miocene, Mexico, Berry 1923b).

Melicocca (=*Melicoccus*, Sapindaceae; Oligocene, Puerto Rico, Hollick 1928)

Mespilodaphne (Lauraceae; Tertiary undifferentiated, Panama, Berry 1918; Tertiary undifferentiated, Haiti, Berry 1923a; Miocene, Mexico, Berry 1923b)

Metopium (Anacardiacea; Miocene, Cuba, Berry 1939)

Mimusops (Sapotaceae; Tertiary undifferentiated, Haiti, Berry 1923a; Miocene, Cuba, Berry 1939)

Misanteca (Lauraceae; Oligocene, Puerto Rico, Hollick 1928)

Moquillea (Chrysobalanaceae; Miocene, Mexico, Berry 1923b)

**Mussophyllum* (Mussaceae; Oligocene, Puerto Rico, Hollick 1928)

**Myrcia* (Myrtacea; Miocene, Mexico, Berry 1923b; Miocene, Cuba, Berry 1939; Oligocene, Puerto Rico, Hollick 1928)

Myristicophyllum (Myristicaceae; Tertiary undifferentiated, Panama, Berry, 1918)

Myrsine (Myrsinaceae; Oligocene, Puerto Rico, Hollick 1928)

Nectandra (Lauraceae; Tertiary undifferentiated, Costa Rica, Berry 1921a; Miocene, Mexico, Berry 1923b)

Oreodaphne (Lauraceae; Oligocene, Puerto Rico, Hollick 1928)

**Palmacites* (Palmae; Tertiary undifferentiated, Costa Rica, Gomez-P. 1971; Oligocene, Puerto Rico, Hollick 1928)

**Palmocarpon* (Palmae; Miocene, Panama, Berry 1928; Oligocene, Puerto Rico, Hollick 1928)

**Palmophyllum* (Palmae; Oligocene, Puerto Rico, Hollick 1928)

**Palmoxylon* (Palmae; Tertiary undifferentiated, Mexico, Felix & Nathorst 1893; Tertiary undifferentiated, Panama, Berry 1918; Tertiary undifferentiated, Antigua, Stenzel 1897)

Phytelephas (Palmae; Miocene, Antigua, Kaul 1943)

**Piperites* (Piperaceae; Tertiary undifferentiated, Costa Rica, Berry 1921a)

TABLE 1. *(Concluded)*

Pisonia (Nyctaginaceae; Tertiary undifferentiated, Dominican Republic, Berry 1921c; Tertiary undifferentiated, Haiti, Berry 1923a; Miocene Cuba, Berry 1939)

Pithecolobium (=*Pithecellobium*; Leguminosae, Subfam. Mimosoideae; Tertiary undifferentiated, Dominican Republic, Berry 1921c; Miocene, Cuba, Berry 1939; Oligocene, Puerto Rico, Hollick 1928)

Plumiera (Apocynaceae; Oligocene, Puerto Rico, Hollick 1928)

**Poacites* (Gramineae; Tertiary undifferentiated, Dominican Republic, Berry 1921c)

Pseudolmedia (Moraceae; Miocene, Cuba, Berry 1939)

Psidium (Myrtaceae; Oligocene, Puerto Riço, Hollick 1928)

Reynosia (Rhamnaceae; Miocene, Cuba, Berry 1939)

Rheedia (Guttiferae; Miocene, Cuba, Berry 1939)

Rhizophora? (Rhizophoraceae; Oligocene, Puerto Rico, Hollick 1928)

Rondeletia (Rubiaceae; Tertiary undifferentiated, Panama, Berry 1918; *Rondeletia?*, Miocene, Mexico, Berry 1923b)

**Rubiacites* (Rubiaceae; Tertiary undifferentiated, Panama, Berry 1918)

Sapindus (Sapindaceae; Tertiary undifferentiated, Dominican Republic, Berry 1921c; Miocene, Cuba, Berry1939; Oligocene, Puerto Rico, Hollick 1928)

Sapota (Sapotaceae; Oligocene, Puerto Rico, Hollick 1928)

Schmidelia (Sapindaceae; Tertiary undifferentiated, Panama, Berry 1918)

Sideroxylon (Sapotaceae; Oligocene, Puerto Rico, Hollick 1928)

Simaruba (Simarubaceae= Simaroubaceae; Tertiary undifferentiated, Haiti, Berry 1923a; Miocene, Mexico, Berry 1923b; Miocene, Cuba, Berry 1939)

Sophora (Leguminosae, Subfam. Papilionoideae; Tertiary undifferentiated, Dominican Republic, Berry 1921c; Miocene, Cuba, Berry 1939; *Sophora?*, Oligocene, Puerto Rico, Hollick 1928)

Swietenia (Meliaceae; Miocene, Cuba, Berry 1939)

**Taenioxylon* (Leguminosae, Subfam. unassigned, Papilionoideae?; Tertiary undifferentiated, Panama, Berry 1918)

Tapirira (Anacardiaceae; Oligo-Miocene, Mexico, Miranda 1963)

Trichilia (Meliaceae; Miocene, Cuba, Berry 1939; Oligocene, Puerto Rico, Hollick 1928)

Zizyphus (Rhamnaceae; Miocene, Cuba, Berry 1939; Oligocene, Puerto Rico, Hollick 1928)

FAMILY INDEX

Incertae Sedis
- **Antholithus*
- **Chondrites*
- **Phyllites*
- **Ramulus*

Charophyta (algae)
- Characeae
  - *Chara*

Lycopsida
- Isoetaceae
  - *Isoetes?*

Filicineae (ferns)
- Cyatheaceae
- *Hemitelia*
- Gleicheniaceae
  - *Gleichenia*
- Gymnogrammaceae
  - *Gymnogramme*

Pteridaceae
- *Acrostichum*

Polypodiaceae
- *Grammitis*

Uncertain
- **Mixoneura?*
- **Pecopteris?*

Gymnospermae
- *Zamia*

Angiospermae
- Anacardiaceae
  - **Anacardites*
  - *Metopium*
  - *Tapirira*
- Annonaceae
  - *Annona/Anona*
  - *Guatteria*
- Apocynaceae
  - *Allamanda*
  - **Apocynophyllum*
  - *Aspidosperma*
  - *Echites*
  - *Echitonium?*
  - *Hancornia*
  - *Plumiera*
- Bignoniaceae
  - *Bignonia*
  - **Bignonoides*
  - *Crescentia*

Thelypteridaceae
- *Thelypteris?*

Bromeliacea
- **Karatophyllum*

Capparidaceae
- *Capparis*

Celastraceae
- *Celastrus*

Chrysobalanaceae
- *Moquillea*

Combretaceae
- *Bucida*
- *Combretum*
- *Laguncularia*

Connaraceae
- *Connarus*

Ebenaceae
- *Diospyros*

Euphorbiaceae
- *Drypetes*

Lauraceae
- *Acrodiclidium*
- *Goeppertia*
- *Hufelandia*
- *Mespilodaphne*
- *Misanteca*
- *Nectandra*
- *Oreodaphne*

Lecythidaceae
- **Lecythidophyllum*

Leguminosae
- Caesalpinioideae
  - *Caesalpinia*
  - **Caesalpinites*
  - *Cassia*
  - *Cynometra*
  - *Gymnocladus*
- Mimosoide

FAMILY INDEX –*Cont'd*

Plant microfossils reported from the Gulf/Caribbean Tertiary.
Asterix (*) designates genera of exclusively fossil plants.

Arranged by Age/Country

Eocene

Panama

Selaginella, *Ceratopteris*, Pteris *Alfaroa/Engelhardia*, cf. Araliaceae, *Arrabidaea* (as cf. *Paragonia/Arrabidaea)*, cf. *Campnosperma*, *Cardiospermum*, *Casearia*, cf. *Chrysophyllum*, *Coccoloba*, *Combretum/Terminalia*, *Crudia*, *Engelhardia* (as *Alfaroa/Engelhardia)*, *Eugenia/Myrcia*, *Faramea*, cf. *Ficus*, *Ilex*, *Lisianthius*, Malpighiaceae, *Mortoniodendron*, Palmae, cf. *Paragonia/Arrabidaea*, *Paullinia*, *Pelliceria*, cf. *Protium*, *Rhizophora*, *Serjania*, *Terminalia* (as *Combretum/Terminalia)*, cf. *Tetragrastis*, cf. *Tillandsia*, cf. *Tontalea* (Graham, 1985; *Lisianthius* also Graham, 1984; *Pelliceria* also Graham, 1977)

Cuba

**Bombacacidites* (Areces Mallea, 1985)

Jamaica

Pelliceria (Graham, 1977)

Oligocene

Puerto Rico

Lycopodium, *Selaginella*, *Cyathea*, *Hemitelia (Cnemidaria)*, *Jamesonia (Erisosorus)*, *Pteris*, *Podocarpus*, *Abutilon*, *Acacia*, *Aetanthus*. *Alchornea*, *Bernoullia*, *Bombax*, *Brunellia* *Bursera*, *Casearia*, *Catostemma*, *Chrysophyllum*, *Corynostylis*, *Dendropanax*, *Engelhardia*, *Eugenia*, *Fagus*, *Faramea*, *Guarea*, *Hauya*, *Ilex*, *Jacaranda*, *Liquidambar*, *Marcgravia*, *Merremia*, *Myrcia*, *Norantea*, *Nyssa*, *Oxalis*, Palmae, *Pelliceria*, *Pleodendron*, *Rauwolfia*, *Rhizophora*, *Salilix*, *Tecoma*, *Tetrorchidium*, *Tournefortia*, *Zanthophyllum* (Graham & Jarzen, 1969)

Oligo-Miocene

Mexico

Podocarpus, *Engelhardia*, *Pachira*-type, *Pelliceria*, *Rhizophora* (Langenheim et al., 1967)

Costa Rica

Microthyrium–type (fungi), *Phaeoceros* (Bryophyta), Muscae, *Lycopodium*, *Selaginella*, *Cnemidaria (Hemitelia)*, cf. *Hymenophyllum*, *Lophosoria*, *Pityrogramma*, *Pteris*, *Podocarpus*, *Alchornea*, cf. *Banisteriopsis*, Bombacaceae Compositae, Ericaceae, *Eugenia/Myrcia*, cf. *Glycycendrum*, cf. *Hiraea*, *Ilex*, *Lisianthus*, Melastomataceae, *Rhizophora* (Graham, 1987)

Dominican Republic

**Geotrichites* (fungi; Stubblefield et al., 1985)

Miocene

Mexico

Psilotum, *Lycopodium*, *Selaginella*, *Alsophilia*, *Ceratopteris*, *Cnemidaria* [as *Hemitelilia*, =*Cnemidaria]*, *Cyathea*, *Discranopteris*, *Hemitelia (Cnemidaria)*, *Lomariopsis (Stenochlaena)*, *Pityrogramma*, *Pteris*, *Sphaeropteris/Trichipteris*, *Stenochlaena* [as *Lomariopsis (Stenochlaena)]*, *Trichipteris* (as *Sphaeropteris/Trichipteris*, *Abies*, *Picea*, *Pinus*, *Podocarpus*, cf. *Acacia*, *Alchornea*, cf. *Alibertia*, *Allophylus*, *Alnus*, *Amaranthaceae* (as Amaranthaceae-Chenopodiaceae) cf. *Astrocaryum*, cf. *Attalea*, cf. *Bernardia*, *Borreria*, cf. *Brahea*, *Bravaisia*, cf. *Bredemeyera*, *Buettneria*, *Bursera*, *Casearia*, *Cedrela*, *Celtis*, cf. *Chamaedorea*, Chenopodiaceae-Amaranthaceae, *Cleyera*, *Coccoloba*, *Combretum/Terminalia*, *Comocladia*, Compositae, *Cupania*, *Cuphea*, Cyperaceae, *Daphnopsis*, *Desmanthus*, *Dichapetalum*, *Engelhardia*, *Eugenia/Myrcia*, *Faramea*, Gramineae, *Guarea*, *Gustavia*, *Hampea/Hibiscus*, *Hedyosmum*, cf. *Hiraea*, *Ilex*, *Iresine*, *Juglans*, *Justicia*, *Laetia*, *Laguncularia*, *Liquidambar*, *Ludwigia*, cf. *Mapig-*

Malpighia, *Matayba*, cf. *Maximiliana* type, *Meliosma*, cf. *Mezia* (?) – *type*, Mimosa, Mortoniodendron, *Myrica*, *Passiflora*, cf. *Paullinia*, *Populus*, *Protium*, *Quercus*, *Rajania*, *Rhizophora*, cf. *Sapium*, cf. *Securidaca*, Serjania, *Smilax*, *Spathiphyllum*, cf. *Stillingia*, *Struthanthus*, *Symphonia*, *Terebrania*. *Terminalia* (as *Combretum/Terminalia)*, cf. *Tetrorchidium*, *Thalictrum*, cf. *Tithymalusus* *Tournefortia*, *Ulmus*, *Utricularia* (Graham, 1976a; *Mortoniodendron*, *Saphaeropteris/Trichipteris* also Graham 1979)

Panama

Micractinium (algae, Graham, 1981), *Mortoniodendron* (Graham, 1979)

Arranged Taxonomically

Algae

Micractinium (Chlorophyta; lower Miocene, Panama, Graham 1981)

Fungi

**Geotrichites* (Deuteromycotina, fungi imperfecti; Oligo-Miocene, Dominican Republic, Stubblefield et al. 1985)

Microthyrium–type (Ascomycetes, Microthyriaceae; Oligo-Miocene, Costa Rica, Graham 1987)

Bryophyta

Phaeoceros (Anthocerotaceae; Oligo-Miocene, Costa Rica, Graham 1987)

Muscae (Oligo-Miocene, Costa Rica, Graham 1987)

Psilopsida

Psilotum (Psilotaceae; Miocene, Mexico, Graham 1976a)

Lycopsida

Lycopodium (Lycopodiaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969; Oligo-Miocene, Costa Rica, Graham 1987; Miocene, Mexico, Graham 1976a)

Selaginella (Selaginellaceae; Eocene, Panama, Graham 1985; Oligocene, Puerto Rico, Graham & Jarzen 1969; Oligo–Miocene, Costa Rica, Graham 1987; Miocene, Mexico, Graham 1976a)

Filicineae (ferns)

Alsophila (Cyatheaceae; Miocene, Mexico. Graham 1976a)

Ceratopteris Pteridaceae; Eocene, Panama, Graham 1985; Miocene, Mexico, Graham 1976a)

Cnemidaria [also as *Hemitelia (Cnemidaria)*, Cyatheaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969; Oligo-Miocene, Costa Rica, Graham 1987; Miocene, Mexico, Graham 1976a]

Cyathea (Cyatheaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969; Miocene, Mexico, Graham 1976a)

Dicranopteris (Gleicheniaceae; Miocene, Mexico, Graham 1976a)

Eriosorus (see *Jamesonia)*

Hermitelia (see Cnemidaria)

cf. *Hymenophyllum* (Hymenophyllaceae; Oligo-Miocene, Costa Rica, Graham 1987)

Jamesonia [as *Jamesonia (Eriosorus)*, Pteridaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969]

Lomariopsis [as *Lomariopsis (Stenochlaena)*, Dryopteridaceae; Miocene, Mexico, Graham 1976a]

Lophosoria (Lophosoriaceae; Oligo–Miocene Costa Rica, Graham 1987)

Pityrogramma (Pteridaceae; Oligo–Miocene, Costa Rica, Graham 1987; Miocene, Mexico, Graham 1976a)

Pteris (Pteridaceae; Eocene, Panama, Graham 1985; Oligocene, Puerto Rico, Graham & Jarzen 1969; Oligo–Miocene, Costa Rica, Graham 1987; Miocene, Mexico, Graham 1976a)

Sphaeropteris (as *Sphaeropteris/Trichipteris*, Cyatheaceae; Miocene, Mexico, Graham 1976a)

Stenochlaena (see *Lomariopsis)*

Trichipteris (see *Sphaeropteris)*

Gymnospermae

Abies (Pinaceae; Miocene, Mexico, Graham 1976a)

Picea (Pinaceae; Miocene, Mexico, Graham 1976a)

Pinus (Pinaceae; Miocene, Mexico, Graham 1976a)

Podocarpus (Podocarpaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969; Oligo–Miocene, Mexico, Langenheim et al. 1967; Oligo–Miocene, Costa Rica, Graham 1987; Miocene, Mexico, Graham 1976a)

Angiospermae

Abutilon (Malvaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969)

Acacia (Leguminosae, Subfam. Mimosoideae; Oligocene, Puerto Rico, Graham & Jarzen 1969; cf. *Acacia*, Miocene, Mexico, Graham 1976a)

Aetanthus (Loranthaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969)

Alchornea (Euphorbiaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969; Oligo-Miocene, Costa Rica, Graham 1987; Miocene, Mexico, Graham 1976a)

Alfaroa (as *Alfaroa/Engelhardia*, Juglandaceae; Eocene, Panama, Graham 1985; as *Engelhardia*-Oligocene, Puerto Rico, Graham & Jarzen 1969; Oligo-Miocene, Mexico, Langenheim et al. 1967; Miocene, Mexico, Graham 1976a)

cf. *Alibertia* (Rubiaceae; Miocene, Mexico, Graham 1976a)

Allophylus (Sapindaceae; Miocene, Mexico, Graham 1976a)

Alnus (Betulaceae; Miocene, Mexico, Graham 1976a);

Amaranthaceae (see Chenopodiaceae/Amaranthaceae)

cf. Araliaceae (Eocene, Panama, Graham 1985)

Arrabidaea (see *Paragonia/Arrabidaea)*

cf. *Astrocaryum* (Palmae; Miocene, Mexico, Graham 1976a)

cf. *Attalea* (Palmae; Miocene, Mexico, Graham 1976a)

cf. *Banisteriopsis* (Malpighiaceae; Oligo-Miocene, Costa Rica, Graham 1987)

cf. *Bernardia* (Euphorbiaceae; Miocene, Mexico, Graham 1976a)

Bernoullia (Bombacaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969)

Bombacaceae (Oligo-Miocene, Costa Rica, Graham 1987)

**Bombacacidites* (Bombacaceae; Eocene, Cuba, Areces Mallea 1985)

Bombax (Bombacaceae; Oligocene, Puerto Rico; Graham & Jarzen 1969)

Borreria (Rubiaceae; Miocene, Mexico, Graham 1976a)

cf. *Brahea* (Palmae; Miocene, Mexico, Graham 1976a)

Bravaisia (Acanthaceae; Miocene, Mexico, Graham 1976a)

cf. *Bredemeyera* (Polygalaceae; Miocene, Mexico, Graham 1976a) *Brunellia* (Brunelliaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969) *Buettneria* (Sterculiaceae; Miocene, Mexico, Graham 1976a) *Bursera* (Burseraceae; Oligocene, Puerto Rico, Graham & Jarzen 1969; Miocene, Mexico, Graham 1976a) cf. *Campnosperma* (Anacardiaceae; Eocene, Panama, Graham 1985) *Cardiosperum* (Sapindaceae; Eocene, Panama, Graham 1985) *Casearia* (Flacourtiaceae; Eocene, Panama, Graham 1985; Oligocene, Puerto Rico, Graham & Jarzen 1969; Miocene, Mexico, Graham 1976a) *Catostemma* (Bombacaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969) *Cedrela* (Meliaceae; Miocene, Mexico, Graham 1976a) *Celtis* (Ulmaceae; Miocene, Mexico, Graham 1976a) cf. *Chamaedorea* (Palmae; Miocene, Mexico, Graham 1976a) Chenopodiaceae (as Chenopodiaceae/ Amaranthaceae; Miocene, Mexico, Graham 1976a) *Chrysophyllum* (Sapotaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969; cf. Chrysophyllum, Eocene, Panama, Graham 1985) *Cleyera* (Theaceae; Miocene, Mexico, Graham 1976a) *Coccoloba* (Polygonaceae; Eocene, Panama, Graham 1985; Miocene, Mexico, Graham 1976a) *Combretum/Terminalia* (Combretaceae; Eocene,	Panama, Graham 1985; Miocene, Mexico, Graham 1976a; see also Graham 1980) *Comocladia* (Anacardiaceae; Miocene, Mexico, Graham 1976a) Compositae (Oligo-Miocene, Costa Rica, Graham 1987; Miocene, Mexico, Graham 1976a) *Corynostylis* (Violaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969) *Crudia* (Leguminosae, Subfam. Caesalpinioideae; Eocene, Panama, Graham 1985) *Cupania* (Sapindaceae; Miocene, Mexico, Graham 1976a) *Cuphea* (Lythraceae; Miocene, Mexico, Graham 1976a) Cyperaceae (Miocene, Mexico, Graham 1976a) *Daphnopsis* (Thymeliaceae; Miocene, Mexico, Graham 1976a) *Dendropanax* (Araliaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969) *Desmanthus* (Leguminosae, Subfam. Papilionoideae; Miocene, Mexico, Graham 1976a) *Dichapetalum* (Dichapetalaceae; Miocene, Mexico, Graham 1976a) *Englehardia* (see *Alfaroa/Engelhardia)* Ericaceae (Oligo-Miocene, Costa Rica, Graham 1987) *Eugenia* (see *Eugenia/Myrcia*) *Eugenia/Myrcia* (Myrtaceae; Eocene, Panama, Graham 1985; Oligo-Miocene, Costa Rica, Graham 1987; Miocene, Mexico, Graham 1976a; as *Eugenia*, Oligocene, Puerto Rico, Graham & Jarzen 1969; see also Graham 1980) *Fagus* (Fagaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969) *Faramea* (Rubiaceae; Eocene, Panama, Graham 1985; Oligocene, Puerto Rico, Graham & Jarzen 1969; Miocene, Mexico, Graham 1976a)	cf. *Ficus* (Moraceae; Eocene, Panama, Graham 1985) cf. *Glycydendrum* (Euphorbiaceae; Oligo-Miocene, Costa Rica, Graham 1987) Gramineae (Miocene, Mexico, Graham 1976a) *Guarea* (Meliaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969; Miocene, Mexico, Graham 1976a) *Gustavia* (Lecythidaceae; Miocene, Mexico, Graham 1976a) *Hampea/Hibiscus* (Malvaceae; Miocene, Mexico, Graham 1976a) *Hauya* (Onagraceae; Oligocene, Puerto Rico, Graham & Jarzen 1969) *Hedyosmum* Chloranthaceae; Miocene, Mexico, Graham 1976a) *Hibiscus* (see *Hampea/Hibiscus*) cf. *Hiraea* (Malpighiaceae; Oligo-Miocene, Costa Rica, Graham 1987; Miocene, Mexico, Graham 1976a) *Ilex* (Aquifoliaceae; Eocene, Panama, Graham 1985; Oligocene, Puerto Rico, Graham & Jarzen 1969; Oligo-Miocene, Costa Rica, Graham 1987; Miocene, Mexico, Graham 1976a) *Iresine* (Amaranthaceae; Miocene, Mexico, Graham 1976a) *Jacaranda* (Bignoniaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969) *Juglans (*Juglandaceae; Miocene, Mexico, Graham 1976a) *Justicia* (Acanthaceae; Miocene, Mexico, Graham 1976a) *Laetia* (Flacourtiaceae; Miocene, Mexico, Graham 1976a) *Laguncularia* (Combretaceae; Miocene, Mexico, Graham 1976a)

TABLE 2. *(Concluded)*

Liquidambar (Hamamelidaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969; Miocene, Mexico, Graham 1976a)
Lisianthius (Gentianaceae; Eocene, Panama, Graham 1985; Oligo-Miocene, Costa Rica, Graham 1987)
Ludwigia (Onagraceae; Miocene, Mexico, Graham 1976a)
cf. *Malpighia* (Malpighiaceae; Miocene, Mexico, Graham 1976a)
Malpighiaceae (Eocene, Panama, Graham 1985)
Marcgravia (Marcgraviaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969)
Matayba (Sapindaceae; Miocene, Mexico, Graham 1976a)
cf. *Maximiliana* type (Palmae; Miocene, Mexico, Graham 1976a)
Melastomataceae (Oligo-Miocene, Costa Rica, Graham 1987)
Meliosma (Sapindaceae; Miocene, Mexico; Graham 1976a)
Merremia (Convolvulaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969)
cf. Mezia (?)-type (Malpighiaceae; Miocene, Mexico, Graham 1976a)
Mimosa (Leguminosae, Subfam. Mimosoideae; Miocene, Mexico, Graham 1976a)
Mortoniodendron (Tiliaceae; Eocene, Panama, Graham 1985; Miocene, Panama, Graham 1979; Miocene, Mexico, Graham 1976a)
Myrcia (see *Eugenia/Myrcia)*
Myrica (Myricaceae; Miocene, Mexico, Graham 1976a)
Norantea (Marcgraviaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969)
Nyssa (Nyssaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969)
Oxalis (Oxalidaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969)
Pachira-type (Bombacaceae; Oligo-Miocene, Mexico, Langenheim et al. 1967)
Palmae (Eocene, Panama, Graham 1985; Oligocene, Puerto Rico, Graham & Jarzen 1969)
cf. *Paragonia/Arrabidaea* (Bignoniaceae; Eocene, Panama, Graham 1985)
Passiflora (Passifloraceae; Miocene, Mexico, Graham 1976a)
Paullinia (Sapindaceae; Eocene, Panama, Graham 1985; Miocene, Mexico, Graham 1976a)
Pelliceria (Theaceae; Eocene, Panama, Graham 1985; Eocene, Jamaica, Graham 1977; Oligocene, Puerto Rico, Graham & Jarzen 1969; Oligo-Miocene, Mexico, Langenheim et al. 1967)
Pleodendron (Canellaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969)
Populus (Salicaceae; Miocene, Mexico, Graham 1976a)
Protium (Burseraceae; Miocene, Mexico, Graham 1976a; cf. *Protium* Eocene, Panama, Graham 1985)
Quercus (Fagaceae; Miocene, Mexico, Graham 1976a)
Rajania (Dioscoreaceae; Miocene, Mexico, Graham 1976a)
Rauwolfia (Apocynaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969)
Rhizophora (Rhizophoraceae; Eocene, Panama, Graham 1985; Oligocene, Puerto Rico, Graham & Jarzen 1969; Oligo-Miocene, Mexico, Langenheim et al. 1967; Oligo-Miocene, Costa Rica, Graham 1987; Miocene, Mexico, Graham 1976a)
Salix (Salicaceae; Oligocene, Puerto Rico Graham & Jarzen 1969)
cf. *Sapium* (Euphorbiaceae; Miocene, Mexico, Graham 1976a)
cf. *Securidaca* (Polygalaceae; Miocene, Mexico, Graham 1976a)
Serjania (Sapindaceae; Eocene, Panama, Graham 1985; Miocene, Mexico, Graham 1976a)
Smilax (Liliaceae; Miocene, Mexico, Graham 1976a)
Spathiphyllum (Araceae; Miocene, Mexico, Graham 1976a)
cf. *Stillingia* (Euphorbiaceae; Miocene, Mexico, Graham 1976a)
Struthanthus (Loranthaceae; Miocene, Mexico, Graham 1976a)
Symphonia (Guttiferae; Miocene, Mexico, Graham 1976a)
Tecoma (Bignoniaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969)
Terebrania (Rubiaceae; Miocene, Mexico, Graham 1976a)
Terminalia (see *Combretum/Terminalia)*
cf. *Tetragrastis* (Burseraceae; Eocene, Panama, Graham 1985)
Tetrorchidium (Euphorbiaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969; cf. *Tetrorchidium*, Miocene, Mexico, Graham 1976a)
Thalictrum (Ranunculaceae; Miocene, Mexico, Graham 1976a)
cf. *Tillandsia* (Bromeliaceae; Docene, Panama, Graham 1985)
cf. *Tithymalus* (Euphorbiaceae; Miocene, Mexico, Graham 1976a)
cf. *Tontalea* (Hippocrateaceae; Eocene, Panama, Graham 1985)
Tournefortia (Boraginaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969; Miocene, Mexico, Graham 1976a)
Ulmus (Ulmaceae; Miocene, Mexico, Graham 1976a)
Utricularia (Lentibulariaceae; Miocene, Mexico, Graham 1976a)
Zanthophyllum (Rutaceae; Oligocene, Puerto Rico, Graham & Jarzen 1969)

FAMILY INDEX

Algae

Chlorophyta
Micractinia
Fungi
Deuteromycotina
*Geotrichites
Ascomycetes
Microthyriaceae
Microthyrium-type
Bryophyta
Anthocerotaceae
Phaeoceros
Muscae
Psilopsida
Psilotaceae
Psilotum
Lycopsida
Lycopodiaceae
Lycopodium
Selaginellaceae
Selaginella
Filicineae (ferns)
Cyatheaceae
Alsophila
Cnemidaria
Cyathea
Hemitelia (=Cnemidaria)
Sphaeropteris/Trichipteris
Amaranthaceae
Iresine
Anacardiaceae
cf. *Campnosperma*
Comocladia
Apocynaceae
Rauwolfia
Aquifoliaceae
Ilex
Araceae
Spathiphyllum
Araliaceae
Dendropanax
cf. Araliaceae
Betulaceae
Alnus
Bignoniaceae
Jacaranda
Paragonia/Arrabidaea
Tecoma
Bombacaceae
Bernoullia
**Bombacacidites*
Bombax
Catostemma

Canellaceae
Pleodendron
Chloranthaceae
Hedyosmum
Convolbulaceae
Merremia

Dryopteridaceae
Lomariopsis (Stenochlaena)
Gleicheniaceae
Dicranopteris
Hymenophyllaceae
cf. *Hymenophyllum*
Lophosoriaceae
Lophosoria
Pteridaceae
Ceratopteris
Jamesonia (Eriosorus)
Pityrogramma
Pteris
Gymnospermae
Pinaceae
Abies
Picea
Pinus
Podocarpaceae
Podocarpus
Angiospermae
Acanthaceae
Bravaisia
Justicia
Amaranthaceae (as Chenopodiaceae/Amaranthaceae)
Boraginaceae
Tournefortia
Bromeliaceae
cf. *Tillandsia*
Brunelliaceae
Brunellia
Burseraceae
Bursera
Protium
cf. *Protium*
cf. *Tetragrastic*
Chenopodiaceae/Amaranthaceae
Combretaceae
Combretum/*Terminalia*
Laguncularia
Compositae
Cyperaceae
Dichapetalaceae
Dichapetalum
Dioscoreaceae
Rajania
Ericaceae
Euphorbiaceae
Alchornea
cf. *Bernardia*

Pachira-type
Marcgraviaceae
Marcgravia
Norantea
Melastomataceae
Meliaceae
Cedrela
Guarea
Moraceae
cf. *Ficus*
Myricaceae
Myrica
Myrtaceae
Eugenia
Eugenia/Myrcia
Nyssaceae
Nyssa
Onagraceae
Hauya
Ludwigia
Oxalidaceae
Oxalis
Palmae
cf. *Astrocaryum*
cf. *Attalea*
cf. *Brahea*
cf. *Chamaedorea*
cf. *Maximiliana*
cf. *Sapium*
cf. *Stillingia*
Tetrorchidium
cf. *Tithymalus*
Fagaceae
Fagus
Quercus
Flacourtiaceae
Casearia
Laetia
Gentianaceae
Lisianthus
Gramineae
Guttiferae
Symphonia
Hamamelidaceae
Liquidambar
Hippocrateaceae
cf. *Tontalea*
Juglandaceae
Alfaroa/Engelhardia
Engelhardia
Juglans
Lecythidaceae
Gustavia
Paullinia
Serjania
Sapotaceae
Chrysophyllum
cf. Ch…

cf. *Glycydendrum*
Passifloraceae
Passiflora
Polygalaceae
cf. *Bredemeyera*
cf. *Securidaca*
Polygonaceae
Coccoloba
Ranunculaceae
Thalictrum
Rhizophoraceae
Rhizophora
Rubiaceae
cf. *Alibertia*
Borreria
Faramea
Terebrania
Rutaceae
Zanthophyllum
Salicaceae
Populus
Salix
Sapindaceae
Allophylus
Cardiospermum
Cupania
Matayba
Meliosma
Leguminosae
Caesalpinioideae
Crudia
Mimosoideae
Acacia
cf. *Acacia*
Mimosa
Papilionoideae
Desmanthus
Lentibulariaceae
Utricularia
Liliaceae
Smilax
Loranthaceae
Actanthus
Struthanthus
Lythraceae
Cuphea
Malpighiaceae
cf. *Banisteriopsis*
cf. *Hiraea*
cf. *Malpighia*
cf. *Mezia (?)* - type
Malvaceae
Abutilon
Hampea/Hibiscus

FAMILY INDEX *(Continued)*

LITERATURE CITED

Areces Mallea, A. E. 1985. Una nueva especie de *Bombacacidites* Couper emend, Krutzsch del Eoceno medio de Cuba. Geologia(Cuba) 20: 3–8.

Berry, E. W. 1916. The lower Eocene floras of southeastern North America. U. S. Geol. Surv. Prof. Paper 91. 481 pp.

. 1918. The fossil higher plants from the Canal Zone. In: Contributions to the Geology and Paleontology of the Canal Zone, Panama, and Geologically Related Areas in Central America and the West Indies. Bull. U. S. Natl. Mus. 103:15–44.

———. 1921a. Tertiary fossil plants from Costa Rica. Proc. U. S. Natl. Mus. 59:169–185.

———. 1921b. A palm nut from the Miocene of the Canal Zone. Proc. U. S. Natl. Mus. 59: 21–22.

———. 1921c. Tertiary fossil plants from the Dominican Republic. Proc. U. S. Natl. Mus. 59: 117–127.

———. 1923a. Tertiary fossil plants from the Republic of Haiti. Proc. U. S. Natl. Mus. 62: 10 pp.

———. 1923b. Miocene plants from southern Mexico. Proc. U. S. Natl. Mus. 62: 1–27.

———. 1928. A palm fruit from the Miocene of western Panama. Jour. Wash. Acad. Sci. 18: 455-457.

———. 1930. Revision of the lower Eocene Wilcox flora of the southeastern states. U. S. Geol. Surv. Prof. Paper 156. 196 pp.

———. 1939. A Miocene flora from the gorge of the Yumari River, Matanzas, Cuba. Johns Hopkins Univ. Studies Geol. 13: 95–135.

Brown, K. S. 1975. Geographical patterns of evolution in neotropical Lepidoptera. Systematics and derivation of known and new Heliconiini (Nymphalidae· Nymphalinae). Jour. Entomol. 44:201-242.

———. P. M. Sheppard & J. R. G. Turner. 1974. Quaternary refugia in tropical America: evidence from race formation in *Heliconius* butterflies. Proc. Roy. Soc. London(B) 187: 369–378.

Chaney, R. W. 1959. Part 1. Composition and Interpretation. In: R. W. Chaney & D. I. Axelroad, Miocene Floras of the Columbia Plateau. Carnegie Inst. Wash. Publ. 617. pp. 1–134.

Deevey, E. S. 1949. Biogeography of the Pleistocene. Bull. Geol. Soc. Amer. 60: 1315–1416.

Dilcher, D. L. & G. E. Dolph. 1970. Fossil leaves of *Dendropanax* from Eocene sediments of southeastern North America. Amer. Jour. Bot. 57: 153–160.

——— & B. Mehrotra. 1969. A study of leaf compressions of *Knightiophyllum* from Eocene deposits of southeastern North America. Amer. Jour. Bot. 56: 936–943.

Donnelly, T. W. 1985. Mesozoic and Cenozoic plate evolution of the Caribbean region. In. F. G. Stehli & S. D. Webb (eds.), The Great American Biotic Interchange. Plenum, N. Y. pp. 89–121.

Felix, J. & A. G. Nathorst. 1893. Versteinerungen aus dem Mexicanischen Staat Oaxaca. In: J. Felix & H. Lenk, Beitrage Geologie und Paleontologie der Republik Mexico, Teil 2. Felix, Leipzig. pp. 39–54.

Gomez-P., L. D. 1970. A first report on fossil fern-like Pteropsida from Costa Rica. Rev. Biol. Trop. 16: 255-258.

———. 1971. *Palmacites berryanum*, new palm fossil from the Costa Rican Tertiary. Rev. Biol. Trop. 19: 121-132.

———. 1972. *Karatophyllum bromelioides* L. D. Gomez (Bromeliaceae), nov. gen. et sp., del Terciario medio de Costa Rica. Rev. Biol. Trop. 20: 221-229.

———. 1982. *Grammitis succinea*, the first New World fern found in amber. Amer. Fern Jour. 72: 49-52.

Gose, W. A. 1985. Caribbean tectonics from a

LITERATURE CITED

paleomagnetic perspective. In: F. G. Stehli & S. D. Webb (eds.), The Great American Biotic Interchange. Plenum, B. Y. pp. 285-301.

Graham, Alan. 1965. The Sucker Creek and Trout Creek Miocene Floras of Southeastern Oregon. Kent State Univ. Bull., Res. Ser. IX. 147 pp.

——. 1973. History of the arborescent temperate element in the northern Latin American biota. In: Alan Graham (ed.), Vegetation and Vegetational History of Northern Latin America. Elsevier, Amsterdam. pp. 301-314.

——. 1976a. Studies in neotropical paleobotany. I. The Miocene communities of Veracruz, Mexico. Ann. Missouri Bot. Gard. 63: 787-842.

——. 1976b. Late Genozoic evolution of tropical lowland vegetation in Veracrux, Mexico. Evolution 29: 723-735.

——. 1977. New records of *Pelliceria* (Theaceae/Pelliceriaceae) in the Tertiary of the Caribbean. Biotropica 9: 48-52.

– – –. 1979. *Mortoniodendron* (Tiliaceae) and *Sphaeropteris/Trichipteris* (Cyatheaceae) in Cenozoic deposits of the Gulf-Caribbean region Ann. Missouri Bot. Gard. 66: 572-576.

——. 1981. Un alga fosil micractiniaceae de la Zona del Canal de Panama. Biotica 6: 229-232.

——. 1984. *Lisianthius* pollen from the Eocene of Panama. Ann. Missouri Bot. Gard. 71: 987-993.

——. 1985. Studies in neotropical paleobotany. IV. The Eocene communities of Panama. Ann. Missouri Bot. Gard. 72: 504-534.

——. 1987a. Miocene communities and Paleoenvironments of southern Costa Rica. Amer. Jour. Bot. 74, in press.

——. 1987b. Tropical American Tertiary floras and paleoenvironments: Mexico, Costa Rica and Panama. Amer. Jour. Bot. 74, in press.

——. & D. M. Jarzen. 1969. Studies in neotropical paleobotany. I. The Oligocene communities of Puerto Rico. Ann. Missouri Bot. Gard. 56: 308-357.

Haffer, J. 1969. Speciation in Amazonian birds. Science 165: 131-137.

——. 1970. Geo-climatic history and zoogeographic significance of the Uraba region in northwestern Colombia. Caldasia 10: 603-636.

—— .1974. Avian Speciation in Tropical South America. Publ. Nuttall Ornithological Club No. 14. Cambridge, Mass. 390 pp.

——. 1981. Quaternary biogeography of tropical lowland South America. Mus. Nat. Hist. Univ. Kansas, Monogr. 7:107-140.

——. 1982. General aspects of the refuge theory. In: G. T. Prance (ed.), Biological Diversification in the Tropics. Columbia Univ. Press. N. Y. pp. 6-24.

Hollick, A. 1928. Paleobotany of Porto Rico. N. Y. Acad. Sci. Sci. Surv. Porto Rico and the Virgin Islands 7: 177–393.

Hubbard, R. N. & M. C. Boulter. 1983. Reconstruction of Paleogene climate from palynological evidence. Nature 301: 147-150

Jones, D. S. & P. F. Hasson. 1985. History and development of the marine invertebrate faunas separated by the Central American isthmus. In: F. G. Stehli & S. D. Webb (eds.), The Great American Biotic Interchange. Plenum, N. Y. pp. 325-355.

Jones, H. H. & D. L. Dilcher. 1980. Investigations of angiosperms from the Eocene of North America. *Rhamnus marginatus* (Rhamnaceae) re-examined. Amer. Jour. Bot. 67: 959-967.

Kaul, K. N. 1943. A palm stem from the Miocene of Antigua, W. I. – *Phytelephas sewardii* sp. nov. Proc. Linn. Soc. London 155: 3-4.

Langenheim, J. H., B. L. Hackner & A. Bartlett. 1967. Mangrove pollen at the depositional site of Oligo-Miocene amber from Chaipas, Mexico. Bot. Mus. Leafl. Harvard Univ. 21: 289-324.

Leyden, B. W. 1984. Guatemalan forest synthesis after Pleistocene aridity. Proc. Natl. Acad. Sci. 81. 4856-4859.

Liu, Kam-biu & P. A. Colinvaux. 1985. Forest changes in the Amazon Basin during the last glacial maximum. Nature 318: 556-557.

Livingstone, D. A. & T. van der Hammen. 1978. Palaeogeography and Palaeoclimatology. In: Tropical Forest Ecosystems, pp. 61-90. Natural Resources Research XIV, UNESCO/UNEP/FAO, Paris. Marshall, L. G. 1985. Geochronology and land-mammal biochronology of the transamerican funal interchange. In: F. G. Stehli & S. D. Webb (edds.), The Great American Biotic Interchange. Plenum, N. Y. pp. 49-85.

Marshall, L. G., R. F. Butlar, R. E. Drake & G. H. Curtis. 1982. Geochronology of type Uquian (late Cenozoic) land mammal age, Argentina. Science 216: 986-989.

——, ——, ——, ——, & R. H. Tedford. 1976. Calibration of the great American interchange. Science 204: 272-279.

——, S. D. Webb, J. J. Sepkoski & D. M. Raup. 1982 Mammalian evolution and the great American interchange. Science 215: 1351-1357.

—— et al. 1981. Calibration of the beginning of the Age of Mammals in Patagonia. Science 212: 43-45.

Miranda, F. 1963. Two plants from the amber of the Simojovel, Chiapas, Mexico, area. Jour. Paleontol. 37: 611-614.

Mullerried, F. K. G. 1939 [illegible]

del instituto de Geologia, acerca del material colectado en el municipio de Tlácolulan, estado de Veracruz. Bol. Soc. Geol. Mex. 10: 203-206.

Prance, G. T. 1979. Distribution patterns of lowland neotropical species with relation to history, dispersal and ecology with special reference to Chrysobalanaceae, Caryocaraceae and Lecythidaceae. In K. Larsen and L. Holm-Nielsen (eds.), Tropical Botany, Academic Press, N. Y. pp. 59-87.

——— (ed.). 1982. Biological Diversification in the Tropics. Columbia Univ. Press, N. Y. 714 pp.

Savin, S. M. 1977. The history of the Earth's surface temperature during the past 100 million years. Ann. Rev. Earth Planet. Sci. 5. 319-355.

——— & R. G. Douglas. 1985. Sea level, climate, and the Central American land bridge In: F. G. Stehli & S. D. Webb (eds.). The Great American Biotic Interchange. Plenum, N. Y. pp. 303-324.

———, ———, & F. G. Stehli. 1975. Tertiary marine paleotemperatures. Geol. Soc. Amer. Bull. 86: 1499-1510.

Smith, D. L. 1985. Caribbean plate relative motions. In: F. G. Stehli & S. D. Webb (eds.), The Great American Biotic Interchange. Plenum, N. Y. pp. 17-48.

Stehli, F. G. & S. D. Webb (eds.). 1985. The Great American Biotic Interchange. Plenum, N, Y. 532 pp.

Stenzel, K. G. W. 1897. *Palmoxylon iriateum* n. sp., ein fossiles palmholz aus Antigua. Kgl. Svensk. Vet. Akad. Handl. 22: 1-17.

Stubblefield, S. P., C. E. Miller, T. N. Taylor & G. T. Cole. 1985. *Geotrichites glaesarius*, a conidial fungus from Tertiary Dominican amber. Mycologia 77: 11-16.

Sullivan, W. 1974. Continents in Motion. McGraw-Hill, N. Y. 399 pp.

Tanai, T. & K. Huzioka. 1967. Climatic implications of Tertiary floras in Japan. 11th Pacific Sci. Cong. (Tokyo, 1966), Symposium 25, pp. 77-87.

van der Hammen, T. & E. Gonzalez. 1960. Upper Pleistocene and Holocene climate and vegetation of the "Sabana de Bogota" (Colombia, South America). Leidse Geol. Meded. 25: 261-315.

van Waterschoot van der Gracht, W. A. J. M. et al. 1928 Theory of Continental Drift — A Symposium on the Origin and Movement of Land Masses both Inter-Continental and Intra-continental, as proposed by Alfred Wegener. Amer. Assoc. Petrol. Geol. (Tulsa, Okla., 1926). 240 pp.

Webb, S. D. 1976. Mammalian faunal dynamics of the great American Interchange. Paleobiology 2: 220-234.

———. 1978. A history of svanna vertebrates in the New World. Part II. South America and the Great interchange. Ann. Rev. Ecol. Syst. 9: 393-426.

———. 1985. Late Cenozoic mammal dispersals between the Americas. In: F. S. Stehli & S. D. Webb (eds.), The Great American Biotic Interchange. Plenum, N. Y. pp. 357-386.

Wolfe, J. A. 1978. A paleobotanical interpretation of Tertiary climates in the northern hemisphere. Amer. Sci. 66: 694-703.

——— & D. M. Hopkins. 1967. Climatic changes recorded by Tertiary land floras in northwestern North America. 11th Pacific Sci. Cong. (Tokyo, 1966), Symposium 25, pp. 67-76.

Woodring, W. P. 1966. The Panama land bridge as a sea barrier. Trans. Amer. Philos. Soc. 110: 425-433.