

Catalog and Literature Guide for Cretaceous and Cenozoic Vascular Plants of the New
World

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541.

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NULLIS IN VERBA (take no man's word for it)

Motto on the coat of arms of the Royal Society (London) granted by Charles II,

September 17, 1662

Notes: Most identifications above family level and tentative generic identifications (e.g., 'cf.' or 'type') are not included. Fl.= flora; Fm.= formation; NLR= nearest living relative (see Mosbrugger, 1999; Mosbrugger & Utescher, 1997).

Among records of particular biogeographic interest, 1) Hansen et al. (2001) report pollen similar to regionally extinct taxa (including some Asian exotics) in deposits as young as 'after 2.8 Ma' (latest Pliocene) from Polk Co., FL: cf. *Zamiaceae*, cf. *Ginkgo*, cf. *Sciadopitys*, *Tsuga/Sciadopitys*, *Tsuga canadensis*-type, cf. *Tsuga mertensiana*, cf. *Dacrydium*, *Podocarpus*, *Pterocarya*, cf. *Engelhardtia* [*Alfaroa-Oreomunnea*], cf. *Zelkova* [*Ulmus/Zelkova*]. Some of these exotics (*Alangium*, *Engelhardtia*, *Sciadopitys*) have been reported from the late middle to early late Miocene Bryn Mawr Formation along the mid-Atlantic Coast (head of Chesapeake Bay, MD; Pazzaglia et al., 1997). 2) Elsik (1974) reports pollen of *Nothofagus* from the Eocene of the Gulf Coastal Plain and elsewhere in North America.

A summary of the Late Cainozoic (Cenozoic) floras of Iceland is presented by Denk et al. (2011), Cenozoic palynofloras of Patagonia by Quattrocchio et al. (2013), and a study of the middle Miocene palynofloras of the Tehuacán Formation of Puebla, Mexico that includes a summary for other Cenozoic Mexican formations by Ramírez-Arriaga et al. (2014).

The composition used here for the middle Eocene (44 Ma) Clarno flora of OR (Manchester, 1994), and macrofossils of the latest Eocene (34.1 Ma) Florissant flora of CO (Manchester, 2001, table 1, and revisions and additions on pp. 141-147 to MacGinitie's 1953 study) include further updates kindly provided by Steven Manchester (pers. comm., April, 2011). See also Retallack et al., 2000, appendices 7-11, Eocene-Oligocene, Clarno area, OR).

Radiometric dates for various sites within the John Day Formation, OR (late Eocene to early Oligocene) are 33.6-32.2 Ma (Bridge Creek flora, Meyer & Manchester, 1997, p. XV); about 38.8 Ma (lower part of the formation, Whitecap Knoll locality, Manchester, 2000, p. 51); and 36.2 Ma (near Post, OR, Manchester & McIntosh, 2007, p. 7).

A summary of late Paleocene to early Eocene floras, and middle Eocene to late Eocene and Oligocene floras in North America is provided by Pigg & DeVore (2010) and DeVore & Pigg (2010). A comparison of the palynomorphs and megafossils in the late Paleocene Almont flora of North Dakota is given in Zetter et al., 2011 (table 1). The composition used here for the middle Eocene Republic flora of Washington State was kindly provided by Kathleen Pigg (pers. comm., 2011; see also Pigg, DeVore, & Volkman, 2011).

Steffi Ickert-Bond (pers. comm., 2011) provided updates on the fossil record and molecular dating of divergences in *Ephedra*.

For a summary of the upland Eocene forests of western USA (mostly Idaho, also Montana, Nevada), at the generic level see Axelrod (1996). Several identifications, the suggested nearest living relatives (NLRs), and particularly the proposed associations often conform closely to geoflora concepts; the identifications are now undergoing

revision (Erwin & Schorn, 2005). For a review of western Eurasian-western North American, dry-adapted disjunct taxa (Madrean-Tethyan region) see Kadereit & Baldwin (2012: ... “independent ecological shifts to dry environments and long-distance dispersal probably account for the majority of taxon-disjunctions studied; migration of lineages (pre)adapted to dry conditions across either the Beringian or the North Atlantic Land Bridges, much discussed in the literature, only rarely needs to be invoked” (p. 3). For other discussions of the history and biogeography of dry vegetation see references under *Pickeringia* (Fabaceae).

The influence of regional history on the angiosperm history of the Mexican lowland tropical forests is discussed by Magallón et al. (2014).

A revised list of plant taxa from the Neogene of Panama described by Berry (1918, 1921) and a summary of the palynological record in Panama for the past 20 million years is provided by Jaramillo et al., 2014 (tables 4, 6). A morphological-based system is used for naming the palynomorphs and suggested related genera are cited. The extant higher-level categories and families are: Bryophyta- Anthocerotaceae; ferns and allied groups- Adiantaceae, Blechnaceae, Cyatheaceae, Dryopteridaceae, Lycopodiaceae, Lygodiaceae, Marattiaceae, Ophioglossaceae, Polypodiaceae, Pteridaceae, Schizaeaceae, Selaginelliaceae; gymnosperms- Podocarpaceae; angiosperms- Acanthaceae, Amaranthaceae, Anacardiaceae, Annonaceae, Apocynaceae, Aquifoliaceae, Araceae, Arecaceae, Asteraceae, Betulaceae, Bignoniaceae, Bombacoideae, Boraaginaceae, Bromeliaceae, Burseraceae, Byttnerioideae, Cacompaceae, Caesalpinioideae, Chloranthaceae, Clusiaceae, Combretaceae, Connaraceae, Cucurbitaceae, Cyperaceae, Dilleniaceae, Dioscoreaceae, Ericaceae, Euphorbiaceae, Fabaceae, Faboideae, Fagaceae,

Gentianaceae, Grewioideae, Juglandaceae, Labiatae, Lamiaceae, Lentibulariaceae, Loranthaceae, Malpighiaceae, Malvaceae/Malvoideae, Melastomataceae, Meliaceae, Mimosoideae, Myrtaceae, Nymphaeaceae, Ochnaceae, Onagraceae, Phyllanthaceae, Poaceae, Polygalaceae, Rhizophoraceae, Rubiaceae, Rutaceae, Salicaceae, Sapindaceae, Sapotaceae, Symplocaceae, Mimosoideae, Tetrameristaceae, Ulmaceae, Verbenaceae, Vochysiaceae.

For reference to the Guiana Shield as an ancestral area see Givnish et al. (2011; for Bromeliaceae), Merckx et al. (2013; Gentianaceae), and Givnish et al. (2004) and Janssen & Bremer (2004; Rapateaceae).

A summary of Early Cretaceous plant fossils from southern Patagonia is provided by Del Fueyo et al., 2007. See also Limarino et al., 2012; Archangelsky, Archangelsky, and Cladera, 2012.

Barreda and Palazzesi (2014, table 1) present a summary of the fossil palynomorphs from the Miocene Chenque and Puerto Madryn formations of Patagonia. A morphological-based system is used to name the fossils and they are referred to the following extant families with suggested generic affinities. Bryophyta: Bartramiaceae, Riellaceae, Sphagnaceae; ferns and related groups: Azollaceae, Blechnaceae, Cyatheaceae, Dicksoniaceae, Gleicheniaceae, Hymenophyllaceae, Lycopodiaceae, Polypodiaceae, Pteridaceae, Schizaeaceae; gymnosperms: Araucariaceae, Cupressaceae, Ephedraceae, Podocarpaceae; angiosperms: Amaranthaceae, Anacardiaceae, Aquifoliaceae, Arecaceae, Bromeliaceae(?), Asteraceae, Cactaceae, Calyceraceae, Casuarinaceae, Celastraceae, Chloranthaceae, Convolvulaceae, Cyperaceae, Ericaceae/Epacridaceae, Euphorbiaceae, Fabaceae, Goodeniaceae, Gunneraceae,

Haloragaceae, Juncaceae(?), Liliaceae, Loranthaceae, Malvaceae, Malvaceae, Myrtaceae, Nothofagaceae, Onagraceae, Paracryphiaceae, Poaceae, Proteaceae, Polygonaceae, Rosaceae, Rubiaceae, Salicaceae(?), Sapindaceae, Sparganiaceae, Symplocaceae, Thymeleaceae, Vivianiaceae, Winteraceae,

Poole et al. (2005; see also Cantrill & Nichols, 1996, Cantrill & Poole, 2005) are used here for cataloging the fossil plants, suggested affinities, geologic formations, and primary literature for the various Late Cretaceous (Coniacian-Campanian) to middle Eocene floras of the Antarctic Peninsula.

For a note on “the known issues of estimating extinction rates from molecular phylogenetics based upon extant taxa in the absence of a complete fossil record (Rabosky, 2009, 2010; reviewed in Quental and Marshall, 2010,” see D. E. Soltis et al., 2013 (Saxifragales).

An inclusive compilation intended to eventually include ‘all angiosperm fossils and fossil sites globally from the Cenozoic’ is the developing Cenozoic Angiosperm Database (<http://paleodb.org/cgi-bin/bridge.pl>) within the Paleobiology Database (<http://paleodb.org>). There is NESCent’s (National Evolutionary Synthesis Center), The Fossil Calibration Database (A New Bioinformatic Tool for Dating Divergences of Extant Lineages by Synthesizing Paleontological and Molecular Data. Another focusing on fossil and recent pollen and spores is the PalDat- Palynological Database (<http://www.paldat.org/>; Buchner, R. & M. Weber 2000). There is the Paleobotany Project, Denver Museum of Nature and Science (<http://www.paleobotanyproject.org/>), Austrofossils for Austria and vicinity (<http://www.oeaw.ac.at/austrofossil>), and a compendium index of North American Mesozoic and Cenozoic fossil plants at the

Peabody Museum (<http://peabody.research.yale.edu/pbci>) . See also Wen et al. (2013, p.920- Integrative Biogeography Data Portal). A catalog of vegetation databases (21 treated in detail, 150 mentioned) is presented by Jürgen Dengler et al. (2012) at <http://www.biodiversity-plants.de> (see notice, *Frontiers of Biogeography* 2012, 4:4).

There is a glossary of palynology by Peter Hoen on the University of Utrecht's website (<http://www.bio.uu.nl/-palaeo/glossary/glos-int.thm>) based on Punt et al. (2007). A world flora for extant plants is currently being developed (search: world flora online), the International Plant Names Index (IPNI) is a database of names and bibliographic information for extant vascular plants (www.ipni.org/index.html; Manchester 2009), and the Index Nominum Genericorum (ING) lists generic names for extant and fossil plants covered under the International Code of Botanical Nomenclature (Manchester 2009).

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ADDENDUM- In the presentation “The Miocene- Before and After” (2014) as part of the symposium “The Miocene Vegetation and Environment of Western North America (Botany14, Boise, Idaho meetings, Richard Dilhoff, Caroline Strömberg, Thomas Dilhoff, and Regan Dunn, organizers) it was noted that references mentioned/used in the presentation would be provided in this Catalog and Literature Guide. These are as follows:

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FILICINEAE (and associated non-seed vascular plant groups)

General summaries- Collinson, 2001; Rothwell, 1999; Cretaceous cicatricose (*Anemia*, *Mohria*) spores, Argentina- see Narváez et al., 2013)

INCERTAE SEDIS (Filicineae)

Cladophlebis cinerrium- Cretaceous (Aptian), Anfiteatro de Ticó Fm., Santa Cruz

Province, Argentina, fronds, rhizomes, adventitious roots; Carrizo et al., 2011.

Striatisperma coronapunctatum- middle Eocene (44 Ma), Clarno Fm., OR, Manchester,

1994 = *Equisetum* root nodules (Steven Manchester, pers. comm., April, 2011).

Cryptogam spores from the Late Cretaceous (Campanian) to Paleocene of Seymour Island, Antarctica (Askin, 1989) identified by a morphological system necessitated by the age of the deposits include *Clavifera triplex* (gleicheniaceous fern) and massulae of *Azolla*-type (salviniaceous; pp. 112-113).

Acrostichum type (Pteridaceae)- late Miocene, Upper Belugia Fm., south coast Alaska, spore; Reinink-Smith & Leopold, 2005.

Adiantopsis (Pteridaceae)- Link-Pérez et al. (2011): “Biogeographic analyses suggest an origin for the genus in South America, with a minimum of three migrations into the Caribbean”) p. 1255).

Allantodiopsis (undetermined genus, Dryopteridaceae)- late Miocene, Vasa Park Fl., King Co., WA, leaf; Dillhoff et al., 2014.

Anemia quatsinoensis (Schizaeaceae)- Lower Cretaceous, Longarm Fm. equivalent, Apple Bay locality, Vancouver Is., British Columbia, Canada, vegetative and fertile organs; Hernandez-Castillo et al., 2006. ?A. type- late Miocene, Upper Belugia Fm., south coast Alaska, spore; Reinink-Smith & Leopold, 2005.

Arcellites humilis, *A. pentagonalis*, *A. santacrucensis*, *A. sp. A* (Marsileaceae)-

Cretaceous (late Albian possibly extending into the Cenomanian), Argentina,

Patagonia, spores; Villar de Seoane & Archangelsky, 2008.

Azolla (Azollaceae)- "...the *Azolla* event of 49m years ago- a giant bloom... that

coincided with one of the biggest climatic shifts known" (Economist, 2014). *Azolla*

sp.- Maastrichtian to lowermost Danian López de Bertodiano Fm., Seymour Island,

Antarctica, spores; Bowman et al., 2014 [numerous other palynomorphs identified to

genus by artificial system, some referred to family- e.g., Polypodiaceae, Araucariaceae,

Podocarpaceae, Ericaceae, Loranthaceae, Monimiaceae, Nothofagaceae, Proteaceae,

Ranunculaceae].

Azolla circinata (Azollaceae)- Late Cretaceous, Loncoche Fm., Mendoza, Argentina,

massulae; Puebla et al., 2014. *A. stanleyi* (Azollaceae)- late Paleocene, Joffre Bridge

Fl., Red Deer Valley, Alberta, Canada, Hoffman & Stockey, 1994, 1999; Pigg &

DeVore, 2010. *A. sp.*- Paleogene, Ñirihuau Basin, Argentina, megaspores;

Quattrocchio et al., 2012. Late Miocene, Upper Beluga Fm., south coast Alaska,

megaspore; Reinink-Smith & Leopold, 2005.

Baculatisporites comaumensis (Osmundaceae)- Paleogene, Ñirihuan Basin, Argentina,

spores; Quattrocchio et al., 2012. *B. primarius* (Osmundaceae)- late Paleocene (~60

Ma), Sagwon, North Slope, Alaska, spores; Daly et al., 2011. *B. turbioensis*

(?Osmundaceae)- Paleogene, Ñirihuau Basin, Argentina, spores; Quattrocchio et al.,

2012. *B. sp.* (cf. Osmundaceae)- late Paleocene, Almont Fl., Williston Basin, ND,

spore; Zetter et al., 2011.

Bacutriletes guttula (Selaginellaceae)- Cretaceous (late Albian possibly extending into

the Cenomanian), Argentina, Patagonia, spores; Villar de Seoane & Archangelsky, 2008.

Balmeisporites holodictyus (Salviniaceae)- Cretaceous (late Albian possibly extending into the Cenomanian), Argentina, Patagonia, spores; Villar de Seoane & Archangelsky, 2008.

Biretisporites crassilabratus (?Hymenophylleaceae)- Paleogene, Ñirihuau Basin, Argentina, spores; Quattrocchio et al., 2012.

cf. *Boodlepteris* (Gleicheniaceae)- Late Cretaceous (late Santonian), Buffalo Creek Member, Gaillard Fm., Allon Fl., GA, pinnules; Herendeen et al., 1999.

Botrychium wightonii (Ophioglossaceae)- late Paleocene, Alberta Basin, Genesee Fl., Canada, Rothwell & Stockey, 1989; Pigg & DeVore, 2010. *B.* type- late Miocene, Upper Beluga Fm., south coast Alaska, spore; Reinink-Smith & Leopold, 2005.

Cicatricosisporites (some spores similar to those of modern species of *Anemia*), *Ruffordiaspora* (Anemiaceae)- Lower Cretaceous, Austral Basin, Patagonia, Argentina, spores; Archangelsky & Archangelsky, 2010.

Cingutriteles australis (*Sphagnum*)- Paleogene, Ñirihuau Basin, Argentina, spores; Quattrocchio et al., 2012.

Conantiopteris schuchmanii (Cyatheaceae)- Lower Cretaceous (Aptian), upper Chickabally Member, Budden Canyon Fm., near Cottonwood, CA, trunk, frond bases, adventitious roots; Lantz et al., 1999: [Cladistic analyses “indicate that the new genus is nested among a paraphyletic assemblage of dicksoniaceae, lophosoriaceae, and metaxylaceae species that subtend a monophyletic Cyatheaceae s.s.”, p. 361].

Contignisporites cooksoniae, *C. glebulentus*, *C. burgeri* (Pteridaceae)- Early Cretaceous

- (Hauterivian to Albian), Austral Basin, Argentina, Patagonia, spores; Archangelsky & Archangelsky, 2006.
- Crybelosporites pannuceus* (Marsileaceae)- Late Cretaceous, Loncoche Fm., Neuquén Basin, Mendoza, Argentina, microspore; Puebla et al., 2014
- Cryptogramma* (Pteridaceae)- late Miocene, Upper Beluga Fm., south coast Alaska, spore; Reinink-Smith & Leopold, 2005.
- Cyathea cranhamii* (Cyatheaceae)- Early Cretaceous (Barremian), Longarm Fm. equivalent, Apple Bay locality, Vancouver Is., British Columbia, Canada, sori (indusia, sporangia with annulus, spores); Smith et al., 2003.
- Cyatheacidites annulatus* (Lophosoria, Lophosoriaceae)- Paleogene, Ñirihuau Basin, Argentina, spores; Quattrocchio et al., 2012.
- Cyathidites subtilis* (Cyatheaceae/Dicksoniaceae)- Paleogene, Ñirihuau Basin, Argentina, spores; Quattrocchio et al., 2012.
- Davallia* (Davalliaceae)- late Miocene, Upper Beluga Fm., south coast Alaska, spore; Reinink-Smith & Leopold, 2005.
- Deltoidospora adriennis* (Pteridaceae)- late Paleocene (~60 Ma), Sagwon Bluffs, North Slope, Alaska, spores; Daly et al., 2011. *D. australis*, *D. minor* (Polypodiaceae, *Acrostichum*)- Paleogene, Ñirihuau Basin, Argentina, spore; Quattrocchio et al., 2012.
- Dennstaedtia blomstrandii* (Dennstaedtiaceae)- late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada; Hoffman & Stockey, 1999.
- Dickwhitea allenbyensis* (Athyriaceae)- middle Eocene, Allenby Fm., Princeton Chert Member, British Columbia, Canada, rhizome; Karafit et al., 2006.
- Dictyophyllidites harrisii* (Matoniaceae, *Phlebopteris*)- Paleogene, Ñirihuau Basin,

Argentina, spore; Quattrocchio et al., 2012.

Dryopteris sp. (Dryopteridaceae)- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007.

cf. *Dryopteris*- late Miocene, Upper Beluga Fm., south coast Alaska, spore; Reinink-Smith & Leopold, 2005.

Equisetum lyellii (Equisetaceae; see also Incertae Sedis, Filicineae)- Lower Cretaceous

(upper Albian), Potomac Group, VA, stem; Upchurch et al., 1994. *E.* sp.- late

Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflores, Johnson, 2002;

Paleocene, Ludlow Member of Fort Union Fm., ND, SD, megaflores, Johnson, 2002;

Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada, Hoffman & Stockey,

1999; late Paleocene (Tiffanian)- Paskapoo Fm., Alberta, Canada, stems, rhizomes,

tubers, Stockey et al., 2014; middle Eocene (45 Ma), Thunder Mountain Fl., ID,

underground tubers, Axelrod, 1998; Oligocene (30.7 Ma), Haynes Creek Fl., ID,

Axelrod, 1998a ; Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR,

stem, Meyer & Manchester, 1997; late Miocene, Vasa Park Fl., King Co., WA, spore,

bulbil, nodal sheath, spore(?), Dillhoff et al., 2014; late Miocene (Clarendonian, 12

Ma), Ironside Fm., OR, Retallack, 2004; Miocene (15-6 Ma), Iceland, Grimsson &

Denk 2007.

Gleichenia appianensis (Gleicheniaceae)- middle Eocene, Oyster Bay Fm., Appian Way

locality, Vancouver Is., British Columbia, Canada; Mindell et al., 2006.

Gleicheniidites argentinus (Gleicheniaceae)- Paleogene, Ñirihuau Basin, Argentina,

spores; Quattrocchio et al., 2012.

Goolangia minnesotensis (Marattiaceae)- Cretaceous (latest Albian to earliest

Cenomanian), Dakota Fm., Courtland Clay Pit, New Ulm, central MN, sporangia and

synangia; Hu et al., 2006.

Grapnelispora (extinct)- Late Cretaceous, Loncoche Fm., Neuquén Basin, Mendoza, Argentina, megaspore; Puebla et al., 2014.

Hausmannia morinii (Dipteridaceae)- Lower Cretaceous (Hauterivian-Barremian boundary), Longarm equivalent, Apple Bay locality, Vancouver Is., British Columbia, Canada, foliage; Stockey et al., 2006a.

Hydropteris pinnata (for family relationships see Pryer, 1999)- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflores; Johnson, 2002.

Hymenophyllopsis (Hymenophyllopsidaceae)- late Miocene, Upper Beluga Fm., south coast Alaska, spore; Reinink-Smith & Leopold, 2005.

Hymenophyllum (Hymenophyllaceae)- late Miocene, Upper Beluga Fm., south coast Alaska, spore; Reinink-Smith & Leopold, 2005. cf. *Hymenophyllum caudiculatum*- Paleogene, Ñirihuau Basin, Argentina, spores; Quattrocchio et al., 2012.

Ischyosporites aerapunctatis (Dicksoniaceae)- Paleogene, Ñirihuau Basin, Argentina, spores; Quattrocchio et al., 2012.

Isoëtes horridus (Isoëtaceae)- late Paleocene, Williston Basin, Beicegel, Golden Valley, Ravenscrag Fls., US/Canada, Brown, 1962, Hickey, 1977, McIver & Basinger, 1993, Pigg & DeVore, 2010. *I. cf. horridus*- late Paleocene, Beicegel Fl., megaspores; Matthews et al., 2007. *I. sp.*- late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada; Hoffman & Stockey, 1999.

Kuylisporites (*K. mirabilis*, *K. separatus*, *K. scutatus*, *K. waterbolkii*; Cyatheaceae)- Cretaceous, Cenozoic, widespread, spores; Mohr & Lazarus, 1994: ["...genus originated in the Northern Hemisphere in the late Cretaceous; *K. waterbolkii*... closely

related to or identical with extant *Cnemidaria...*”, p. 765].

Laevigatosporites hardtii (Polypodiaceae)- late Paleocene (~60 Ma), Sagwon Bluffs, North Slope Alaska, spores; Daly et al., 2011. *L. ovatus* (Blechnaceae)- Paleogene, Ñirihuau Basin, Argentina, spores; Quattrocchio et al., 2012. *L. sp.* (Thelypteridaceae)- Miocene, Tepoztlán Fm., Mexico, spores; Lenhardt et al., 2013.

Leptolepidites macroverrucosus (Dennstaedtiaceae)- Paleogene, Ñirihuau Basin, spores; Quattrocchio et al., 2012.

Lycopodium Lycopodiaceae)- late Miocene, Upper Beluga Fm., south coast Alaska, spore; Reinink-Smith & Leopold, 2005. Late Miocene, Vasa Park Fl., King County, WA, spore; Dilhoff et al., 2014.

Lycopodiumsporites reticulatus (Lycopodiaceae)- late Paleocene (~60 Ma), Sagwon Bluffs, North Slope Alaska, spores; Daly et al., 2011.

Lygodium kaulfussii (Schizaeaceae)- Eocene, WY, foliage with intact sori, Manchester & Zavada, 1987, Pigg & DeVore, 2010. *L. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, spores, Leopold & Clay-Poole, 2001; late Miocene, Upper Beluga Fm., south coast Alaska, spore, Reinink-Smith & Leopold, 2005.

Makopteris princetonensis (Athryiaceae)- middle Eocene, Princeton Chert, Princeton Group, Allenby Fm., southern British Columbia, Canada, rhizomes, fronds, stipes, rachis, pinnules, sori, spores; Stockey et al., 1999: [“...documents that essentially modern athyrioids were present in the flora of North America by the early Tertiary” , p. 1047].

Matonisporites ornamentalis (Dicksoniaceae)- Paleogene, Ñirihuau Basin, Argentina, spores; Quattrocchio et al., 2012.

Mendozaphyllum loncochese (Marsileaceae)- Late Cretaceous, Neuquén Basin, Mendoza, Argentina, macrofossils; Puebla et al., 2014.

Mesozoisynanangia trilobus (Marattiaceae)- Cretaceous (latest Albian to earliest Cenomanian), Dakota Fm., Courtland Clay Pit, New Ulm, central MN, sporangia and synangia; Hu et al., 2006.

Midlandia nishidae (Blechnaceae)- Upper Cretaceous (Campanian), Horseshoe Canyon Fm., near Drumheller, Alberta, Canada, rhizomes, stipe bases; Serbet & Rothwell, 2006. [“...strongly support hypotheses that these highly derived ferns originated before the Upper Cretaceous” (p. 703)].

Millerocaulis embreei (Osmundaceae)- Early Cretaceous (Aptian), upper Chickabally Member, Budden Canyon Fm., near Ono, CA, stem; Stockey & Smith, 2000. [Other fossil records are listed in table 1, p. 164].

Minerisporites aequatus, *M. laceratus* (Isoetaceae)- Cretaceous (late Albian possibly extending into the Cenomanian), Argentina, Patagonia, spores; Villar de Seoane & Archangelsky, 2008.

Mohria-like spores (Anemiaceae)- Early Cretaceous (Albian), Piedra Clavada Fm., Austral Basin, Argentina, Patagonia; Archangelsky, 2009.

Muricingulisporis annulatus (Pteridaceae)- Early Cretaceous (Hauterivian to Albian), Austral Basin, Argentina, Patagonia, spores; Archangelsky & Archangelsky, 2006. *M. chenquensis*- Paleogene, Ñirihuau Basin, Argentina, spores; Quattrocchio et al., 2012.

Onoclea senisbilis (Dryopteridaceae)- late Paleocene, Alberta Basin, Munce’s Hill Fl., Rothwell & Stockey, 1991, Pigg & DeVore, 2010; Stockey et al., 2014.

Osmunda cinnamomea (Osmundaceae)- Upper Cretaceous, Horseshoe Canyon Fm., near

Drumheller, Alberta, Canada, small trunks, stems, frond bases; Serbet & Rothwell, 1999: [with other specimens “reveals the more or less continuous presence of *O. cinnamomea* L. in western North America for at least 70 million years”, p. 425; includes other records, p. 427]. *O. macrophylla*- late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada; Hoffman & Stockey, 1999. *O. occidentale*- middle Eocene (45 Ma), Thunder Mountain Fl., ID, pinnules; Axelrod, 1998. Oligocene (30.7 Ma), Haynes Creek Fl., ID, pinnae; Axelrod, 1998a. *O. vancouverensis*- Lower Cretaceous, Longarm Fm. equivalent, Apple Bay locality, Vancouver Is., British Columbia, Canada, fertile fronds; Vavrek et al., 2006. *O. parschlugiana*, Miocene (15-6 Ma), Iceland; Grimmson & Denk, 2007. *O. sp.*- late Miocene, Upper Beluga Fm., south coast Alaska, spore; Reinink-Smith & Leopold, 2005.

Paleoazolla patagonica (Salviniaceae)- Late Cretaceous, Neuquén Basin, Mendoza, Argentina, massulae; Puebla et al., 2014.

Paralygodium meckertii (Schizaeaceae)- Upper Cretaceous (Coniacian), Comox Fm., Eden Main localities, Vancouver Is., British Columbia, Canada, fertile pinnules; Karafit & Stockey, 2008. *P. vancouverensis*- middle or late Eocene Appian Way locality, Vancouver Is., British Columbia, Canada, fertile pinnules; Trivett et al., 2006: [“...supports interpretations that the diversity of Schizaeaceae s.l. was greater during the Cretaceous and Paleogene than it is today” (p. 675)].

Perinomonoletes sp. (Polypodiaceae, cf. *Asplenium*, *Blechnum*)- Miocene, Tepoztlán Fm., Mexico, spore; Lenhardt et al., 2013.

Peromonolites vellosus (Blechnaceae)- Paleogene, Ñirihuau Basin, Argentina, spores; Quattrocchio et al., 2012.

Polypodiaceae (taxonomically, stratigraphically, geographically widespread generalized monolete fern spores; e.g., Bowman et al., 2014, see *Azolla*).

Polypodium deweyensis (Polypodiaceae)- middle Eocene (45 Ma), Thunder Mountain Fl., ID, terminal portion pinnule blade; Axelrod, 1998. *P. sp.*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997.

Polypodium vulgare complex- [Sigel et al., 2014, p. 1042: “The *P. vulgare* complex is resolved as sister to the Neotropical *P. plesiosorum* group and these, in turn, are sister to the Asian endemic *Pleurosoriopsis makinoi*. Using divergence time analyses incorporating previously derived age constraints and fossil data, we estimate an early Miocene origin for the *P. vulgare* complex and a late Miocene-Pliocene origin for the four major diploid lineages of the complex, with the majority of extant diploid species diversification from the late Miocene through the Pleistocene. Finally, we use our node age estimates to reassess previous hypotheses, and to propose new hypotheses, about the historical events that shaped the diversity and current geographic distribution of the diploid species of the *P. vulgare* complex.”

Polypodiisporites inangahuensis (Polypodiaceae)- Paleogene, Ñirihuau Basin, Argentina, spores; Quattrocchio et al., 2012.

Pteridophyta sp. (Dennstaedtiaceae)- Miocene, Tepoztlán Fm., Mexico, spores; Lenhardt et al., 2013.

“*Pteris*” *silvicola* (Pteridaceae)- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997.

Pterisorus radiata (family unknown, combines characters of Pteridaceae and tree ferns)- Lower Cretaceous (Valanginian-Hauterivian boundary), Longarm Fm. equivalent,

Apple Bay locality, Vancouver Is., British Columbia, Canada, fertile frond; Rothwell & Stockey, 2006.

Regnellidium thomas-taylorii (Marsileaceae)- Upper Cretaceous (Campanian-Maastrichtian), La Colonia Fm., Chubut Province, Argentina, rhizomes with roots, petiolate compound leaves; Cúneo et al., 2013.

Reticuloidosporites tenellis (Polypodiaceae)- Paleogene, Ñirihua Basin, Argentina, spores; Quattrocchio et al., 2012.

Retitriletes sp. (*Lycopodium*)- Miocene, Tepoztlán Fm., Mexico, spores; Lenhardt et al., 2013.

Rickwoodopteris hirsuta (Cyatheaceae)- Late Cretaceous (late Campanian), Spray Fm., Shelter Point, Vancouver Is., British Columbia, Canada, stem; Stockey & Rothwell, 2004.

Ruffordiaspora (see *Cicatricosisporites*)

Salvinia sp. (Salviniaceae)- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflores; Johnson, 2002.

Schizaea (Schizaeaceae)- late Miocene, Upper Beluga Fm., south coast Alaska, spore; Reinink-Smith & Leopold, 2005.

Selaginella sp. (Selaginellaceae)- latest Eocene (34.1 Ma), Florissant Fl., CO, spores; Leopold & Clay-Poole, 2001. Late Miocene, Vasa Park Fl., King Co., WA, spore; Dillhoff et al, 2014.

Sotasporites elegans, *S. triangularis*, *S.* sp. (Pteridaceae)- Early Cretaceous (Hauterivian to Albian), Austral Basin, Argentina, Patagonia, spores; Archangelsky & Archangelsky, 2006.

Speirseopteris orbiculata (Thelypteridaceae)- late Paleocene (late Tiffanian), Paskapoo Fm., central Alberta, Canada, fronds, fertile pinnules, spores; Stockey et al., 2006b; Pigg & DeVore, 2010; Stockey et al., 2014

Stereisporites sterieoides (Sphagnaceae, *Sphagnum*)- late Paleocene (~60 Ma), Sagwon Bluffs, North Slope Alaska, spores; Daly et al., 2011. *S. sp.* (cf. *Sphagnum*)- Miocene. Tepoztlán Fm., spores; Lenhardt et al., 2013.

Stramineopteris aureopilosus (family unknown)- Lower Cretaceous (Valanginian to Hauterivian), Longarm Fm. equivalent, Apple Bay locality, Vancouver Is., British Columbia, Canada, rhizomes, stipe bases, adventitious roots; Little et al., 2006.

cf. Thelypteridaceae- late Paleocene, Almont Fl., Williston Basin, ND, spore; Zetter et al., 2011).

Trawetsia princetonensis (Blechnaceae)- middle Eocene, Allenby Fm., Princeton Chert Member, British Columbia, Canada, rhizomes, stipes, fronds; Smith et al., 2006.

Verrucingulatisporites sp. (Pteridaceae)- Miocene, Tepoztlán Fm., Mexico, spores; Lenhardt et al., 2013.

Wessiea oroszii (Dryopteridaceae)- Upper Cretaceous (Campanian), Horseshoe Canyon Fm., near Drumheller, Alberta, Canada, rhizomes, stipe bases; Serbet & Rothwell, 2006; *W. yakimaensis*- middle Miocene, Grande Ronde Basalt of the Columbia River Basalt Group, 15.6 +/- 0.2 Ma, Yakima County, WA, rhizomes, frond bases; Pigg & Rothwell, 2001.

Woodwardia gravida (Blechnaceae)- Paleocene, Ludlow Member of Fort Union Fm., ND, SD, megaflores; Johnson, 2002. *W. virginica*, middle Miocene, Grande Ronde Basalt of the Columbia River Basalt Group, 15.6 +/- 0.2 Ma, Yakima County, WA,

pinules, rhizomes, stipes, indusiate sori, and sporangia; Pigg & Rothwell, 2001: [“... emphasize the exceptional species longevity of some homosporous pteridophytes”, p. 777]. *W. sp.*- late Paleocene, Williston Basin, Beicegel, Ravenscrag Fls., U.S./Canada, fronds, McIver & Basinger, 1993; Pigg & DeVore, 2010; Pigg et al., 2006 (Beicegel Fl.); late Miocene, Vasa Park Fl., King Co., WA, leaf, Dillhoff et al., 2014.

GYMNOSPERMAE

Gymnosperm microfossils from the Late Cretaceous (Campanian) to Paleocene of Seymour Island, Antarctica (Askin, 1989) identified by a morphological system necessitated by the age of the deposits include *Phyllocladidites mawsonii* (cf. extant *Lagarostrobus franklini*, western Tasmanian rainforest), *Phyllocladidites* types, and “pollen related to extant *Dacrydium*, *Dacrycarpus*, *Podocarpus*, and *Microcachrys* species” (p. 113), in addition to *Cycadopites* (Cycadales or Ginkgoales), *Araucariacites australis*, and *Ephedra notensis* (“...which first appeared during the Maastrichtian throughout the Weddellian Province”, p. 114).

ARAUCARIACEAE- Escapa & Catalano (2013): “Results support the monophyly of living and fossil *Araucaria* (including *Araucarites*), whereas the remaining extinct genera are placed as the stem of the agathoid clade” (p. 1153). ...”depict *Araucaria* as the sister group of the agathoid clade formed by *Wollemia* and *Agathis*” (p. 1163). “...inferred the diversification of the crown group of *Araucaria* at the Late Cretaceous-Paleocene” (p. 1164). “...whereas the *Araucaria* clade achieved its modern morphology at least by the Middle Jurassic, the evidence presented here suggests that the acquisition of derived traits

present in extant species of the agathian clade occurred much later, during the Cretaceous or Paleogene” (p. 1164). [see also *Azolla*, Bowman et al., 2014].

Alkastrobos peltatus- Early Cretaceous (Aptian), Anfiteatro de Ticó Fm., Baqueró Group, Santa Cruz Province, Argentina, Patagonia, pollen cone associated with twigs and leaves of *Brachyphyllum mirandai* with in situ pollen of *Cyclusphaera psilata*; Del Fueyo & Archangelsky, 2005; Archangelsky & Del Fueyo, 2010.

Araucaria grandifolia (Section *Araucaria*)- Early Cretaceous (Aptian), Punta del Barco Fm., Baqueró Group, Santa Cruz Province, Argentina, Patagonia, branches with leaves; Archangelsky & Del Fueyo, 2010.

cf. *Araucaria* sp.- Lower Cretaceous, Crato Fm., Araripe Basin, Brazil, strobilus, squamata (= cone scales); Kunzmann et al., 2004.

Araucariaceae (cf. *Araucaria* sect. *Eutacta*)- middle Eocene. Antarctic Peninsula, leaf; Poole et al., 2005.

Araucariacites australis- lower middle Eocene, Antarctic Peninsula, pollen; Poole et al., 2005. Paleogene, Ñirihuau Basin, Argentina, spores; Quattrocchio et al., 2012.

A. sp.- late Paleocene, Almont Fl., Williston Basin, North Dakota, pollen; Zetter et al., 2011.

Araucarioid wood types 1-3- Upper Cretaceous (Aguja, Javelina Fms.) and Paleocene (Black Peaks Fm.), Big Bend National Park, TX; Wheeler & Lehman, 2005.

Araucariostrobus sp. (aff. Araucariaceae)- Lower Cretaceous, Crato Fm., Araripe Basin, Brazil, cones attached to leafy shoots; Kunzmann et al., 2004.

Araucariopitys- Late Cretaceous (Coniacian to Campanian), Antarctic Peninsula, wood, pollen; Poole et al., 2005.

Araucarioxylon- Late Cretaceous (late Maastrichtian), mid-early Paleocene, lower middle Eocene, Antarctic Peninsula, wood (Maastrichtian with pollen), Poole et al., 2005.

Araucariacites australis- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, pollen; Poole et al., 2005.

Araucarites aquiensis- Lower Cretaceous (upper Albian), Potomac Group, VA, cone scales; Upchurch et al., 1994.

Brachyphyllum obesum (cf. Araucariaceae)- Lower Cretaceous, Crato Fm., Araripe Basin, Brazil, vegetative shoots; Kunzmann et al., 2004.

Cylusphaera radiata- Cretaceous (Albian), Piedra Clavada Fm., Santa Cruz Province, Patagonia, Argentina, pollen; Del Fueyo et al., 2012.

Dammarites sp.- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Elatides longifolia- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Nothopheuen brevis- Early Cretaceous (Aptian), Baqueró Group, Santa Cruz Province, Argentina, Patagonia, twigs with leaves of the *Brachyphyllum* type; Archangelsky & Del Fueyo, 2010.

CEPHALOTAXACEAE

Cephalotaxus nevadensis- middle Eocene (45 Ma), Thunder Mountain Fl., ID, needle; Axelrod, 1998. *C*-type- middle Eocene, Republic Fl., WA; Schorn & Wehr, 1996.

CHEIROLEPIDIACEAE (Coniferales, extinct)

Pseudofrenelopsis parceramosa- Lower Cretaceous (upper Albian), Potomac Group, VA, shoots; Upchurch et al., 1994.

CUPRESSACEAE (see also Taxodiaceae)

“...Cupressaceae (162 species, 32 genera) exhibit patterns expected from the Jurassic/Cretaceous breakup of Pangea...originated during the Triassic...vicariance occurred around 153 Ma (124-183 Ma), when Gondwana and Laurasia were separating” Mao et al., 2012, p. 7793).

“Phylogenetic studies demonstrate that...these taxa all share a single common ancestor; by extension, they also share a common ancestral habitat.. We conclude that the modern biogeography of the Cupressaceae conifers was shaped in large part by their capacity to adapt to drought” (Pittermann et al., p. 9647).

Athrotaxis ungeri- Early Cretaceous (Aptian Anfiteatro de Ticó Fm., early Albian Piedra Clavada Fm, late Albian Kachaike Fm.), Argentina, Patagonia, Alexander Is.,

Antarctica, branches, leaves, ovuliferous cones; Archangelsky & Del Fueyo, 2010.

Calocedrus schornii- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf, ovulate cone; Meyer & Manchester, 1997. cf. *C. sp.*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, leafy twigs; Dillhoff et al., 2005.

Chamaecyparis sp. [*C. edwardsii* in Axelrod, 1998, p. 32; 1998a, p. 41]- middle Eocene, Thunder Mountain Fl., central ID, vegetative axes; Erwin & Schorn, 2005:

[[“Radiometrically dated at 46-45 Ma, it [the Thunder Mountain Flora] represents one of the oldest montane conifer-dominated assemblages recovered from the Northern

Hemisphere”, p. 125]]. *C. sp.*- late early Eocene (49-52 Ma), McAbee Fl., British

Columbia, Canada, leafy twigs, cones, Dillhoff et al., 2005; latest Eocene (34.1 Ma),

Florissant Fl., CO, leaves, cones, Manchester, 2001; middle Eocene, Republic Fl., WA,

Schorn & Wehr, 1996. *C. edwardsii*- Oligocene (30.7 Ma), Haynes Creek Fl., ID,

terminal branchlets with leaves; Axelrod, 1998a. *C. linguaefolia*- late Miocene, Vasa Park Fl., King Co., WA, leaves, leafy twigs; Dillhoff et al., 2014.

Cryptomeria-type- middle Eocene, Republic Fl., WA, branches; Schorn & Wehr, 1996.

Cunninghamiostrobus goedertii- early Oligocene, Jansen Creek Member, Makah Fm., northern shore Olympic Peninsula, WA, stems, leaves (cone axes of seed cones occur at the same locality); Miller, 1990: “These remains are similar to those of the modern *Cunninghamia lanceolata* but differ from this species too much to be treated in the modern genus” (p. 970). [The deposit also contains *Picea eichhornii* (Miller, 1989), *Pinus buchananii* (Underwood & Miller, 1980), *Pinus escalantensis* (Banks et al., 1981), and *Pityostrobus makahensis* (Crabtree & Miller, 1989)].

Cunninghamia chaneyi- Oligocene (33.6-32.2 Ma), John Day Fm, Bridge Creek Fl., OR, leaf, cone scale; Meyer & Manchester, 1997. *C. hornbyensis*- Cretaceous (Campanian), Northumberland Fm., Nanaimo Group, Collishaw Point, Hornby Island, British Columbia, Canada; Brink et al., 2009. *C. marquetii*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, branchlets, cones; Axelrod, 1998a. *C. sp.*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, leafy twigs, cones; Dillhoff et al., 2005. *C. taylorii*- Upper Cretaceous (Campanian), Horseshoe Canyon Fm., Drumheller badlands,, Alberta, Canada, stems, leafy shoots, leaves, ovuliferous cones, pollen cones; Serbet et al. 2013.

Curpessinocladus interruptus- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, Megafloora, Johnson, 2002; Paleocene, Ludlow Member of Fort Union Fm., ND, SD, megafloora, Johnson, 2002.

Cupressinoxylon- Upper Cretaceous (Aguija, Javeline Fms.) and Paleocene (Black Peaks

- Fm.), Big Bend National Park, TX, wood, Wheeler & Lehman, 2005; middle Eocene, Lower middle Eocene, Antarctic Peninsula, leaf, wood (*Libocedrus*); Poole et al., 2005.
- Fitzroya cupressoides*- last interglacial (MIS 5e- called Valdivia in southern Chile), Mancera interglacial sequence, Mancera Island, Chile, wood; Astorga & Pino, 2011.
- Fokieniopsis catenulata*- Late Cretaceous (Maastrichtian), Hell creek Fm., ND, SD, Megafloora, Johnson, 2002; Paleocene, Ludlow Member, Fort Union Fm., ND, SD, megafloora, Johnson, 2002. *F. praedecurrens*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, foliage; Meyer & Manchester, 1997.
- Glyptostrobus europaeus*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megafloora, Johnson, 2002; Paleocene, Ludlow Member of Fort Union Fm., ND, SD, megafloora, Johnson, 2002; late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada, Hoffman & Stockey, 1999; Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. *G. sp.*- Late Cretaceous (Maastrichtian), Hell creek Fm., ND, SD, megafloora; Johnson, 2002. *G.*-type- middle Eocene, Republic Fl., WA, branches; Schorn & Wehr, 1996.
- Homalcoia littoralis*- Eocene, Appian Way locality, south of Campbell River, Vancouver Is., British Columbia, Canada, pollen cones; Hernandez-Castillo et al., 2005.
- Inaperturopollenites dubius* (*Cupressus*), *I. hiatus* (*Metasequoia*)- late Paleocene (~60 Ma), Sagwon, North Slope Alaska, pollen; Daly et al., 2011. *I. sp. 1* (*Cupressaceae*)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.
- Juniperus sp.*- Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO; Gregory & McIntosh, 1996.
- Metasequoia foxii*- Paleocene (late Tiffanian), Paskapoo Fm., Munce's Hill, central

Alberta, Canada, leaves, pollen cones, pollen, ovulate cones, seeds, Stockey et al., 2001; Falder et al., 1999, Pigg & DeVore, 2010; Stockey et al., 2014. *M. occidentalis*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora, Johnson, 2002; Paleocene, Ludlow Member of Fort Union Fm., ND, SD, megaflora, Johnson, 2002; late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta Canada, Hoffman & Stockey, 1999; late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, leafy twigs, cones, Dillhoff et al., 2005. *M. sp.*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora, Johnson, 2002; late Paleocene, Almont, ND, seeds, Pigg & DeVore (pers. comm. from Manchester); early Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, foliage, ovulate cones, seeds, pollen cones; Meyer, 2005; Meyer & Manchester, 1997. *Metasequoia*-like- Paleocene, Paskapoo Fm., near Red Deer, Alberta, Canada, seedlings, branches; Falder et al., 1999. [Deposits also include *Equisetum*, *Onoclea sensibilis*, and *Joffrea speirsii* (cercidiphyllaceous dicot, Crane & Stockey, 1985)]. *M. sp.*- middle Eocene, Republic Fl., WA; Schorn & Wehr, 1996.

Pilgerodendron uviferum- last interglacial (MIS 5e- called Valdivia in southern Chile), Mancera interglacial sequence, Mancera Island, Chile, wood; Astorga & Pino, 2011.

Sequoia abietina- Miocene (16-6 Ma), Iceland; Grimsson & Denk, 2007. *S. affinis*- middle Eocene (45 Ma), Thunder Mountain Fl., ID, branchlets, cones; Axelrod, 1998. Oligocene (30.7 Ma), Haynes Creek Fl., ID, foliage, cones; Axelrod 1998a. Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997; cf. *Sequoia sp.*- middle Eocene, Thunder Mountain Fl., central ID, needle; Erwin & Schorn, 2005. *S. sp.*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD,

megaflora, Johnson, 2002; late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, Dillhoff et al., 2005; latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, cones, Manchester, 2001; middle Eocene, Republic Fl., WA, Schorn & Wehr, 1996; late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997.

Sequoia/Metasequoia- late Miocene, Vasa Park Fl., King Co., WA, pollen; Dillhoff et al., 2014.

Sequoiapollenites polyformosus (*Sequoia*)- late Paleocene (~60 Ma), Sagwon Bluffs, North Slope Alaska, pollen; Daly et al., 2011.

Taxodiaceapollenites sp. (taxodiaceous, cf. *Glyptostrobus*, *Metasequoia*, *Taxodium*)- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011.

Taxodioxylon sp.- Early Cretaceous (late Albian), Neptune Glacier Fm., Antarctica, wood; Archangelsky & Del Fueyo, 2010; Falcon-Lang & Cantrill, 2001.

Tetraclinis potlachensis- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, ovulate cone, seed; Meyer & Manchester, 1997.

Thuja dimorpha- middle Eocene (45 Ma), Thunder Mountain Fl., ID, branchlets; Axelrod, 1998. *T.* sp.- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, leafy twigs, cones, Dillhoff et al., 2005; middle Eocene, Republic Fl., WA; Schorn & Wehr, 1996.

Thujopsis idahoensis- middle Eocene (45 Ma), Thunder Mountain Fl., ID, twig; Axelrod, 1998. *T.* sp.- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, leafy twigs; Dillhoff et al., 2005.

CUPRESSOID/PODOCARPOID wood, short ray, tall ray groups- Upper Cretaceous

(Aguja, Javelina Fms.), Paleocene (Black Peaks Fm.), Big Bend National Park, TX;
Wheeler & Lehman, 2005.

CYCADALES

Brunoa santarrosensis (Zamiaceae)- Upper Cretaceous, Allen Fm., Bajo de Santa Rosa,
Río Negro Province, Argentina, stems; Artabe et al., 2004.

Centricycas- Late Cretaceous (Coniacian to Campanian), Antarctic Peninsula, stem;
Poole et al., 2005.

Cycadopitys- Late Cretaceous (late Maastrichtian), lower middle Eocene, Antarctic
Peninsula, pollen, Poole et al., 2005.

Eostangeria pseudopteris (Cycadaceae)- late Paleocene, Green River Basin, WY, CO,
UT, Kvaček & Manchester, 1999, Pigg & DeVore, 2010.

Nilssonia yukonensis- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD,
megaflores; Johnson, 2002.

Restrepophyllum chiguoides (Zamiaceae)- Early Cretaceous (Aptian), Anfiteatro Fm.,
Santa Cruz Province, Argentina, leaf; Passalia et al., 2010.

Worsdellia bonettiae (Zamiaceae)- Upper Cretaceous, Allen Fm., Bajo de Santa Rosa,
Río Negro Province, Argentina, stems; Artabe et al., 2004.

EPHEDRACEAE

Ephedra archaeorhytidosperra- Early Cretaceous (Barremian), Jianshangou Beds,
Yixian Fm., Huangbanjigou village, Shangyuan District of Beipiao City, western
Liaoning Province, NE China, fertile reproductive shoots and seeds; Yang et al., 2005.
[Huang & Price (2003) give an age estimate of 8-32 Ma for extant *Ephedra*; see also
papers on age estimates and former diversity based on fossils and molecules, Rydin et

al. 2004; Rydin et al., 2006]. Ickert-Bond et al., 2009: “Results from a relaxed clock with an uncorrelated rates model and fossil-based calibration reveal that New World species are monophyletic and diverged from their mostly Asian sister clade some 30 mya, fitting with many other Beringian disjunctions. The split between the single North American and the single South American clade occurred approximately 25 mya, well before the closure of the Panamanian Isthmus. Overall, the biogeographic history of *Ephedra* appears dominated by long-distance dispersal, but finer-scale studies are needed to test this hypothesis” (p. 444). Ickert-Bond & Rydin, 2011: “Traverse ridges occur in several Early Cretaceous fossil seeds with affinity to *Ephedra*. However, our results indicate that the resemblance between these fossils and extant taxa with similar features is superficial and convergent. In line with other recent studies, we find that Cretaceous ephedroids are extinct stem relatives to the extant clade” (p. 36). *E. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001. *Ephedripites sp. (Ephedra)*- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

GINKGOACEAE

Ginkgo adiantoides- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora, Johnson, 2002; Paleocene, Sentinel Butte Fm., Almont, Beicegel, ND, leaves, seeds, ovulate stalks, Crane et al. 1990, Pigg & DeVore, 2010; Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaf; Axelrod, 1998a. *G. biloba*, *G. dissecta*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage; Dillhoff et al., 2005. *G. cranei*- upper Paleocene, Sentinel Butte Fm., ND, ovulate organs, associated leaves; Zhou et al., 2012. *G. dissecta*- middle Eocene, Republic Fl., WA (possibly a

juvenile foliage form? Kathleen Pigg, pers. comm., 2011). *G. sp.*- late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada, Hoffman & Stockey, 1999; middle Eocene, Republic Fl., WA, Schorn & Wehr, 1996.

Monocolpopollenites tranquillus (Ginkgo)- late Paleocene (~60 Ma), Sagwon Bluffs, North Slope Alaska, pollen; Daly et al., 2011.

Monosulcites crescentus- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011.

GNETALES

Drewria potomacensis- Lower Cretaceous (probably Aptian), Potomac Group, VA, stems, leaves, reproductive structures with seeds, dispersed pollen, aff. cf. *Welwitschia*; Crane & Upchurch, 1987.

PINACEAE [see also *Cunninghamiostrobus*, Taxodiaceae]

Abies bracteata- Eocene and Oligocene (Colorado), Oligocene (Oregon), Miocene (Oregon, Nevada, Idaho), macrofossils, Leopold & Zaborac-Reed, 2014. *A. idahoensis*- Oligocene (30.7 Ma), Haynes Creek, Fl., ID, leafy branchlet, seeds; Axelrod, 1998a. *A. milleri*, late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, leafy twigs, cone scales, winged seeds, *Abies* pollen, Dillhoff et al. 2005; middle Eocene, Klondike Mountain Fm., Republic Fl., WA, seeds, leaves, cones, cone scales, Schorn & Wehr, 1986. *Abies sp.*, cf. *Abies sp.* [*A. deweyensis* in Axelrod, 1998]- middle Eocene, Thunder Mountain Fl., central ID, vegetative axes, winged seeds, leaves; Erwin & Schorn, 2005. *A. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, seed, Manchester, 2001, pollen, Leopold & Clay-Poole, 2001; Oligocene (32.9 Ma), Pitch-Pinnacle Fl., CO, Gregory & McIntosh, 1996; Oligocene (33.6-32.2 Ma),

- John Day Fm., Bridge Creek Fl., OR, ovulate cone scale, Meyer & Manchester, 1997; Miocene (16-15 Ma), Iceland, Grimsson & Denk, 2007; late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014.
- Abiespollenites* sp. (*Abies*)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.
- Abietineapollenites foveoreticulatus* (*Picea*)- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011. *A. latisulcatus* (Pinaceae)- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011.
- Abietites longifolius* (undetermined leaves)- Lower Cretaceous (upper Albian), Potomac Group, VA; Upchurch et al., 1994.
- Cedripites*, aff. *Cedrus*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005. cf. *Cedripites* (*Cedrus* sp.)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.
- Cedrus* sp. (pollen, extinct type)- latest Eocene (34.1 Ma), Florissant Fl., CO; Leopold & Clay-Poole, 2001. Late Miocene, Vasa Park Fl., King Co., WA, pollen; Dillhoff et al., 2014.
- Dacrydium*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen (with *Dacrydiumites*), Reinink-Smith & Leopold, 2005.
- Keteleeria ptesimosperma*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, seed; Meyer & Manchester, 1997.
- Keteleeriaepollenites megasaccus*- late Miocene, Upper Beluga Fm., south coast Alaska,

pollen; Reinink-Smith & Leopold, 2005.

Larix lemhiensis- Oligocene (30.7 Ma), Haynes Creek Fl., ID, cone, seeds; Axelrod, 1998a. *L. sp.* [*L. leonardii* in Axelrod, 1998]- middle Eocene, Thunder Mountain Fl., central ID, vegetative axes, winged seeds; Erwin & Schorn, 2005. See review of the fossil record of *Larix* by LePage & Basinger, 1995a (table 1): (“...long distributed throughout the high latitudes of North America and northeastern Asia but reached Europe only in the last few million years” p. 19). *L. altoborealis*- Eocene, Buchanan Lake Fm., Axel Heiberg Is., Canadian High Arctic, fertile and vegetative remains; LePage & Basinger, 1991, table 1. *L. sp.*- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. [see also *Pseudotsuga/Larix* (pollen) below].

Midoriphyllum piceoides (*Picea*-like)- Lower Cretaceous (Valanginian-Hauterivian boundary), Apple Bay locality, Vancouver Is., British Columbia, Canada, leaves; Stockey & Wiebe, 2008.

Picea sp. (winged seeds), *P. sp.* (vegetative axes, leaves), *P. sp. A* (ovulate cone) [*P. magna*, *P. coloradensis*, *P. deweyensis* in Axelrod, 1998]- middle Eocene, Thunder Mountain Fl., central ID; Erwin & Schorn, 2005. *P. sp.*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, leafy twigs, winged seeds, cones, *Picea* pollen, Dillhoff et al., 2005; middle Eocene, Republic Fl., WA, Schorn & Wehr, 1996; latest Eocene (34.1 Ma), Florissant Fl., CO, seeds, Manchester, 2001, pollen, Leopold & Clay-Poole, 2001. Late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014. *P. coloradensis*, *P. deweyensis*, *P. magna*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, seeds, cone; Axelrod, 1998a. *P. sp.* (sect. *Picea*)- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. *P. sp.*- Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO,

Gregory & McIntosh, 1996; late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005.

Piceapollis spp. (*Picea*)- late Paleocene (~60 Ma), Sagwon Bluffs, North Slope Alaska, pollen; Daly et al., 2011. cf. *Piceapollis* sp. (*Picea* sp.)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

Pinus arnoldii- middle Eocene, Princeton Chert Fl., British Columbia, Canada, ovulate cone; Klymiuk et al., 2011.

Pinus baileyi (Subgenus *P. sensu*, Section *P. sensu*, cf. Subsection *P. sensu*)- middle Eocene, Thunder Mountain Fl., central ID, ovulate cone; Erwin & Schorn, 2005. *P. alvordensis*, *P. baileyi*, *P. ponderosoides*, *P. prestrobus*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, cones, seeds, leaves; Axelrod, 1998a. *P. johndayensis*, Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, foliage, ovulate cone, seed, pollen cone; Meyer & Manchester, 1997. *P. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001. cf. *Pinus crossii* (Subgenus *strobus*, Subsection *balfourianae*)- middle Eocene, Thunder Mountain Fl., central ID, 5-needled fascicles; Erwin & Schorn, 2005. *Pinus mathewsii* (subgenus *Pinus*, Subsection *contortae*)- Pliocene, basal unit 1 of the section, Ch'ijee's Bluff, Porcupine River, near Old Crow in the Bluefish Basin, Yukon Territory, Canada, ovulate cones; McKown et al., 2002. *P. sp.*- middle Eocene, Republic Fl., WA, Schorn & Wehr, 1996; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dilhoff et al., 2014.

cf. *Pinus sanjuanensis* (Subsection ?*cembroides*)- middle Eocene, Thunder Mountain

Fl., central ID, short, 2-needled fascicles; Erwin & Schorn, 2005.

cf. *Pinus*- late Paleocene, Beicegel Fl., ND, ovule cone, Pigg & DeVore, 2010 (pers. comm. from Manchester).

Pinus sp. (Subgenus *P. sensu*)- middle Eocene, Thunder Mountain Fl., central ID, long, 2-needled fascicles; Erwin & Schorn, 2005. *Pinus* sp. (subgenus indeterminate)- middle Eocene, Thunder Mountain Fl., central ID, winged seeds, ovulate cones; Erwin & Schorn, 2005. [Axelrod, 1998 treats the Thunder Mountain specimens of *Pinus* as *P. alvordensis* (needles), *P. baileyi* (base of cone with cone scales), *P. balfouroides* (needles, cone scales, seeds), *P. resinosoides* (needles, seeds)]. *P.* sp.- middle Eocene (44 Ma), Clarno Fm., OR, wood, pollen, pollen cone; Manchester, 1994. *P.* sp.- Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO, Gregory & McIntosh, 1996; Miocene (15-6 Ma), Iceland, Grimsson & Denk, 2007.

Pinus (section *Strobus*), *P.* (Section *Pinus*) sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, cones, seeds; Manchester, 2001.

Pinus sp.- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, leafy twigs, foliage, cones, winged seeds, *Pinus* pollen, Dillhoff et al., 2005; late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997.

Pinuspollenites elongates (*Pinus*)- late Paleocene, Almont Fl., Williston Basin, North Dakota, pollen; Zetter et al., 2011. *P.* sp. (*Pinus*)- Miocene, Tepoztlán Fm., pollen; Lenhardt et al., 2013.

Pityosporites spp. (*Pinus*)- late Paleocene (~60 Ma), Sagwon Bluffs, North Slope Alaska, pollen; Daly et al., 2011.

Pityostrobus beardii- Late Cretaceous (Campanian), Spray Fm., Nanaimo Group, Shelter

Point, Vancouver Is., British Columbia, Canada, cones; Smith & Stockey, 2002.
 [oldest *Pinus* cited as in the Cretaceous, p. 185; molecular estimate 128 +/- 4 Ma,
 Eckert & Hall, 2006]. *P. californiensis*- Lower Cretaceous (Aptian), Upper
 Chickabally Member, Budden Canyon Fm., near Ono, CA, cone; Smith & Stockey,
 2001. *P. makahensis*- early Oligocene, Makah Fm., Olympic Peninsula, seed cone;
 Crabtree & Miller, 1989.

Pseudolarix amabilis, *P. wehrii*- Eocene, Buchanan Lake Fm., Axel Heiberg Is.,
 Canadian Arctic Archipelago, reproductive and vegetative remains; LePage &
 Basinger, 1995b: ["...The fossil record of *Pseudolarix* (Pinaceae) reveals wide
 distribution in North America and Eurasia from at least the Early Cretaceous
 (Berriasian) and possibly the Late Jurassic (Portlandian) to the Plio-Pleistocene", p.
 910; tables 1-4 list other fossil records for the genus]. *P. sp.*- late early Eocene (49-52
 Ma), McAbee Fl., British Columbia, Canada, cones, foliage, winged seeds, Dillhoff et
 al., 2005; *P. wehrii*- middle Eocene, Republic Fl., WA, Gooch, 1992.

Pseudotsuga glaucooides- middle Eocene, Thunder Mountain Fl., ID, cones, winged
 seeds; Axelrod, 1998. *P. sp.*- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007.
P./Larix- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole,
 2001. *P./Larix* type, Late Miocene, Vasa Park Fl., King Co., WA., pollen, Dillhoff et
 al., 2014.

TCT (= Taxodiaceae/Cupressaceae/Taxaceae pollen undifferentiated) and *Sequoia affinis*
 pollen- latest Eocene (34.1 Ma), Florissant Fl., CO, Leopold & Clay-Poole, 2001; TCT-
 late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith &
 Leopold, 2005.

Tsuga sp. [*T. mertensioides* in Axelrod, 1998]- Eocene, Thunder Mountain Fl., central ID, leaf, winged seed; Erwin & Schorn, 2005. *T. mertensioides*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, seeds; Axelrod, 1998a. *T. sp.*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, pollen, Dillhoff et al., 2005; middle Eocene, Republic Fl., WA, Schorn & Wehr, 1996; latest Eocene (34.1 Ma), Florissant Fl., CO, pollen, Leopold & Clay-Poole, 2001; Miocene (15-6 Ma), Iceland, Grimsson & Denk, 2007; late middle to early late Miocene, Bryn Mawr Fm., pollen, Pazzaglia et al., 1997; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014.

PODOCARPACEAE [see also *Azolla*, Bowman et al., 2014].

Apterocladus- Early Cretaceous, Argentina, Patagonia, leaves, pollen cones with *Callialasporites* pollen; Archangelsky & Del Fueyo, 2010.

?*Dacrycarpites australiensis*- Paleogene, Ñirihua Basin, Argentina, pollen; Quattrocchio et al., 2012.

Dacrycarpus chilensis (cf. modern *D. dacrydioides*, lowlands, New Zealand)- Eocene, Coronel, Chile, foliage; Wilf, 2012.

D. puertae (cf. modern *D. imbricatus*, montane, Burma to Fiji)- Eocene, Laguna del Hunco (ca. 52.2 Ma), Patagonia, Argentina, Río Pichileufú (47.7 Ma), Argentina, seeds, cones, foliage, pollen; Wilf, 2011.

Dacrydimites florinii- Late Cretaceous (late Maastrichtian), mid-early Paleocene, lower middle Eocene, Antarctic Peninsula, pollen, Poole et al., 2005.

Microcachyridites antarcticus (*Microcachrys*)- mid-early Paleocene, lower middle

- Eocene, Antarctic Peninsula, pollen, Poole et al., 2005. Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012. *M. sp.*- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, pollen; Poole et al., 2005.
- Morenostrobus*- Early Cretaceous, Patagonia, Argentina, leaves of the *Elatocladus* type, pollen cones with *Podocarpidites* pollen; Archangelsky & Del Fueyo, 2010.
- Phyllocladoxylon*-Late Cretaceous (late Maastrichtian), mid-early Paleocene, lower middle Eocene, Antarctic Peninsula, wood; Poole et al., 2005.
- Phyllocladites mawsonii*- Late Cretaceous (late Maastrichtian), mid-early Paleocene, lower middle Eocene, Antarctic Peninsula, pollen; Poole et al., 2005. Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.
- Podocarpidites marwickii*- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012; *P. sp.*- Late Cretaceous (late Maastrichtian), lower middle Eocene, Antarctic Peninsula, pollen; Poole et al., 2005.
- Podocarpoid wood type- Upper Cretaceous, Big Bend National Park, TX; Wheeler & Lehman, 2005.
- Podocarpoxydon* – Late Cretaceous (late Maastrichtian, wood, pollen), lower middle Eocene, middle Eocene, Antarctic Peninsula, leaf, wood; Poole et al., 2005.
- Podocarpus dacrydioides*-mid-early Paleocene, lower middle Eocene, Antarctic Peninsula, pollen, Poole et al., 2005. *P. mazzonii*- early Paleocene (Danian, 61.7 ± 0.2 Ma), Salamanca Fm., Province of Chubut, Argentina, wood; Brea et al., 2011.
- Podocarpus sp.*- Eocene, western TN, leafy shoots, Dilcher, 1969; late Miocene, Upper Beluga Fm., south coast Alaska (with *Podocarpidites*), pollen, Reinink-Smith & Leopold, 2005; Pliocene-Quaternary (ca. 2.7 Ma), High Plain Bogotá, Colombia,

pollen, Hooghiemstra, 1995. *P. matudae* (modern, as a possible pre-Quaternary relict), two plastid DNA markers suggest a divergence time between the unique haplotypes from a Guatemalan population and the two most common haplotypes from the Sierra Madre Oriental in Mexico of between 10 and 20 Ma, and further haplotype divergence in the poorly resolved clade of the Sierra Madre Oriental between 3 and 0.5 Ma; findings support a Miocene age for temperate floristic elements in Mesoamerican cloud forests, whereas further haplotype divergence within the Sierra Madre Oriental, Chiapas and Guatemala occurred more recently, coinciding with Pleistocene cloud forest refugia (Ornelas et al., 2010).

Saxegothaea conspicua- last interglacial (MIS 5e- called Valdivia in southern Chile), Mancera interglacial sequence, Mancera Island, Chile, wood, leaves; Astorga & Pino, 2011.

Squamastrobis- Early Cretaceous, Argentina, Patagonia, leaves of the *Brachyphyllum* type, pollen cones with *Podocarpidites* pollen, ovuliferous cones; Archangelsky & Del Fueyo, 2010.

Trisaccites microsaccatum- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

Trisacocladus- Early Cretaceous, Argentina, Patagonia, twigs, leaves, pollen cones with *Trisaccites* pollen, ovuliferous cones with seeds; Archangelsky & Del Fueyo, 2010.

SCIADOPITYACEAE

Sciadopitipollenites- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011.

Sciadopitys- late middle to early late Miocene, Bryn Mawr Fm., MD, pollen; Pazzaglia et

al., 1997. cf. *Sciadopitys*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen;
Reinink-Smith & Leopold, 2005.

TAXACEAE

Amentotaxus-type- middle Eocene, Republic Fl., WA; Schorn & Wehr, 1996. cf.

Amentotaxus/cf. *Torreya*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia,
Canada, leafy twigs, foliage; Dillhoff et al., 2005.

Diploporus torreyoides- middle Eocene (44 Ma), Clarno Fm., OR, seed; Manchester,

1994. *D. sp.*- late Eocene (36 Ma), lower John Day Fm., OR, seed; Manchester &
McIntosh, 2007: "First described from the middle Eocene Nut Beds locality,

Diploporus is also known from the Paleocene of Almont, ND (Pigg and

Manchester, unpublished data" p. 8); also Beicegel Fl., ND, Pigg & DeVore, 2010;

Crane et al., 1990.

Taxus masonii- middle Eocene (44 Ma), Clarno Fm., OR, seeds; Manchester, 1994. *T.*-
type, middle Eocene, Republic Fl., WA; Schorn & Wehr, 1996.

Torreya clarnensis- middle Eocene (44 Ma), Clarno Fm., OR, seeds; Manchester, 1994.

T. masonii- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf;

Meyer & Manchester, 1997. *T. sp.*- late Paleocene, Almont Fl., ND, seeds, Pigg &

DeVore, 2010 (pers. comm. from Manchester); middle Eocene, Republic Fl., WA;

Schorn & Wehr, 1996.

TAXODIACEAE (see also Cupressaceae)

Athrotaxis sp.- Lower Cretaceous (upper Albian), Potomac Group, VA, terminal
shoot with seed cone; Upchurch et al., 1994.

Cyptomeria anglica- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007.

Inaperturopollenites sp. (cf. *Sequoia*)- Miocene, Tepoztlán Fm., Mexico; Lenhardt et al., 2013.

Sphenolepsis sternbergina- Lower Cretaceous (upper Albian), Potomac Group, VA, shoots with attached seed and pollen cones; Upchurch et al., 1994.

cf. *Parataxodium*- Paleocene, Sentinel Butte Fm., Almont, Beicegel, ND, leafy shoots, ovulate and pollen cones, seeds; Crane et al., 1990; Pigg & DeVore, 2010.

Taxodiaceapollenites hiatus- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

Taxodium dubium- Oligocene (30.7 Ma), Haynes Creek Fl., ID, branchlets; Axelrod, 1998a. *T. olrikii*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflores, Johnson, 2002; Paleocene, Ludlow Member, Fort Union Fm., ND, SD, megaflores, Johnson, 2002.

WELWITSCHIACEAE

Cratonia cotyledon- Early Cretaceous (late Aptian), Crato Fm., Brazil; Rydin et al., 2003.

Welwitschiella austroamericana- stems with attached paired leaves, *Welwitschiophyllum brasiliense*- isolated leaves, *Welwitschiostrobus murili*- axes bearing male cones, Early Cretaceous (late Aptian), Crato Fm., Brazil; Dilcher et al., 2005.

WELWITSCHIOID

Bicatia- Friis, E. M. et al., 2014, p. 175: “*Bicatia* gen et sp. nov. from the Early Cretaceous of the Northern Hemisphere is described based on three species of dispersed seeds: *Bicatia costata* from the Juncal and Famalicão localities (western Portugal) and Kenilworth locality (eastern North America), *B. juncalensis* from the Juncal locality, and *B. rugosa* from the Puddledock locality (eastern North America). The combination

of seed and pollen features seen in *Bacatia* provides the strongest documentation so far of *Welwitschia*-like plants in the Northern Hemisphere during the Early Cretaceous.”

WILLIAMSONIACEAE

Williamsonia bockii- Late Cretaceous (lower Campanian), Haslam Fm., Nanaimo Basin, Vancouver Is., British Columbia, Canada, seed cone; Stockey & Rothwell, 2003.

INCERTAE SEDIS (Gymnospermae)

Lindlleycladus sp.- Lower Cretaceous, Crato Fm., Brazil; Kunzmann et al., 2004.

ANGIOSPERMAE

General summaries (see also Monocotyledons)

Angiosperm microfossils from the Late Cretaceous (Campanian) to Paleocene of Seymour Island, Antarctica (Askin, 1989) identified by a morphological system necessitated by the age of the deposits include (pp. 114-116) *Bombacacidites bombaxoides* (Bombacaceae), *Nothofagus* (Fagaceae), *Cranwellia striata* (Loranthaceae), *Anacolosidites sectus* (Olacaceae), *Proteacidites*, *Propylipollis*, *Cranwellipollis*, *Beaupreaidites verrucosus*, *B. elegansiformis*, *Peninsulapollis* (Proteaceae), *Cupanieidites orthoteichus* (Sapiindaceae), and *Polycolpites langstonii* (Pedaliaceae?).

Martínez-Millán (2010)- Asteridae, four main clades (Cornales, Ericales, Lamiids, and Campanulids; last two collectively the Euasteridae). “The results suggest that the Asteridae dates back to at least the Turonian, Late Cretaceous (89.3 mya) and that by the Late Santonian-Early Campanian (83.5 mya) its four main clades were already represented in the fossil record” (p. 83). Friis et al. (2006): “ANITA grade angiosperms [= *Amborella*, Nymphaeales, Illiciaceae, Trimeniaceae, Austrobaileyaceae] and Chloranthaceae, as well as other magnoliids, early monocots and early eudicots,

differentiated almost simultaneously during the Early Cretaceous. There is also strong evidence for extensive diversification of core eudicots during the Late Cretaceous” (p. 251).

Wang et al. (2009): “The rosid clade diversified rapidly into these major lineages, possibly over a period of <15 million years, and perhaps in as little as 4 to 5 million years. The timing of the inferred rapid radiation of rosids [108 to 91 million years ago (Mya) and 107-83 Mya for Fabidae and Malvidae, respectively] corresponds with the rapid rise of the angiosperm-dominated forests and the concomitant diversification of other clades that inhabit these forests, including amphibians, ants, placental mammals, and ferns” (p. 3853).

Sun et al. (2011), re *Leefructus mirus*: “...morphological features suggest that its affinities are with the Ranunculaceae, a basal eudicot family. The fossil co-occurs with *Archaeofructus sinensis* and *Hyracantha decussate* whereas *Archaeofructus liaoningensis* comes from more ancient sediments. Multiple radiometric dates of the Lower Cretaceous Yixian Formation place the bed yielding this fossil at 122.6-125.8 million years old. The earliest fossil records of eudicots are 127 to 125 million years old, on the basis of pollen. Thus, *Leefructus* gen nov. suggests that the basal eudicots were already present and diverse by the latest Barremian and earliest Aptian” (p. 625; see also Ranunculaceae).

McInnes et al. (2011): “Pulses of diversification are only detected easily if they occurred recently and if the rate of species turnover at equilibrium is low; rates reported for fossil mammals suggest that the power to detect a doubling of species diversity falls to 50 per cent after less than 50 Myr even with a perfect phlogeny of extant species. Extinction does eventually draw a veil over past dynamics, suggesting that some

questions are beyond the limits of inference, but sudden clade-wide pulses of speciation can be detected after many millions of years, even when overall diversity is constrained. Applying our methods to existing phylogenies of mammals and angiosperms identifies intervals of elevated diversification in each” (p. 3294).

INCERTAE SEDIS (Angiospermae; see also early undescribed angiosperms from the Lower Cretaceous Crato Formation, Brazil, Mohr & Friis, 2000, Mohr et seq.).

Archaeanthus Dilcher & Crane (1984)- mid-Cretaceous (uppermost Albian-mid-Cenomanian), Dakota Fm., KS, fruit (and associated perianth parts); Dilcher & Crane (1984).

Archaeofructus liaoningensis (Archaeofructaceae)- Yixian Fm., China [originally considered Jurassic in age, now mid-Early Cretaceous, Friis et al., 2006, p. 256]; Sun et al. (1998, 2002).

Carpolithus sp. 12- middle Eocene (44 Ma), Clarno Fm., OR, capsule; Manchester, 1994. [Meliaceae, either in *Toonia* or *Cedrela*; Steven Manchester, pers. comm., April, 2011].

C. sp.- late Eocene, Tonosi Fl., Pacific coast central Panama, disseminule; Herrera et al., 2012.

Ferrignocarpus bivalvis (= *Carpolithus* sp. 38 of Reid and Chandler, 1933), middle Eocene (44 Ma), Clarno Fm., OR, fruit; Manchester, 1994 “belongs in Fagales near or in Ticodendraceae (see Manchester & Renner Abstract, IBC Vienna)” Manchester, pers. comm., April, 2011.

Iara Iguassu (aquatic angiosperm)- Lower Cretaceous, Santana Fm. (Crato palaeoflora), Araripe Basin, NE Brazil, filamentous stem, leaves; Fanton et al., 2006.

Kachaikenia compuesta- late Early Cretaceous, Kachaiken Fm., So. Argentina, leaves;

Cunéo & Gandolfo, 2005.

Laculifructus tonosiense- late Eocene, Tonosi Fl., Pacific coast central Panama, fruit;

Herrera et al., 2012

Lagokarpos lacustris- latest Paleocene to early middle Eocene, Green River Fm. (WY,

UT, CO, OR, British Columbia, Canada), Ulrich's Quarry near Fossil Butte National

Monument, southwestern WY, winged fruits; McMurrin & Manchester, 2010: "No

modern fruit was found to exhibit the combination of characters seen in *Lagokarpos*, and we conclude that it represents an extinct genus of as yet unknown familial affinity"

(p. 227).

Metacalfeoxylon kirtlandense (Malvids-Eurosids II)- Late Cretaceous (Maastrichtian),

Crevasse Canyon Fm., NM, wood; Estrada-Ruiz et al., 2012.

Noferinia fusicarpa- Late Cretaceous (Santonian), GA, flower; Lupia et al., 2002.

Ozakia emryi ("...formerly attributed to *Heptacadium* (Caprifoliaceae) and *Amelanchier* (Rosaceae)...") now "...considered to represent an extinct eudicot genus..."

Manchester and Uemure, 2013).

Paraphyllanthoxylon cf. *P. anzasii* (Magnoliids, or Eudicots probably Lauraceae)- Late

Cretaceous (Maastrichtian), Crevasse Canyon Fm., NM, wood; Estrada-Ruiz et al.,

2012.

Pygmaeoxyton paucipora (Magnoliid clade)- Late Cretaceous (Maastrichtian), McRae

Fm., NM, wood; Estrada-Ruiz et al., 2012.

Rogersia australis- late Early Cretaceous, Kachaike Fm., So. Argentina, leaves; Cunéo &

Gandolfo, 2005.

Thorphyllum cúneo- late Early Cretaceous, Kachaike Fm., So. Argentina, leaves; Cunéo

& Gandolfo, 2005.

Trapago angulata- Upper Cretaceous (Maastrichtian), St. Mary River Fm., Alberta, Canada, leaves, rhizomes, flowers; Stockey & Rothwell (1997): [“Although *Trapago* has commonly been placed in the Trapaceae, the similarities between extant *Trapa* and *Trapago* could be attributed to convergence, and the familial affinities of the fossil remain uncertain” p. 83].

Tripartisemen bonesii- middle Eocene (44 Ma), Clarno Fm., OR, seed; Manchester, 1994 now *Toricellia bonesii* (Toricelliaceae; Steven Manchester, pers. comm., April, 2011).

ACANTHACEAE- “We demonstrate differences in age estimates depending on fossil selection, and that enforcement of maximum age priors substantially alters estimated clade ages... Our results suggest that long-distance dispersal events explain present-day distributions better than do Gondwanan or northern land bridge hypotheses.. Our data support a minimum of 13 Old World (OW) to New World (NW) dispersal events but, intriguingly, only one in the reverse direction. Remarkably, if minimum age estimates approximate true history...11 of these 13 events occurred within the past ~20 Myr even though Acanthaceae s.s. is over 3 times as old. Finally, we review reports of fossils that have been assigned to Acanthaceae that are substantially older than the lower Cretaceous estimate for Angiosperms as a whole...” (Tripp and McDade, 2014, p. 660).

ACERACEAE (see Sapindaceae)

ACTINIDIACEAE

Actinidia oregonensis- middle Eocene (44 Ma), Clarno Fm., OR, seed; Manchester, 1994.

Parasaurauia allonensis- Late Cretaceous (late Santonian), Buffalo Creek Member, Gaillard Fm., Allon Fl., GA, flowers; Herendeen et al., 1999.

cf. *Saurauia*- late Paleocene, Almont, Beicegel Fls., ND, seeds, fruits, Crane et al., 1990;
Pigg & DeVore, 2003, 2010.

ADOXACEAE

cf. *Rousea patagonica*- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

Sambucus sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, leaf, leaflets; Manchester, 2001.

ALANGIACEAE (see Cornaceae)

ALISMATACEAE

Alismaphyllites grandifolius- late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada; Hoffman & Stockey, 1999.

Caldesia brandoniana- early Miocene, Brandon Lignite Fl., VT, fruits; Haggard & Tiffney, 1997.

Sagittaria sp.- late Miocene (Clarendonian, 12 Ma), Ironside Fm., OR; Retallack, 2004.

ALTINGIACEAE

Liquidambar sp.- middle Eocene, Claiborne Group, TN, fruit, Dilcher & Lott, 2005;
middle Eocene, Republic Fl., WA, seeds, Wehr & Manchester, 1996; Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf, Meyer & Manchester, 1997;
late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997.
L. or *Altingia*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005. Late Miocene, Vasa Park Fl., King Co., WA, pollen; Dillhoff et al., 2014.

AMARANTHACEAE (see also Chenopodiaceae/Amaranthaceae)

Chenopodipollis sp. (cf. *Iresine*)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

‘AMENTIFERAE’- Crepet, 1981.

ANACARDIACEAE- [records of fossils from Germany and elsewhere are reviewed by Manchester et al., 2007].

Anacardiaceae- late Eocene (36 Ma), lower John Day Fm., OR, fruit; Manchester & McIntosh, 2007.

cf. *Anacardium*- middle Miocene, Pebas Fm., w. Amazon Basin, Iquitos, Peru, wood; Pons & de Franceschi, 2007.

Astronium-type pollen- latest Eocene (34.1 Ma), Florissant Fl., CO; Leopold & Clay-Poole, 2001.

Dracontomelon macdonaldii- late Eocene, Tonosi Fl., Pacific coast central Panama, endocarp; Herrera et al., 2012.

Edenoxylon parviareolatum- late early Eocene (ca. 49 Ma), Bridger Fm., Big Sandy Reservoir, SW Wyoming, wood; Bouchai & Manchester, 2012.

Loxopterygium laplayense- middle Miocene (13.0-10.2 Ma), Azogues or Guapá member, Azogues Fm., near Azogues, Ecuador; Siltstone Member, (10.7 +/- 1.6 to 10.0 +/- 1.4 Ma), San Cayetano Fm., Loja Basin, Ecuador; winged fruits; Burnham & Carranco, 2004.

Maureroxylon crystalliphorum- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Pentoperculum minimum- middle Eocene (44 Ma), Clarno Fm., OR, fruits; Manchester, 1994.

Pseudosmodingium mirandae- Oligocene, Pie de Vaca Fm., near Tepexi de Rodríguez, Puebla state, Mexico, leaves; Ramírez et al., 2000.

Rhus lesquereuxii (leaf), *R. sp.* (fruit)- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fm., OR; Meyer & Manchester, 1997. *R. malloryi*- middle Eocene, Republic Fl., WA, leaves; Wolfe & Wehr, 1987. *R. rooseae*- middle Eocene (44 Ma), Clarno Fm., OR, fruit; Manchester, 1994. *R. sonorensis*- middle Miocene, Mint Canyon Fl., (preliminary study), so. CA; Axelrod, 1940. *R. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, Manchester, 2001; Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO, leaves, Gregory & McIntosh, 1996. *R. type*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Schinus- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves; Gayó et al., 2005.

Tapirira clarnonensis- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Terrazoxydon ductifera- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Toxicodendron wolfei- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaflet; Meyer & Manchester, 1997.

ANNONACEAE

Annona- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves; Gayó et al., 2005.

Annonoxylon bonesii- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Anonaspermum cf. pulchrum, *A. bonesii*, *A. rotundum*- middle Eocene, Clarno Fm., OR, seeds; Manchester, 1994.

Duguetia sp.- middle Eocene, Claiborne Group, TN, leaves; Dilcher & Lott, 2005.

Guatteria- Erkens et al. (2007) infer from four plastid regions (*matK*, *rbcL*, *trnL-trnF*, *psbA-trnH*) “three major biogeographical events in the history of the genus: (1) a trans-oceanic Miocene migration from Central into South America before the closing of the Isthmus of Panama; (2) a major diversification of the lineage within South America; and (3) several migrations of South American lineages back into Central America via the closed Panamanian land bridge. Therefore, *Guatteria* is not an Amazonian centered-genus *sensu* Gentry but a major Miocene diversification that followed its dispersal into South America” (p. 399). The authors state (p. 404) that there are no known fossils of the genus, but in addition to *Guatteria*-type phytoliths reported from the Quaternary of Central America, macrofossils (*G. culebrensis*) are reported from the Miocene of Panama and Peru (unverified; for additional reports of Annonaceae and for references, see Graham, 2010, Appendix 2.2, p. 588).

APIACEAE [Apiales- Nicholas and Plunkett, 2014: “Our analyses in BEAST estimated the origin of Apiales to Australasia, with the youngest family (Apiaceae) originating in the Late Cretaceous, c. 87 Ma. Long-distance dispersal appears as the likely explanation for many younger lineages within major clades...” (p. 30)].

Azorella, *Laretia*, and *Mulinum*- Nicolas and Plunkett, 2012: “Biogeographic reconstructions, conducted using RASP, suggest that the group most likely has an Austral-Antarctic origin, with subantarctic South America as the ancestral area of the ingroup. The “*Mulinum* clade” and the “*Schizeilema* clade” appeared to have followed opposite dispersal routes out of subantarctic South America either across the Subantarctics into New Zealand and Australia (“*Schizeilema* clade”), or into Patagonia

and then to the upper Andes (“*Mulinum* clade”) (p. 826) ... Due to the lack of fossils, we were unable to produce reliable estimates for times of divergence in the group, and therefore estimated historical biogeographic reconstructions using the statistical dispersal-vicariance method in RASP v.1.107 (Yu & al., 2011), which does not require timing estimates” (p. 830).

Carpites ulmiformis- Late Cretaceous (Maastrichtian), Lance Fm., WY, MT, seeds; Manchester & O’Leary, 2010: [“Compressed fruits of *Carpites ulmiformis* Dorf (1942)...are likely to represent Apiaceae”, p. 63].

APOCYNACEAE

Apocynophyllum sp.- middle Eocene, Claiborne Group, TN, leaves; Dilcher & Lott, 2005.

Apocynospermum sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, seeds; Manchester, 2001.

Asclepias- Fishbein et al., 2011: “Our results support a scenario in which *Asclepias* s.l. originated in Africa, migrated only once to North America, and thence only once to South America... times are difficult to ascertain in the absence of fossil calibrations for molecular dating...argues against Gondwanan disjunction and against frequent dispersal between these centers of diversity...consistent with Africa to America migration via either the North Atlantic or Bering land bridges or via long-distance transoceanic dispersal. Until recently, the possibility of range expansion of temperate or subtropical taxa through the North Atlantic route was thought to have ended in the early Eocene (Tiffney 1985). The timing (40-50 my before present) could be too early for the migration of *Asclepias* to the Americas. However, recent paleobotanical discoveries and dated phylogenies for several groups have increasingly supported the hypothesis that

range expansion across the North Atlantic may have been possible until the mid-Miocene or even later (Tiffney, 2008). Because recent long-distance dispersal could have occurred at any time, it must be considered as an alternative hypothesis, especially if the time of origin of the American-African disjunction is found to be too recent for migration over Tertiary land bridges” (p. 1016). [Author assessment: The transitory physical disruption of the North Atlantic land bridge reached a point by the middle Eocene that continuous or near-continuous land surfaces were significantly diminished. The transitory change in climate in the high latitudes from subtropical/warm temperate to more cool/cold temperate also reached a point at about this time when migration of the former diminished and migration of the latter was enhanced. Superimposed on these gradual and fluid conditions are the variables of dispersability and the ecological characteristics of the specific taxon under consideration. Thus, whether range expansion across the North Atlantic ended in the early Eocene, or was possible until the mid-Miocene or even later is decidedly taxon-dependent. As a generalization, the tipping-interval for the North Atlantic land bridge as a migration route from being widely available to more selective began in about the middle Eocene].

Tabernaemontana sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

Triporopollenites sp. 2- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

Tylophora and *Vincetoxicum*- Liede-Schumann et al., 2012: “The early branching clades of *Vincetoxicum* s.l. all grow in Africa, where the group originated ca. 18 Ma ago, correlating with the closure of the Tethys Ocean. The first round of differentiation took place between 12 and 15 Ma ago, resulting in Tylophorinae being distributed over

almost all of their present range except for South Africa, Arabia and Europe. Two unrelated lineages of temperate, mostly erect plants hitherto named “*Vincetoxicum*” have arisen from more tropical lineages, hitherto named “*Tylophora*”. One clade of African species is nested inside the Australasian assemblage; this clade contains exclusively polyploid species and its re-immigration to Africa took place in the Messinian, at ca. 6.8 Ma. The European *Vincetoxicum* species split from erect steppe plants of temperate Asia at ca. 4.5 Ma, coinciding with the uplift of the Tibetan plateau. This group contains two species that are presently aggressively spreading in North America after chance introductions” (p. 803).

AQUIFOLIACEAE

Ilex- late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997; Late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014; Pliocene-Quaternary (ca. 2.7 Ma), High Plain Bogotá, Colombia, pollen, Hooghiemstra, 1995.

Ilexpollenites- Late Cretaceous (late Maastrichtian), lower middle Eocene, Antarctic Peninsula, pollen, Poole et al., 2005. cf. *Ilexpollenites* sp., Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

Nemopanthus- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

ARACEAE- “Araceae began to diversify in the Early Cretaceous (when the breakup of Pangea was in its final stages), and all eight subfamilies existed before the K/T boundary.

Early lineages persist in Laurasia, with several relatively recent entries into Africa, South America, South-East Asia and Australia” (Nauheimer et al., 2012).

Cobbania corrugata- Upper Cretaceous, Dinosaur Park Fm., Alberta, Canada, stems, attached leaves and roots interconnected by stolons; Stockey et al., 2007: [“We develop a reconstruction of the plant based on attached organs and compare the fossils with the fossil *Limnobiophyllum* and extant *Pistia*, revealing a greater systematic and ecological diversity of Late Cretaceous Araceae than previously recognized” (p. 609).

Keratosperma allenbyense- middle Eocene, Allenby Fm., Princeton Chert, near Allenby, British Columbia, Canada, seeds; Smith & Stockey, 2003: [“...represents the oldest known member of the lasioid clade” (p. 239)].

cf. *Lemnospermum* sp.- late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada; Hoffman & Stockey, 1999.

Limnobiophyllum scutatatum- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora, Johnson, 2002; Paleocene, Ludlow Member of Fort Union Fm., ND, SD, megaflora, Johnson, 2002; late Paleocene Joffre Bridge Fl., Red Deer Valley, Alberta, Canada; Hoffman & Stockey, 1999.

Philodendron limnestis- Eocene, Claiborne Fm., TN, leaves; Dilcher & Daghljan, 1977.

aff. *Philodendron*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

“*Pistia*” *corrugata*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Spixiarum kipea gen et sp. nov.- Early Cretaceous, Crato Fm., northeastern Brazil; Coiffard et al., 2013

ARALIACEAE (see also Rutaceae-*Rhiopites*)

Araliaceous fruits- latest Eocene (34.1 Ma), Florissant Fl., CO; Manchester, 2001.

cf. *Aralia* sp.- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage; Dillhoff et al., 2005.

Dendropanax- Li & Wen (2013): “Based on biogeographic analyses and fossil-calibrated Bayesian dating, *Dendropanax* was hypothesized to have originated in the Old World and migrated into the New World via the North Atlantic land bridge in the early Tertiary. The amphi-Pacific intercontinental disjunction of *Dendropanax* was dated to be 41.83 mya with a 95% high posterior density [HPD] interval of 28.46-56.15 mya” (p. 536). *D. eocenensis*- middle Eocene, Claiborne Group, TN, leaves; Dilcher & Dolph, 1970; Dilcher & Lott, 2005.

Hedera- Green et al. (2011): ” Reports of *Hedera* from the Dakota Formation and other North American sites are almost certainly invalid...Among verified fossils nearly all specimens were collected from Europe and Asia” [Green et al., 2011 list several Old World occurrences dating from the late Miocene to the Holocene, p. 1124).

Paleopanax oregonensis- middle Eocene (44 Ma), Clarno Fm., OR, fruit, styles; Manchester, 1994. cf. *Paleopanax*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, fruits; Dillhoff et al. 2005.

Plerandroxylon nutbedensis, *P. oregonensis*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Toricellia sp.- Late Paleocene, Almont Fl., ND, fruit; Manchester et al., 2009; Pigg & DeVore, 2010.

ARECACEAE (early records New World and outside the New World: “The earliest unequivocal fossil palm material probably dates from the early to mid Late Cretaceous (Turonian > Coniacian > Santonian”); Harley, 2006, p. 39). Areaceae pollen- latest Eocene (34.1 Ma), Florissant Fl., CO; Leopold & Clay-Poole, 2001. See also Baker and Couvreur, 2013.

According to Couvreur et al. (2011), diversification of extant lineages of palms started during the mid-Cretaceous period about 100 million years ago in a tropical rain forest-like environment at northern latitudes, and “conform to a constant diversification model...at least until the Neogene, with no evidence for any change in diversification rates even through the Cretaceous/Paleogene mass extinction event. In contrast to other plant studies, our results suggest that ancient and steady evolutionary processes dating back to the mid-Cretaceous period can contribute, at least in part, to present day species richness” (9:44).

?Palmae (Arecaceae)- *Ailanthipites*, *Arecipites*, *Ericipites*, *Gemmamonocolpites pilulus*, *Polypolpites* cf. *langstonii*, *Retistephanocolporites* sp. A, *Stellidiopollis annulatus*, *Triporopollenites*- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, pollen; Poole et al., 2005.

Amesoneuron and/or *Sabalites*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megafloora, Johnson, 2002; Paleocene, Ludlow Member of Fort Union Fm., ND, SD, megafloora; Johnson, 2002.

Astrocaryum- Roncal et al. (2013): “Cladogenesis of Western Amazonian *Astrocaryum* spp. (c. 6 Ma) post-dated the drainage of the aquatic Pebas system...The ancestral distribution of *Astrocaryum* spp. in the Guiana Shield supported the hypothesis of an

old formation that acted as a source area from which species colonized adjacent regions, but an earliest branching position for Guianan species was not confidently recovered. A twofold increase in diversification rate was found in a clade, the ancestor of which occupied the Guiana Shield (*c.* 13 Mya, a time of climatic change and Andean uplift)” (p. 120).

Bactridinae- [“Bactridinae include about 150 species of spiny Neotropical palms in five genera that are ecologically important in several vegetation types such as open woodland (*Acrocomia*), lowland rainforest (*Astrocaryum*, *Bactris*), and montane forest (*Aiphanes*). A Bayesian dating analysis using the relaxed-clock model indicates that most genera of the Bactridinae diverged during a relatively short period around the Eocene-Oligocene boundary, which might explain the difficulties in resolving the phylogenetic backbone of the group. The most Andean genus *Aiphanes* shows an initial radiation of early lineages in the Oligocene (around 25 Ma ago) corresponding to an early uplift phase of the cordillera. These taxa are now restricted to the mountain forests of Columbia and Ecuador. The main diversification of Andean *Aiphanes* began in the Miocene (around 11 Ma ago)” Eiserhardt et al., 2011, p. 485].

Ceroxyloideae (wax palm subfamily)- disjunct distribution (Caribbean lineage, Southern Hemisphere disjunction, amphi-Andean element) based on DNA sequences from three plastid and two nuclear genomic regions was due to mid-Tertiary dispersal with radiation coinciding largely with the major uplift of the Andes (Trénel et al., 2007).

Cocos sp.- middle to late Paleocene, Cerrejón Fm., Ranchería River Valley, northern Colombia, fruits; Gomez-Navarro et al., 2009; also reported are fossil Arecoideae inflorescences; fossil Arecaceae sp. 1 (fragments of pinnate leaves), fossil Arecaceae

sp. 2 (fragments of costapalmate or palmate leaves).

Gemmamonocolpites (Araceae?)- lower middle Eocene, Antarctic Peninsula, pollen;

Poole et al., 2005.

Gemmamonocolpites pilulus (?Arecaceae)- mid-early Paleocene, Antarctic Peninsula,

pollen; Poole et al., 2005.

Grimsdalea magnaclavata- “Based on the new observations of the pollen morphology we

conclude that the records from Cretaceous and Paleogene sediments in North and West

Africa are invalid. *G. magnaclavata* is clearly restricted to northern South America

from the Miocene to Pleistocene. The parent plant...probably grew in upper coastal

plain or around swamps...nearest living relatives are the genera *Mauritia* and

Mauritiella” (Pocknall and Jarzen, 2012, p. 1).

Monocolpopollenites sp. 2- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al.,

2013.

Nypa sp.- middle to late Paleocene, Cerrejón Fm., Ranchería River Valley, northern

Colombia, fruits; Gomez-Navarro et al., 2009. Middle Eocene, Laredo Fm., Webb Co.,

TX, pollen (*Spinozonocolpites prominatus*); Westgate & Gee [1990: “Fossil *Nypa*

pollen, described under the form genus name *Spinozonocolpites*, has a fossil record

extending from the Late Cretaceous to the Recent (Frederiksen, 1985; Thanikaimoni,

1987”, p. 171].

Palmacites sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, leaf; Manchester, 2001.

Ruminosemen panamensis- late Eocene, Tonosi Fl., Pacific coast central Panama,

seed; Herrera et al., 2012.

Sabal bracknellensis, *S. jenkinsii*- middle Eocene (44 Ma), Clarno Fm., OR, seeds;

Manchester, 1994. *Sabal* sp.- late Eocene (36 Ma), lower John Day Fm., OR, seed casts; Manchester & McIntosh, 2007. (see also *Amesoneuron*).

Palmoxylon macginitiei- late early Eocene (ca. 49 Ma), Bridger Fm., Big Sandy Reservoir, SW Wyoming, wood; Bouchai & Manchester, 2012.

Socratea brownii (Iriarteinae: Arecoideae)- Oligo-Miocene, La Quinta Fm., Simojovel, Chiapas, Mexico, flowers; Poinar, 2002.

Spinozonocolpites- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012

Trithrinax dominicana (Thrinacinae: Coryphoideae)- Miocene, Dominican amber (mines, northern mountain ranges), flowers; Poinar, 2002.

ASTERACEAE- middle Eocene, Patagonia, capitulescence with long pedunculate capitula, pollen (cf. *Mutisiapollis telleriae*, Patagonia and *Tubuliforidites viteauensis*, Africa), Barreda et al., 2010a; Stuessy, 2010; see also Barreda et al., 2010b; Graham, 1996; Katinas et al., 2007; Zavada & de Villiers, 2000- *Tubuliforidites antipodica*, *T. viteauensis* (pollen) from the Paleocene-Eocene, South Africa. Numerous records Eocene onwards: Late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005. Late Miocene, Vasa Park Fl., King Co., WA, pollen; Dillhoff et al., 2014.

Subfamily Carduoideae, Tribe Cardueae- Barres et al. (2013): “Tribe Cardueae is inferred to have originated around the Mid Eocene in West Africa, which is also the ancestral area of most subtribes within Cardueae. Diversification within each subtribe began during the Oligocene-Miocene period” (p. 867); “...new fossil evidence assigned to basal subfamilies (such as Barnadesioideae) within Compositae (Barreda et al, 2010a,b)...”

(p. 868); see also p. 872 (Age constraints and the fossil record; divergence times), p. 877 Historical biogeography of Cardueae; Origin in West Asia and Mediterranean diversification), p. 880 (Colonization of the New World).

Subfamily Cichorioideae, Tribe Liabeae- Funk et al. (2012): “The phylogeny slightly alters previous assumptions about the biogeography and it seems that Liabeae originated in the central and northern Andes and spread north and south with several independent introductions into Mexico and Central America and one into the Caribbean” (p. 437). See also Biogeography (pp. 450-452).

Artemisiapollenites sp. (*Artemesia*)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

Compositoipollenites sp. 1- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013

Grindelia- Moore et al., 2012: There are two major clades of North American *Grindelia*, primarily east and west of the Rocky Mountains. “Given that the Rocky Mountains have been at approximately their current elevation since the end of the Laramide Orogeny in the Eocene...and that the origin of the asteroid tribes (including Astereae) has been dated to approximately 30 million years ago..., dispersal is more likely than vicariance to explain this distribution. In addition, the more northern taxa are nested well within the two clades, as would be expected from a pattern of colonization from the south, but not from a pattern of vicariance due to uplift of the Rocky Mountains” (p. 226).

Raiguenrayum cura- Eocene (47.5 Ma), Huitera Formation, northwestern Patagonia, Argentina, Río Negro Province, Estancia Don Hipólito locality, capitulescence; Barreda

et al., 2012.

ATHEROSPERMATACEAE

Atherospermoxylon- Late Cretaceous (Coniacian to Campanian), Late Cretaceous (late Maastrichtian), early-late Paleocene, lower middle Eocene, Antarctic Peninsula, wood, Poole et al., 2005.

Laurelites jamesrossii- Late Cretaceous (Coniacian to Campanian), Late Cretaceous (late Maastrichtian), mid-early Paleocene, middle Eocene, Antarctic Peninsula, wood, Poole et al., 2005.

AUCUBACEAE

Aucuba smileyi- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997.

BERBERIDACEAE

Berberis ahuehuetensis, *B. lozanofolia*, *B. poblana*, *B. tepexiana*- Oligocene, lowest member Pie de Vaca Fm., Los Ahuehuetes locality near Tepexi de Rodríguez, Puebla, Mexico, leaves; Ramírez & Cevallos-Ferriz, 2000. *B. hirsutus*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaf; Axelrod, 1998a. *B. sp.*- Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO, leaves; Gregory & McIntosh, 1996. *B. darwinii*- last interglacial (MIS 5e, called Valdivia in southern Chile), Mancera interglacial sequence, Mancera Island, Chile, leaves; Astorga & Pino, 2011.

Mahonia deweyensis, *M. reticulata*- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaflets; Axelrod, 1998. *M. creedensis*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaflet; Axelrod, 1998a. *M. grantiana*, *M. limirivuli*- Oligocene, Horse-Prairie Basin, southwestern MT, leaf; Becker, 1962. *M. lobodonta*- Oligocene, Ruby Fl.,

southwestern MT, leaf; Becker, 1959. *Mahonia martinezii*- Oligocene, lowermost member Pie de Vaca Fm., Los Ahuehuetes locality near Tepexi de Rodríguez, Puebla, Mexico, leaves; Ramírez & Cevallos-Ferriz, 2000. *M. simplex*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaflet, Axelrod, 1998a; Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf, Meyer & Manchester, 1997. *M. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, leaflets, Manchester, 2001; Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO, leaves, Gregory & McIntosh, 1996. *M. mohavensis*- middle Miocene, Mint Canyon Fl. (preliminary study), so. CA; Axelrod, 1940. *Mahonia/Berberis*- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

BETULACEAE- using ribosomal DNA sequences “we found that the age of the crown group and stem lineage of Betulaceae vary from 115.2 to 130.6 million years and 211.2 to 302.6 million years (Aptian or before). These results are older than current paleobotanical data. We calculated paleobotanical confidence intervals using methods based on the occurrence of fossils on a stratigraphic column and the lengths of the gaps between these occurrences. We apply these methods to the fossil record of *Alnus* and related extinct genera; however, only in some cases were molecular- and fossil-based estimates reconciled” (Forest et al., 2005, p. 118). The stem lineage may go back into the Late Cretaceous depending on the degree of affinity with the extinct Normapolles group. See also Sims et al. (1999), ‘higher’ hamamelids (Juglandaceae, Rhoipteleaceae, Myricaceae, Betulaceae).

Alnipollenites scoticus, *A. versus* (*Alnus*)- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011. *A. versus* (*Alnus*)- late Paleocene (~60 Ma), Sagwon

Bluffs, North Slope Alaska, pollen; Daly et al., 2011. *A. versus* (*Alnus*)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

Alnus- “The earliest records of the genus *Alnus*...are from the Paleocene of the Kenai Peninsula, Kachemak Bay, Alaska...(Hollick, 1936, p. 95), from the Middle Eocene of southern England (*Alnus poolensis* Chandler; Chandler 1963), from the Middle Eocene Clarno Formation of Oregon..., and from the Paleocene and Eocene of the USSR (*A. beringiana* Budantsev; Budantsev 1982)” (Crane & Stockey, 1987, p. 2498). *A.* subgenus *Alnus*- middle Eocene Clarno Fm., Oregon, leaves and associated catkins, pollen, and fruits, Liu et al., 2014; *A. cecropiifolia*, *A. gaudinii*, *A. cf. kefersteinii*- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. *A. fairii*, *A. hallii*, *A. latahensis*, *A. lemhiensis*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves, seed cones; Axelrod, 1998a. *A. heterodonta* (leaf), *A. newberryi* (leaf), *A. sp.* (leaves, infructescence, fruit, staminate catkins)- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR; Meyer & Manchester, 1997. *A. microdontoides*- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaves; Axelrod, 1998. *A. parvifolia*- middle Eocene, Republic Fl., WA, fruits, Wehr & Manchester, 1996; late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage, ovulate cones, *Alnus* pollen, *Alnus*, 2 sp., cones, Dillhoff et al., 2005. *A. sp.*- late Eocene (36 Ma), lower John Day Fm., OR, infructescences, Manchester & McIntosh, 2007; late middle to early late Miocene, Byrn Mawr Fm., MD, pollen, Pazzaglia et al., 1997; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl., King Co., WA, leaves, pollen, Dillhoff et al., 2014.

Astrocarpinus perplexans- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl.,

OR, fruit; Meyer & Manchester, 1997. cf. *Asterocarpinus*, late Eocene (36 Ma), lower John Day Fm., OR, nuts; Manchester & McIntosh, 2007. *A. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, fruits; Manchester, 2001.

Bedellia pusilla- Late Cretaceous (late Santonian), Buffalo Creek Member, Gaillard Fm., Allon Fl., GA, staminate flowers; Herendeen et al., 1999.

Betula angustifolia- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf, bract, fruit; Meyer & Manchester, 1997. *B. cristata*, *B. islandica*, *B. sect. Costatae*, *B. subnivalis*- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. *B. clarnoensis*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002. *B. leopoldae*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage, aments, *Betula* pollen, Dillhoff et al., 2005; middle Eocene Republic Fl., WA, Wolfe & Wehr, 1987, Crane & Stockey, 1987; middle Eocene, Allenby Fm., Princeton, British Columbia, Canada; leaves, infructescences, fruits, staminate inflorescences, pollen; Crane & Stockey, 1987: [The authors review the fossil record of the family, p. 2498]. *B. ashleyi*, *B. eoluminifera*, *B. lemhiensis*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves; Axelrod, 1998a. *B. sp.*- late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014.

aff. *Carpinus sp.*, *C. perryae*- middle Eocene, Republic Fl., WA, infructescence, fruit, Wehr & Manchester, 1996, Pigg et al., 2003 *C. sp.*-Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007.

Carpinus/Ostrya- late Miocene Fl., King Co., WA, pollen; Dillhoff et al., 2014.

- Carpinidites* sp. (*Carpinus* cf. *tropicalis* subsp. *mexicana*)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.
- Corylites* sp.- late Paleocene, Almont, Beicegel Fls., ND, leaves, Crane et al., 1990, Manchester et al., 2004, Pigg & DeVore, 2010.
- aff. *Corylus* sp., *C.* sp.- Paleocene, Ludlow Member of Fort Union Fm., ND, SD, megaflora, Johnson, 2002; middle Eocene, Republic Fl., WA, fruit, Wehr & Manchester, 1996. cf. *Corylus* sp. (*Corylus*-type pollen)- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada; Dillhoff et al., 2005. *C. johnsoni*- middle Eocene, Republic Fl., WA, infructescence, fruit; Pigg et al., 2003. *C.* sp. 1, 2- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. *Corylus* and types- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.
- Coryloides hancockii*- middle Eocene (44 Ma), Clarno Fm., OR, nut; Manchester, 1994. *C.* sp.- late Eocene (36 Ma), lower John Day Fm., OR, nut; Manchester & McIntosh, 2007.
- Cranea wyomingensis* (Coryloideae)- Paleocene, Fort Union Fm., Wind River, Bighorn, and Powder River Basins, WY, and lower Eocene, Willwood Fm., Bighorn Basin, WY, infructescences, leaves, staminate inflorescences, pollen, Manchester & Chen, 1996, 1998; Pigg & DeVore, 2010.
- Kardiasperma parvum*- middle Eocene (44 Ma), Clarno Fm., OR, locule casts; Manchester, 1994.
- Ostrya oregoniana*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf, fruit; Meyer & Manchester, 1997. *Ostrya/Carpinus*-type pollen, latest Eocene (34.1 Ma), Florissant Fl., CO, Leopold & Clay-Poole, 2001; late Miocene, Upper

Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005.

Palaeocarpinus aspinosa- Paleocene, Fort Union Fm., WY, infructescences, fruits, staminate inflorescences, leaves, pollen, Manchester & Chen, 1996, 1998; Bighorn, Green River Basins, Pigg & DeVore, 2010. *P. barksdaliae*- middle Eocene, Republic Fl., WA, fruit; Pigg et al., 2003. *P. dakotensis* (Betulaceae: Coryloideae), late Paleocene, Sentinel Butte Fm., Almont and Beicegel Creek floras, ND, infructescences with associated staminate catkins, pollen, and leaves, Crane et al., 1990; Manchester et al., 2004; Pigg & DeVore, 2010. *P. joffrensis*- late Paleocene, Alberta Basin, Munce's Hill, Canada, Sun & Stockey, 1992; Pigg & DeVore, 2010; Stockey et al, 2014. *P. sp.*- middle Eocene, Republic Fl., WA, fruits; Wehr & Manchester, 1996.

Paracarpinus chaneyi- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997. *P. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, leaves; Manchester, 2001.

Tripoporollenites coryloides ("Grains of this type were observed *in situ* by Manchester et al. (2004) in catkins associated with *Palaeocarpinus dakotensis*, a common plant at Almont. Pollen fitting this description also occurs in stamens of catkins associated with extinct betulaceous infructescences and fruits known as *Cranea* from the Paleocene of Wyoming ... in Manchester and Chen, 1998)" (Zetter et al., 2011)- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011. Late Paleocene (~60 Ma), Sagwon Bluffs, North Slope Alaska, pollen; Daly et al., 2011

Trivestibulopollenites betuloides (*Betula* sp.)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

BIGNONIACEAE (family, middle Eocene, Republic Fl., WA, seeds; Wehr & Manchester, 1996; see also Solonaceae).

Bignoniaceae- “Two fossils identified as *Callichlamys* (Chaney and Sanborn, 1933) and *Paragonia/Arrabidaea*—currently *Tanaecium/Fridericia*—(Graham, 1985) were placed at nodes 32 and 102 of the resulting phylogeny, with estimated ages of 34.8 +/- 0.22 Myr and 35.35 +/- 1.65 Myr, respectively” (Alcantara & Lohmann, 2010, p. 3). “Our analyses suggest that the crown group of Bignoniaceae originated in South American rainforests approximately 50 Mya. Ancestral area reconstructions for the early divergences are equivocal, although the resulting *Adenocalymma-Neojobertia* and core Bignoniaceae clades appear to have occurred in eastern South America and lowland Amazonia, respectively” (Lohmann et al., 2013, p. 154).

Adenocalymma- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves; Gayó et al., 2005.

Catalpa sp.- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek fl., OR, seed; Meyer & Manchester, 1997.

Lundia- Kaehler et al. (2012): “These results suggest that the genus may have originated in the western part of South America and subsequently occupied drier areas of central Brazil and the humid forests of southeastern Brazil. However, this hypothesis remains to be tested with more robust analyses involving formal ancestral area reconstructions of the distribution of the various taxa, in combination with divergence-time estimates that would provide a temporal component for the interpretation of the distribution patterns within a geological framework (Kaehler & al., in prep.)” (p. 377).

BIXACEAE

Choclospermum (Choclospermaceae)- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves; Gayó et al., 2005.

BOMBACACEAE

Bombacacidites bombaxoides- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, pollen; Poole et al., 2005.

BORAGINACEAE (see also Heliotropiaceae)

Boragineae- "...there is a rich fossil record of putative Boraginaceae nutlets from the Miocene and Pliocene of North America (Gabel 1987; Gabel et al. 1998; Segal 1966; Thomasson 1977, 1979). Some can be assigned to the *Lithospermum*-species group of Lithospermeae (†*L. dakotense*; Gabel 1987; Gabel et al. 1998; Weigend et al. 2009), others to the Cynoglosseae (*Cryptantha* and †*Prolappula*; Segal 1966; Thomasson 1979). Three fossil taxa (†*Biorbia*, †*Eliasiana*, and †*Prolithospermum*) have been tentatively assigned to Borgineae (Thomasson, 1979), a group not at present native to North America" (Weigend et al., 2010, p. 409; see also pp. 416-417).

Cryptantha- Hasenstab-Lehman & Simpson, 2012: "Although sampling is incomplete, this study generally supports the hypothesis of repeated unidirectional dispersal events, from North to South America" (p. 738).

Tiquilia- combined sequence data from three chloroplast markers (*matK*, *ndhF*, and *rps 16*) and two nuclear markers (ITS and *waxy*) suggest "that the stem lineage of *Tiquilia* split from its nearest extant relative in the Paleocene or Eocene (~59-48 Ma). This was followed by a relatively long period before the first divergence in the crown group near the Eocene/Oligocene boundary (~33-29 Ma), shortly after the greatest Cenozoic episode of rapid aridification. Several major lineages show a marked increase in

diversification concomitant with the onset of more widespread semi-arid and then arid conditions beginning in the late Miocene (~7 Ma). This sequence of divergence events in *Tiquilia* agrees well with earlier researchers' ideas concerning North American desert flora assembly" (Moore & Jansen, 2006, p. 668).

BRASSICACEAE (see Koch, 2012 for Old World, mid-Miocene (13.8 Ma) divergence of *Ionopsidium* and *Cochlearia* associated with the Messinian salinity crisis in the late Miocene).

Descurainia- Goodson et al. (2011): Old World origin with recent diversification within the Canary Islands and the New World...multiple independent dispersals between North and South America...As a calibration point the age of the node joining *Arabidopsis* to *Brassica* was fixed at 43.2 myr (Beilstein et al., 2010). ...origin of the *Descurainieae* 23.18 +/- 2.2 myr with the last common ancestor of Canary Island taxa arising 1.57 +/- 0.57 mya...last common ancestor of *Robeschia-Descurainia*, New World *Descurainia*, and Canary Island *Descurainia* as 22.45 +/- 1.41 mya, 5.20 +/- 5.20 mya, and 2.40 +/- 0.45 mya, respectively. Geographic expansion of *Descurainia* out of ancestral areas appears to have begun in the late Miocene with diversification accelerating during the late Pliocene or early Pleistocene. The ancestral species arrived in the Canary Islands 1-2.8 mya, probably from the Iberian Peninsula...New World species of *Descurainia* are of Pliocene/early-Pleistocene origin, with molecular clock calculations from cpDNA data estimating a date of 4.7-5.7 myr for the last common ancestor of all New World taxa, and ITS data suggesting an origin of approximately two mya for each of the three major New World clades. The greater genetic diversity within North America relative to South America argues for North America as the

continent of initial establishment, and is consistent with the general distribution pattern observed in New World Brassicaceae. Any introduction from Europe via a North Atlantic land bridge can be ruled out; such a land connection is believed to have been broken by the early Eocene (Tiffney 1985; Tiffney and Manchester 2001). [see *Asclepias*].

Thlapsi primaevum- early Oligocene, MT, fruit; Manchester & O’Leary, 2010: [“The observed features of fruit morphology are consistent with Brassicaceae, and the distinctive ornamentation of the seeds, taken along with the fruit characters, confirm Becker’s [1961] assignment of this fossil to extant *Thlaspi*” p. 67].

Tricolpopollenites sp. 1 (cf. Brassicaceae)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013. *T.* sp. 4 (cf. Brassicaceae, cf. Oleaceae)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

BROMELIACEAE- “Analyses based on *ndhF* sequence variation indicate that Rapateaceae and Bromeliaceae...underwent crown radiation around 41 and 23 Ma, respectively. Among bromeliads, *Pitcairnia feliciana*...appears to be the product of long-distance dispersal ca. 12 Ma..., the Guiana Shield was ...cradle of the bromeliads. Bromeliad acquisition of key adaptations to drought...17 Ma appears to have coincided with and help cause the centripetal invasion of drier, more seasonal regions beyond the Guyana Shield...” (Givnish et al., 2004, p. 535).

“Bromelids arose in the Guyana Shield ca. 100 million years ago (Ma), spread centrifugally in the New World beginning ca. 16-13 Ma, and dispersed to West Africa ca. 9.3 Ma. Modern lineages began to diverge from each other roughly 19 Ma. Nearly two-thirds of extant bromeliads belong to two large radiations: the core tillandsioids,

originating in the Andes ca. 14-2 Ma, and the Brazilian Shield bromelioids, originating in the Serro do Mar and adjacent regions ca. 9.1 Ma” (Givnish et al., 2011, p. 872).

Karatothylum bromelioides- Middle Tertiary, Alajuela Province, Costa Rica, leaf impression; Baresch et al., 2011. [Noted previously in Graham, 2010, p. 333, 589].

Puya- Jabaily & Sytsma, 2013): The genus originated in central Chile and first moved into the Cordillera Oriental of the central Andes via inter-Andean valleys.

Caldogenesis progressed in a general south to north direction tracking the final uplift of the Andes. Repeated evolutionary transitions of lineages up and down in elevation are suggestive of allopatric speciation driven by Pleistocene glaciation cycles” (p. 201).

BURSERACEAE- Based on nuclear and chloroplast data “Our data support a North American Paleocene origin for the Burseraceae followed by dispersal of ancestral lineages to eastern Laurasia and Southern Hemisphere continents” (Weeks et al., 2005, p. 85). “...the earliest known fossils attributable to the eudicotyledon lineage and the Sapindales date to ca. 125 Ma (Doyle and Hotton, 1991; Magallón et al., 1999) and ca. 65 Ma (Knobloch and Mai, 1986), respectively” (Weeks et al., 2005, p. 86).

Bursera- Becerra et al. (2012): “New calculations of the age of Burseraceae date the beginning of its diversification to at least 93 million years ago” (p. 333). See also Divergence time estimation (pp. 335-336), Timing the divergence of Burseraceae (pp. 336-337), and Discussion (pp. 340-341).

Bursericarpum oregonense, *B.* sp.- middle Eocene (44 Ma), Clarno Fm., OR, fruits, Manchester, 1994; late Eocene (36 Ma), lower John Day Fm., OR, endocarps, locule casts, Manchester & McIntosh, 2007.

BUXACEAE

Erdtmanipollis cretaceous (*Pachysandra*, *Sarcococca*)- late Paleocene, Almont Fl.,
Williston Basin, pollen; Zetter et al., 2011.

CABOMBACEAE

Brasenites kansense (cf. Cabombaceae)- Lower Cretaceous (Albian), Dakota Fm.,
Hoisington III locality, Barton Co., KS, leaves; Wang & Dilcher (2006).

Cabomba- late Miocene/Pliocene, Gatun Fm., Canal region, Panama, pollen; Graham
1991.

CACTACEAE

Harrisia- Franck et al., 2013: “Using the four-marker Bayesian tree, the r8s penalized
likelihood analysis estimated the origin of *Harrisia* to be 3.45-6.53 Ma ago. The crown
age of the first split within *Harrisia* was dated at 1.75-3.30 Ma ago. The crown age of
the divergence between the Gran Chaco species and *H. tetracantha* was 0.69-1.30 Ma
ago. Diversification of the Gran Chaco species was estimated at 0.20-0.38 Ma ago.
The Caribbean species and *H. adscendens* had a divergence date of 0.81-1.53 Ma ago.
The split between *H. earlei* and the rest of the Caribbean species was estimated at 0.24-
0.45 Ma ago. The rest of the Caribbean species had a diversification date of 0.20-0.37
Ma ago” (pp. 212-216).

CALCEOLARIACEAE (see also Lamiales)

Jovellana- Nylinder et al. (2012): “...the presence of *Jovellana* in New Zealand is the
result of long-distance dispersal across the Pacific Ocean from South America” (p.
381). The authors further review the fossil record and divergence times of the
Calceolariaceae and related taxa (pp. 383-388).

CANELLACEAE

Wilsonoxylon edenense- late early Eocene (ca. 49 Ma), Bridger Fm., Big Sandy Reservoir, SW Wyoming, wood; Bouchai & Manchester, 2012.

CANNABACEAE (*Aphananthe*, *Celtis*, *Trema* formerly in Ulmaceae)

Aphananthe maii- middle Eocene (44 Ma), Clarno Fm., OR, endocarp, locule casts, Manchester, 1994; late Eocene (36 Ma), lower John Day Fm., OR, endocarp, Manchester & McIntosh, 2007. *A. sp.*- late Paleocene (Tiffanian), Paskapoo Fm., Alberta, Canada, leaves, Stockey et al, 2014.

Celtis aspera- late Paleocene, Bighorn Basin, WY; Manchester et al., 2002; Pigg & DeVore, 2010. *C. burnhamae*, *C. sp.*- middle Eocene (44 Ma), Clarno Fm., OR, endocarps; Manchester, 1994.

aff. *Humulus*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflores; Johnson, 2002.

Trema nucilecta- middle Eocene (44 Ma), Clarno Fm., OR, endocarps, locule casts; Manchester, 1994.

CAPRIFOLIACEAE (see *Ozakia*, Angiospermae incertae sedis)

Diplodipelta reniptera- Oligocene (30.7 Ma), Haynes Creek Fl., ID, fruits; Axelrod, 1998a: "Many of the fossil fruits assigned earlier to *Pteleaecarpum* (Kvaček, Bůžek, and Manchester, 1991) are now known, chiefly through the research of Manchester, to represent two different families. The genus *Craigia* of the Tiliaceae [and] *Dipelta* of the Caprifoliaceae, are now living in southeastern Asia. The present fossils are assigned to an extinct genus, *Diplodipelta*, that is closely allied to *Dipelta*" (p. 55). Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, Fruit; Meyer & Manchester, 1997. *D. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, fruits;

Manchester, 2001.

Lonicera sp.- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. *L.* and types- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Sambucus sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

Symphoricarpos salmonensis- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves; Axelrod, 1998a.

Viburnum sp.- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaves; Axelrod, 1998. *V.* sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

Weigelia- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

CARYOPHYLLACEAE

Stellaria or *Silene*-type- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

CASUARINACEAE

Gymnostoma argentinum, *G. archangelskyi*, *G. patagonicum* (branchlets, leaves, infrutescences, fruiting cones), *G.* male inflorescences (with pollen grains of *Haloragacidites harrisii* type)- Early Eocene (51.91 +/- 0.22 Ma), Tufolitas Laguna del Hunco Fl., northwestern Chubut Province, Argentina; Zamaloea et al., 2006.

Haloragacidites harrisii- lower middle Eocene, Antarctic Peninsula, pollen; Poole et al., 2005.

CELASTRACEAE

Baasia armendarisense- Late Cretaceous (Maastrichtian), McRae Fm., NM, wood;

Estrada-Ruiz et al., 2012.

Paxistima deweyensis- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaves;

Axelrod, 1998. *P. lemhiensis*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves;

Axelrod, 1998a.

CELTIDACEAE- (see Cannabaceae)

CERATOPHYLLACEAE

Ceratophyllum echinatum, *C. fossilium*- upper Miocene, Esmeralda Fm., NV, fruits,

Herendeen et al., 1990; *C. furcatispinum*- Paleocene, Fort Union Fm., MT, fruits,

Herendeen et al., 1990; *C. incertum*- Eocene, Green River Fm., WY, and middle

Eocene Claiborne Fm., TN, fruits, Herendeen et al., 1990. *C. lesii*- Upper Cretaceous

(late Campanian), Cerro del Pueblo Fm., Coahuila, Mexico, fruit; Estrada-Ruiz et al.,

2009. *C. sp.*- Paleocene, Ludlow Member of Fort Union Fm., ND, SD, megafloora,

Johnson, 2002; Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007.

CERCIDIPHYLLACEAE

Cercidiphyllum alalongum- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler &

Manchester, 2002. *C. crenatum*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaf;

Axelrod, 1998a: ["This species was recorded earlier from Salmon, Idaho, as

Ceanothus", p. 56]. Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR,

leaf, fruit; Meyer & Manchester, 1997. Late Miocene- Vasa Park Fl., King Co., WA,

leaf (with *C.*-type pollen); Dillhoff et al., 2014. *C. ellipticum*- Late Cretaceous

(Maastrichtian), Hell Creek Fm., ND, SD, megafloora, Johnston, 2002; Paleocene,

Ludlow Member of Fort Union Fm., ND, SD, megaflora, Johnson, 2002. *C. genetrix*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora, Johnson, 2002; Paleocene, Ludlow Member, Fort Union Fm., ND, SD, megaflora, Johnson, 2002. *C.* sp.- earliest Paleocene, basal Fort Union Fm., ND, seeds, Bercovici et al., 2008; late Paleocene, Almont Fl., Williston Basin, ND, pollen, Zetter et al., 2011; middle Eocene, Republic Fl., WA, pods, Wehr & Manchester, 1996; Miocene (15-6 Ma), Iceland, Grimsson & Denk, 2007. aff. *Cercidiphyllum*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Cercidiphyllum sp.- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011; cf. *Cercidiphyllum*- late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014.

Joffrea speirsii (*Cercidiphyllum*-like)- late Paleocene, Paskapoo Fm., Joffre Bridge, near Red Deer, Alberta, Canada; pistillate inflorescences, seeds, Stockey & Crane, 1983; Crane & Stockey, 1986; Crane & Stockey, 1985: [“Fossil leaves resembling those of the extant dicotyledon *Cercidiphyllum* Siebold et Zuccarini are widespread in Upper Cretaceous and Tertiary floras throughout North America, Europe, and Asia (Brown 1939; Bell 1949; Iljinskaja 1974; Jahnichen et al. 1980; Tanai 1981)”, p. 340]; see also Hoffman & Stockey, 1999’ Stockey et al., 2014]. *J.* sp.- late early Eocene (49-52 Ma), McAbee Fl., British

Columbia, Canada, foliage, fruits, Dillhoff et al., 2005; middle Eocene, Republic Fl., WA, fruits, seeds, stamens, Wehr & Manchester, 1996.

Nyssidium arcticum- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora, Johnson, 2002; Paleocene, Ludlow Member of Fort Union Fm., ND, SD,

megaflora, Johnson, 2002; Paleocene, Sentinel Butte Fm., Almont, ND, follicles, leaves, staminate inflorescences; Crane et al., 1990; Pigg & DeVore, 2010.

“*Populus*” *nebrascensis*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, Megaflora, Johnson, 2002; Paleocene, Ludlow Member of Fort Union Fm., ND, SD, megaflora, Johnson, 2002.

CHENOPODIACEAE/AMARANTHACEAE (see also Amaranthaceae; undifferentiated pollen = chenoam)- latest Eocene (34.1 ma), Florissant Fl., CO, Leopold & Clay-Poole, 2001; late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014.

Chenopodipollis chenopodiaceoides- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012. *C. sp. 3*- Miocene, Tepoztlán Fm., Mexico, pollen; Lendardt et al., 2013.

CHLORANTHACEAE- fossil record summarized by Herendeen et al., 1993, p. 865.

Chloroanthaceae- Late Cretaceous (Coniacian to Campanian), Antarctic Peninsula, pollen; Poole et al., 2005.

Chloranthistemon crossmanensis (*Chloranthus*-like)- Late Cretaceous (Turonian, ca. 90 Ma), Raritan Fm., NJ, stamens, pollen; Herendeen et al., 1993.

Clavamonocolpites polygonalis- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, pollen; Poole et al., 2005.

Clavatipollenites hughesi- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, pollen; Poole et al., 2005.

Hedyosmum- Antonelli and Sanmartin (2011): “Our results, based on analyses of plastic and nuclear sequences for 40 species, suggest that the ancestor of Chloranthaceae and

the *Hedyosmum* stem lineages were widespread in the Holarctic in the Late Cretaceous. High extinction rates, possibly associated with Cenozoic climatic fluctuations. May have been responsible for the low extant diversity of the family. Crown group *Hedyosmum* originated c. 36-43 Ma and colonized South America from the north during the Early-Middle Miocene (c. 20 Ma). This coincided with an increase in diversification rates, probably triggered by the uplift of the Northern Andes from the Mid-Miocene onward” (p. 596). Martínez et al. (2013): “The first appearance of *Hedyosmum*-like pollen was in the Early Cretaceous (~112 Ma). The next unequivocal record of *Hedyosmum*-like pollen (*Clavainaperturites microclavatus*) occurred in the early Miocene” (p. 161). Late Pliocene-Quaternary (ca. 2.7 Ma), High Plain Bogotá, Colombia, pollen; Hooghiemstra, 1995.

CHRYSOBALANACEAE- Bardon et al. (2013): “... most probably originated in the Palaeotropics about 80 Mya” ... dispersed into the Neotropics at least four times beginning 40-60 Mya, with at least one back-dispersal to the Palaeotropics” (p. 19).

CLUSIACEAE

cf. *Calophyllum*- middle Miocene, Pebas Fm., w. Amazon Basin, Iquitos, Peru, wood; Pons & de Franceschi, 2007.

Paleoclusia chevalieri- Late Cretaceous (Turonian), Raritan or Lower Magothy Fm., Sayreville, NJ, flowers, anthers with pollen, young ovules, fruits; Crepet & Nixon, 1998.

Symphonia (*Pachydermites diedrexi*)- “The first pollen fossils of *Symphonia* appear in Africa at ~45 Ma (Jan-du-Chene et al., 1978). The first Mesoamerican fossils of *S. globulifera* appear in the early/middle Miocene (15.5-18.2 Ma; Fournier 1982) and in

South America by the mid-Miocene (~15 Ma; Germeraad et al., 1968...and mid-Pliocene (~4 Ma) sediments in Mexico (Graham, 1976; A. Graham, personal communication), in the Plio-Pleistocene of southeast Costa Rica (Graham and Dilcher, 1998...)” (Dick et al., 2003, p. 692).

CHOCLOSPERMACEAE (see Bixaceae)

COMBRETACEAE

cf. *Buchenavia*- middle Miocene, Pebas Fm., w. Amazon Basin, Iquitos, Peru, wood; Pons & de Franceschi, 2007.

Dilcherocarpon combretoides- Cretaceous (Albian to Cenomanian), Dakota Fm., KS (Cloud Co.), NB (Decatur), seeds; Manchester & O’Leary, 2010: [“The presence of the Combretaceae in the late Cretaceous has been indicated previously based on well preserved flowers from the Campanian-Maastrichtian of Portugal (Friis et al., 1991) and early Santonian of Japan (Takahashi et al., 1999), but these winged fruits are still older, and provide an additional indication that the syndrome of characters typical of the extant family were established relatively early”, p. 63].

Terminalia oregona- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, fruit; Meyer & Manchester, 1997. cf. *Terminalia*- middle Miocene, Pebas Fm., w. Amazon Basin, Iquitos, Peru, wood; Pons & de Franceschi, 2007.

CORNACEAE/CORNALES

Alangium [“Recent molecular data support the conclusion that *Alangium* is close to *Cornus* and should be placed in the Cornaceae” (Wheeler & Manchester, 2002, p. 36)]. *A. eydei* (fruits), *A. rotundicarpum* (fruits), *A. oregonensis* (wood)- middle Eocene (44 Ma), Clarno Fm., OR; Manchester, 1994, Wheeler & Manchester, 2002.

A. sp.- late Eocene (36 Ma), lower John Day Fm., OR, endocarps; Manchester & McIntosh, 2007. cf. *Alangium*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Amersinia obtrullata- Paleocene, WY, MT, ND, Alberta, Canada, China, Kamchatka, northeastern Russia, infructescences, foliage, fruits, seeds, Manchester et al., 1999, Hoffman & Stockey, 1999; late Paleocene, Almont, Beicegel Fl.s, ND, fruits, seeds, Crane et al., 1990, Manchester et al., 1999, Pigg & DeVore, 2010. *A. sp.*- Paleocene, Ludlow Member of Fort Union Fm., ND, SD, megafloora, Johnson, 2002.

Amersinia/Beringiaphyllum- late Paleocene, Williston Basin, Almont, Beicegel. Golden Valley Fls., Manchester et al., 1999; Pigg & DeVore, 2010.

Beringiaphyllum cupanioides, *B. kingiensis*, *B. pseudoantiquum*- Paleocene, "...the presumed leaves of *Amersinia*..." (Manchester et al., 1999). *B. cupanioides*- late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada; Hoffman & Stockey, 1999. *B. sp.*- Almont, Beicegel Fls., ND, leaves, Crane et al., 1990, Manchester et al., 1999, Pigg & DeVore, 2010.

Browniea- late Paleocene, Williston Basin, Ravenscrag Fl., WY; Manchester & Hickey, 2007; Pigg & DeVore, 2010; Zetter et al., 2011.

Caprifoliipites paleocenicus ("...*in situ* in anthers of flowers of the nyssaceous megfossil genus *Browniea* in the Paleocene of Montana (Manchester and Hickey 2007)", (Zetter et al., 2011). *C. sp.*- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011.

Cornophyllum newberryi- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megafloora, Johnson, 2002; earliest Paleocene, basal Fort Union Fm., ND, leaves,

Bercovici et al., 2008, Johnson, 2002.

Cornus- Manchester et al. (2009) review the fossil record of *Cornus* and based on structurally preserved fossil fruits (Eyde 1988; Manchester 1994; Xiang et al. 2003), leaves of *C. krassilovii* (Russia) and *C. swingii*, and other records, they conclude that "...the extant genus was well established in the Northern Hemisphere early in the Tertiary" (p. 132). *C. clarnensis*- middle Eocene (44 Ma), Clarno Fm., OR, endocarps; Manchester, 1994. *C. swingii*- Paleocene, Fort Union Fm., WY, MT, ND, leaves; Manchester et al., 2009. *C. sp./cf. C. sp.*- Paleocene, Sentinel Butte, Almont, Beicegel Fls., ND, endocarps, Crane et al., 1990, Xiang et al., 2003; Pigg & DeVore, 2010; late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, Dillhoff et al., 2005; middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaf, Axelrod, 1998; Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf, Meyer & Manchester, 1997.

Davidia antiqua- Paleocene, Fort Union Group, ND, MT, WY, leaves, infructescence fruits, Manchester, 2002; Almont Fl., ND, Pigg & DeVore, 2010. *D. sp.*- late Eocene (36 Ma), lower John Day Fm., OR, fruits; Manchester & McIntosh, 2007.

Diplopanax eydei- middle Eocene, Allenby Fm., Princeton Chert, British Columbia, Canada, fruit; Stockey et al., 1998. cf. *Diplopanax*- late Paleocene, Almont Fl., ND, endocarp, Pigg & DeVore, 2010 (pers. comm. from Manchester).

Langtonia bisulcata- Paleocene to earliest Eocene, WY, endocarps, Tiffney & Haggard, 1996; middle Eocene (44 Ma), Clarno Fm., OR, endocarps, locule casts, Manchester, 1994.

Mastixia eydei, *M. oregonense*, cf. *Mastixia* # 1, cf. *Mastixia* # 2 (Mastixioideae- first appears in the Late Cretaceous of Europe, Knobloch & Mai, 1986)- middle Eocene,

Clarno Fm., OR, late Eocene, CA, fruits; Tiffney & Haggard, 1996: (“...widespread in the early Tertiary of western North America” p. 29, 50). *M. sp.*- middle Eocene (44 Ma), Clarno Fm., OR, endocarp, locule cast; Manchester, 1994; Bighorn Basin, Pigg & DeVore, 2010.

Mastixicarpum occidentale- middle Eocene, Clarno Fm., OR, fruits; Tiffney & Haggard, 1996; endocarps, locule casts; Manchester, 1994. Late Eocene (36 Ma), lower John Day Fm., OR, fruits; Manchester & McIntosh, 2007.

Mastixioidiocarpum oregonense (Scott, 1954, Manchester 1994, Clarno Fl.)- transferred to *Mastixia* (Tiffney & Haggard, 1996).

Nyssa eolignitica- middle Eocene, Claiborne Group, TN, endocarp; Dilcher & Lott, 2005.

N. scottii, *N. spatulata*, *N. sp.*- middle Eocene (44 Ma), Clarno Fm., OR, endocarps; Manchester, 1994. *N. sp.*- late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014.

Nyssapollenites- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011.

Nyssidium arcticum (*Nyssa*)- late Paleocene (~60 Ma), Sagwon Bluffs, North Slope Alaska, leaf; Daly et al., 2011.

Tsakada davidiiifolia (probably congeneric with *Davidia*, pers. comm., Steven Manchester to Kathleen Pigg)- middle Eocene, Republic Fl., WA, leaves; Wolfe & Wehr, 1987.

CROSSOSOMATACEAE

Crossosoma sp.- middle Miocene, Mint Canyon Fl. (preliminary study), so. CA; Axelrod, 1940.

CUNONIACEAE

Caldcluvioxylon collinsensis- middle Eocene, Antarctic Peninsula, wood; Poole et al., 2005.

Cunoniaceae/Elaeocarpaceae- lower middle Eocene, Antarctic Peninsula, pollen (*Tricolporites*); Poole et al., 2005.

Eucryphia cordifolia (Eucryphiaceae)- last interglacial (MIS 5e- called Valdivia in southern Chile), Mancera interglacial sequence, Mancera Island, Chile, leaves; Astorga & Pino, 2011.

Eucryphiaceoxylon eucryphioides- mid-early Paleocene, lower middle Eocene, Antarctic Peninsula, wood, Poole et al., 2005. *E. fildense*- middle Eocene, Antarctic Peninsula, wood, leaf; Poole et al., 2005.

Weinmannioxylon, *W. nordenskjoeldii*- lower middle Eocene, middle Eocene, Antarctic Peninsula, wood, leaf; Poole et al., 2005. *W. ackamoides*, *W. nordenskjoeldii*- Late Cretaceous (Coniacian to Campanian), Antarctic Peninsula, wood; Poole et al., 2005.

CYPERACEAE- “Schoeneae originated in Australia in the Paleocene...rapid divergence ca. 50 Ma, in Australia,...traversed the austral oceans with remarkable frequency, a total of 29 distinct dispersal events being reported here. Transoceanic dispersal generally involved habitat stasis” (Vilhoen et al., 2013, p. 2494).

(family)- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. late

middle to early late Miocene, Bryn Mawr Fm., MD, pollen; Pazziaglia et al., 1997.

Cyperacaepollis sp.- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

Cyperacites sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, Manchester, 2001;
middle Miocene, Mint Canyon Fl., (preliminary study), so. CA, Axelrod, 1940.

CYRILLACEAE

?Cyrillaceae- *Cyrillia* type, late Miocene, Upper Beluga Fm., south coast Alaska,
pollen; Reinink-Smith & Leopold, 2005.

DROSERACEAE

Droseridites, *Fischeripollis*- lower middle Eocene, Antarctic Peninsula, pollen; Poole et
al., 2005.

DIOSCOREACEAE (*Dioscorea* fruit listed for the latest Eocene (34.1 Ma) Florissant
Fl., CO, Manchester, 2001 now considered uncertain; Manchester, pers. comm., April,
2011).

EBENACEAE

Diospyros sp.- middle Miocene, Mint Canyon Fl. (preliminary study), so. CA; Axelrod,
1940.

ELAEOCARPACEAE (see also Cunoniaceae/Elaeocarpaceae)

Vallea- late Pliocene-Quaternary (ca. 2.7 Ma), High Plain Bogotá, Colombia, pollen;
Hooghiemstra, 1995.

ELEAGNACEAE

Eleagnus- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole,
2001.

EPACRIDACEAE/ERICACEAE

Ericipites scabratus- lower middle Eocene, Antarctic Peninsula, pollen; Poole et al.,
2005.

ERICALES (Ericaceae or Pyrolaceae; pollen undifferentiated)- latest Eocene (34.1 Ma), Florissant Fl., CO; Leopold & Clay-Poole, 2001.

Raritaniflora tomentosa, *R. sphaerica*, *R. glandulosa* (family unplaced, near Cyrillaceae and Ericaceae)- Late Cretaceous (Turonian), Raritan Fm., New Jersey, flowers, pollen, fruits, seeds; Crepet et al., 2013.

ERICACEAE [see also *Azolla*, Bowman, 2014; late Miocene, Vasa Park Fl., King Co., WA, pollen, ericaceous; Dillhoff et al., 2014].

Arbutus sp.- Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO, leaves; Gregory & McIntosh, 1996.

Arctostaphylos cuneata- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaf; Axelrod, 1998. cf. *Arctostaphylos* sp.- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007.

Gaultheria type- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Ledum idahoensis- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaf; Axelrod, 1998. Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves; Axelrod, 1998a.

cf. *Phyllodoce*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Tribe Phyllodoceae- Gillespie & Kron (2013): “As a whole, the Phyllodoceae represent a biogeographic pattern consistent with the Arcto-tertiary flora, with the majority of extant taxa occurring in the Pacific Northwest of North America, eastern North America, the Caucasus, and eastern Asia” (p. 761). [see ref. to discussions of the suitability of the geoflora concept in the introduction and in Graham 1999]

Rhododendron chaneyi- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves, Axelrod, 1998a. *R. deweyensis*- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaves; Axelrod, 1998. *R. aff. ponticum*- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2005. cf. *Rhododendron* sp.- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage?, ericaceous pollen; Dillhoff et al., 2005. *R. sp./cf./type*- Miocene (15-6 Ma), Iceland, Grimsson & Denk, 2007; late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005.

Vaccinium deweyensis, *V. palaeocorymbosum*, *V. serrulatum*- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaves; Axelrod, 1998. cf. *Vaccinium* sp.- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007.

ERIOCAULACEAE

Paepalanthus- Trovó, et al., 2013): “Biogeographical reconstructions suggest that the current distribution patterns may be related to vicariance and a few long-distance dispersal events” (p. 225). “The occurrence of both subfamilies in Africa and South America may suggest a Gondwanan origin of Eriocaulaceae, roughly consistent with its crown node estimated at c. 105 Mya (Janssen & Bremer, 2004)” (p. 235).

EUCRYPHIACEAE (see Cunoniaceae)

EUCOMMIACEAE

Eucommia- (Call & Dilcher, 1997 review the fossil record of the family for North America): *E. eocenica* (middle Eocene, Mississippi Embayment, MO, TN, MS), *E. montana* (early Eocene to early Oligocene, WA, OR, UT, CO, MT; British Columbia, Canada), *E. constans* (neogene, central Mexico), and *E. jeffersonensis* (latest Eocene or

earliest Oligocene, John Day Fm., OR), reproductive and vegetative remains. *E.* sp./type- middle Eocene, Republic Fl., WA, fruit, Wehr & Manchester, 1996; latest Eocene (34.1 Ma), Florissant Fl., CO, fruit, Manchester, 2001; pollen, Leopold & Clay-Poole, 2001; late Miocene, Upper Beluga Fm., south coast Alaska., pollen, Reinink-Smith & Leopold, 2005.

Eucommia? leopoldae- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011.

EUPHORBIACEAE- Dilcher & Manchester (1988, pp. 50-51) discuss the fossil history of the family. Late Eocene (36 Ma), lower John Day Fm., OR, capsule; Manchester & McIntosh, 2007.

Cnidoscolus sp.- Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO, leaves; Gregory & McIntosh, 1996.

Crepetocarpon perkinsii (Tribe Hippomaneae)- middle Eocene, Claiborne Fm., TN, fruits; Dilcher & Manchester, 1988.

Croton sp.- latest Eocene (334.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

Hippomaneioidea warmanensis (Subfamily Euphorbioideae, Tribe Hippomaneae)- middle Eocene, Claiborne Fm., western TN, inflorescences, pollen; Crepet & Daghljan, 1982.

Malvacipollis subtilis- lower middle Eocene, Antarctic Peninsula, pollen; Poole et al., 2005.

EUPTELEACEAE

Euptelea dilcherii- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaf; Axelrod, 1998a.

FABACEAE- (for summaries of the fossil record of the family see Crepet & Taylor,

1985, Herendeen & Dilcher, 1990; for the Caribbean region see Graham, 1992).

Leguminosae gen. et sp. indetermined- middle Eocene, Republic Fl., WA, fruits, Wehr & Manchester, 1996; Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaflet, Meyer & Manchester, 1997.

cf. *Abarema* alliance- middle Miocene, Pebas Fm., w. Amazon Basin, Iquitos, Peru, wood; Pons & de Franceschi, 2007.

Acacia- Miocene, Altamira Fm., Dominican amber, flowers, Dilcher et al., 1992; *A.* type- late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005.

cf. *Andira/Hymenolobium*- middle Miocene, Pebas Fm., w. Amazon Basin, Iquitos, Peru, wood; Pons & de Franceschi, 2007.

Barnebyanthus buchananensis (Papilionoideae, Tribe Sophoreae)- early Eocene, Claiborne Fm., Henry Co., TN, flowers with pollen; Crepet & Herendeen, 1992.

Caesalpinites sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, leaflets; Manchester, 2001.

Calliandra (Mimosoideae)- Miocene, La Ollita Fm., San Juan Province, Argentina, pollen, Caccavari & Barreda (2000): “The first records of Mimosoideae with compound pollen are from the Early Eocene of North America (Crepet and Taylor, 1985), while records for the Middle Eocene are many and the taxa diverse, see for example: Muller (1981), Herendeen (1992), Guinet and Ferguson (1989)... In the Neotropics the fossil pollen record of Mimosoideae is also abundant and varied; Lima and Salard-Chebouldaef (1981), Lima and Amador (1985); Lima et al. (1985a,b); Caccavari and Anzótegui (1987); Barreda and Caccavari (1992); Graham (1992), Graham and Dilcher (1995)” (Caccavari & Barreda, 2000, p. 197).

Cercis maurerae- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, fruit; Meyer & Manchester, 1997. *C. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, fruits; Manchester, 2001.

Cladrastis oregonensis (leaflet), *C. sp.* (fruit), cf. *C.* (leaflet)- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR; Meyer & Manchester, 1997. *Cladrastis*-like leaves, middle Eocene, Claiborne Group, TN; Dilcher & Lott, 2005.

Crudia grahamiana (Caesalpinioideae, Detarieae)- middle Eocene, Claiborne Fm., TN, fruits, leaflets; Herendeen & Dilcher, 1990. *Crudia*- Eocene, Gatuncillo Fm., Panama, pollen, Graham, 1985; Miocene, La Boca Fm., Panama, pollen, Graham, 1989.

Dichrostachyoxylon herendeenii- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Diploptropis (Papilionoideae, Sophoreae)- middle Eocene, Claiborne Fm., TN, KY, fruits; Herendeen & Dilcher, 1990.

Dodonaeites descaisnei- Oligocene, Armissan, France, early Oligocene Tard Clay, Budapest, Hungary, fruit; Manchester & O'Leary, 2010: ["...almost identical in morphology to *Fissicalyx*" p. 67].

Dusia- "Basian phylogenetic dating techniques suggest that: 1) the uplift of the Andean Mountains created a biogeographical barrier to migration but also contributed to speciation; (2) migration between South America and Central America occurred before the closure of the Panamanian isthmus, indicating that for *Dusia* the Pacific Ocean was less of a barrier than the Andes; and (3) the biogeographic affinities of species from the Chocó biogeographical region are with Central America" (Winterton et al., p.389).

Eocaesalpinia herendeenii- middle Eocene, Lower Claiborne Group, Carroll Country, TX, flower; Dilcher et al., 2014.

Eomimosoidea plumosa (Mimosoideae)- Oligocene, Catahoula Fm., near Huntsville, eastern TX, inflorescence, fruit, pollen; Daghljan et al., 1980 (see also Crepet & Dilcher, 1977).

cf. *Euacacioxylon* sp.- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Gleditsia lottii- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaflets; Axelrod, 1998a.

Hoffmannseggia- Nores et al., 2012: “Simpson & al. (2005), using *Zuccagnia* and *Balsamocarpon* as outgroups in their phylogenetic analyses, hypothesized that *Hoffmannseggia* arose in South America and split into a suffrutescent (to shrubby) and an herbaceous clade. During diversification there were at least four independent exchanges between South and North America, potentially mediated by shore birds in the late Cenozoic (late Miocene to Pleistocene). ... the spread of *Hoffmannseggia* from South to North America agrees with Simpson & al.’s (2005) proposal. The split of *Stenodrepanum* and *Hoffmannseggia* from a common ancestor resulted in a tolerance of salinity that allowed survival or colonization of the former in this new niche” (p. 797).

Hymenaea allendis, *H. mexicana*- early Miocene, La Quinta Fm., Simojovel de Allende, Chiapas, Mexico, flowers; Calvillo-Canadell et al., 2010.

Inga eocenica- Eocene, La Carroza Fm., San José de la Popa, Nuevo Leon, Mexico, leaf, leaflets; Calvillo-Canadell et al., 2014.

Leguminocarpon sp.- middle Eocene (44 Ma), Clarno Fm., OR, fruit; Manchester, 1994.

Leguminosites sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, leaflets; Manchester,

2001.

Lonchocarpus- Da Silva et al. (2012): “Analysis of the molecular data reveals that (1) *Lonchocarpus* s. str. originated about 8.7 +/- 0.05 Ma ago in Central America, in contrast to *Dahlstedtia* and *Muelleria* that both arose in South America, 6.3 +/- 0.05 Ma and 8.0 +/- 0.09 Ma ago, respectively; (2) at least three migration events of *Lonchocarpus* have occurred from Central to South America, and one to Africa, the latter best explained by long distance dispersal across the Atlantic Ocean” (p. 93).

Micropodium ovatum- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, fruit; Meyer & Manchester, 1997.

cf. *Mimosoxylon*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Ormosia-like- middle Eocene, Claiborne Group, TN, leaves; Dilcher & Lott, 2005.

Pickeringia- Wojciechowski (2013): “These results, plus an estimated age of ~31 million years for the genus, further substantiate the hypothesis that *Pickeringia* is geographically isolated in the flora of western North America, an old and phylogenetically distinct lineage of an early diverging group of papilionoid legemes that were much more widely distributed throughout temperate North America and Asia during the Tertiary but whose modern relatives are restricted to southern North America, Central America, and eastern Asia. These findings have implications not only for the evolutionary history of *Pickeringia* but also for the age and development of chaparral vegetation in the California flora” (p. 132). [For related article on the Early Pleistocene history of a hyperdiverse sclerophyll flora in SE Australia, see Sniderman et al., 2013; for caesalipnioids in arid or saline areas of southern South America, see

Nores et al., 2012].

Protomimosoidea buchananensis (Mimosoideae, Tribe Mimoseae)- Paleocene-Eocene,

Wilcox Fm., Buchanan, TN, flowers with pollen; Crepet & Taylor, 1986.

Robinia californica- middle Miocene, Mint Canyon Fl. (preliminary study), so. CA;

Axelrod, 1940.

Swartzia sp.- middle Eocene, Claiborne Group, TN, leaves; Dilcher & Lott, 2005.

FAGACEAE- [re *Castanopsoidea*, *Paleojulacea*, and *Trigonobalanoidea* below, “The reproductive structures are the oldest megafossils unequivocally assignable to Fagaceae and represent the oldest remains of subfamily Fagoideae and the oldest megafossil remains of Castaneoideae” (Crepet & Nixon, 1989, p. 842); see also Crepet, 1989; Nixon & Crepet, 1989; Gandolfo, 1996; an earlier review of the Amentiferae (Fagaceae, Juglandaceae, Ulmaceae) is by Crepet, 1981].

Antiquacupula sulcata- Late Cretaceous (Santonian), Buffalo Creek Member, Gaillard

Fm., GA, staminate, bisexual flowers, fruits, cupules, pollen; Sims et al., 1998;

Herendeen et al., 1999. [Age revised from Campanian; p. 404].

Berryophyllum tenuifolia, *B.* sp.- middle Eocene, Claiborne Group, TN, leaves; Dilcher & Lott, 2005.

Cascadiacarpa spinosa- Eocene, Appian Way locality, Vancouver Is., British Columbia, Canada, cupulate fruit; Mindell et al., 2007: [“...the first occurrence of a bipartite gynoecium and the earliest known occurrence of hypogeous fruits in Fagaceae”, p. 351; “The fossil record for the family is extensive, going back to the later Cretaceous, where the family is represented by flowers with in situ Normapolles-type triaperturate pollen (Herendeen et al., 1995). During the Paleogene, fossil fruits and flowers appear that

can be easily accommodated in the diagnoses of extant genera. These include *Quercus* from Europe (Kvaček and Walther, 1989; Palamarev and Mai, 1998) and North America (Daghlian and Crepet, 1983; Manchester, 1994); *Trigonobalanus* from Europe (Kvaček and Walther, 1989); *Castanea* from Tennessee, USA (Crepet and Daghlian, 1980); and *Fagus* (Manchester and Dilhoff, 2004), *Lithocarpus* and *Castanopsis* (Manchester, 1994) from North America”, pp.351-352].

Castanea sp./type- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen, Leopold & Clay-Poole, 2001; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014.

Castaneophyllum sp.- middle Eocene, Klondike Mountain Fm., Republic, WA, leaves; Gandolfo, 1996.

Castanopsis crepetii- middle Eocene (44 Ma), Clarno Fm., OR, fruit; Manchester, 1994.
C. type- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Castanopsoidea columbiana- Paleocene/Eocene boundary, near Buchanan, western TN, pistillate inflorescences, fruits, pollen; Crepet & Nixon, 1989. *C. puryearensis*- middle Eocene, Claiborne Fm., Puryear, TN, inflorescences, pollen; Crepet & Daghlian, 1980: “The nature of these fossils is consistent with observations that several other families of the “Amentiferae” evolved rapidly during the Upper Cretaceous-Middle Eocene...” (p. 739).

Catahoulea grahamii- middle Eocene, Claiborne Fm., KY, TN and Oligocene, Catahoula Fm., Huntsville, TX, involucre containing nutlets; DeVore et al. (2014).

Chrysolepis (Castanopsis) lemhiensis- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves; Axelrod, 1998a.

Cupuliferoidaepollinites liblarensis (Castanea)- late Paleocene (~60 Ma), Sagwon Bluffs,

North Slope, Alaska, pollen; Daly et al., 2011.

Cupuliferoipollenites cingulum subsp. *fuscus (Castanea)*- late Paleocene (~60 Ma),

Sagwon Bluffs, North Slope Alaska, pollen; Daly et al., 2011.

Fagaceoxylon ostryopsoides- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Fagopsis undulata- middle Eocene, Klondike Mountain Fm., Republic, WA, leaf, fruit, Gandolfo, 1996; fruits, Wehr & Manchester, 1996. *F. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, inflorescences, fruits, pollen, Manchester, 2001; pollen (in situ), Leopold & Clay-Poole, 2001.

Fagus friedrichii, *F. gussonii*- Miocene, Selárdalur-Botn Fm. (15 Ma), Dufansdalur-Ketilseyri Fm. (13.5 Ma), Skarðströnd-Mókollsdalur Fm. (9-8 Ma), Iceland, leaves, cupules/nuts; Grímsson & Denk, 2005, 2007. *F. langevinii*- late early to middle Eocene (49-52 Ma), McAbee Fl. (leafy twigs, foliage, cupules, nuts, *Fagus* pollen), British Columbia, Canada, and Republic Fl., WA, fruits, foliage, pollen; Manchester & Dillhoff, 2004: ["...provide an earlier record for the genus *Fagus* than previously accepted for this member of the Fagaceae. Previously, the oldest *Fagus* occurrences confirmed by fruits were early Oligocene (ca. 32 Ma). The recognition of Middle Eocene (ca. 50 Ma) representatives helps reduce the disparity between molecular evidence favoring *Fagus* as a primitive genus within Fagaceae, and fossil evidence,

which had indicated older occurrences of *Castanea* and *Quercus* than *Fagus*” (p. 1509)]. *F. pacifica*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, fruit; Meyer & Manchester, 1997. *F. schofieldii*- middle Eocene, Oyster Bay Fm., Appian Way locality, Vancouver Is., British Columbia, Canada, fruits; Mindell et al., 2009: [“...represent the first permineralized Fagaceae of subfamily Fagoideae in the fossil record” and “provides the earliest evidence of winglessness in Fagoideae and supports the possibility of a North American origin for the genus” (p. 551). *Fagus washoensis*- late Miocene, Vasa Park Fl., King Co., WA, leaf; Dillhoff et al., 2014; *F.* sp.- late Eocene (36 Ma), lower John Day Fm., OR, nut, Manchester & McIntosh, 2007; latest Eocene (34.1 Ma), Florissant Fl., CO, pollen, Leopold & Clay-Poole, 2001; middle Eocene, Klondike Mountain Fm., Republic, WA, leaves; Gandolfo, 1996; late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997. *F.* and types- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014.

Faguspollenites sp. (*Fagus*)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

Knightiophyllum wilcoxianum- middle Eocene, Claiborne Group, TN, leaves; Dilcher & Lott, 2005.

Lithocarpus weidei- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves, fruits; Axelrod, 1998a. *L.* sp.- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaves; Axelrod, 1998.

Paleojulacea laxa- Paleocene/Eocene boundary, near Buchanan, western TN, catkins,

pollen; Crepet & Nixon, 1989.

Protofagacea allonensis- Late Cretaceous (Santonian), Buffalo Creek Member, Gaillard Fm., GA, flowers, fruits, cupules, pollen; Herendeen et al., 1995, 1999. [Age revised from Campanian].

Quercinium centenoae- Late Cretaceous (late Campanian-early Maastrichtian), Olmos Fm., Coahuila, Mexico, wood; Estrada-Ruiz et al., 2007. *Q. crystallifera*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Quercoidites (sp. 1, 2, 3 *Quercus*)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013

Quercus berryi, *Q. consimilis*, *Q. sp.*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaves, fruit; Meyer & Manchester, 1997. *Q. bilobata*, *Q. castormontis*, *Q. haynesii*, *Q. lemhiensis*, *Q. moyei*, *Q. predayana*, *Q. snookensis*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves; Axelrod, 1998a. *Q. catahoulaensis* (leaves), *Q. oligocenensis* (staminate catkins, pollen), *Q. huntsvillensis* (fruits)- Oligocene, Catahoula Fm., near Huntsville, TX; Daghljan & Crepet, 1983. *Q. pollardiana*, *Q. prelobata*, *Q. simulate*- late Miocene (Clarendonian, 12 Ma), Ironside Fm., OR, leaves; Retallack, 2004. *Q. deweyensis*- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaves; Axelrod, 1998. *Q. paleocarpa*- middle Eocene (44 Ma), Clarno Fm., OR, acorn; Manchester, 1994. *Q. convexa*, *Q. dispersa*, *Q. lakevillensis*- middle Miocene, Mint Canyon Fl., (preliminary study), so. CA; Axelrod, 1940. *Q. sp.*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, pollen, Dillhoff et al., 2005; latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, fruits, Manchester, 2001; pollen, Leopold & Clay-Poole, 2001; late Eocene (36 Ma), lower John Day Fm., OR, acorn, Manchester

& McIntosh, 2007; ?*Q.* sp.- middle Eocene, Klondike Mountain Fm., Republic, WA, leaf, Gandolfo, 1996; late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997. *Q.* and types- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005. Late Miocene, Vasa Park Fl., King Co., Wa, pollen, Dillhoff et al., 2014.

Sabinoxylon pasac (Fagaceae?)- Late Cretaceous (late Campanian-early Maastrichtian), Olmos Fm., Coahuila, Mexico, wood; Estrada-Ruiz et al., 2007.

Tricolporopollenites sp. 1 (*Castanea*)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

Trigonobalanoidea americana- Paleocene/Eocene boundary, near Buchanan, western TN, psilate infructescences, dispersed fruits; Crepet & Nixon, 1989.

FLACOURTIACEAE

Casearia- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves; Gayó et al., 2005.

Saxifragispermum tetragonalis- middle Eocene (44 Ma), Clarno Fm., OR, fruits; Manchester, 1994.

GENTIANACEAE- Lower Eocene, Wilcox Fm., northeastern TX; flowers with

Pistillipollenites macgregorii pollen; Crepet & Daghljan, 1981. Merckx et al. (p. 719): “... the current distribution patterns of Gentianaceae lineages in South America strongly suggest that the Guiana Highlands have played a prominent role in the early diversification of Gentianaceae” (p. 719); “... molecular and morphological analyses of Helieae suggest that at least a few of these Guiana Highland genera are early diverging lineages of the tribe (Struwe et al., 2009a [2009 in ref.]). Thus we speculate that Gentianaceae arose in the Guiana Shield during the Cretaceous, similar to what is

inferred for Bromeliaceae (Givnish et al., 2011) and Rapateaceae (Givnish et al., 2004; Jansen and Bremer, 2004)” p. 719.

Voyria- Merckx et al. (2013): “... originated in the neotropics during the Early Eocene but only reached its current transoceanic distribution around the end of the Oligocene. The neotropics were an important area for the early diversification events in Gentianaceae, most of which occurred during the Eocene” (p. 712). “... migration of tropical taxa through Laurasia during the Early Eocene has played an important role in shaping the current global distribution of Gentianaceae” (p. 712). “The estimates date the crown node of Gentianaceae between 47.3 and 69.1 Ma (T1) or 54 and 78.6 Ma (T2). The divergence of *Voyria primuolides* is estimated to have occurred between 12.2 and 26.5 Ma (T1) or 12.4 and 27.7 Ma (T2)” (p. 715). “Under all models (M0, M1, M2) and topologies (T1, T2) the neotropics are inferred to be part of the ancestral area of the common ancestor of Gentianaceae, either as the sole ancestral area or together with the paleotropics” (p. 715). See also Estimation of divergence times (p. 714, 715); Ancestral area reconstructions (p. 714, 715; Table 3); Trans-Atlantic distribution of *Voyria* (p. 715-717); Early diversification history of Gentianaceae (p. 717-719).

GESNERIACEAE- Perret et al. (2013): “Based on molecular dating and biogeographical reconstruction analyses, we suggest that ancestors of Gesneriaceae originated in South America during the Late Cretaceous. Distribution of Gesneriaceae in the Palaeotropics and Australasia was inferred as resulting from two independent long-distance dispersals during the Eocene and Oligocene, respectively” (p. 61). [see also Table 1, p. 65].

GROSSULARIACEAE

Ribes sp.- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage,

Dillhoff et al., 2005; middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaf, Axelrod, 1998; latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, Manchester, 2001; Oligocene (32.9- Ma), Pitch Pinnacle Fl., CO, leaves, Gregory & McIntosh, 1996; Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf, Meyer & Manchester, 1997.

GUNNERACEAE

Clavamonocolpites polygonalis- mid-early Paleocene, Antarctic Peninsula, pollen; Poole et al., 2005.

Gunnera (Tricolpites reticulatus)- Late Cretaceous (late Campanian-Maastrichtian), Vega Is., Antarctic Peninsula, pollen; Wanntorp et al., 2004: [...the genus has a well-documented and relatively unbroken fossil record from the Early Cretaceous to present]; “Almost as old as these fossils...attributable to *Gunnera* (Jarzen, 1980; Jarzen and Dettmann, 1989) are the Turonian (about 90 Ma) specimens from Peru (Brenner, 1968)” (p. 169)].

Tricolpites confessus- Late Cretaceous (late Maastrichtian, Antarctic Peninsula, pollen; Poole et al., 2005. *T. reticulatus*- lower middle Eocene, Antarctic Peninsula, pollen; Poole et al., 2005. *T. sp.*- mid-early Paleocene, Antarctic Peninsula, pollen; Poole et al., 2005. *T. waiparaensis*- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, pollen; Poole et al., 2005. [*Gunnera*].

HALORAGIDACEAE

Haloragacidites- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

Myriophyllum- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

HAMAMELIDACEAE- Benedict et al. (2008, pp. 687-688) review the fossil record of the family; for ‘higher’ Hamamelidae see Crane & Blackmore, 1989; Juglandaceae-Rhiopteleaceae-Myricaceae-Betulaceae see Sims et al., 1999; Normapollen pollen see Batten, 1989. Paleocene, Sentinel Butte Fm., Almont, ND, staminate inflorescences, infructescences; Crane et al., 1990. gen. et sp. indetermined (infructescence)- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR; Meyer & Manchester, 1997.

Allonia decandra- Late Cretaceous (late Santonian), Buffalo Creek Member, Gaillard Fm., Allon Fl., GA, flower, associated seeds; Herendeen et al., 1999.

Corylopsis reedae- Lower Eocene (49-50 Ma), Republic Fl., WA, leaf; Radtke et al., 2005: [“Today this genus occurs only in Asia, but the fossil record, primarily of seeds, indicates it was widely distributed in North America and Europe during the Tertiary” (p. 347)].

Fothergilla malloryi- Lower Eocene (49-50 Ma), Republic Fl., WA, leaf; Radtke et al., 2005: [“...oldest record for the genus, which is also known in the Oligocene of North America and several Neogene Asian localities” (p. 347)]. *F. praeovata*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997.

Fortunearites endressii- middle Eocene (44 Ma), Clarno Fm., OR, infructescence, fruits; Manchester, 1994.

Hamamelidoxylon uniseriatum- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Hamawilsonia boglei- Late Paleocene (Tiffanian 3), Sentinel Butte Fm., Almont Fl., ND, infrutescence, fruits, seeds, associated pollen catkins with in situ tricolpate pollen; Benedict et al., 2008: [”...an extinct Late Paleocene genus with a combination of

characters not seen in any extant hamamelid genus” (p. 687)]; Crane et al., 1990, Pigg & DeVore, 2010.

Langeria magnifica- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage, Dillhoff et al., 2005; middle Eocene Republic Fl., Wa, leaves [extinct genus established by Wolfe & Wehr, 1987 for large leaves with hooklike teeth. Steven Manchester questions whether these might be Platanaceae (pers. comm., to Kathleen Pigg); Pigg, pers. comm., 2011].

Parrotia brevipetiolata- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997.

Retitrescolpites anguloluminosus (aff. originally cited as with *Salix* fide Norton & Hall, 1969; now with Hamamelidaceae, e.g., *Corylopsis*, Zetter et al., 2011)- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011.

Retitrescolpites catenatus (“The pollen is known *in situ* from catkins associated with *Hamawilsonia* infructescences (Benedict et al., 2008). *Hamawilsonia* is an extinct genus known from anatomically preserved fruits, infructescences, and seeds that combines features of *Sinowilsonia*, *Hamamelis* and several other extant genera of Hamamelidaceae.” Zetter et al., 2011, pp. 196-197)- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011.

Subfamily Altingioideae- Late Cretaceous (late Santonian), Buffalo Creek Member, Gaillard Fm., Allon Fl., GA, inflorescences and pistillate flowers; Herendeen et al., 1999.

HAMAMELIDACEOUS/PLATANOID AFFINITIES- Late Cretaceous, Raritan Fm. (Turonian, ca. 88.5-90.4 Ma), NJ, staminate, pistillate inflorescences, detached

stamens, pollen; Crepet et al., 1992. Fragments of platanoid foliage- Lower Cretaceous (upper Albian), Potomac Group, VA; Upchurch et al., 1994. Subclass Rosidae and Hamamelididae- *Sapindopsis magnifolia/variabilis*, *S. minutifolia*, Lower Cretaceous (upper Albian), Potomac Group, VA, leaves; Upchurch et al., 1994.

HELIOTROPIACEAE (see also Boraginaceae)- “Timing of the diversification in the Andean lineages of *Heliotropium* sects. *Heliothamnus*, *Cochranea*, *Heliotropium*, *Hypsogenia*, *Plagiomeris*, *Platygyne* clearly correspond to a rapid, late Miocene uplift of the Andes and a Pliocene development of arid environments in South America” (Luebert et al., 2011).

HERNANDIACEAE

Illigera eocenica- middle Eocene, Clarno Fm., Jefferson Co., OR, Green River Fm., CO, UT, WY, Wagon Bed Fm., WY, fruits; Manchester & O’Leary, 2010. [As *Ptelea cassioides* in MacGinitie, 1969].

HIPPOCASTANACEAE (SAPINDACEAE)

Aesculus hickeyi- Paleocene, Fort Union Fm., ND, WY, leaves, fruits; Manchester, 2001: [“...traditionally placed...in the Hippocastanaceae...some phylogenetic evaluations place [it] as a clade within the Sapindaceae...” (p. 985)]. *Aesculus* sp.- Williston Basin, Almont Fl., ND, leaf, Manchester 2001, Pigg & DeVore, 2010; late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage, Dillhoff et al., 2005; Miocene (15-6 Ma), Iceland, Grimsson & Denk, 2007.

HUMIRIACEAE- Herrera et al., 2010: “A review of prior published reports of fossil fruits attributed to Humiriaceae led to the rejection and/or reattribution of some records but supports recognition of *Vantanea*, *Humiria*, *Humiriastrum*, and *Sacoglottis*. The

available characters do not support recognition of multiple fossil species of *Sacoglottis*. We recognize the occurrence of *Sacoglottis tertiaria* Berry emend. Herrera from Peru, Ecuador, Colombia, and a newly collected Miocene site from Panama. The Cenozoic fossil record of Humiriaceae in South and Central America, together with discreditation of former reports from Europe, strongly supports a Neotropical origin for this family” (p. 392). “In total, 15 reports of fossil endocarps and pollen are upheld as valid for Humiriaceae: *Vantanea* (Eocene and Miocene), *Sacoglottis* (Early Miocene and Late Pliocene), *Humiria* (Miocene and Pliocene), *Humiriastrum* (Miocene and Early Pliocene)” (p. 406).

cf. *Humariastrum*- middle Miocene, Pebas Fm., w. Amazon Basin, Iquitos, Peru, wood; Pons & de Franceschi, 2007.

Lacunofructus cuatrecasana- late Eocene, Tonosi Fl., Pacific coast central Panama, seed; Herrera et al., 2012.

HYDRANGEACEAE

Hydrangea bendirei- late Miocene, Vasa Park Fl., King Co., WA, leaf, Dillhoff et al., 2014; *H. knowltonii*- middle Eocene (44 Ma), Clarno Fm., OR, infructescence, seeds; Manchester, 1994. *H. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, calyxes, Manchester, 2001, Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, infructescence, calyx, Meyer & Manchester, 1997.

Philadelphus-like leaves- latest Eocene (34.1 Ma), Florissant Fl., CO; Manchester, 2001.

ICACINACEAE- Kvaček & Bůžek (1995) and Rankin et al. (2008, p. 305) review the fossil record of the family, and the biogeography is summarized by Manchester (1999).

Comicalabium atkinsii- middle Eocene (44 Ma), Clarno Fm., OR, endocarps, locule casts;

Manchester, 1994.

Croomiocarpon mississippiensis- early-middle Eocene (Claiborne Group), Tallahatta Fm., MS, fruit; Stull et al., 2011.

Icacinicarya collinsonae- late Paleocene, Almont Fl., ND, endocarp, Pigg et al., 2008; Pigg & DeVore, 2010. *P. dictyota*- late Paleocene, Beicegel Fl., ND, endocarp; Pigg et al., 2008.

Iodes multireticulata, *I. chandlerae*- middle Eocene (44 Ma), Clarno Fm., OR, endocarps, locule casts, seeds; Manchester, 1994. *I. sp.*- middle Eocene, Republic Fl., WA, fruit; Wehr & Manchester, 1996.

Iodicarpa ampla, *I. lenticularis*- middle Eocene (44 Ma), Clarno Fm., OR, fruits; Manchester, 1994.

Natsiatum wilcoxiana- Middle Eocene (Claiborne Group), Grenada and Cockfield Fms., TN, fruits; Stull et al., 2011.

Palaeophytocrene handcockii, *P. pseudopersica*- middle Eocene (44 Ma), Clarno Fm., OR, endocarps; Manchester, 1994. *P. hammenii*- middle-late Paleocene, Bogatá Fm., Cundinamarace, Colombia; Stull et al., 2012. *P. piggae*- late Paleocene, Sentinel Butte Fm., Almont, ND, endocarps, Stull et al., 2012. *P. vancouverensis*- Eocene, Oyster Bay Fm., Appian Way locality, Vancouver Is., British Columbia, Canada, endocarp; Rankin et al., 2008. *P. sp.*- Paleocene, Sentinel Butte Fm., Almont, ND, fruits, Crane et al., 1990, Pigg & DeVore, 2010. Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, endocarp, Meyer & Manchester, 1997.

Phytocrene densipunctata- middle Eocene (Claiborne Group), Cockfield Fm., TN, fruits; Stull et al., 2011.

Platea- Paleocene, Oak Hill Member, Naheola Fm., Alabama, pollen (*Favitricolporites baculiferus*); Lobreau-Callen & Srivastava, 1974.

Pyrenacantha austroamericana- late early Oligocene, Belén Fl., Peru, endocarps; Stull et al, 2012. *P. occidentalis*- middle Eocene (44 Ma), Clarno Fm., OR, endocarps; Manchester, 1994.

ILLICIACEAE

Illicioxylon- Late Cretaceous (Coniacian to Campanian), Late Cretaceous (late Maastrichtian), mid-early Paleocene, Antarctic Peninsula, wood, Poole et al., 2005.

JUGLANDACEAE- see Manos et al., 2007; an earlier review of the Amentiferae (Fagaceae, Juglandaceae, Ulmaceae) is by Crepet, 1981. See also Sims et al. (1999), fossil flowers with Normapolles pollen possibly of the ‘higher’ hamamelids- Juglandaceae, Rhiopteleaceae, Myricaceae, Betulaceae.

Alfaroa (*Oreomunnea/Engelhardia/Alfaroa* pollen (*Momipites*) undifferentiated- latest Eocene (34.1 Ma), Florissant Fl., CO, Leopold & Clay-Poole, 2001; see also Hansen et al., 2001.

Beardia vancouverensis- Eocene, Appian Way locality, Vancouver Is., British Columbia, Canada, fruits; Elliott et al., 2006.

Carya bendirei- late Miocene (Clarendonian, 12 Ma), Ironside Fm., OR, leaf; Retallack, 2004. *C. sp./type*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, Dillhoff et al., 2005; latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, leaflets, staminate inflorescences, fruits, Manchester, 2001, pollen, Leopold & Clay-Poole, 2001; late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997. *C. sp. 1* (leaflet), *C. sp. A* (fruit)- Oligocene (33.6-32.2 Ma), John Day

- Fm., OR, nuts, Manchester & McIntosh, 2007; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014. *Carya* type- late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005.
- Carya/Juglans*- middle Eocene, Republic Fl., WA, fruit; Wehr & Manchester, 1996.
- Caryapollenites imparalis*- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011. *C. sp.*- Miocene, Tepoztlán Fm., Mexico, pollen' Lenhardt et al., 2013.
- Casholdia*- (England and France; see *Polyptera*).
- Clarnoxylon blanchardii*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.
- Cruciptera simsonii*- middle Eocene (44 Ma), Clarno Fm., OR, samara; Manchester, 1994. *C. sp.*- middle Eocene, Republic Fl., WA, fruit, Wehr & Manchester, 1996; Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, fruit, Meyer & Manchester, 1997.
- Cyclocarya*- (see also *Polyptera*)- *C. brownii*- Paleocene, Sentinel Butte Fm., Almont, Beicegel Fls., ND, fruits, leaves, Crane et al., 1990, Manchester & Dilcher, 1982, Pigg & DeVore, 2010, Taylor 2007. *C. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001. cf. *Cyclocarya*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.
- Engelhardioxylon nutbedensis*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002. *Engelhardia/Alfaroa[/Oreomunnea]* pollen- latest Eocene (34.1 Ma), Florissant Fl., CO; Leopold & Clay-Poole, 2001. *E.*-type, late middle to early late

Miocene, Bryn Mawr Fm., MD, pollen; Pazzaglia et al., 1997.

Eoengelhardia puryearensis- middle Eocene, Claiborne Fm., TN, catkins, pollen; Crepet et al., 1980.

Eokachyra aeolius- middle Eocene, Claiborne Fm., Weakly County, TN, catkins, pollen; Crepet et al., 1975: [“Three different juglandaceous pollen types had already differentiated by the Upper Cretaceous (Nichols, 1973), and by the Middle Eocene the Juglandaceae are represented by a variety of fruit types (Berry, 1916; Scott, 1954; MacGinitie, 1969)”, p. 813].

Juglandicarya- (see *Polyptera*)

Juglandiphyllites cryptatus- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaflet; Meyer & Manchester, 1997.

Juglans clarnensis- middle Eocene (44 Ma), OR, fruit; Manchester, 1994. *J.*

wheelerensis- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaflet; Meyer & Manchester, 1997. *J. sp.*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, Dillhoff et al., 2005; latest Eocene (34.1 Ma), Florissant Fl., CO, pollen, Leopold & Clay-Poole, 2001; late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014.

Momipites annelus (“Grains of this type occur *in situ* within catkins that consistently co-occur with the extinct genus *Polyptera* (Manchester & Dilcher, 1982, 1997; Manchester, 1989”, Zetter et al., 2011). *M. triorbicularis*- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011. *M. sp.*- late Paleocene (~60 Ma),

Sagwon Bluffs, North Slope Alaska, pollen; Daly et al., 2011. Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012. *M. sp. (Engelhardtia)*- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

Oreopanax grahamii- early Miocene, Lower Cucaracha Fm., Gaillard Cut, Canal Zone, Panama, fruits, Herrera et al., 2014.

Palaeocarya cf. olsonii- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, fruit; Meyer & Manchester, 1997. *cf. Palaeocarya clarnensis*- middle Eocene (44 Ma), Clarno Fm., OR, nutlets, locule casts; Manchester, 1994 (probably *Engelhardtia*, Manchester, pers. comm., April, 2011).

Palaeoplatycarya? hickeyi- middle Eocene (44 Ma), Clarno Fm., OR, infructescences, locule casts; Manchester, 1994.

Platycarya sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001. *cf. Platycarya*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Polyptera manningii (Hicorieae, Juglandaeae)- Paleocene, Fort Union Fm., 56-64 Ma, WY, MT, infructescences, fruits, staminate catkins, leaves, pollen; Manchester & Dilcher, 1997: [“Occurrences in the Torrejonian and Tiffanian stages of the Paleocene place *Polyptera* as the oldest unequivocal record of Juglandaceae” p. 649; “Four genera are known based upon fruits from the Paleocene: *Cyclocarya* from Wyoming, Montana, and North Dakota (Manchester and Dilcher, 1982; Manchester, 1987, 1989), *Casholdia* from England and France (Crane and Manchester, 1982; Manchester, 1989), *Juglandicarya* (Brown, 1962; Manchester, 1987, 1989), and *Polyptera* (Manchester and Dilcher, 1982; Manchester, 1987, 1989) from Wyoming and Montana”, p. 649]; Pigg &

DeVore, 2010.

Pterocarya idahoensis- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaflet;
 Axelrod, 1998. *P. occidentalis*, *P. sp.*- Oligocene (33.6-32.2 Ma), John Day Fm.,
 Bridge Creek Fm., OR, leaflet, fruit; Meyer & Manchester, 1997. *P. sp.*- late early
 Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, Dillhoff et al., 2005; latest
 Eocene (34.1 Ma), Florissant Fl., CO, pollen, Leopold & Clay-Poole, 2001; Miocene
 (15-6 Ma), Iceland, Grimsson & Denk, 2007; late Miocene, Upper Beluga Fm., south
 coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl.,
 King Co., WA, pollen, Dillhoff et al., 2014.

LAMIACEAE/LAMIALES

Cruxifructus eocenicus (Verbenaceae/Lamiaceae)- late Eocene, Tonosi Fl., Pacific coast
 central Panama, fruit; Herrera et al., 2012.

Lepechinia- Drew & Sytsma (2011): “This preliminary sampling of *Lepechinia* (and
 other Salviinae) thus suggests the hypotheses that (1) the subtribe Salviinae originated
 in Eurasia, (2) *Lepechinia* s.l. first diversified in Mexico (or more broadly in Central
 America), (3) at least two movements out of Mexico and subsequent radiations in
 South America occurred, and (4) at least one radiation from Mexico to Mediterranean
 California occurred” (p. 1046). Drew & Sytsma (2013): “Divergence time estimation
 using BEAST shows *Lepechinia* had a mid/late Miocene origin, perhaps as a response
 to global cooling patterns. Cladogenesis in most South American *Lepechinia* is shown
 to have occurred within the past 5 Myr, presumably as a response to climatic and
 orogenic events” (p. 171).

Pogogyne- Silveira & Simpson (2013): ... “stem node is estimated...to have arisen an average of 5.1-7.7 million years ago, although with considerably wide confidence intervals. This date corresponds well with the *Pogogyne* stem node age of approximately 6 million years ago from the analyses of Drew and Sytsma (2012)...” (p. 793). ... “for that of the crown node is 0.9-1.9 million years ago...” (p. 782). “This compares with an estimated age of 0.6-4 million years before present for many vernal pool soils...dates are quite rough estimates...” (p. 793).

LAURACEAE- see Chanderbali et al., 2001; Rohwer, 1993; Little et al., 2009: [“The diverse fossil record of Lauraceae begins in the Cretaceous and includes flowers, fruits, leaves, and wood (Drinnan et al., 1990; Herendeen, 1991; Kvaček, 1992; Herendeen et al., 1994; Crane et al., 1994), Eklund and Kvaček, 1998; Mickle, 1996; Frumin et al., 2004). Fruits and cupulate structures commonly occur throughout the fossil record (Chandler, 1964; Mai, 1971, 1999, 2001; Manchester, 1994, Pingen et al., 1994; Eklund, 2000; Frumin et al., 2004), but few are known anatomically, with some exceptions (Drinnan et al., 1990; Eklund and Kvaček, 1998; Frumin et al., 2004)” p. 637].

Nishida and van der Werff (2011): “Cuticular characters...are often used in the taxonomy and classification of fossil or extant Lauraceae. However, there is no consensus on their usefulness, especially as to which characters take priority and at which taxonomic level. Because the number of character states is limited, cuticle features by themselves cannot be used to define genera or clades or will not allow the identification of specimens” (p. 348). The main obstacle is that genera like *Ocotea* and *Nectandra* (and probably the large Asian genera *Litsea* and *Lindera*) are not monophyletic. However, if

leaf fossils thought to be Lauraceous, and with preserved cuticles that can be studied microscopically by specialists familiar with both cuticle morphology and the systematics of the Lauraceae, it may be possible in some instances to refer the specimens to an extant genus. It would be interesting to assemble such specimens for examination (van der Werff, pers. comm., 2011).

Araliaphyllum polevoi- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

“*Artocarpus*” *lessigiana*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Bisonia niemii- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Cinnamomophyllum bendirei, *C. knowltonii*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaves; Meyer & Manchester, 1997.

Cinnamomoxylon oleiferum- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002. *C. sp.*- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves; Gayó et al., 2005.

Cissites insignis, *C. lobata*, *C. puilosokensis*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Cryptocaryoxylon hancockii, *C. meeksii*, *C. radiporosum*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

“*Ficus*” *planicostata*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Goepertia- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves; Gayó et al., 2005.

- Laurinoxylon stichkai*- late early Eocene (ca. 49 Ma), Bridger Fm., Big Sandy Reservoir, SW Wyoming, wood; Bouchai & Manchester, 2101.
- Laurocalyx wheelerae*- middle Eocene (44 Ma), Clarno Fm., OR, fruit; Manchester, 1994.
- Laurocarpum hancockii*, *L. nutbedensis*, *L. raisinoides*- middle Eocene (44 Ma), Clarno Fm., OR, fruits; Manchester, 1994.
- Laurophyllum* sp. 1 (“*Laurus*”)- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007.
- Lindera clarnensis*- middle Eocene (44 Ma), Clarno Fm., OR, endocarps, seeds, cotyledons; Manchester, 1994.
- Litseaephyllum presanguinea*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997.
- Marmarthia pearsonii*, *M. trivialis*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflores; Johnson, 2002.
- Mauldinia* sp.- Late Cretaceous (late Santonian), Buffalo Creek Member, Gaillard Fm., Allon Fl., GA, inflorescence units, flowers; Herendeen et al., 1999.
- Mezilaurinoxylon eiporosum*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.
- Nectandra*- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves; Gayó et al., 2005.
- Notophoebe*- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves; Gayó et al., 2005.
- Ocotea obtusifolia*- Eocene, TN, leaves; Dilcher, 1963. *O.* sp.- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves, Gayó et al., 2005; middle Eocene, Claiborne Group, TN, leaves, Dilcher & Lott, 2005.
- Paraperseoxylon scalariforme*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler

& Manchester, 2002.

Paraphyllanthoxylon marylandense- mid-Cretaceous (Cenomanian), Potomac Group, wood; Herendeen, 1991: [“...established by Bailey (1924) for angiosperm wood from the Upper Cretaceous of Arizona...Subsequently, numerous *Paraphyllanthoxylon* species have been described from Cretaceous and Tertiary sediments in North America, Europe, South Africa, India, and Japan (Spackman, 1948; Mädler, 1962; Cahoon, 1972; Thayne et al., 1983; Thayne and Tidwell, 1984; Prakash et al., 1986; Wheeler et al., 1987; Wheeler, 1991”, p. 277].

Persea pseudocarolinensis- late Miocene, Vasa Park Fl., King Co., WA, leaf, Dillhoff et al., 2014; *P.* sp- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves; Gayó et al., 2005.

Perseanthus crossmanensis- Late Cretaceous (Turonian), Raritan Fm., NJ, flowers, pollen; Herendeen et al., 1994.

Phoebe- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves; Gayó et al., 2005.

Sassafras ashleyi- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves; Axelrod, 1998a.

S. ferrettianum- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. *S. hesperia*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage; Dillhoff et al., 2005.

Sassafrasoxylon- Late Cretaceous (Coniacian to Campanian), Late Cretaceous (late Maastrichtian), Antarctic Peninsula, wood; Poole et al., 2005.

Ulmium magnioleiferum- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

LAURALES

Dicotylophyllum ovato-decurrrens- Lower Cretaceous (upper Albian), Potomac Group, VA, leaves; Upchurch et al., 1994.

Landonia cf. *L. calophylla*- Lower Cretaceous (upper Albian), Potomac Group, VA, leaf fragment; Upchurch et al., 1994.

aff. *Pabiania* sp. 1- Lower Cretaceous (upper Albian), Potomac Group, VA, leaves; Upchurch et al., 1994.

LECYTHIDACEAE

cf. *Cariniana*- middle Miocene, Pebas Fm., w. Amazon Basin, Iquitos, Peru, wood; Pons & de Franceschi, 2007.

cf. *Echweilera*- middle Miocene, Pebas Fm., w. Amazon Basin, Iquitos, Peru, wood; Pons & de Franceschi, 2007.

LEMNACEAE

Limnobiophyllum scutatatum- Paleocene, Paskapoo Fm., near Red Deer, Alberta Canada, leaves, stolons, roots, staminate flowers, pollen; Stockey, Hoffman, & Rothwell (1997): ["Results of the [cladistic] analysis indicate that the Lemnaceae plus *Pistia* form a monophyletic group within the Araceae" (p. 355)]; Pigg & DeVore, 2010.

LILIACEAE [pollen attributed to the Liliaceae, Vasa Park Fl., King Co. WA, late Miocene; Dillhoff et al., 2014]

Liliacidites- Late Cretaceous (late Maastrichtian), lower middle Eocene, Antarctic Peninsula, pollen, Poole et al., 2005. *L. kaitangataensis*, *L. variegates*, *L. sp.*- mid-early Paleocene, Antarctic Peninsula, pollen; Poole et al., 2005.

Monocolpopollenites sp.- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

LIMNOCHARITACEAE

Cardstonia tolmanii- Upper Cretaceous (Campanian-Maastrichtian), St. Mary Fm., Alberta, Canada, leaves; Riley & Stockey, 2004.

LOGANIACEAE

Rhoipites mimusculus- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

LORANTHACEAE [see also *Azolla*, Bowman et al., 2014]

Arceuthobium- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Cranwellia striata- Late Cretaceous (Coniacian to Campanian), Antarctic Peninsula, pollen; Poole, 2005.

LYTHRACEAE (Graham & Graham, 1971; S. Graham, 2013).

Adenaria- Pliocene, Colombia, seeds (S. Graham, 2013, p. 53).

Antholithus heimiaformis- Miocene, Yumuri Gorge Fl., Cuba, flower; Berry, 1939; rejected as a flower of *Heimia*, relationship unknown, S. A. Graham, 2013, p. 72.

Crenea (Verrutricolporites)- see S. Graham, 2013, pp. 55-57.

Cuphea (see S. Graham, 2013, pp. 57-59)- Miocene part of Mio-Pliocene Citronelle Fm., AL, pollen, Leopold, unpublished, in Graham & Graham, 1971, p. 335; Miocene, Pichucalco Fl., Chiapas, Mexico, pollen, Palacios Chavez & Rzedowski, 1993; middle Pliocene, Paraje Solo Fm., Veracruz, Mexico, pollen, Graham, 1976.

Decodon tiffneyi- Late Cretaceous (late Campanian), Cerro del Pueblo Fm., Coahuila, Mexico, seed; Estrada-Ruiz et al., 2009; *D. allenbyensis*, middle Eocene, Allenby Fm., Princeton Chert Fl., British Columbia, Canada, roots, stems, leaves, fruits, seeds;

Cevallos-Ferriz & Stockey, 1988; Little & Stockey, 2003, 2006. *D. brownii*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997. *D. sp.*- middle Eocene (44 Ma), Clarno Fm., OR, fruits; Manchester, 1994. See also S. Graham, 2013, pp. 59-63.

Duabanga allenbyensis- middle Eocene, Allenby Fm., Princeton Chert Fl., British Columbia, Canada, leaf; Little et al., 2004.

Hemitrapa- see S. Graham, 2013, p. 72.

Lafoensia- Quaternary, Panama, pollen; Bartlett & Barghoorn, 1973. Pleistocene-Holocene, Brazil, pollen, Barberi et al., 2000. See also S. Graham, 2013, p. 72.

Lawsonia-like, middle Eocene, Allenby Fm., Princeton Chert Fl., British Columbia, Canada, seed; Cevallos-Ferriz & Stockey, 1988; relationship to *Lawsonia* unconfirmed. See also S. Graham, 2013, pp. 75-76.

Lythrum elkensis- Late Cretaceous (Lower Campanian), Eagle Fm., Montana Group, WY, pollen, Grímsson et al., 2011; “This is the earliest record of *Lythrum* worldwide” (p. 1803); also reports pollen of *L. wilhelmii* from the late Miocene (upper Pannonian, ca. 9.5 Ma), Austria. See S. Graham, 2013, pp. 76-78.

Microdiptera- see S. graham, 2013, pp.78-79

Peplis eaglensis- Late Cretaceous (Lower Campanian; 82-81 Ma), Montana Group, Eagle Fm., WY, pollen, Grímsson et al., 2011: “This is the earliest record of *Pemphis* worldwide” (p. 1809); also reports pollen of *P. yakuitana* from the Late Cretaceous (Upper Campanian/lower Maastrichtian; 72-68 Ma), Siberia, Russia. See also S. Graham, 2013, p. 81.

Quereuxia- See S. Graham, 2013, p. 84.

Shirleya (...”an extinct member of the Lythraceae and closely related in the family to modern *Lagerstroemia*; S. Graham, 2013, p. 88). Middle Miocene, Yakima Canyon Fl., WA, fruits and seeds; Pigg & DeVore, 2005; Pigg & Wehr, 2002.

Striasyncolpites zwaardii (pollen form-genus of *Cuphea*), middle Miocene to Recent, Trinidad, Germeraad et al., 1968; Miocene to Pliocene, northeastern Brazilian continental shelf, Pares Regali et al., 1974.

Trapa americana- late Miocene (Clarendonian, 12 Ma), Ironside Fm., OR; Retallack, 2004. cf. *Trapa*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005. See also S. Graham, 2013, pp. 92-103.

Tripartisemen bonesii- see S. Graham, 2013, p. 103.

MAGNOLIACEAE [late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014].

Liriodendron (four-lobed *Liriodendron*)- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002. *L. sp.*- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007.

Liriodendrites bradacii- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Liriodendroxylon multiporosum- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Magnolia muldoonae, *M. paroblunga*, *M. tiffneyi*- middle Eocene (44 Ma), Clarno Fm., OR, infructescence, seeds; Manchester, 1994. *M. pageae*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002. *Magnolia sp.*- late Eocene (36 Ma), lower John Day Fm., OR, seeds casts, Manchester & McIntosh, 2007; Miocene

(15-6 Ma), Iceland, Grimsson & Denk, 2007.

Magnoliaceoxylon angulata, *M. cutleri*, *M. longiradiata*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

MAGNOLIIDAE- see Crepet & Nixon, 1994, Turonian *Magnoliidae*.

Araripia florifera (cf. Laurales)- Lower Cretaceous (Aptian, possibly Albian; now late Aptian), Crato Fm., Brazil, axes, attached leaves, flower buds; Mohr & Eklund, 2003.

Archaeanthus linnenbergeri- Middle Cretaceous (uppermost Albian- mid-Cenomanian), Dakota Fm., KS, fruit linked with perianth parts (*Archaeopetala beekeri*, *A. obscura*), bud scales (*Kalymmanthus walkeri*), and leaves (*Liriophyllum kansense*, *L. populoides*); Dilcher & Crane, 1984.

cf. *Detrusandra* (Magnoliales)- Late Cretaceous (late Santonian), Buffalo Creek Member, Gaillard Fm., Allon Fl., GA., flowers; Herendeen et al., 1999.

Endressinia brasiliiana- Lower Cretaceous (late Aptian), Crato Fm., Brazil, axes, leaves, flowers; Mohr & Bernardes-de-Oliveira, 2004.

Lesqueria elocata- Middle Cretaceous (uppermost Albian- mid-Cenomanian), Dakota Fm., KS, and Woodbine Fm., northeastern TX, fruiting axis; Crane & Dilcher, 1984.

MALVACEAE

Carvalho, et al. (2011): “We describe fossil leaves of Malvoideae from the middle-late Paleocene Cerrejón Formation in Colombia, which contains evidence for the earliest known neotropical rainforest. Fossil pollen from the same formation was also assessed. The [56] leaf compressions, the oldest for Eumalvoideae, indicate a minimum divergence time of 58-60 Ma, older than existing estimates from molecular analyses of living species. The abundance of eumalvoid leaves and of bombacoid pollen in the middle

Paleocene of Colombia suggests that the Malvatheca group (Malvoideae + Bombacoideae) was already a common element in neotropical forests and does not support an Australasian origin for Eumalvoideae” (p. 1337).

Baumannipollis- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

Chattawayia paliforme- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002: [“Manchester (1980) found the closest resemblance to some species of the extant *Pterospermum*, although the characteristic winged seeds of that modern genus have not been found as fossils” p. 91].

Craigia- Eocene, TN, fruit; Manchester & O’Leary, 2010: [“...widespread in the Tertiary of the Northern Hemisphere...traced back to the Eocene in eastern Asia and western North America (Kvaček, 2005)”]; reexamined type of *Ptelea eocenica* (Berry, 1930)...similar to fruits of extant *Craigia* and *Maxwellia* (p. 73)].

Florissantia quilchenensis- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, flowers, Dillhoff et al., 2005; middle Eocene, Republic Fl., WA, Manchester, 1992.

Fremontia (*Fremontodendron*)- see Sterculiaceae.

Gossypium- Patterson et al., 2012: “Here we show that an abrupt five- to sixfold ploidy increase approximately 60 million years (Myr) ago, and allopolyploidy reuniting divergent *Gossypium* genomes approximately 1-2 Myr ago, conferred about 30-36-fold duplication of ancestral angiosperm (flowering plant) genes in elite cottons (*Gossypium barbadense*), genetic complexity equaled only by *Brassica* among sequenced angiosperms.” “A-genome diploids native to Africa and Mexican D-genome diploids diverged ~5-10 Myr ago. They were reunited ~1-2 Myr ago by trans-oceanic dispersal

of a maternal A-genome propagule resembling *G. herbaceum* to the New World, hybridization with a native D-genome species resembling *G. raimondii*, and chromosome doubling. The nascent A_tD_t allopolyploid spread throughout the American tropics and subtropics, diverging into at least five species; two of these species (*G. hirsutum* and *G. barbadense*) were independently domesticated to spawn one of the world's largest industries (textiles) and become a major oilseed." "Shortly after its divergence from an ancestor shared with *Theobroma cacao* at least 60 Myr, the cotton lineage experienced an abrupt five- to sixfold polyploidy increase" (p, 423). *G.* sp.- late Miocene, Vasa Park Fl., King Co., WA., leaf, Dillhoff et al., 2014.

Javelinoxylon multiporosum- Late Cretaceous, Javelin Fm., Big Bend National Park, TX, wood; Wheeler et al., 1994. *J. weberi*- Late Cretaceous (late Campanian-early Maastrichtian), Olmos Fm., Coahuila, Mexico, wood; Estrada-Ruiz et al., 2007.

Malvaceous pollen- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

Malvacipollis argentina- Cullen Fm., late Eocene to middle Oligocene, NE Isla Grande de Tierra del Fuego, Argentina, pollen; Zamaloa & Romero et al., 1990.

Palaeoaster cordatum- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflores; Johnson, 2002

Triplochitioxylon oregonensis- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

MELASTOMATACEAE- Renner et al., 2001: "Based on fossils, ranges of closest relatives, tree topology, and calibrated molecular divergences, Melastomataceae initially diversified in Paleocene/Eocene times in tropical forest north of the Tethys.

Their earliest (Eocene) fossils are from northeastern North America, and during the Oligocene and Miocene melastomes occurred in North America as well as throughout Eurasia. They also entered South America, with earliest (Oligocene) South American fossils representing Merianieae. One clade (Melastomeae) reached Africa from the neotropics 14-12 million years ago and from there spread to Madagascar, India, and Indochina” (p. 1290). “Earliest fossils are Eocene leaves from northwestern North America (Hickey, 1977; Wehr and Hopkins, 1994), an Oligocene leaf from Andean Colombia (Huertas, 1977), and Miocene seeds from throughout Eurasia (Dorofeev, 1960, 1963, 1988; Collinson and Pinggen, 1992; Dyjor et al., 1992; Fairon-Demaret, 1994; Mai, 1995, 2000). Pollen records are much younger” (p. 1291; but see Graham, 2010, p. 497-498; Morley & Dick, 2003).

Melastomeae- Michelangeli et al. (2013): “The clade formed by *Tibouchina* and allies appears to have arisen in savannas in lowland South America and later expanded to forest, campo, and high Andean biomes” (p. 38).

Miconia- late Pliocene-Quaternary (ca. 2.7 Ma), High Plain Bogotá, Colombia, pollen; Hooghiemstra, 1995.

Rhexia- Renner & Meyer, 2001: “Age estimates obtained were 22 million years ago (Myr) for the divergence of *Rhexia* from its sister group, 12 Myr for the dispersal of Melastomeae from the New World to West Africa, and 1 Myr for the diversification of *Melastoma* in Southeast Asia” (p. 1315).

MELIACEAE- Muellner et al. (2006, p. 241): “The fossils of *Ailanthus confucii* [Simaroubaceae, outgroup] have been dated to be 52 million years (my) old (Early Eocene; Corbett and Manchester, 2004)...*Toona* [Meliaceae], from the London clay,

which also dates to the Early Eocene and therefore is of at least 49 my of age (DeVore et al., 2005; Reid and Chandler, 1933).”

Aglaiia- Mio/Pliocene, India (K. B. Pigg, personal communication, 2005 to Muellner et al., 2006).

Carapoxylon- middle Miocene, Bavaria (Selmeier, 1983).

Cedrela merrillii- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf, seed; Meyer & Manchester, 1997. *C. sp.*- Muellner et al., 2006, pp. 242-243: early Eocene, Chalk Bluffs Fl., western central Sierra Nevada, CA, Leopold, 1984, MacGinitie, 1941, in Millar, 1996); Middle Eocene, Kisinger Lake, Fremont, WY (MacGinitie, 1974); Late Eocene, Florissant Fl., CO (MacGinitie, 1953, Manchester, 2001, Meyer, 2003); late Eocene (36 Ma), lower John Day Fm., OR, fruits, Manchester & McIntosh, 2007; Eocene, Wind River, WY (MacGinitie, 1974); Eocene, Kamchatka, USSR (K. B. Pigg, personal communication, 2005 to Muellner et al., 2006); Late Oligocene, Grays Ranch, Crook, OR (Meyer & Manchester, 1997); Oligocene, MT (Becker, 1961; 1962- lists *Cedrela*); middle Miocene, Tehachapi Fl., Sierra Nevada, CA (Axelrod 1939; Chaney, 1944); middle and late Miocene, OR, ID (Chaney & Axelrod, 1959), NV (Axelrod, 1985, 1991); late Miocene (now middle Pliocene), Paraje Solo Fm., Veracruz, Mexico, pollen, Graham, 1976; Miocene, Hungary (Mai, 1995); early Miocene La Quinta Fm., Chiapas, Mexico, pollen, Graham, 1999; Miocene, Gatun Fm., central Panama, pollen, Graham, 1991. cf. *C.*- Pliocene, Amazonas Fm., w. Amazon Basin, Iquitos, Peru, wood; Pons & de Franceschi, 2007. *Cedrela* or *Toona* seeds- latest Eocene (34.1 Ma), Florissant Fl., CO; Manchester, 2001. *Chisochetonoxylon*- Miocene, Birbhum District, West Bengal, India (Ghosh & Roy,

1979).

Entandrophragma- Miocene, Kenya, Chesters, 1957 in Mabberley et al., 1995.

Guarea ceratops, Late Cretaceous, Lance and Hell Creek Fms., WY, fruits; Graham, 1962. *G. sp.*- Oligocene, San Sebastiaian Fm., Puerto Rico, pollen, Graham & Jarzen, 1969; early Miocene, La Quinta Fm., Chiapas, Mexico, pollen, Graham, 1999; middle Miocene, Pebas Fm., w. Amazon Basin, Iquitos, Peru, wood, Pons & De Franceschi, 2007; middle Pliocene, Paraje Solo Fm., Veracruz, Mexico, pollen, Graham, 1976; Quaternary, High Plain, Bogotá, Colombia, pollen, Hooghiemstra, 1984.

Melia- lower Miocene, Poland (K. B. Pigg, pers. comm., 2005 to Muellner et al., 2006); middle Miocene, Yakima Canyon Fl., WA, (K. B. Pigg, pers. comm., 2005 to Muellner et al., 2006). *M. yakimaensis*- middle Miocene, Columbia River Basalt Group, central Washington state, U.S.A., fruits; Pigg et al., 2014.

Meliaceoidites- late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005.

Toona (Muellner et al., 2006, p. 243): early Eocene, London Clay, England (Collinson, 1983; Reid & Chandler, 1933), recently re-investigated by noninvasive CT-scanning technique (DeVore et al., 2005); middle Eocene, AK, (K. B. Pigg, pers. comm., 2005 to Muellner et al., 2006).

Trichilia- lower Miocene, Cameroon; Salard-Cheboldaeff, 1978.

MELIOSMACEAE (see SABIACEAE)

MENISPERMACEAE- Doria et al., 2008: “The oldest record identified with some confidence is an endocarp from the Turonian (Upper Cretaceous, 91 Ma) of central Europe (Knobloch and Mai, 1984, 1986), but fossil leaves found in North America

(Fontaine, 1889; Berry, 1916; Hollick, 1927; Seward, 1927; Hollick and Martin, 1930; Bell, 1956; Doyle and Hickey, 1976) and Asia (Takhtajan, 1974; Spicer et al., 2002) suggest that the family can be traced to the Early Cretaceous. Fossil pollen has been widely reported since the Early Cretaceous in many different geographic areas (Table 3). The tropical fossil record of Menispermaceae is very sparse and consists of endocarps (Chesters, 1957) and leaves (Jacobs and Kabuye, 1987) from the Miocene of Kenya, leaves from the Eocene of Borneo (Andrews, 1970) [supplements by Blazer, 1975, and Watt, 1982], and pollen from the Miocene of Tunisia (Méon and Tayech, 1986) and Taiwan (Huang, 1980; Song et al., 2004) and Pleistocene of Ethiopia (Bonnefille et al., 1987). In South America the fossil record of the family is reduced to fossil leaves from the Paleocene of Argentina (Iglesias et al., 2007) and the Eocene (De Lima and Salard-Cheboldaeff, 1981) and Pliocene of Brazil (Dolianiti, 1949; Mello et al., 2000), one liana fossil wood probably related to Ranunculales from the Miocene of Argentina (Lutz and Martínez, 2007), and fossil pollen from the Oligocene to Recent of British Guiana (van der Hammen and Wijmstra, 1964) and the Miocene of Suriname (Amstelveen, 1971)” (pp. 955-956). Late Eocene (36 Ma), John Day Fm., OR, fruits; Manchester & McIntosh, 2007. Wefferling et al., (2013): “...menispermaceous endocarps appear often in the fossil record and indicate the presence of a wet forest ecosystem” (p. 883); Two recent studies explored divergence time estimates incorporating fossil data and biogeographic patterns (Jacques et al, 2011; Wang et al., 2012) (p. 883); see also pp. 883-884, 901 (Fossil record and biogeography- The discovery of northern South American Paleocene fossil pushes back the crown age of the *SPACC* clade as presented in Wang et al. (2012) by 6-7 million years to ~60 Ma (Herrera et al.,

2011) and raises the possibility of a Gondwanan center of diversification for at least some Menispermoidae” (p. 901). For a summary of the global fossil record of the family taking into account the unconfirmed nature of many older identifications see Jacques (2009, especially table 2 and fig. 1).

Anamirta leiocarpa- middle Eocene (44 Ma), Clarno Fm., OR, fruit; Manchester, 1994.

Atriaecarpum clarnense- middle Eocene (44 Ma), Clarno Fm., OR, endocarps; Manchester, 1994.

Calyccarpum crassicrustae- middle Eocene (44 Ma), Clarno Fm., OR, endocarps, locule casts; Manchester, 1994. *C. sp.*- middle Eocene, Republic Fl., WA, fruit; Wehr & Manchester, 1996.

cf. *Canticocculus*- Paleocene, Sentinel Butte Fm., Almont, ND, fruits; Crane et al., 1990, 2007, Pigg & DeVore, 2010.

Chandlera lacunosa- middle Eocene (44 Ma), Clarno Fm., OR, endocarps; Manchester, 1994.

Curvitinospora formanii- middle Eocene (44 Ma), Clarno Fm., OR, locule cast; Manchester, 1994.

Daviscarpum limacioides- middle Eocene (44 Ma), Clarno Fm., OR, endocarp; Manchester, 1994.

Diploclisia auriformis- middle Eocene (44 Ma), Clarno Fm., OR, fruit, locule casts; Manchester, 1994.

Eohypserpa scottii- middle Eocene (44 Ma), Clarno Fm., OR, locule casts; Manchester, 1994.

Menispermites cerrejonensis, *M. cordatus*, *M. guajiraensis*, *M. horizontalis*- middle to

- Late Paleocene, Cerrejón Fm., Guajira, Colombia, leaves; Doria et al., 2008.
- cf. *Menispermum*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, endocarp; Meyer & Manchester, 1997.
- Menispina evidens*- middle to late Paleocene, Bogatá Fm., Colombia, endocarps; Herrera et al., 2011.
- Odontocaryoidea nodulosa*- middle Eocene (44 Ma), Clarno Fm., OR, endocarps, locule casts; Manchester, 1994.
- Palaeoluna bogotensis*- middle to late Paleocene, Bogatá Fm., Colombia, endocarps; Herrera et al., 2011.
- Palaeosinnomenium venablesii*- middle Eocene (44 Ma), Clarno Fm., OR, endocarps, locule casts; Manchester 1994.
- Stephania palaeosudamericana*- middle to late Paleocene, Cerrejón Fm., Colombia, endocarps; Herrera et al., 2011.
- Thanikaimonia geniculata*- middle Eocene (44 Ma), Clarno Fm., OR, locule cast; Manchester, 1994.
- cf. *Tinomiscium* sp.- late Paleocene, Almont Fl., ND, fruit; Pigg & DeVore, 2010 (pers. comm. from Manchester).
- Tinomiscoidea occidentalis*- middle Eocene (44 Ma), Clarno Fm., OR, locule casts; Manchester, 1994.
- Tinospora elongata*, *T. hardmanae*- middle Eocene (44 Ma), OR, locule casts, endocarps; Manchester, 1994.
- MONIMIACEAE [asee also *Azolla*, Bowman et al., 2014]
- Hedycaryoxylon tambourissoides*- Late Cretaceous (Coniacian to Campanian), Antarctic

Peninsula, wood, pollen; Poole et al., 2005.

MONOCOTYLEDONS- (Mohr & Rydin, 2002, pp. 335-336; includes review of fossil monocotyledons): “The oldest flowering organs containing *in situ* pollen which can be putatively placed in the monocots, possibly with affinities to the Alismatales, were described from the Barremian to Aptian of Portugal (Friis et al., 2000). The North American fossils from the Aptian of the Potomac Group, such as *Acaciaephyllum* are considered to be ambiguous (Gandolfo et al., 2000). But seeds which resemble *Epipremnum* (Araceae or Alismatales) are known from the Albian of North America (Herendeen & Crane 1995), Unequivocal flowers of monocots are from the Turonian (Gandolfo et al., 1998) of North America (New Jersey). Cretaceous leaves, *Zingiberopsis*, which are considered to belong to the Zingiberaceae, are from the ...Maastrichtian of Colorado (Hickey & Peterson, 1978). Seeds of the extinct genus *Spirematospermum* (Musaceae) have been recovered from...the Campanian of North America (Friis, 1988).” Mohr & Rydin (2002) includes a general review of fossil monocotyledons; see also Stockey (2006).

Trifurcatia flabellata (monocotyledon)- Lower Cretaceous, Crato Fm., northeast Brazil, shoot fragments with leaves; Mohr & Rydin, 2002.

MORACEAE

Ficus-like- middle Eocene, Claiborne Group, TN, leaves; Dilcher & Lott, 2005.

Morus-type pollen- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

Pseudolmedia sp.- middle Eocene, Claiborne Group, TN, leaves; Dilcher & Lott, 2005.

MUSACEAE [see discussion in Graham, 2010, p. 387 re *Musa/Ensete*].

Ensete oregonense- middle Eocene (44 Ma), Clarno Fm., OR, seeds; Manchester, 1994.

E. sp.- middle Eocene, Republic Fl., WA, fruits with seeds; Wehr & Manchester, 1996.

Musopsis/Musophyllum- late Paleocene/early Eocene, Greenland, leaf; Boyd, 1992.

MYRICACEAE- see Sims et al. (1999), 'higher' hamamelids (Juglandaceae, Rhiopteleaceae, Myricaceae, Betulaceae).

Comptonia columbiana- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage, Dillhoff et al., 2005; middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaves, Axelrod, 1998; middle Eocene, Republic Fl., WA, leaves, Wolfe and Wehr, 1987; Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf, Meyer & Manchester, 1997. *C. hesperia*- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007.

Myrica sp.- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Striatricolporites- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

Triatropollenites subtriangulus (Myrica)- late Paleocene (~60 Ma), Sagwon Bluffs, North Slope Alaska, pollen; Daly et al., 2011.

MYRTACEAE- Sytsma et al., 2004: "the results indicate that the PHMV [Psiloxylaceae, Heteropyxidaceae, Myrtaceae, Vochysiaceae] differentiated during the late Cretaceous. The African lineage of Vochysiaceae is nested within a South American clade and probably arose via long-distance dispersal in the Oligocene at a time when the Atlantic had already rifted 80 m.yr. at the equatorial region. The African/Mascarene Island families, most closely related to Myrtaceae, differentiated during the late Eocene, with subsequent but recent long-distance dispersal from Africa

to the Mascarenes” (p. 585).

Amomyrtus meli- last interglacial (MIS 5e- called Valdivia in southern Chile), Mancera interglacial sequence, Mancera Island, Chile, leaves; Astorga & Pino, 2011.

Eucalyptus sp.- early Eocene (ca. 51.9 Ma), Laguna de Hunco Fl., Chubut Province, Argentina, leaves, infructescences, capsules, flower buds, single flower; Gandolfo et al., 2011: “These are the only illustrated *Eucalyptus* fossils that are definitely Eocene in age, and the only conclusively identified extant or fossil eucalypts naturally occurring outside of Australasia and adjacent Mindanao. Paleoecological data indicate that the Patagonian *Eucalyptus* dominated volcanically disturbed areas adjacent to standing rainforest surrounding an Eocene caldera lake”.

Eugenia[*Myrcia*]- late Pliocene-Quaternary (ca. 2.7 Ma), High Plain Bogotá, Colombia, pollen; Hooghiemstra, 1995.

Fulleroxylon armendarisense- Late Cretaceous (Maastrichtian), McRae Fm., NM, wood; Estrada-Ruiz et al., 2012.

Luma apiculata- last interglacial (MIS 5e- called Valdivia in southern Chile), Mancera interglacial sequence, Mancera Island, Chile, leaves; Astorga & Pino, 2011.

Myceugenelloxylon antarcticus- Late Cretaceous (late Maastrichtian), mid-early Paleocene, middle Eocene, Antarctic Peninsula, wood, Poole et al., 2005.

Myrceugenia- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves; Gayó et al., 2005.

Myrcia- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves, Gayó et al., 2005; middle Eocene, Claiborne Group, TN, leaves, Dilcher & Lott, 2005.

Lucas et al., 2011 (pp. 931-932): “...tentatively assume eastern tropical South America

to be the ancestral area of *Myrcia* s.l. ...ancestors of *Myrcia* s.l. could have migrated north and east through the tropical forests that covered the continent to 45°S during the late Paleocene and Eocene (~50 Ma; Landrum, 1981). Raven and Axelrod (1974) suggest that fleshy-fruited Myrtaceae subsequently dispersed farther northward, eventually reaching Central America, the West Indies, and relatively northern parts of North America, such as British Columbia, where fossil *Paleomyrtinae* is found (Pigg et al., 1993). ...undergone disjunction...(Ortiz-Jaureguizar and Cladera 2006) over Patagonia, Bolivia, and Peru (55-24 Ma) and in the Amazon (26-11 Ma). This is in line with an age of Myrteae of ~32 Ma, as suggested by Biffin et al. (2010).”

Myrtaceae- Late Cretaceous (Coniacian to Campanian), Antarctic Peninsula, pollen; Poole et al., 2005.

Myrtaceidites- Late Cretaceous (late Maastrichtian), lower middle Eocene, Antarctic Peninsula, pollen, Poole et al., 2005. *M. verrucosus*, *M. sp.* (cf. *Myrceogenia*)- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

Paleomyrtinaea sp.- middle Eocene, Republic Fl., WA, fruit, Wehr & Manchester, 1996; Williston Basin, Almont, Beicegel Fls., ND, SD, MT, adjacent Canada, fruits, seeds, Crane et al., 1990, Pigg et al., 1993, Pigg & DeVore, 2010.

?*Psidium*- Paleocene, Sentinel Butte Fm., Almont, ND, fruits, seeds; Crane et al., 1990; Pigg et al., 1993

MYRTACEOUS AFFINITY

Syzgioides americana- middle Eocene, Parachute Member, Green River Fm., CO, compressed twigs showing attachment of leaves, axillary panicles of flowers and fruits; Manchester et al., 1998.

NELUMBONALES

Nelumbites extenuinervis, *N. cf. N. minimus*- Lower Cretaceous (upper Albian), Potomac Group, VA, leaves; Upchurch et al., 1994.

NELUMBONACEAE

Exnelumbites callejasiae (and *E. morphotypes 1, 2*)- Late Cretaceous (Campanian-Maastrichtian), Olmos Fm., Coahuila, Mexico, Jose Creek Member of the McRae Fm., NM, leaves; Estrada-Ruiz et al., 2011.

Nelumbium montanum- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002; Paleocene Member of Fort Union Fm., ND, SD, megaflora, Johnson, 2002.

Nelumbo puertae- Upper Cretaceous (Campanian-Maastrichtian), La Colonia Fm., Chubut Province, Argentina, Patagonia, leaves and associated *Nelumbo*-like reproductive structures; Gandolfo & Cúneo, 2005 (fossil record for the family is discussed on p. 175-176). *N. sp.*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002; *N. (rhizome)*- Paleocene, Ludlow Member, Fort Union Fm., ND, SD, megaflora, Johnson, 2002.

NOTHOFAGACEAE [see also *Azolla*, Bowman et al., 2014]

Nothofagus- Manos (1997): [based on a study of 22 species representing the four subgenera and related outgroups, nuclear ribosomal DNA sequences, "...tropical *Nothofagus* (subgenus *Brassospora*) of New Guinea and New Caledonia are strongly supported as sister to cool-temperate species of South America (subgenus *Nothofagus*)" p. 1137]. *Nothofagus betuloides*- early Miocene, Tierra del Fuego, Argentina, leaves; Gandolfo & Romero, 1990; see also Hill, 2001; Hill & Read, 1991;

Hill & Jordan, 1993; Swenson & Hill, 2001; Dettmann et al., 1990. Fossil pollen = *Nothofagidites*. “The earliest on-land occurrences of *Nothofagidites* cited for South America are *N. rocaensis* from the middle Maastrichtian Jagüel Formation of Río Negro Province (~70 Ma) and *N. dorotensis* from the late Maastrichtian-early Paleocene Cerro Doretea Formation of Santa Cruz Province (~65 Ma). These are ~13.5 Ma or more later than the age cited for Australasia and Antarctica” (Graham, 2010, p. 496; see also Notes, p. 2). *N. dombeyi* (leaves), *N.* sp. (wood)- last interglacial (MIS 5e- called Valdivia in southern Chile), Mancera interglacial sequence, Mancera Island, Chile; Astorga & Pino, 2011.

Nothofagidites- late Eocene, SHALDRIL core, James Ross Basin, Wendell Sea (37-33.7 Ma); *Nothofagidites americanus*, *N. anisoechinatus*, *N. dorotensis*, *N. flemingii*, *N. menziesii*, *N. nanus*, *N. rocaensis*, *N. saraensis*- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

Nothofagoxylon corrugatus, *N. palaeoalessandri*, *N. ruei*, *P. scalariforme*- middle Eocene, Antarctic Peninsula, wood, leaf; Poole et al., 2005. *N. corrugatus*, *N. ruei*, *N. scalariforme*- early-late Paleocene, lower middle Eocene, Antarctic Peninsula, wood; Poole et al., 2005. *N. krauselii*, *N. scalariforme*, *N. ruei*, *N. corrugatus*, *N. triseriatum*- mid-early Paleocene, Antarctic Peninsula, wood; Poole et al., 2005. *N. aconcaguaense*, *N. corrugatus*, *N. krauseli*, *N. ruei*, *N. scalariforme*- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, wood; Poole et al., 2005. *N. scalariforme*- Late Cretaceous (Coniacian to Campanian), Antarctic Peninsula, wood; Poole et al., 2005.

NYMPHAEACEAE/NYMPHAEALES/NYMPHAEALEAN- see Borsch & Soltis (2008; Nymphaeales—The First globally diverse clade? Nymphaeales Symposium, *Taxon* 57: 1051-1158).

Aquatifolia fluitans (cf. Nymphaeaceae)- Lower Cretaceous (Albian), Dakota Fm., Hoisington III locality, Barton Co., KS, leaves; Wang & Dilcher, 2006.

cf. *Nelumbo*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Nuphar wutuensis- late Paleocene, Almont, Beicegel Fls., ND, Chen et al., 2004; Pigg & DeVore, 2010. *N. sp.*- middle Eocene, Republic Fl., WA, seeds, stigmatic disc, Wehr & Manchester, 1996; latest Eocene (34.1 Ma), Florissant Fl., CO, pollen, Leopold & Clay-Poole, 2001. *N. sp.*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005. cf. *Nuphar* (fruit, seed), *Nuphar sp.* (rhizome)- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR; Meyer & Manchester, 1997. cf. *Nuphar sp.*- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007.

Nymphaea, *N. sp.*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Nymphaeaceae gen. et sp. indeterminate- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fm., OR, leaf; Meyer & Manchester, 1997.

Nymphaeites sp.- middle Eocene (45 Ma), Thunder Mountain Fl., ID, impression of root scars; Axelrod, 1998.

Pluricarpellatia peltata (nymphalealean)- Lower Cretaceous, Crato Fm., NE Brazil, roots, cordate peltate leaves, flowering structures with seeds; Mohr et al., 2008.

Susiea newsalemae- late Paleocene, Almont, Beicegel Fl.s, ND, seeds, Taylor et al.,

2006, Pigg & DeVore, 2010.

NYSSACEAE (see Cornaceae)

OCHNACEAE

Ochna sp.- late Paleocene, Almont, Beicegel Fls., ND, Crane et al., 1990, Pigg et al.,

2005, Pigg & DeVore, 2010

OLACACEAE

Anacolosidites sectus- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, pollen,

Poole et al., 2005. *A. sp.*- lower middle Eocene, Antarctic Peninsula, pollen; Poole et al., 2005.

OLEACEAE (see also Brassicaceae, *Tricolpopollenites*)

Fraxinus dayana- late Miocene (Clarendonian, 12 Ma), Ironside Fm., OR, samara;

Retallack, 2004. *F. edentus*- middle Miocene, Mint Canyon Fl. (preliminary study), so.

CA; Axelrod, 1940. *F. stenocarpa*- Oligocene (30.7 Ma), Haynes Creek Fl., ID,

samara; Axelrod, 1998a. *F. sp.*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge

Creek Fl., OR, fruit, Meyer & Manchester, 1997; Miocene (15-6 Ma), Iceland,

Grimsson & Denk, 2007; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff

et al., 2014. *F.*-type pollen, latest Eocene (34.1 Ma), Florissant Fl., CO; Leopold &

Clay-Poole, 2001.

Oleaceae leaf morphotype- middle Eocene, Claiborne Group, TN; Dilcher & Lott, 2005.

ONAGRACEAE- for a record from the Miocene of China see Grímsson et al., 2012; for a review of the fossil record of the family in Australia see Martin (2003; other records are discussed beginning on p. 590 and listed in table 5): “The oldest fossils of the family Onagraceae are Late Cretaceous in age and are found in Brazil, California and Maryland

(Table 5). The Californian Campanian-Maastrichtian fossil is generally similar to *Oenothera* and *Galpinsia* (= *Oenothera*) and almost identical to the Upper Cretaceous specimens from Maryland (Chmura 1973). Photographs show that they are indeed similar and the likeness to *Oenothera* is plausible. The Maastrichtian specimen from Brazil is identified with the Eocene specimens of Columbia (Pares Regali et al., 1974), and the Columbian specimen is identified with *Ludwigia* (Gonzalez Guzman 1967). The photographs of the Eocene specimens clearly show the characteristic ectoaperture of *Ludwigia*. The Brazilian specimen generally looks like *Ludwigia*, with a suggestion of an ectoaperture, but it is not clear. It is clear, however, that the South American specimens are quite different to the North American Late Cretaceous grains. The family had thus diversified into at least two lineages in the Late Cretaceous” (pp. 590-593). [Occurrences elsewhere in the world are discussed on p. 593 et seq.]. Undetermined genus- late Miocene, Vasa Park Fl., King Co., WA, Dillhoff et al., 2014.

Colombipollis sp.- Upper Cretaceous, Mito Juan Fm., western Venezuela, pollen; Pocknall & Jarzen, 2009- the authors list other families with viscin threads.

Corsinipollenites atlantica- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012. *C.* sp.- Paleocene, Los Cuervos Fm., western Venezuela, pollen; Pocknall & Jarzen, 2009.

Crassiorites australis- late Eocene to middle Oligocene, Cullen Fm., Isla Grande de Tierra del Fuego, Argentina, pollen; Zamaló & Romero, 1990 (pp. 130-131).

Fuchsia- Berry et al. (2004): “An ultrametric molecular clock analysis (all minimum dates) places the split between *Fuchsia* and *Ciraea* at 41 million years ago (mya), with the diversification of the modern-day lineages of *Fuchsia* beginning at 31 mya. The

South Pacific *Fuchsia* lineage branches off around 30 mya, consistent with fossil records from Australia and New Zealand. The large Andean section *Fuchsia* began to diversify around 22 mya, preceded by the divergence of the Caribbean *F. triphylla* at 25 mya. The Brazilian members of section *Quelusia* separated from the southern Andean *F. magellanica* around 13 mya, and the ancestor of the Tahitian *F. cyrtandroides* split off from the New Zealand species of section *Skinnera* approximately 8 mya” (p. 601).

Onagraceous flower- latest Eocene (34.1 Ma), Florissant Fl., CO; Manchester, 2001.

Semeiandra aff. *Xylonagra*- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

Trivestibulopollenites sp. (cf. *Oenothera*; Martin, 2003, p. 590)- Late Cretaceous (Campanian-Maastrichtian), Uhalde Fm., western San Joaquin Valley, CA, pollen; Chmura, 1973.

ORCHIDACEAE

Meliorchis caribea (Subtribe *Goodyerinae*)- Miocene, Dominican amber, Dominican Republic, pollinarium attached to the mesoscutellum of an extinct stingless bee, *Prolebeia dominicana*; Ramírez et al., 2007: [Using this find to calibrate a molecular phylogenetic tree the authors conclude “the most recent common ancestor of extant orchids lived in the Late Cretaceous (76-84 Myr ago)” p. 1042].

Orchidamasulitis schlechteri- upper Tertiary (Oligocene), Venezuela; Di Giacomo, 1985; Lorente, 1986.

OROBANCHACEAE

Conopholis- As example of a Mexican disjunct lineage see Rodrigues et al. (2013): for discussions of the origins of the pattern see e.g., Graham (1973a, 1976a, 1999a, 2010,

2011a), Morris et al. ((2008, 2010).

Euphrasia minima complex- Gussarova et al., 2012: “The main split...dated to nearly 6 Ma ago was between one central/southern European alpine lineage (*E. minima* s. str.) and one northern amphi-Atlantic lineage (*E. wettsteinii*). The *E. wettsteinii* lineage consisted of two cpDNA sublineages, both amphi-Atlantic and partly sympatric, estimated to have diverged 1.7 Ma ago. ...as all Svalbard populations were distinctly divergent from each other as well as from all other populations in AFLP marker frequencies, it is unlikely that their establishment in Svalbard is caused by current climate warming or recent human activities. Their divergence is probably due to founder effects and genetic drift following independent earlier immigrations, possibly during the postglacial warm period 9500 to 4000 years ago” (p. 146).

OXALIDACEAE

Averrhoites affinis- late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada; Hoffman & Stockey, 1999.

Oxalis- “The inferred divergence times suggest an Eocene origin for the *Oxalis* crown group. The divergence times of the 7 lineages fall between the Middle Eocene and the Late Miocene. The *O. rosea* clade split from the North American/Eurasian *O. acetosella* clade in the Middle Miocene” (p. 5).

PAPAVERACEAE

Potomacapnos apeleutheron- Early Cretaceous, Potomac Group, Aptian, Dutch Gap locality, near Richmond, VA, leaves; Jud and Hickey, 2013.

PASSIFLORACEAE

Passiflora, subgenus *Decaloba*- Krosnick et al. (2013): “The molecular phylogeny supports a New World origin for *Passiflora*, with two independent radiations to the Old World” (p. 692). “Recent age estimates for the emergence of Passifloraceae s.s. range from 71-65 MYA (Davis et al. 2005; Hearn 2006) to 37 MYA (based on the age of Malesherbiaceae; Gengler-Nowak 2002), whereas *Passiflora* itself appeared ca. 40 MYA (Hearn 2006)” (p. 704).

Turnera- Thulin et al. (2012): “The existence of a trans-Atlantic disjunction in *Turnera* is therefore supported. It is most likely caused by long-distance dispersal and estimated to be not older than late Miocene” (p. 308).

PIPERACEAE- Smith et al. (2008): [“Molecular dating is used to place an age for the crown clades of *Piper* and *Peperomia* as well as ages for diversification within the clades. Both genera have origins in the late Cretaceous, but species level diversification occurred much later in the Tertiary” p. 275].

Piper margaritae- Late Cretaceous, middle Guaduas Fm. (66-68 Ma), Cundiamarca, Colombia, leaf compressions; Martínez et al., 2015. “Estimates of age divergence and lineage accumulation reveal that most of the extant diversity of the genus accrued during the last ~30 Myr” (p. 273).

“*Ziziphus*” *fibrillosus*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflores; Johnson, 2002.

PLANTAGINACEAE

Periporopollenites sp. 2 (cf. *Plantago*)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

PLATANACEAE- see Crane (1989) and Crabtree (1987) for reviews of Cretaceous platanoid leaves. Mindell et al. (2006): [“The fossil record for the family extends into the Early Cretaceous. Leaf compressions (Hickey and Doyle 1977) and inflorescences (Friis et al. 1988; Crane et al. 1993; Pedersen et al. 1994) of platanaceous affinity are known from the Albian of eastern North America. Three-dimensionally preserved inflorescences from the Late Cretaceous of Sweden (Friis et al. 1988) and North America (Friis et al. 1988; Magallón Puebla et al. 1997) have shown characters unknown in extant Platanaceae...also known in the Cretaceous to Tertiary genera *Platananthus* Manchester and *Macginicarpa* Manchester, the Paleogene genus of pistillate fructifications (Manchester 1986)... “ (pp. 591-592)]. Platanaceae- Paleocene, Sentinel Butte Fm., ND, leaf types A-C, staminate inflorescences; Crane et al., 1990. Late Eocene (36 Ma), lower John Day Fm., OR, infructescence; Manchester & McIntosh, 2007.

Ambiplatanus washingtonensis- Late Cretaceous (Coniacian), Comox Fm., Eden Main locality, Vancouver Island, British Columbia, Canada, inflorescences, pollen; Mindell, Karafit, and Stuckey, 2014.

“*Celastrus*” *taurenensis*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Erlingdorfia Montana- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Gynoplatananthus oysterbayensis- middle Eocene, Oyster Bay Fm., Appian Way locality, Vancouver Is., British Columbia, Canada, staminate inflorescences, associated pistillate fructifications; Mindell et al., 2006.

Grewiopsis saportana- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD,

megaflora; Johnson, 2002.

Leepierceia preartocarpoides- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Macginicarpa manchesteri- late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada; Hoffman & Stockey, 1999. *M. glabra*- middle Eocene (44 Ma), Clarno Fm., OR, infructescences; Manchester, 1994. *M. sp.*- late Paleocene, Almont Fl., ND, infrutescence, Pigg & DeVore, 2010 (pers. comm.. from Manchester); middle Eocene, Republic Fl., WA, fruits; Wehr & Manchester, 1996.

Macginitiea gracilis- late Paleocene, Almont, Beicegel Fls., ND, leaves, Pigg & DeVore, 2010 (pers. comm. from Manchester); late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage, Dillhoff et al., 2005; middle Eocene Republic Fl., WA, leaves, Wolfe and Wehr, 1987; Manchester, 1986.

Platanites marginata- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Platanoxylon haydenii- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002. *P. sp.* (Platanaceae?)- Late Cretaceous (Maastrichtian), McRae Fm., NM, wood; Estrada-Ruiz et al., 2012.

Platananthus speirsiae- late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada; Hoffman & Stockey, 1999.

Platanus condonii- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997. *P. dissecta*- late Miocene (Clarendonian, 12 Ma), Ironside Fm., OR, leaf; Retallack, 2004; late Miocene, Vasa Park Fl., King Co., WA, leaf, Dillhoff et al., 2014 *P. hirticarpa*- middle Eocene (44 Ma), Clarno Fm., OR,

infructescences; Manchester, 1994. *P. idahoensis*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves; Axelrod, 1998a. *P. leucophylla*- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. *P. nobilis*- late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada; Hoffman & Stockey, 1999. *P. paucidentata*- middle Miocene, Mint Canyon Fl., (preliminary study), so. CA; Axelrod, 1940. *P. raynoldsii*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megafloora, Johnson, 2002; earliest Paleocene, basal Fort Union Fm., ND, leaves, Bercovici et al., 2008; Paleocene, Ludlow Member, Fort Union Fm., ND, SD, megafloora, Johnson, 2002. *P. salmonense*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves; Axelrod, 1998a. *P.* sp.- middle Eocene, Claiborne Group, TN, leaves; Dilcher & Lott, 2005; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014. cf. *Platanus*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Tanyoplatanus cranei- middle Eocene (44 Ma), Clarno Fm., OR, infructescences; Manchester, 1994.

Tricolpites hians (*Platanus*)- late Paleocene (~60 Ma), Sagwon Bluffs, North Slope Alaska, pollen; Daly et al., 2011.

“*Vitis*”, aff. *V. stantonii*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megafloora; Johnson, 2002.

cf. *Wardiaphyllum daturaefolium*- Paleocene, Ludlow Member of Fort Union Fm., ND, SD, megafloora; Johnson, 2002.

POACEAE (Strömberg, 2004, and personal communication, 2011). Early records from New World and outside the New World: “Presumed grass pollen (*Monoporites*) in the Maastrichtian to Paleocene [70 to 60 million years ago (Ma)] of South America, India,

and North Africa marks the earliest fossil record of Poaceae [Grass Phylogeny Working Group, 2001; Jacobs et al., 1999], and unequivocal macrofossils of crown-group Poaceae appear no earlier than the Late Paleocene [Jacobs et al., 1999; Bremer, 2002]” Prasad et al., 2005, p. 1177; phytoliths, Late Cretaceous dinosaur coprolites, India, Prasad et al., 2005; 2011. pollen undifferentiated- latest Eocene (34.1 Ma), Florissant Fl., CO, Leopold & Clay-Poole, 2001; Late Miocene (Clarendonian, 12 Ma), Ironside Fm., OR, Retallack, 2004; late middle to early late Miocene, Bryn Mawr Fm., Md., Pazzaglia et al., 1997; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014. *Changii indicum*- Late Cretaceous (67-65 Ma), phytoliths in coprolites from red clays, Lameta Fm., Pisdura East and Pisdura South, India; Prasad et al., 2011.

Graminidites- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

Phalaris- Voshell et al. (2011): “...it appears that Mediterranean Europe is likely to be the center of origin for the genus, rendering western North America, as a secondary center of diversity and polyploidy. However, a biogeographic study is underway to evaluate this hypothesis” (p. 1314).

Phragmites sp.- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007.

Paleocene/Eocene Wilcox Fm. (specimens now regarded as from the Eocene part of the Wilcox Fm.), western TN, spikelets, inflorescence fragments with included pollen; Crepet & Feldman, 1991.

Late Eocene Chadron Fm., early Oligocene Brule Fm. (White River Group), late Oligocene-early Miocene Monroe Creek Fm., early Miocene Harrison Fm. and Anderson Ranch Fm. (Arikaree Group), early Miocene Runningwater Fm. and Box

Butte Fm. (Ogallala Group), northwestern NB; phytoliths; Strömberg, 2004.

Stipa (or a similar genus of grass fruits)- latest Eocene (34.1 Ma), Florissant Fl., CO; Manchester, 2001.

Tateokai deccana- Late Cretaceous (67-65 Ma), phytoliths, septaria, concretions in clays, Lameta Fm., Dhamni, India; Prasad et al., 2011: “The new Oryzeae fossils suggest substantial diversification within Ehrhartoideae by the Late Cretaceous, pushing back the time of origin of Pooideae as a whole. These results, therefore, necessitate a re-evaluation of current models for grass evolution and palaeobiogeography” (p. 1).

Zea mays- Holocene (3940 to 2450 ¹⁴C yrs BP), packrat middens, Chaco Canyon, NM; Hall, 2010.

POLYGALACEAE

Paleosecuridaca curtisii- late Paleocene, Williston Basin, Almont, Beicegel Fls., Crane et al., 1990, Pigg et al., 2008, Pigg & DeVore, 2010.

POLYGONACEAE

Polygonocarpum johnsonii- Late Cretaceous (Maastrichtian), Slope Co., ND, fruit; Manchester & O’Leary, 2010: [Family previously known from the Oligocene (Germany) and Miocene (Switzerland), “It is now possible to extend the fossil record of Polygonaceae considerably farther back in time based on fossil fruits from the Late Cretaceous and Paleocene of North America” (p. 69). “Two additional representatives of Polygonaceae are recognized from the Paleocene of North America. Fruits similar to those of *Polygonocarpum johnsonii* occur in the Paleocene of Wyoming and North Dakota” (p. 70)]. *P. curtisii*- Paleocene, ND, fruit; Manchester & O’Leary, 2010.

Polygonum- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Podopterus antiqua- Paleocene, ND, fruit; Manchester & O’Leary, 2010; considered *Ulmus* by Brown, 1962; ‘biwinged fruit’, Crane et al., 1990).

POTAMOGETONACEAE

Potamogeton sp.- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaf, Axelrod, 1998; latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, fruits, Manchester, 2001; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014.

PROTEACEAE- see also Bowman et al., 2014, latest Cretaceous/earliest Paleocene, Seymour Island, Antarctica; Gonzalez et al. (2007) for a review of Proteaceae macrofossils from Patagonia, Argentina: *Tufolitas* Laguna del Hunco (early Eocene), Chubut Province; *Ventana* (middle Eocene), Río Negro Province; and the Río Nirihuau (late Oligocene- early Miocene), Río Negro Province: “The authors confirm the presence of *Lomatia preferruginea*, *L. occidentalis*, *L. patagonica*, *Roupala patagonica*, and *Orites bivascularis*; *Embothrium precoccineum* and *E. pregrandiflorum* doubtful” (pp. 235-236).

Banksieaidites- lower middle Eocene, Antarctic Peninsula, pollen; Poole et al., 2005.

Beaupreadites verrucosus- mid-early Paleocene, Antarctic Peninsula, pollen; Poole et al., 2005. *B.* sp.- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, pollen; Poole et al., 2005.

Cranwellia cf. *striatus*- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, pollen,

Poole et al., 2005.

Cranwellipollis palisadus- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, pollen, Poole et al., 2005.

Gevuina avellana- last interglacial (MIS 5e- called Valdivia in southern Chile), Mancera interglacial sequence, Mancera Island, Chile, leaves; Astorga & Pino, 2011.

Granodiporites- lower middle Eocene, Antarctic Peninsula, pollen; Poole et al., 2005.

Lomatia dentata- last interglacial (MIS 5e- called Valdivia in southern Chile), Mancera interglacial sequence, Mancera Island, Chile, leaves; Astorga & Pino, 2011.

Peninsulapollis askinae- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, pollen, Poole et al., 2005. *P. gillii*, *P. truswelli*- mid-early Paleocene, Antarctic Peninsula, pollen; Poole et al., 2005. *P. gillii*- Late Cretaceous (late Maastrichtian), Antarctic Peninsula, pollen; Poole et al., 2005.

Propylipollis- mid-early Paleocene, Antarctic Peninsula, pollen; Poole et al., 2005. *P. rynthius*- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

Proteaceae- middle Eocene, Antarctic Peninsula, pollen, leaf; mid-early Paleocene, lower middle Eocene, early-late Paleocene, Late Cretaceous (late Maastrichtian), Late Cretaceous (Coniacian to Campanian), Antarctic Peninsula, pollen, Poole et al., 2005. [Pollen of several modern genera cited as similar].

Proteacidites subscabratus- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012. *P. symphyonemoides*- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

RANUNCULACEAE- the fossil record of the family is reviewed by Pigg & DeVore (2005, pp. 1650-1651 and table 1). See also Bowman et al., 2014, latest Cretaceous/earliest Paleocene, Seymour Island, Antarctic Peninsula.

Anemone type- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005. Hoot et al., 2012: “The topology ... suggest that the anemones originated in the Northern Hemisphere and subsequently spread to the Southern Hemisphere, a pattern that is shared with other members of the Ranunculaceae” (p. 139).

Echitricolpites supraechinatus (possibly Ranunculaceae)- late Paleocene, Almont Fl., ND, Williston Basin, pollen; Zetter et al., 2011.

Leefructus mirus- Lower Cretaceous (122.6-125.8 Ma), Yixian Fm., China, leaves attached to stem; Sun et al., 2011 (see also Angiospermae).

Paleoactaea nagelii- late Paleocene, Almont, Beicegel Fls., ND, fruit, seeds; Pigg & DeVore, 2005: [“This fruit bears a striking resemblance to extant *Actea*, the baneberry (Ranunculaceae)... A second species, *Paleoactaea bowerbanki*... is recognized from the early Eocene London Clay flora” (p. 1650)]; Crane et al., 1990, Pigg & DeVore, 2010.

RAPATEACEAE (see discussion under Bromeliaceae)

RESTIONACEAE

Milfordia- lower middle Eocene, Antarctic Peninsula, pollen; Poole et al., 2005.

Restioniidites- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

RHAMNACEAE- Correa et al. (2010): [“The Maastrichtian age of these fossils [*Berhamniphyllum*, *Archaeopaliurus*] predates the ages previously estimated for the

Rhamnaceae tribe (28.5 Ma) and the Paliureae tribe (31.6 Ma) using a modified clock approach. There are worldwide records of megafossils leaves from Rhamnaceae with the oldest report coming from the Albian-Cenomanian of the Russian Federation (Spicer et al., 2002)” (p. 71)]. The specimen recorded earlier from Salmon, Idaho, as *Ceanothus* (Brown, 1935) is considered by Axelrod (1998a, p. 56) to be *Cercidiphyllum crenatum*.

Archaeopaliurus boyacensis- Late Cretaceous (upper Maastrichtian), Guaduas Fm. (ca. 68 Ma), Colombia, leaves; Correa et al., 2010.

Berhamniphyllum claibornense- middle Eocene, Claiborne Group, TN, leaves; Dilcher & Lott, 2005. *B. sp.*- Late Cretaceous (upper Maastrichtian), Guaduas Fm. (ca. 68 Ma), Colombia, leaves, Correa et al., 2010; middle Eocene, Claiborne Group, TN, leaves, Dilcher & Lott, 2005.

Ceanothus precuneatus, *C. sp.*- middle Miocene, Mint Canyon Fl. (preliminary study), so. CA; Axelrod, 1940. [see note under family].

Hovenia oregonensis- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997.

Paliurus clarenensis, *P. favonii*- genus middle Eocene to late Miocene (North America), Late Eocene to Pleistocene (Asia), Oligocene to Pliocene (Europe), fossil history based on fruits and biogeography of the genus summarized by Burge and Manchester, 2008.

P. blakei- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR; Meyer & Manchester, 1997.

Rainbowia rhamnoides- Eocene, Green River Fm., UT, fruit; Manchester & O’Leary, 2010: [“...similar to those of *Gouania* “ (p. 73)].

Rhamnus columbiana- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves; Axelrod, 1998a. *R. deweyensis*, *R. pushoides*- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaves; Axelrod, 1998. “*Rhamnus*” *cleburni*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002. cf. “*Rhamnus*” *goldiana*- earliest Paleocene, basal Fort Union Fm., ND, leaves; Bercovici et al., 2008.

RHOIPTLEACEAE

aff. *Rhoiptelea* sp.- latest Eocene (34.1 Ma), Florissant Fl., pollen; Leopold & Clay-Poole, 2001.

ROSACEAE (see also *Ozakia*, *Angiospermae incertae sedis*)

Amelanchier covea, *A. grayi*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR; Meyer & Manchester, 1997. *A. deweyensis*- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaf; Axelrod, 1998. *A. dignatus*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves; Axelrod, 1998a. *A.* sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, leaves; Manchester, 2001.

Cercocarpus cuneatus- middle Miocene, Mint Canyon Fl. (preliminary study), so. CA; Axelrod, 1940. *C. myricaefolius*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaf; Axelrod 1998a. *C. ovatifolius*- late Miocene (Clarendonian, 12 Ma), Ironside Fm., OR; Retallack, 2004. *C.*-like leaves, fruits- latest Eocene (34.1 Ma), Florissant Fl., CO; Manchester, 2001.

Crataegus bakeri, *C. cuspicaulis*, *C. haynesii*, *C. spathulatoides*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves, stem; Axelrod, 1998a. *C. merriamii*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997. cf. *Crataegus* sp.- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada,

foliage; Dillhoff et al., 2005. *C. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, fruits; Manchester, 2001. cf. *Crataegus sp.*- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007.

Eleopoldia sp.- Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO, leaves; Gregory & McIntosh, 1996.

Heteromeles sp.- Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO, leaves; Gregory & McIntosh, 1996.

Holodiscus lisii- late Eocene, Florissant Fl., CO, leaves; Schorn, 1998. *H. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, Manchester, 2001; Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO, leaves, Gregory & McIntosh, 1996.

Lyonothamnus mohavensis- middle Miocene, Mint Canyon Fl. (preliminary study), so. CA; Axelrod, 1940.

Maloidoxylon annae- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Malus collardii- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaf; Axelrod, 1998. *M.*-like leaves- latest Eocene (34.1 Ma), Florissant Fl., CO; Manchester, 2001. cf. *Malus* or *Pyrus*- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen, Leopold & Clay-Poole, 2001; Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997.

Neviusia dunthornei (Tribe Kerrieae)- lower-middle Eocene, Allenby Fm., near Princeton, British Columbia, Canada; leaves; DeVore et al., 2004, other fossil rosaceous leaves are discussed by the authors, p. 199; middle Eocene, Republic Fl., WA, DeVore et al., 2004.

Oemleria janhartfordae (Subfam. Spiraeoideae, Tribe Osmaronieae)- late early Eocene, Republic Fl., WA; flowers; Benedict et al., 2011.

Photinia pagae- middle Eocene, Republic Fl., WA; Wolfe & Wehr, 1987.

Prunus cathybrownae (Subfam. Spiraeoideae, Tribe Amygdaleae)- late early Eocene, Republic Fl., WA, Benedict et al., 2011; *P. chaneyii*- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaves; Axelrod, 1998. [“The endocarps from Wutu [Shandong Province, China] represent the earliest record [early Eocene] of *Prunus* in Asia. The fossil data suggest that the genus first appeared in the early Eocene of North America and Asia, then extended to Europe in the middle Eocene” Li et al., 2011, p. 555]. cf. *Prunus gummosa*, *P. sp.*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002. *P. olsonii*, *P. weinsteinii*- middle Eocene (44 Ma), Clarno Fm., OR, fruits; Manchester, 1994. *P.*-like leaves, latest Eocene (34.1 Ma), Florissant Fl., CO; Manchester, 2001. cf. *Prunus sp.*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage; Dillhoff et al., 2005. cf. *Pyracantha*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997.

Pyrus (see *Malus*)

Rosa hillae- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaflet, Axelrod, 1998; Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf, Meyer & Manchester, 1997; Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaflets, Axelrod 1998a; latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, leaflets, Manchester, 2001; Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, fruit, Meyer & Manchester, 1997.

Rosaceous prickly stems- late Eocene (36 Ma), lower John Day Fm., OR, Manchester & McIntosh, 2007; Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, Meyer & Manchester, 1997.

Rubus ameyeri (leaf), *R. fremdii* (leaf), *R. sp.* (fruit)- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR; Meyer & Manchester, 1997. *R. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, leaves; Manchester, 2001.

Sorbus cassiana, *S. mcjannetii*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaflets; Axelrod, 1998a. *S. oblongifolia*- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaflet; Axelrod, 1998.

Spiraea idahoensis- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaf, Axelrod, 1998; Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaf, Axelrod, 1998a.

Subclass Rosidae and Hamamelididae (see Hamamelididae)

Vauquelinia sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, Manchester, 2001; Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaf, Axelrod, 1998a.

RUBIACEAE [early records- *Emmenopterys* (middle Eocene, OR, WA); *Faramea* (late Eocene, Panama); *Guettarda* (as *Guettardidites*, late Eocene, Australia); *Canthium* (as *Rubipollis oblatus*, late Eocene, Australia); Graham 2009].

Dicotyloxylon pluriperforatum- middle Eocene, Antarctic Peninsula, wood; Poole et al., 2005.

Emmenopterys dilcheri- middle Eocene (44Ma), Clarno Fm., OR, infructescences and fruits; Manchester 1994. *E. sp.*- middle Eocene, Republic Fl., WA, fruit; Wehr & Manchester 1996.

Faramea- late Eocene, Gatuncillo Fm., Panama, pollen; Graham, 1985.

cf. *Paleorubiaceophyllum* sp.- middle Eocene, Claiborne Group, TN, leaves, Dilcher & Lott, 2005.

Pinckneya dilcheri- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, seed; Meyer & Manchester, 1997.

RUPPIACEAE

?*Ruppia*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

RUTACEAE

aff. *Evodia* sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

Ptelea enervosa- Miocene, Hog Creek, Succor Creek (near OR-ID border), Stinking Water (OR) Fls., samaras; Call & Dilcher, 1995. *P. miocenica*- late Miocene (Clarendonian, 12 Ma), Ironside Fm., OR; Retallack, 2004. ?*Ptelea*- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

Rhoipites baculatus (Rutaceae-?Araliaceae)- Paleogene, Ñirihuau Basin, Argentina, pollen; Quattrocchio et al., 2012.

Tricolporopollenites sp. 3+4 (cf. *Zanthoxylum*)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

Zanthoxylum sp.- late Eocene (36 Ma), lower John Day Fm., OR, seeds, Manchester & McIntosh, 2007; cf. *Xanthoxylum*- late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005.

SABIACEAE (MELIOSMACEAE)

Meliosma beusekomii, *M. bonesii*, *M. elongicarpa*, *M. cf. jenkinsii*, *M. leptocarpa*-

middle Eocene (44 Ma), Clarno Fm., OR, endocarps; Manchester, 1994. *M. brehmii*, *M. deweyii*, *M. dodosonii* (+ subgenera, wood groups I-VI)- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002. *M. rostellata*- Paleocene, Sentinel Butte Fm., Almont, Beicegel Fls., ND, fruits, Crane et al., 1990, Pigg & DeVore, 2010; late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada, Hoffman & Stockey, 1999. *M. sp.*- middle Eocene, Republic Fl., WA, fruit; Wehr & Manchester, 1996.

Sabia americana- middle Eocene (44 Ma), Clarno Fm., OR, endocarps, locule casts; Manchester, 1994. *S. sp.*- middle Eocene, Republic Fl., WA, fruits, Wehr & Manchester, 1996; late Eocene (36 Ma), lower John Day Fm., OR, endocarp, Manchester & McIntosh, 2007.

SALICACEAE

Populus sp.- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage, Dillhoff et al., 2005; middle Eocene, Claiborne Group, TN, leaves, Dilcher & Lott, 2005; middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaves, Axelrod, 1998; latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, fruits, Manchester, 2001, pollen, Leopold & Clay-Poole, 2001; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014. *P. sp.* (ex group *P. tremula*), *P. sp.* 1-3- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. *P. sp.*- late Miocene (Clarendonian, 12 Ma), Ironside Fm., OR; Retallack, 2004. *P. nebrascensis*- earliest Paleocene, basal Fort Union Fm., ND, leaves; Bercovici et al., 2008. *P. cinnamomoides*, *P. eotremuloides*, *P. sp.*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaf; Axelrod, 1998a. *P. sp.*-

Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO, leaves; Gregory & McIntosh, 1996.

See also “*Populus*”, Cercidiphyllaceae

Salix gruberi- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. *S. lemhiensis*, *S. salmonensis*, *S. sp.*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves, Axelrod 1998a. *S. sp.*- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaves, Axelrod, 1998; latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, Manchester, 2001, pollen- Leopold & Clay-Poole, 2001; Oligocene (32.9-29 Ma), Pitch Pinnacle Fl., CO, leaves, Gregory & McIntosh, 1996; late Miocene (Clarendonian, 12 Ma), Ironside Fm., OR, Retallack, 2004; late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014.

SAPINDACEAE/SAPINDALES/SAPINDALEAN (see also Hippocastanaceae)

Acer- based on up to seven chloroplast loci “The nine North American species of *Acer* diverged from their nearest relatives at widely different times: eastern American *Acer* diverged in the Oligocene and Late Miocene; western American species in the Late Eocene and Mid Miocene; and the *Acer* core clade, including *A. saccharum*, dates to the Miocene” (Renner et al., 2008, p. 795). “The oldest described *Acer* fossils are Paleocene fruits from North America and Eurasia (Wolfe & Tanai, 1987; Crane et al., 1990; Manchester, 1999; Kittle et al., 2005), but still older fruits from the Maastrichtian (66.5 Ma) Hell Creek formation in South Dakota also conform morphologically to *Acer* (K. R. Johnson, personal communication [to Renner], August 2008). None of these ancient isolated fruits, however, can securely be assigned to an

extant clade” (Renner et al., 2008, p. 798). Wolfe & Tanai, 1987.

Acer crenatifolium subsp. *islandicum*, *A. askelssonii*- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. *A. hueberi*, *A. idahoensis*, *A. macginitiei*, *A. osmonti*, *A. salmonensis*, *A. septilobatum*, *A. tiffneyi*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves, seeds; Axelrod, 1998a. *Acer ashwillii*, *A. cranei*, *A. glabroides*, *A. kluckingii*, *A. manchesteri*, *A. oligomedianum*, *A. osmontii*, *A. sp. 1*, *2*, *A. sp. A*, *B*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaves, fruits; Meyer & Manchester, 1997. *A. integrifolioxylon*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002: [“To our knowledge, this is the oldest report of fossil wood with characteristics of the genus *Acer*” (p. 36)]. *A. rousei*, *A. stewarti*, *A. wehri*, *A. sp.* (foliage)- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, fruits; Dillhoff et al., 2005. cf. *Acer*- late Paleocene, Almont, Beicegel Fls., ND, fruit, Crane et al., 1990, Kittle et al., 2005, Pigg & DeVore, 2010. *A. sp.*- late middle Eocene (ca. 45 Ma), Green River Fl., CO, UT, leaves, McMurrin & Manchester, 2010; latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, fruits, Manchester, 2001, pollen-Leopold & Clay-Poole, 2001; middle Eocene, Republic Fl., WA, fruits, Wehr & Manchester, 1996; late Eocene (36 Ma), lower John Day Fm., OR, endocarp, Manchester & McIntosh, 2007; Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO, leaves, Gregory & McIntosh, 1996; late middle to early late Miocene, Bryn Mawr Fm., MD, pollen, Pazzaglia et al., 1997; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005; late Miocene- Vasa Park Fl., King Co., WA, leaves, seeds, pollen, Dillhoff et al., 2014.

Aesculipollis wyomingensis- Late Paleocene, Almont Fl., Williston Basin, North

Dakota, pollen; Zetter et al., 2011.

Aesculus sp.- late Miocene, Vasa Park Fl., King Co., WA, leaf, Dillhoff et al., 2014.

Bohlenia americana- middle Eocene, Republic Fl., WA, fruits, Wehr & Manchester, 1996; Wolfe & Wehr, 1987.

Bridgesia bovavensis- Eocene, Bovay Clay Pit, Holly Springs, MS, fruit; Manchester & O'Leary, 2010: ["...interesting biogeographic implications because the genus is known today only in South America" (p. 76)].

Cardiospermum sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

Cupania- early Eocene, Caleta Cocholgue Fl., central Chile, leaves; Gayó et al., 2005.

Cupanieidites orthoteichus (Sapindaceae-Cupanieae)- Late Cretaceous (late Maastrichtian), lower middle Eocene, Antarctic Peninsula, pollen; Poole et al., 2005.

Cupanites sp.- middle Eocene, Claiborne Group, TN, leaflet; Dilcher & Lott, 2005.

Deviacer wolfei- middle Eocene (44 Ma), Clarno Fm., OR, samara; Manchester, 1994.

D. ("*Acer*" *arcticum*) sp.- late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada, Hoffman & Stockey, 1999; middle Eocene, Republic Fl., WA, fruits, Wehr & Manchester, 1996.

Dipteronia- ["The earliest fossils of *Dipteronia* (McClain & Manchester, 2001) are from the Paleocene Fort Union Formation in central Wyoming and are 60 to 63 Myr.

Dipteronia fruits are also well represented at Middle Eocene localities in Washington, Oregon, and British Columbia, and at Late Eocene localities in Colorado, western Montana, and Oregon (McClain & Manchester, 2001). The only locality of Oligocene age is from the Bridge Creek flora of Oregon, 32 Myr" (Renner et al., 2008. p. 797-

798)]. *Dipteronia brownii*- McClain & Manchester (2001) review the fossil record of *Dipteronia* (sister genus to *Acer*), Paleocene to Oligocene, greatest number in middle to late Eocene of western North America (no known fossil occurrences outside of North America), fruits; *D. brownii*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage, Dillhoff et al., 2005; middle Eocene, Republic Fl., WA, [*Bohlenia* was originally proposed by Wolfe & Wehr, 1987 for fruits and leaves; McClain & Manchester, 2001 suggest fruits could all be recognized under *Dipteronia* and that *Bohlenia* could be used for just the associated leaves]. *D. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, fruits, perhaps leaves, Manchester, 2001. Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, fruit, Meyer & Manchester, 1997.

Koelreutaria sp.- middle Eocene, Republic Fl., WA, fruits, Wehr & Manchester, 1996; latest Eocene (34.1 Ma), Florissant Fl., CO, fruits, perhaps leaves, Manchester, 2001, pollen, Leopold & Clay-Poole, 2001.

Palaeoalloyphylus globosa, *P. gordonii*- middle Eocene (44 Ma), Clarno Fm., OR, seeds; Manchester, 1994.

Ptelea paliuruoides- middle Eocene, Parachute Creek Member, Green River Fm., CO, UT; Manchester & O'Leary, 2010.

Pteleaecarpum- [affinities originally suggested with Sapindaceae, now considered as tiliaceous; Kvaček et al., 1991].

Sapindoxylon klaassenii- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

cf. *Sapindus*- late Paleocene, Almont Fl., ND, fruit, Pigg & DeVore, 2010 (pers. comm.

from Manchester).

Striatopollis tectatus- late Paleocene, Almont Fl., Williston Basin, ND, pollen; Zetter et al., 2011.

Incertae sedis:

Landeenia aralioides [extinct sapindalean genus]- middle Eocene, Bridger Fm., WY, flowers, pollen infructescences, fruits, seeds; Manchester & Hermsen, 2000.

[see also *Aesculus*, Hippocastanaceae; *Sapindopsis*, Subclass Hamamelididae].

SAPOTACEAE

Subfamily Chrysophylloideae- (Bartish et al., 2010): [“...earliest diversification of Chrysophylloideae was in the Campanian of Africa *c.* 73-83 Ma. A narrow time interval for colonization from Africa to the Neotropics (one to three dispersals) and Australasia (a single migration) indicates a relatively rapid radiation of this subfamily in the latest Cretaceous to the earliest Palaeocene (*c.* 62-72 Ma)”, p. 1. [The authors review the fossil record of the family].

Brumelia? globosa, *B.? subangularis*- middle Eocene (44 Ma), Clarno Fm., OR, seeds; Manchester, 1994: [*Bumelia? globosa* Manchester was transferred to *Sargentodoxa globosa* (Manchester) Manchester 1999. This was moved out of Sapotaceae and into Sargentodoxaceae.

SARGENTODOXACEAE (see *Brumelia* above)

SAURURACEAE

Saururus tuckerae- middle Eocene, Allenby Fm., Princeton Group, Princeton, British Columbia, Canada, flowers, pollen; Smith & Stockey, 2007: [“To date only two fossil species are known for Saururaceae, and there are few confirmed reports of fossil

Piperaceae. Fruits and seeds of *Saururus bilobatus* have been recognized from the Late Eocene to Pliocene of Europe and Siberia (Mai and Walther, 1978; Friis, 1985; Stuchlik et al., 1990; Lesiak, 1994), and seeds of *Houttuynia bavarica* (Mai, 1999) from the Miocene of Germany. These are known from gross morphology and have not been anatomically examined. No fossil vegetative or pollen remains have been firmly placed in the family Saururaceae. However, we recently recognized that fossil flowers from the Middle Eocene Princeton Chert, previously thought to have affinities to Alismatales ... have many similarities to saururaceous flowers” (p. 1642)].

SAXIFRAGALES- Soltis, D. E. et al. (+ 7 authors): “The earliest fossil evidence of Saxifragales is within the Turonian-Campanian, providing a minimum age of 89.5 Myr for the group (Magallón et al., 1999; Hermsen et al., 2006).” (p. 917, see other references in paragraph to fossil record of Saxifragales). “Again, we acknowledge the known issues of estimating extinction rates from molecular phylogenetics based upon extant taxa in the absence of a complete fossil record (Rabosky, 2009, 2010; reviewed in Quental and Marshall, 2010), and these findings warrant future investigation.” (p. 925-926).

SCHISANDRACEAE

Schisandra oregonensis- middle Eocene (44 Ma), Clarno Fm., OR, seeds; Manchester, 1994.

SIMAROUBACEAE

Ailanthus confucii- Muellner et al., 2006: [“dated to be 52 million years (my) old (Early Eocene; Corbett and Manchester, 2004)”, p. 241] . *S. sp.*- latest Eocene (34.1 Ma), Florissant Fl., CO, fruits, Manchester, 2001; late middle Eocene (ca. 45 Ma), Green River Fm., CO, UT, leaves, McMurrin & Manchester, 2010.

SMILACACEAE- P. Li et al., 2013: “The Upper Midwest Driftless Area previously has been identified in geological and palynological studies as an ice-free area that may have served as a northern glacial refugium for temperate deciduous forests and their biological inhabitants...Our study of the *Smilax herbacea* complex provides the first documented example that understory herbs also may have persisted in the Driftless Area as a Midwest northern refugium disjunct from far northwestern and southern refugia in the United States during the LGM” (p. 812). [see also Soltis et al., 2006].

Smilax lehmiensis- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaf; Axelrod, 1998a. *S. magma*, late Miocene, Vasa Park Fl., King Co., WA, leaf, Dillhoff et al., 2014; *S. sp. 1* & 2- middle Eocene, Claiborne Group, TN, leaves; Dilcher & Lott, 2005. *S. sp.* Miocene (15-6 Ma), Iceland, Grimsson & Denk, 2007.

SOLANACEAE- Olmstead (2013): “Recent molecular phylogenetic studies of Solonales and Lamiales show that Solanaceae, Verbenaceae and Bignoniaceae all diversified in South America. Estimated dates for the stem lineages of all three families imply origins in the Late Cretaceous, at which time South America had separated from the united Gondwanan continent” (p. 80).

A preliminary press report by Oskin (2013; <http://www.livescience.com/40935-oldest-tomatillo-fossil-south-america.html>) of Solonaceae from 52.2. Ma deposits in South America refers to *Physalis* currently under study (Wilf, pers. comm., 2013).

Brunfelsia- Filipowicz & Renner, 2012: “Our results imply that *Brunfelsia* is 16-21 Myr old and entered the Antilles from South America early during its history, with subsequent expansion along the island arc. The only shift to hummingbird pollination occurred on Cuba, which also harbors the largest single radiation, with 11 species (10 included in our

study) that apparently arose over the past 4 Myr. Jamaica, Hispaniola, and Puerto Rico each sustained smaller radiations” (p. 1).

Datura sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

Solanum morelliforme- Simon et al. (2011): Hawkes (1990) hypothesized section *Petota* to have originated in the late Cretaceous to Eocene eras in North and Central America...He also suggested that some of these species migrated during the mid-Eocene to Pliocene eras to South America. Recent molecular clock data (Wang et al. 2008) indicated that eggplant and tomato/potato shared a common ancestor approximately 14 MYA and potato and tomato seven MYA, so it seems unlikely that the timing for the events proposed by Hawkes really took place in the Cretaceous-Eocene eras... literally all sister groups of section *Petola* are confined to South America (p. 1065).

SPARGANIACEAE

Sparganium- late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005.

STAPHYLEACEAE (see Tapisciaceae)

STERCULIACEAE

Dicotyophyllum washburnii- middle Eocene, Antarctic Peninsula, leaf; Poole et al., 2005.

Florissantia quilchenensis- middle Eocene, Republic Fl., WA, flowers, stamens; Wehr & Manchester, 1996. *F. speirii*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, flower, fruit; Meyer & Manchester, 1997. *F.* sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, flowers, fruits, Manchester, 2001, pollen (*F.*- type), Leopold &

Clay-Poole, 2001.

Fremontia (Fremontodendron; Sterculiaceae/Malvaceae) lobata- middle Miocene, Mint

Canyon Fl. (preliminary study), so. CA; Axelrod, 1940.

Sterculia- early Eocene, Caleta Cocholgüe Fl., central Chile, leaves; Gayó et al., 2005.

STYRACACEAE

Flectorivus microdontos- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl.,

OR, leaf; Meyer & Manchester, 1997.

Halesia sp.- Oligocene (32.9-29 Ma), Pitch-Pinnacle Fl., CO, leaves; Gregory &

McIntosh, 1996.

SYMPLOCACEAE

Symplocos nooteboomii- middle Eocene (44 Ma), Clarno Fm., OR, endocarps;

Manchester, 1994. *S.* sp.- late middle to early late Miocene, Bryn Mawr Fm., MD, pollen; Pazzaglia et al., 1997.

TAPISCIACEAE

Tapiscia occidentalis- middle Eocene (44 Ma), Clarno Fm., OR, fruit, seed cast;

Manchester, 1994. [formerly placed in the Staphyleaceae].

TETRACENTRACEAE

Tetracentron sp.- middle Eocene, Republic Fl., WA, Pigg et al., 2007; Miocene (15-6

Ma), Iceland; Grimsson & Denk, 2007.

THEACEAE

Cleyera grotei- middle Eocene (44 Ma), Clarno Fm., OR, seed; Manchester, 1994.

cf. *Gordonia* sp.- middle Eocene, Claiborne Group, TN, flower, Dilcher & Lott, 2005;

late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith &

Leopold, 2005.

Ternstroemites sp.- middle Eocene, Claiborne Group, TN, leaves; Dilcher & Lott, 2005.

TICODENDRACEAE- Gómez-Laurito & Gómez P., 1989; Hammel & Burger, 1991; see also *Incertae Sedis* (angiospermae).

Ferrignocarpus bivalis (*Ticodendron*)- middle Eocene, Clarno Fm., OR, fruits;

Manchester, 2011

Ticodendron- (Graham, 2010): “Once the distinctive features [of the extant species] became known, fossil leaf and fruit collections were re-examined for specimens with these features. Both leaves and fruits of *Ticodendron*, or with *Ticodendron* affinities, have been found in North America (*Ferrignocarpum* from the middle-late Eocene Clarno flora of Oregon; fruits about one-third the size of *Ticodendron*) and Europe (*Carpolithus* sp. 38 from the early Eocene London Clay flora of England, now *Ferrignocarpus*, see above; Steven Manchester, Susanne Renner, personal communication, 2005). Fossils of *Ticodendron* have not been found in Latin America (the pollen is similar to *Carpinus* and *Corylus* of the Betulaceae), but it, or its progenitor, apparently is another amentiferous woody genus like *Alfaroa* and *Oreomunnea* that migrated from the north or differentiated in the temperate cloud forests of Mexico and Central America” (p. 176-177).

TILIACEAE- Manchester, 1994: [“The radiation of Tiliaceae...was underway by the Late Cretaceous, as indicated by fossil wood (Wheeler et al., 1987) and pollen (Muller, 1978), but the first reliable evidence of the genus *Tilia* is about 20 million years later in the Tertiary” (p. 1176)].

Craigia brononii, *C. oregonensis*- Tertiary, Eurasia, North America, fruits; Kvaček et al.,

1991, [affinities originally cited as with Sapindaceae; Bůžek et al., 1989]: “Tertiary fruit remains of *Pteleaecarpum*...interpreted as valves of winged capsules of an extinct sapindaceous genus, are now recognized as belonging to a living genus of Tiliaceae.

The fossil fruits, which are common in the Tertiary of western North America, Europe, and Asia, are virtually identical in morphology and anatomy to fruits of *Craigia* W. W. Smith and Evans, an extant tiliaceous genus of southern China” p. 522]. *Craigia oregonensis*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, fruits, Axelrod, 1998a; Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, fruit, Meyer & Manchester, 1997. *C. sp.*- middle Eocene, Republic Fl., WA, fruit; Wehr & Manchester, 1996.

Intratriporopollenites sp. (*Tilia*)- Miocene, Tepoztlán Fm., Mexico, pollen; Lenhardt et al., 2013.

Plafkeria obliquifolia- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997.

Pteleaecarpum (see *Craigia*).

Tilia aspera- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves; Axelrod, 1998a. *T. circularis* (type A bracts)- early Oligocene, John Day Fm., Bridge Creek Fl., Lyons Fl., OR. *T. circularis*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves; Axelrod, 1998a. *T. pedunculata* (type B bracts)- late Eocene to middle Miocene of western North America, lower Miocene to Pliocene of western and central Europe, Eagle Creek and Bridge Creek Fl., OR; Type C bracts (Asia), Manchester, 1994. *T. circularis*, *T. pedunculata*, *T. aspera*, *T. fossilensis*, *T. lamottei*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, bracts, fruits, leaves; Meyer & Manchester, 1997. *T.*

johnsoni- middle Eocene, Republic Fl., WA.; Wolfe & Wehr, 1987. *T. selardalense*- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007. *T. sp.*- late middle to early late Miocene, Bryn Mawr Fm., MD, pollen; Pazzaglia et al., 1997. *T.* and types- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Tiliaephyllum tsagajanicum (Tilia)- late Paleocene (~60 Ma), Sagwon Bluffs, North Slope Alaska, leaf; Daly et al., 2011.

TORICELLIACEAE (see Incertae Sedis, angiospermae, *Tripartisemen bonesii*; for European fossil record see Meller, 2006).

Toricellia bonesii- middle Eocene (44 Ma), Clarno Fm., OR, seed; Manchester, 1994. [formerly *Tripartisemen bonesii*]. *T. sp.*- late Paleocene, Almont Fl., Williston Basin, ND, fruit; Zetter et al., 2011

TRAPACEAE (see Lythraceae)

cf. TRIURIDACEAE (trimerous staminate flower)- Late Cretaceous (late Santonian), Buffalo Creek Member, Gaillard Fm., Allon Fl., GA; Herendeen et al., 1999.

TRIMENIACEAE

Periporopollenites polyoratus- lower middle Eocene, Antarctic Peninsula, pollen; Poole et al., 2005.

TROCHODENDRACEAE- the fossil history of the family is discussed by Manchester et al., 1991, pp. 357-358; Pigg et al., 2001, 2007; and Crane et al., 1991:

“Trochodendrales ...first appear in the mid-Cretaceous (Doyle and Hickey, 1976; Hickey and Doyle, 1977; Crabtree, 1987; Upchurch and Wolfe, 1987) but are particularly common during the Paleocene” (pp. 1311-1312).

- Nordenskioldia borealis*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megafloora, Johnson, 2002; Paleocene, Ludlow Member of Fort Union Fm., ND, SD, megafloora, Johnson, 2002; Paleocene, Sentinel Butte Fm., Almont, Beicegel Fls., ND, fruits, dispersed achenes, leaves, Crane et al., 1990, 1991, Pigg et al., 2001.
- N. interglacialis*- Miocene, Latah and associated floras (14.5-16.5 Ma), British Columbia, Canada, WA, ID, infructescences, seeds, and *Nordenskioldia* sp. infructescence and *Zizyphoides*-like leaves, Manchester et al., 1991.
- Nordenskioldia/Zizyphoides*- late Paleocene, Williston Basin, Almont, Beicegel Fls.; Pigg & DeVore, 2010.
- Tetracentron hopkinsii*- early/middle Eocene, Allenby Fm., Okanogan Highlands, McAbee, British Columbia, Canada, leaves; Pigg et al., 2007 [also report *Tetracentron* sp. from the Republic Fl., WA].
- Trochodendron drachukii*- early/middle Eocene, unnamed Fm. of the Kamloops Group, Okanogan Highlands, McAbee, British Columbia, Canada, infructescence, seeds, associated *Trochodendron*-like leaves; Pigg et al., 2007; *T. nastae*- middle Eocene, Klondike Mountain Fm., Republic, WA, leaves, associated infructescences, fruits; Pigg et al., 2001. See also Wang et al., 2009. *T. sp.*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, leafy twigs, foliage, fruits, Dillhoff et al., 2005; middle Eocene, Republic Fl., WA, fruits, Wehr & Manchester, 1996.
- Trochodendroides nebrascensis*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megafloora; Johnson, 2002.
- Zizyphoides auriculata*- Miocene, Cook Inlet, AK, WA, Idaho; leaves; Manchester et al., 1991. *Z. flabella*- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD,

Megaflora, Johnson, 2002; Paleocene, Ludlow Member, Fort Union Fm., ND, SD, megaflora, Johnson, 2002; late Paleocene, Almont, Beicegel Fls., ND, leaf, Crane et al., 1990, 1991, Pigg & DeVore, 2010. *Z. sp.*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage; Dillhoff et al., 2005.

TURNERACEAE (see Passifloraceae)

TYMELIACEAE

Daphne sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

TYPHACEAE

Typha lesquereuxi- middle Eocene (45 Ma), Thunder Mountain Fl., ID, leaf; Axelrod, 1998. Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves, stems; Axelrod, 1998a.

Typha/Sparganium (pollen undifferentiated)- latest Eocene (34.1 Ma), Florissant Fl., CO; Leopold & Clay-Poole, 2001. Late Miocene, Vasa Park Fl., King Co., WA, pollen; Dillhoff et al., 2014.

ULMACEAE (see also Canabaceae)

Carpites ulminiformis- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megaflora; Johnson, 2002.

Cedrelospermum lineatum- middle Eocene (44 Ma), Clarno Fm., OR, samara; Manchester, 1994. Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf, fruit; Meyer & Manchester, 1997. *C. sp.*- middle Eocene, Republic Fl., WA, fruit, Wehr & Manchester, 1996; latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, fruits, Manchester, 2001.

Chaetoptelea microphylla- late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta,

Canada; Hoffman & Stockey, 1999.

Eoceltis dilcherii- middle Eocene Claiborne Fm., TN, flowers; Zavada & Crepet, 1981.

Planera type- late Miocene, Upper Beluga Fm., south coast Alaska, pollen; Reinink-Smith & Leopold, 2005.

Polyporopollenites undulosus (Ulmus)- Miocene, Tepoztlán Fm., Mexico, pollen
Lenhardt et al., 2013.

Pteroceltis sp.- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

Ulmipollenites tricostatus- late Paleocene, Almont Fl., Williston Basin, ND, pollen;
Zetter et al., 2011.

Ulmus- Denk & Dillhoff, 2005: “The fossil record of *Ulmus* extends back to the late Early Eocene of western North America, based on leaves co-occurring with fruits (MacGinitie 1941; Burnham 1986; Manchester 1989), while leaf remains attributed to *Ulmus* or showing closest affinities to the genus have been reported from Paleocene to Eocene sediments from North America, Russia, Spitsbergen, China, and Japan” (p. 1664). *U. chuchuanus*- early-middle Eocene, British Columbia, Canada, Republic, WA, leaves; Denk & Dillhoff, 2005. *U. danielii*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002. *U. knowltoni*- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaf; Axlerod, 1998a. *U. okanaganensis*- early-middle Eocene, Okanagan Highlands, McAbee, British Columbia, Canada, Republic, WA, leaves, flower fascicles, fruits; Denk & Dillhoff, 2005. *U. chaneyi*, *U. speciosa*, *U. sp. 1, 2, A, B*,- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek, Fl., OR, leaves, fruits;

Meyer & Manchester, 1997. *U. speciosa*- late Miocene, Vasa Park Fl., King Co., WA, leaf, Dillhoff et al., 2014; *U. sp.*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, leafy twigs, foliage, fruit, *Ulmus/Zelkova* pollen, Dillhoff et al., 2005; early-middle Eocene, Republic, WA, fruits, Denk & Dillhoff, 2005; middle Eocene, Republic Fl., WA, fruits, Wehr & Manchester, 1996; latest Eocene (34.1 Ma), Florissant Fl., CO, leaves, fruits, Manchester, 2001, *U./Zelkova* pollen, Leopold & Clay-Poole, 2001; Oligocene (32.9-29 Ma), Pitch Pinnacle Fl., CO, leaves, Gregory & McIntosh, 1996; late middle to early late Miocene, Bryn Mawr Fm., MD, Pazzoaglia et al., 1997; late Miocene, Upper Beluga Fm., south coast Alaska, pollen, Reinink-Smith & Leopold, 2005. *U. cf. pyramidalis*, *U. sp.*,- Miocene (15-6 Ma), Iceland; Grimsson & Denk, 2007; *U. sp.*- late Miocene, Vasa Park Fl., King Co., WA, pollen, Dillhoff et al., 2014.

Zelkova brownii- Oligocene (30.7 Ma), Haynes Creek Fl., ID, leaves; Axelrod, 1998a. “*Zelkova*” *hesperia*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, leaf; Meyer & Manchester, 1997.

VERBENACEAE (see also Solonaceae; Lamiales)

“Phylogenetic inference suggests a South American origin for Verbenaceae, with approximately six colonization events having given rise to the Old World species” (Marx et al., 2010).

Lantaneae- Lu-Irving & Olmstead (2013): “Lantaneae have shifted into the Neotropics from the southern temperate subtropics and have colonized Africa in at least two separate long-distance dispersal events’ (p. 103).

VITACEAE- late Eocene (36 Ma), lower John Day Fm., OR, seeds; Manchester & McIntosh, 2007 (family assignment).

Ampelocissus auriforma, *A. scottii*- middle Eocene (44 Ma), Clarno Fm., OR, seeds; Manchester, 1994. *A. sp.*- late Paleocene, Almont, Beicegel Fls., ND, leaf, Pigg & DeVore, 2010 (pers. comm. from Manchester).

Ampelopsis rooseae- middle Eocene (44 Ma), Clarno Fm., OR, seed; Manchester, 1994. cf. *Leea*- late Eocene, Tonosi flora, Pacific coast central Panama, seed; Herrera et al., 2012

Parthenocissus angustisulcata, *P. clarnensis*- middle Eocene (44 Ma), Clarno Fm., OR, seeds; Manchester, 1994. *P./Cissus*- latest Eocene (34.1 Ma), Florissant Fl., CO, pollen; Leopold & Clay-Poole, 2001.

Saxuva draculoidea- late Eocene, Tonosi Fl., Pacific coast central Panama, seed; Herrera et al., 2012.

Vitaceoxylon carlquistii, *V. tiffneyi*- middle Eocene (44 Ma), Clarno Fm., OR, wood; Wheeler & Manchester, 2002.

Vitis margnisperma, *V. tiffneyi*- middle Eocene (44 Ma), Clarno Fm., OR, seeds; Manchester, 1994. cf. *Vitis sp.*- late early Eocene (49-52 Ma), McAbee Fl., British Columbia, Canada, foliage; Dillhoff et al., 2005. *V. sp.*- Oligocene (33.6-32.2 Ma), John Day Fm., Bridge Creek Fl., OR, seed; Meyer & Manchester, 1997.

VOCHYSIACEAE- Sytsma et al. (2004): “No fossils have been reported that unambiguously belong to the Heteropyxidaceae, Psiloxylaceae, or the Vochysiaceae” (p. 589). “The African lineage of Vochysiaceae is nested within a South American clade and probably arose via long-distance dispersal in the Oligocene at a time when

the Atlantic had already rifted 80 m.yr. at the equatorial region” (p. 585). There are, however, several reports, at least of *Vochysia*, in the Quaternary and Tertiary of Latin America (Graham, 2010, p. 601).

ZINGIBERACEAE

Spirematospermum chandlerae- Upper Cretaceous (Santonian or Campanina), Black Creek Fm., Neuse River Cut-Off, NC, seeds; Friis, 1988: [“Recently seeds of *Spirematospermum* have been recovered from Upper Cretaceous strata in Europe (Knobloch & Mai, 1986) and North America (present study). *S. chandlera* described here from the Upper Cretaceous of North America is the first report of the genus outside Eurasia and represents the earliest known occurrence of the genus. During the Tertiary remains of *Spirematospermum wetzleri* first appear in the Upper Eocene strata of southern England, become abundant in the Upper Oligocene and Miocene strata of Europe and Siberia, and in Europe persist into the Pliocene” (p. 7). *S. sp.*- late Paleocene, Almont, Beicegel Fls., ND, embryo, seed, Crane et al., 1990, Benedict et al., 2007; Pigg & DeVore, 2010.

Zingiberopsis attenuata- Late Cretaceous (Maastrichtian), Hell Creek Fm., ND, SD, megafloora, Johnson, 2002; Paleocene, Paskapoo Fm., Alberta, Canada, leaves, Hickey & Peterson (1978); late Paleocene, Joffre Bridge Fl., Red Deer Valley, Alberta, Canada, Hoffman & Stockey, 1999.

ZYGOPHYLLACEAE

Gauiacum minuta- early middle Eocene, Aycross Fm., WY; megafossils; Leopold & MacGinitie, 1972, p. 193.

Larrea- Lia et al. (2001): “under the molecular clock hypothesis, nucleotide sequence

divergence between *L. divaricata* and *L. tridentata* suggests a Late Neogene (8.4 to 4.2 mybp) time of arrival of the diploid ancestors of *L. tridentata* to North American deserts” (p. 309).

Laport, R. G et al. (2012): “These findings suggest a recent origin of the North American creosote bush via long distance dispersal, with establishment of polyploid populations accompanying its rapid spread through the Northern Hemisphere” (p. 153).

[Tentative identifications, ordinal referrals, informal citation of biological affinities].

The reliability of these identifications and referrals to extant taxa is partly a function of the age of the strata, the principal purpose of the study (stratigraphic or biological), the extent to which adequate reference collections were used in suggesting possible biological affinities, background of the investigator(s), and degree of collaboration with morphologists and taxonomic specialists in extant plant groups. The biological affinity of fossil material in general, and these citations in particular, should be assessed before using them in phylogenic, biogeographic, or paleoenvironmental reconstructions [see Graham, 2010, pp. xii-xiii, 245-246, 371].

HAMAMELIDALES *Platanophyllum groenlandicum*, *P. prenobile*, Early Cretaceous,

Greenland, leaves; Boyd, 1998.

LAURALES. *Trilaurus sassopsis*, Early Cretaceous, Greenland, leaves; Boyd, 1998.

MYRICALES. *Myricompia groenlandica*, Early Cretaceous, Greenland, incomplete leaves; Boyd, 1998.

NYMPHAEALES. *Panefolium limnophilum*, Early Cretaceous, Greenland, leaves; Boyd, 1998.

RANUNCULALES. *Ceratophytum schornii*, *Menispermites ravnkloeftensis*, Early Cretaceous, Greenland, leaves; Boyd, 1998.

ROSALES. *Sapindopsis ravnkloeftensis*, Early Cretaceous, Greenland, incomplete stems with leaves; Boyd, 1998.

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