(SS37) The flora of the Paleogene: diversity, distribution and regional to global responses to changing climates

Date: August 29, 30
Place: Room 5234 (oral), Room 6317 (poster)
Organizers: Carlos Jaramillo, Diana Ochoa & Monica Carvalho
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Purpose: The (shifting) warm-to-cold climates of the Paleogene seem to correlate with plant dispersal and diversification during the initial stages of the Cenozoic. This symposium aims to present a scenario to 1) integrate the latest discoveries from Paleogene floras around the world; 2) evaluate the responses of vegetation to long-term climate fluctuations; and 3) discuss past distribution and biogeographic patterns, in search of potential commonalities in dispersal routes across tropical and temperate plant lineages.
A proper review and integration of worldwide Paleogene floras will help to better understand local and regional geographic and climatic features that influenced plant dispersal, as well as the post K/Pg boundary recovery and the initial diversification of early Cenozoic floras that established the onset for modern biota. Finally, the data brought to this symposium will contribute an adequate state of art on which to base for independently testing hypotheses derived from phylogeographic and biogeographic inferences of modern taxa.

Oral Presentation

Aug. 29 [AM1] Room: 5234

Chair: Carlos Jaramillo

9:00-9:40 **[Keynote] Revisiting the boreotropical forest** SS37-O01 (304)

Steven R. Manchester

9:40-10:00 **Proteaceae: key family of plant geography, in time and space, living and fossil, ecology and phylogeny** SS37-O02 (61) (Cancelled)

Raymond John Carpenter

9:40-10:00 **First record of a fungal palynomorph "peak" around the probable Oligocene/Miocene boundary, Gulf of Suez, Egypt** GS03-O08 (moved from SS37)

Haytham El Atfy, Rainer Brocke, Dieter Uhl

10:00-10:20 **Winged fruits and associated leaves of *Shorea* from the Late Eocene of South China and their phytogeographic and palaeoclimatic implications** SS37-O03 (124)

Xin-Xin Feng, Tatyana M. Kodrul, Jian-Hua Jin

Aug. 29 [AM2] Room: 5234

Chair: Diana Ochoa

10:50-11:10 **A Late Eocene palynological record of NE Tibet as evidence for xerophytic plant evolution and climatic and tectonic change (Xining Basin, China)** SS37-O04 (197)

Carina Hoorn, Julia Straathof, Roderic Bosboom, Hemmo Abels, Yadong Xu, Torsten Utescher, Kristina Bolinder, Catarina Rydin, Guillaume Dupont-Nivet

11:10-11:30 **The Eocene flora of Svalbard and its climatic significance** SS37-O05 (74)

Abigail Clifton, Jane Francis, Alan Haywood, Maria Jensen, Paul Markwick

11:30-11:50 **Testing for the effects and consequences of mid Paleogene climate change on insect herbivory** SS37-O06 (565)

Torsten Wappler, Conrad C. Labandeira, Jes Rust, Herbert Frankenhäuser, Volker Wilde

11:50-12:10 **Origin and evolution of Asian Dipterocarps: Evidences from resin chemistry and palynological data** SS37-O07 (112)

Suryendu Dutta, Suryakant M. Tripathi, Monalisa Mallick, Runcie P. Mathews, Paul F. Greenwood, Mulagalapalli R. Rao, Roger E. Summons

Aug. 29 [PM2] Room: 5234

Chair: Monica Carvalho

14:30-14:50 **Neotropical carpofloras reveal the floristic and biogeographic evolution of Paleocene to Miocene (~60 to 19 Ma) vegetation** SS37-O08 (186)

Fabiany Herrera, Steven R. Manchester, Carlos Jaramillo, Scott L. Wing, Gregory W. Stull, Mónica R. Carvalho, Camila Martinez

14:50-15:10 **Extinction component of Cenozoic plant diversity in the Neotropics** SS37-O09 (91)

Felipe de la Parra

15:10-15:30 **Diversification patterns in *Ephedra* (Gnetales) based on morphological studies of fossil and recent pollen** SS37-O10 (40)

Kristina Bolinder, Carina Hoorn, Guillaume Dupont-Nivet, Fridgeir Grimsson, Reinhard Zetter, Catarina Rydin

15:30-15:50 **Evolution of insect-mediated pollination indicated by Palaeogene flowers and insects from Central Europe** SS37-O11 (564)

Torsten Wappler

Aug. 29 [PM3] Room: 5234

Chair: Diana Ochoa

16:20-16:40 **Palaeogene legacies to the biogeography of southern South American forest** SS37-O12 (189)

Luis Felipe Hinojosa, María Fernanda Pérez, Ricardo Segovia

16:40-17:00 **Malvaceae and Menispermaceae from the mid-late Paleocene Neotropical rainforests of Northern South America** SS37-O13 (64)

Mónica R. Carvalho, Fabiany A. Herrera, Scott Wing, Steven Manchester, Carlos A. Jaramillo

Aug. 30 [AM1] Room: 5234

Chair: Monica Carvalho

9:00-9:20 **Late Eocene-early Oligocene vegetation changes in southwest Montana inferred from combined phytolith and paleosol analysis** SS37-O14 (486)

Selena Y. Smith, Nathan Sheldon, Caroline Strömberg, Meredith Dennis

Chair: Diana Ochoa

9:20-9:40 ***Inga* (Leguminosae: Mimosoideae) and *Bursera* (Burseraceae) leaves from the Middle Eocene La Carroza Formation.** SS37-O15 (60)

L. Calvillo-Canadell, S.R.S. Cevallos Ferriz

9:40-10:00 **Eocene *Bowenia* (Zamiaceae) macrofossils from far southern latitudes in Australia** SS37-O16 (188)

Kathryn Hill, Robert Hill, Raymond Carpenter, Gregory Jordan

Poster Presentation

Aug. 29 [PM1] Room: 6317

13:30-14:30 **Late Cretaceous and Paleogene forests and climate in Antarctica: signals from fossil wood** SS37-P01 (525)

Laura Tilley, Jane Francis, J. Alistair Crame, Vanessa Bowman

Carbon isotopic analysis of Southern beech (*Nothofagus*) pollen reveals shifts in Antarctic hydrology during the late Eocene SS37-P02 (161)

Kathryn Griener, David M. Nelson, Sophie Warny

Palynological analysis from Ligorio Márquez Formation (46º45´ S), Paleogene, Chile SS37-P03 (62)

Francy Milena Carvajal, Luis Felipe Hinojosa

A bristlecone pine forest from the early Oligocene of southwestern New Mexico, USA: Evidence for vegetation response to the Eocene-Oligocene transition in interior North America SS37-P04 (331)

Herbert W. Meyer

Paleobotanical and pollen evidence from the Antero Formation (Colorado, USA) for climate and floral change during the Eocene-Oligocene transition SS37-P05 (332)

Herbert W. Meyer, Estella B. Leopold, Dena M. Smith, Melissa A. Barton

SS37-O01 (304)
Revisiting the boreotropical forest

Steven R. Manchester

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The concept of a band of Eocene "boreotropical forest" throughout the Northern Hemisphere introduced by Jack Wolfe in the 1970s, has been widely accepted to explain the disjunct extant and fossil distribution patterns of thermophilic plant taxa across the northern continents. As the term suggests, Eocene flora and vegetation indicate anomalously warm climate--in agreement with other proxies for Cenozoic climatic change. However, taxonomic studies of leaf and fruit megafossil floras

favor recognition of paratropical to temperate, rather than fully tropical biomes for most Eocene middle and high latitude boreal floristic assemblages. A newly completed investigation of the middle Eocene (ca 47 Ma) Messel carpoflora of Germany, along with renewed investigations of the early Eocene (ca 50 Ma) London Clay flora provide important data for comparisons between European floras and contemporaneous floras of North America and Asia. A large number of genera are known from the European and North American Eocene that are now endemic to East and/or Southeast Asia, but most of those genera are not known to be present in the Eocene of Asian floras. The early and middle Eocene floras so far known from eastern Asia appear to be cooler, with more conifers and deciduous dicotyledonous elements than the European floras. Evidence for humid tropical vegetation in the Eocene of eastern Asia remains weak, and it is possible that characteristic elements of the modern tropical flora of SE Asia, such as mastixioids, Sabiaceae, *Symplocos*, *Tapiscia*, and diverse Menispermaceae and Icacinaceae dispersed to this region from Europe later in the Tertiary, as the Turgai Seaway receded.

Keywords: Eocene, Northern Hemisphere, Messel, Clarno, London Clay.

SS37-O02 (61)

Proteaceae: key family of plant geography, in time and space, living and fossil, ecology and phylogeny

Raymond John Carpenter

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Proteaceae is well known as one of the most important plant families of the Southern Hemisphere, being ecologically and morphologically diverse, and with numerous biogeographically interesting disjunctions. Although most familiar as dominants in fire-affected Mediterranean-climate heathlands of southern parts of Australia and Africa, the family's greatest generic diversity occurs in rainforests of north-eastern Australia. Other interesting taxa are endemic to cool, wet habitats in Tasmania. Here I review the Paleogene fossil record of Proteaceae and argue that it is critical for informing a range of phylogenetic, biogeographic and ecological hypotheses. Fossils date from the Upper Cretaceous and include pollen, flowers, fruits and leaves. They occur across southern lands including Antarctica. Pollen species include some important taxa that are strongly linked to extant lineages, notably *Beaupreaidites* and *Embothrium* types. Flowers are so far limited to *Musgraveinanthus* inflorescences from southern Australia. Fruits evidently belong to various lineages, and include the typical woody follicles of Proteaceae. Fossil foliar remains (leaves and cuticles) are distinctive, generally well preserved, widespread and very diverse. The best records are of *Banksia*, an iconic genus of Australian heathlands. Examples are given of some Proteaceae fossils that have been found very remote from the distributions of their nearest living relatives, how some fossils are useful for molecular dating studies, and how fossil leaves may be used for interpreting past vegetation and climates.

GS03-O08

First record of a fungal palynomorph "peak" around the probable Oligocene/Miocene boundary, Gulf of Suez, Egypt

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Very well-preserved palynomorph assemblages were recorded from the microscopic examination of 30 subsurface cutting samples of the Nukhul Formation (GH 404-2A Well) from the Gulf of Suez, Egypt. These assemblages witnessed a very minor record of marine palynomorphs (e.g. dinoflagellates) and were dominated mainly by highly diversified fungal taxa, fresh water algae (e.g. *Pediastrum* and *Botryoccocus*), in addition to a sparse record of miospores. The stratigraphy and age of the Nukhul Formation is still highly debated despite its potential as reservoir in the Gulf of Suez. Some authors referred it to the Early Miocene, however, recent publications shift it to the latest Oligocene-Early Miocene. Thus, the Nukhul Formation still forms one among the numerous stratigraphic puzzles of Egyptian stratigraphy. In our material, a considerable fungal proliferation composed of diverse and well-preserved fungal spores, fructifications, and hyphae were recorded. This composition shows a distinct fungal "peak" within the interval from 11370 to 11430 ft. in the GH 404-2A Well which is considered a new finding that has neither been recorded within the Nukhul Formation nor within the Tertiary in Egypt before. This bio-event may be associated with the known Mi-1 glaciation event at the Oligocene–Miocene boundary, although we cannot exclude that it represents more local events related to the rifting of the Gulf of Suez during this period.The rich diversity of the fungal remains may be interpreted as indication of an episodic prevalence of a humid climate in the area of deposition. In addition, the co- occurrence of freshwater algae like *Pediastrum* and *Botryoccocus* with some aquatic fungal genera such as *Involutisporonites*, *Paragrantisporites*, and *Reduviasporonites* suggest the existence of shallow, pond- or lake-like aquatic habitats.

Keywords: Nukhul Formation, Tertiary, *Pediastrum*, *Botryoccocus*.

SS37-O03 (124)

Winged fruits and associated leaves of *Shorea* from the Late Eocene of South China and their phytogeographic and palaeoclimatic implications

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Morphologically preserved winged fruits and associated leaves of Dipterocarpaceae were recovered from the Upper Eocene Huangniuling Formation, Maoming Basin, South China (Wang et al., 1994). The fruits are characterized by ellipsoidal to spherical fruit body with persistent style and three enlarged aliform sepal lobes. Foliage bears a combination of morphological feature: leaf simple; lamina elliptic to ovate, slightly asymmetrical, entirely-margined; apex obtuse and convex, base rounded; venation pinnate, secondary veins eucamptodromous, intersecondary veins present, tertiary veins mixed opposite and alternate percurrent. Based on the morphological comparative work with abundant extant and fossil specimens, the fruits and associated leaves are considered to be conspecific and attributed to Dipterocarpaceae as a new species of *Shorea*. This finding confirms the existence of *Shorea* in the Late Eocene of South China, providing important fossil evidence for investigating the early evolution and phytogeography of this genus and furthermore, discussing the Late Eocene floristic diversity of South China. Dipterocarpaceae is widely considered as the representative component of tropical rainforests, so that this occurrence, together with the Miocene *Dipterocarpus* winged fruit in Fujian Province indicate that there were rainforests in South China

during the Late Eocene to Middle Miocene (Shi and Li, 2010). As the most diversified genus of Dipterocarpaceae, *Shorea* includes approximately 200 species distributed in Bhutan, Cambodia, NE India, Indonesia, Laos, Malaysia, Myanmar, Nepal, Philippines, Thailand, Vietnam with merely two species confined to Yunnan and Xizang, Southwest China (Li et al., 2000). With the method of NLR (Nearest Living Relative), we deduce that the Late Eocene climate of South China was warmer and more humid than present and *Shorea* was widespread in the Maoming Basin, and probably with the climate cooling, *Shorea* retreated southward to its extant distribution. This study was supported by the National Natural Science Foundation of China (Nos. 31070200 and 40972011), the NSFC-RFBR project (Nos. 41111120083 and 11-04-91175), the Guangdong Natural Science Foundation of China (No. 10151027501000020).

Keywords: Dipterocarpaceae, Huangniuling Formation, Maoming Basin, rainforest, palaeoclimate.

SS37-O04 (197)

A Late Eocene palynological record of NE Tibet as evidence for xerophytic plant evolution and climatic and tectonic change (Xining Basin, China)

Carina Hoorn[1], Julia Straathof[2], Roderic Bosboom[2], Hemmo Abels[2], Yadong Xu[3], Torsten Utescher[4], Kristina Bolinder[5], Catarina Rydin[5], Guillaume Dupont-Nivet[6]

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Changes in Asian climate and paleoenvironments were driven by tectonic uplift and sea retreat since the Eocene and are thought to have implications for global climate changes. But continental records so far were not well enough dated to contribute to this model. A sedimentary succession of continental mudflat and ephemeral saline lake deposits in the Xining Basin (NW China) was dated through paleomagnetostratigraphy and proved to have an excellent pollen and spores preservation. Our analysis of selected evaporites and organic-rich clay beds now permits a detailed reconstruction of the local and regional paleoflora and has implications for climatic change and Tibetan Plateau uplift. In addition it contributes to our understanding of the evolution of xerophytic plant taxa such as the Gnetales and Nitrariaceae. High abundances of desert and steppe-desert taxa such as *Ephedripites* and *Nitrariadites/Nitraripollis* occur throughout this record. However, the lower part of the succession (from c. 42 up to 36.4 Ma) can be palynologically differentiated by abundances of *Ulmipollenites, Sapindaceidites* and ferns, and an assemblage of broad leaved forest taxa. The upper part of the section is defined by a sudden increase of Pinaceae (*Pinuspollenites, Piceaepollenites* and *Abiespollenites),* known in Chinese literature as the 'Pinaceae event', and which is dated at 36.1 Ma. Coexistence Approach (CoA) indicates that prior to 36.8 Ma regional climate was warm and wet, while from 36.4 to 33.5 Ma climate tends to be cooler and drier. The increase and subsequent abundance of taxa such as *Piceaepollenites* and *Abiespollenites* indicates a cooling and drying trend prior to the Eocene/Oligocene (E/O) boundary, but also the existence of high altitude mountain habitats in the periphery of the Xining Basin. This marked aridification deduced from both the sedimentary and the palynological records in the Xining Basin was further linked to the sea retreat out of the Tarim Basin.

Keywords: Eocene, Tibet, palynology, uplift, climate.

SS37-O05 (74)

The Eocene flora of Svalbard and its climatic significance

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The Eocene experienced the warmest temperatures in the last 65 million years. During this warm period forests grew up to 80ºN. These fossil forests provide an excellent opportunity for reconstructing the Arctic climate and environment during this globally warm period. The Eocene deposits of the Aspelintoppen Formation on Svalbard contain a rich fossil flora. A new collection of this flora is dominated by angiosperms, which can be divided into 22 morphotypes. These include species from the families Betulaceae (birch), Ulmaceae (elm), Fagaceae (beech) and Cercidiphyllaceae (katsura), along with *Juglans* (walnut) *Corylites* (hazel) and *Aesculus* (horse chestnut). The deciduous conifer *Metasequoia* is common, along with Cypress and ferns. The associated sediments indicate a fluvial floodplain environment subject to frequent flooding with leaves preserved within floodplain mudstones and siltstones, and base of crevasse splay/channel sandstones. Much of the flora is preserved as leaf mats, which is suggestive of an autumnal leaf fall that has been transported on to the floodplain during flooding events. Most fossil leaves are complete, indicating that they were not transported very far and were deposited in quiet water conditions. Initial physiognomic analysis of leaf characters indicate a warm wet climate with a mean annual temperature of 11°C (warm month mean 17°C, cold month mean 5°C) and 120cm mean annual precipitation. These terrestrial proxies provide valuable data to accompany marine proxies and to test the performance of global climate models of that period.

Keywords: Eocene Arctic climate, Aspelintoppen Formation, fossil flora, floodplain environment, physiognomic climate analysis.

SS37-O06 (565)

Testing for the effects and consequences of mid Paleogene climate change on insect herbivory

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The Eocene appears to have been one of the most biodiverse intervals in Earth's history, and is associated with the most extensive recent migration of the subtropical rainforest biome into the

midlatitudinal region. This trend began at the Paleocene-Eocene Thermal Maximum (54.8 Ma), an event defined by a global spike in elevated temperature and a dramatic carbon isotope excursion, as recorded in benthic foraminifera, and an association with increased atmospheric CO_2. Palaeoclimate calculations for the Middle Eocene indicate indicate that the era was also characterized by a subtropical style climate regime. We propose a framework to evaluate how terrestrial food webs evolved approximately 48 – 44 million years ago, close to the atmospheric CO_2 peak, as well as to the thermal and mammalian species-diversity maxima of the early Middle Eocene. The Messel and Eckfeld Maar localities are well known for their great variety of remains ranging from organic molecules, plants and insects and their associations, to articulated mammals exhibiting soft tissue preservation and stomach contents. The ecology of plant-insect associations currently is a significant aspect of modern ecological research. Consequently, studies of insect herbivory on fossil leaves provide crucial information on the ecology of feeding associations and the association of plants and their insect herbivores that cannot otherwise be obtained separately from fossil record of plant macrofossils and insect body fossils. We analyzed insect-feeding damage on 19.868 angiosperm leaves and scored each specimen for the presence or absence of 89 distinctive and diagnosable insect damage types (DT's) found in the total data set, allocated to five main functional feeding groups. The inventory of insect damage occurring on plant hosts indicates an impressive spectrum of plant-insect associations. Interestingly, the work on the European flora from Messel and Eckfeld shows a much greater diversity of insect feeding than comparable, contemporaneous floras from North America, revealing another important, previously unknown component of the plant-host and insect-herbivore diversification event during the European Eocene. In summary, the European middle Eocene previously has not been subjected to such a detailed analysis of plant-insect associations and the proposed project would present a significant, new and extended understanding of Eocene regional climate dynamics and how they differ from those of the present day.

Keywords: plant/insect interactions, Middle Eocene, climate, paleoecology, evergreen plants.

SS37-O07 (112)

Origin and evolution of Asian Dipterocarps: Evidences from resin chemistry and palynological data

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Dipterocarpaceae comprise large trees that dominate the canopy of lowland equatorial forests. They typically contribute to 30% of the total basal area of typical lowland evergreen forests in southeast Asia and play a dominant role in Asian rain forest ecology. Two opposing hypotheses have been proposed to explain the origin of the Asian dipterocarps. Some hypothesize that the family originated in Southeast Asia, most probably from West Malaysia in the late Mesozoic (Lakhanpal, 1970) and migrated into India during the late Cenozoic Era. Others suggest that Dipterocarpaceae have a Gondwanan origin and reached Asia by rafting on the Indian plate (Ducousso et al., 2004). The earliest dipterocarp fossils recorded in SE Asia come from Oligocene (34-23 Ma) sediments of Borneo. Here, we report an occurrence of Asian dipterocarps from approximately 53 Ma sediments from western India based on fossil resin chemistry and palynological data. Early Eocene lignites, carbonaceceous shales and resins were collected from the Cambay, Kutch and Barmer basins of Western India. Cadalene based C_{15} bicyclic sesquiterpenoids and their dimer bicadinanes were

consistently identified as the major pyrolysis products from all Early Eocene resins identifying them as angiosperm Dipterocarpaceae-sourced dammar (Class II) resins (Dutta et al., 2009). We have also recovered angiosperm pollen grains which show close affinity with modern pollen of *Dipterocarpus indicus*. An important implication of the present finding is that Asian dipterocarps must have originated in Gondwana and dispersed out-of-India into Asia once the land connection between Indian and Asian plate was well established during the middle Eocene (49-41 Ma). Moreover, the present study supports the hypothesis which suggests that many angiosperms did not originate in the SE Asian region, but dispersed into the area from western Gondwanaland.

SS37-O08 (186)

Neotropical carpofloras reveal the floristic and biogeographic evolution of Paleocene to Miocene (~60 to 19 Ma) vegetation

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Confident identification of ancient floristic components is key to understanding varying biogeographic patterns and the response of vegetation to tectonic changes in the Neotropics. We are investigating well-preserved fruit and seed floras ranging from ~60 to ~19 million years ago, from the Paleocene (Cerrejón & Bogotá floras), Eocene (Tonosí flora), Oligocene (Belén flora), and Miocene (Cucaracha flora) of Central and northern South America (specifically Colombia, Perú, and Panama), to address the following questions: 1) Was northern South America phytogeographically isolated during the Paleogene? 2) What families first colonized the emergent land in the Panamanian arch during the late Eocene? 3) How did the rise of the Andes affect the Pacific floras in Peru? 4) Did the Panamanian seaway act as a strong geographic barrier between the South and Central American forests in the Miocene? Each of these questions is addressed in numerical sequence below. 1) Preliminary results show that the Paleocene floras in Colombia reached a diverse array of fruit and seed types, sizes, and modes of dispersion after the Cretaceous extinction. Although northern South America was isolated geographically, several fossils (e.g. Menispermaceae, Icacinaceae, Arecaceae, Bombacoideae) show connection with North American paleofloras and extant Old World taxa. 2) The rise of the southern part of Central America has been hypothesized as a result of a volcanic arc. New geological data from Central Panama suggest the presence of large terranes above sea level at least since the late Eocene. Some of the new colonizing plant families/orders identified from disseminules include Arecaceae, the earliest Vitaceae and Humiriaceae in the Neotropics, Anacardiaceae, and Lamiales. At the generic level we have identified *Dracontomelon* and *Leea*, both of which are restricted today to Old World tropical rainforests. 3) From Peru, we have relocated the Belén carpoflora, collected originally by E.W. Berry. A diatom assemblage obtained from the layer that contains the plants indicates a latest early Oligocene age (~30-28.5 Ma), contrary to the Eocene age that has been historically assumed for this flora. Some of the new Belén taxa include endocarps of *Duckesia* (Humiriaceae), a genus endemic today to eastern Amazonia. 4) From the Middle Miocene of Panama we have discovered a rich carpoflora that suggests the presence of a rainforests in the region. Some of the new fossils include *Sacoglottis*, *Parinari*, *Cissus*, and *Spondias*, suggesting that long distance dispersal between Central and South America was very common before the closing of the Panamanian Seaway.

Keywords: permineralized, Neotropical, South America, Cenozoic, biogeography.

SS37-O09 (91)

Extinction component of Cenozoic plant diversity in the Neotropics

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Neotropics hold the highest plant diversity of the world and several studies have shown that this condition have existed at least since the late Paleocene. This high diversity is the result of three interacting factors: extinction, origination and immigration, however the contribution of each component to diversity is not well known. In this work, the contribution of extinction to the plant diversity pattern during the Cenozoic in the neotropics is explored. We used a database hosted by the Colombian Petroleum Institute-Ecopetrol that holds extensive palynological information from outcrops and exploratory oil wells from Northern South America to produce a composite section ranging in age from late Maastrichtian to late Miocene. A diversity curve for this time interval was produced using mean standing diversity. Survivorship analysis were used to estimate rates of extinction of group of species, all of which originated during a given time interval (cohort). Each cohort was tracked in time and the number of species surviving in each time interval was calculated. The results show low and constant diversity values and high extinction rates during the late Cretaceous and Paleocene. Near the Paleocene-Eocene boundary a dramatic change in diversity occurs and the extinction rate abruptly decreases remaining low until the Miocene. The results suggest that rapid diversification episodes like the Paleocene-Eocene Thermal Maximum are characterized by dramatic changes in the extinction rate. The factors controlling these changes are still in debate.

SS37-O10 (40)

Diversification patterns in *Ephedra* (Gnetales) based on morphological studies of fossil and recent pollen

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Recent findings indicate that the evolutionary history of *Ephedra* comprises at least two major diversification periods. A comparatively high diversity of ephedroids was present in the Early Cretaceous, including species that share uniquely derived features with extant *Ephedra*. Apparently, a significant part of this diversity went extinct already during the latter part of the Cretaceous and in the early Paleogene, causing a bottleneck effect in *Ephedra* reflected still today by an extraordinarily low amount of genetic and structural diversity in the group. The fossil record after the Cretaceous-Paleogene (K-P) boundary is less investigated, but indisputable documentation of gnetalean megafossils from the Paleogene and Neogene appears to be lacking. Using pollen

morphology, we investigate ephedran diversity and abundance, mainly after the K-P boundary. We conduct comprehensive studies of inter- and intraspecific variation in pollen morphology of extant *Ephedra*. With the recently resolved phylogeny of the genus as a framework, we trace phylogenetic and ecological patterns. Further, this study of recent *Ephedra* pollen is used as a tool to understand and describe fossil *Ephedra* pollen from an Eocene section of northeastern Tibet, as well as other sets of fossil *Ephedra* pollen from Cenozoic localities in Europe, Asia and North America. With these new data we intend to increase the understanding of evolutionary patterns and processes in *Ephedra*, assess phylogenetic relationships between living and Cenozoic species, as well as describe dispersal patters within the group after the K-P boundary.

Keywords: biogeography, bottleneck effect, Cenozoic, Cretaceous, dispersal patterns.

SS37-O11 (564)

Evolution of insect-mediated pollination indicated by Palaeogene flowers and insects from Central Europe

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Interactions among species are one of the most important drivers of the ecology and evolution of species. Throughout the last years, interesting insights into Palaeogene plant/insect associations from selected European localities (Messel, Eckfeld, Enspel) have been obtained. However, one component that was completely disregarded in all of these studies so far are the insect/flower associations. Because of their outstanding preservation quality of not just flowers and insects, but also direct evidence such as pollen-matching and gut content, the investigated localities offer worldwide unique requirements to study insect/flower associations. These are multifaceted and can be examined from botanical, entomological, ecological and evolutionary viewpoints that are often summarised under the heading of pollination biology. Given the fact that insect pollination is the dominant method of reproduction of flowering plants, which themselves comprise the bulk of the Palaeogene and modern flora, the role of insects in shaping major ecosystems cannot be underestimated.

Keywords: palaeoentomology, insect-plant mutualisms, pollination, climate change, Palaeogene.

SS37-O12 (189)

Palaeogene legacies to the biogeography of southern South American forest

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Southern South American forests have been considered a “Biogeographic Island” due their isolate distribution from other forest units from both Neotropical and extra South American regions. Biogeographically, the geographical distribution of forest taxa indicates that Chilean forests have

conserved their ancient historical links with widely disjunct floras. This blend of phytogeographic elements can be traced back to the ancient palaeofloras that occupied southern South America during the Palaeogene and early Neogene periods, under markedly different climatic and geological settings. In this talk, we will revisit the Palaeogene legacies in the modern forests, with special emphasis in i) phylogenetic signal of leaf character and palaeoclimate estimation; ii) biodiversity distribution and family ages; and iii) the anomalous high proportion of fleshy fruits in the southern forests and their Palaeogene connection. These three aspects of the Chilean forest will be considered, including the modern biodiversity hotspot of central Chile and both palaeobotany and palaeocimatic southern South American models. Acknowledge: FONDECYT # 1120215, 1110929; IMEB PO5-002; PFB-23

Keywords: paleoecology, Chile, southern South America.

SS37-O13 (64)

Malvaceae and Menispermaceae from the mid-late Paleocene Neotropical rainforests of Northern South America

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The middle-late Paleocene forests of northern South America are among the earliest known Neotropical rainforests. Well-supported taxonomic affinities and the phylogenetic placement of the taxa in this flora are required to understand the floristic composition of the early Neotropics and the evolution of high-diversity rainforests. We addressed the taxonomic affinities of leaves and endocarp compressions of Malvaceae and Menispermaceae (respectively) from the middle-late Paleocene Cerrejón flora and the recently discovered Bogotá flora in Colombia. These are dominant plant families in extant tropical rainforests and include lianas (Menispermaceae) as well as some of the largest trees in the Neotropics (Malvaceae). Most Menispermaceae have tropical distributions, whereas Malvaceae are mostly tropical with derived taxa that now thrive in higher latitudes. The sparse fossil record in tropical latitudes obscures interpretations of areas of origination and past distributions. The fossil leaves and fruits were placed in lineages within each family using synapomorphic characters and unique character combinations. A molecular scaffold analysis was used to place fossil endocarps onto recent phylogenetic hypotheses of Menispermaceae. Among the endocarps of Menispermaceae we recognize a compression of *Stephania*, and compressions belonging to the clade comprised of *Stephania+Cyclea+Cissampelos.* Despite convergence of overall leaf architecture among many Malvaceae, *Malvaciphyllum macondicum* can be assigned to the clade Eumalvoideae (Malvoideae). Fossil pollen from the Cerrejón Formation was also assessed, indicating the occurrence of its sister lineage, Bombacoideae. The abundance of leaves and pollen of Malvaceae, as well as endocarps and previously described leaves of Menispermaceae suggests that some derived lineages of these families were already common elements in neotropical forests by the late Paleocene. Some of the identified lineages had been previously interpreted as paleotropical and Australasian based on their extant distributions. Our findings suggest that late Paleocene Neotropical floras included lineages that now have Paleotropical and Australasian, as well as Neotropical, distributions, illustrating the importance of fossils to reconstructing biogeographic change through time.

Keywords: Australasia, biogeography, Cenozoic, fruit, pollen.

SS37-O14 (486)

Late Eocene-early Oligocene vegetation changes in southwest Montana inferred from combined phytolith and paleosol analysis

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Understanding local-to-regional responses of vegetation to changes in abiotic factors such as plate tectonics or climate is important in understanding overall dynamics of biomes. The mid-late Eocene was a period of active tectonism in western North America and saw a global pattern of cooling climate culminating in the Eocene-Oligocene transition (EOT; ~33.7 Ma) from a hothouse to icehouse climate. Documenting vegetation response to these changes is important for our understanding ecosystem evolution of western North America. In southwest Montana, the Renova basin preserves a number of Eocene and Oligocene aged localities that we have used to begin reconstructing Cenozoic vegetation changes in this region. Paleosols and phytolith assemblages from six localities (~39–32 Ma) have been studied. Paleosols are primarily Alfisols, which are consistent with a forested floodplain landscape, and Inceptisols and Entisols, consistent with mixed herbaceous and forest (woodland) vegetation. Paleosol geochemistry and $\partial^{13}C$ of soil carbon indicate slight cooling and drying as part of a long-term climatic deterioration. The oldest site examined, Timberhills A (~39 Ma), produced a high-resolution record dominated by forest indicators including tropical elements such as palms and zingiberaleans. Zingiberalean phytoliths are dominant in some of the assemblages. Given the affinity of many modern zingiberaleans to disturbed habitats at forest margins or gaps, these assemblages may record more open microhabitats within the forest. The overall dominance of forest indicators is punctuated by assemblages indicative of grass-dominated habitats, but this vegetation type appears to have been short-lived. The younger sites examined here lack the tropical zingiberaleans, with palms remain present in low numbers in most assemblages, and show a similar pattern of rare grass-dominated assemblages interspersed with predominantly forest-dominated assemblages. These data suggest that climate change was less drastic in southwest Montana than global temperature records would suggest. While the zingiberaleans become locally absent after ~39 Ma, vegetation was fairly consistently forest during the EOT. In the latest Eocene, however, our data, as well as previous phytolith studies from Montana indicate that grasses became more prevalent in plant communities. Combined with an increase in the cicada trace fossil *Taenidium* in local paleosols, this pattern suggests a shift to more open habitats, which subsequently, in the earliest Oligocene, become reforested.

Keywords: Eocene, Oligocene, tropical vegetation.

SS37-O15 (60)

***Inga* (Leguminosae: Mimosoideae) and *Bursera* (Burseraceae) leaves from the Middle Eocene La Carroza Formation.**

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Though the dry tropical flora in Low Latitude North America seems to be a relatively recent development of the tropical vegetation, some of its members seem to have a large history, as suggested by the Middle Eocene La Carroza Formation flora, in North Eastern Mexico. Presence of leaflets with narrow elliptic-oblong, asymmetric lamina, cuneate-convex base; serrate margin except in proximal zone. First order venation pinnate, well developed mid-vein, secondary veins eucamptodromous. Weak interior secondary veins present, third-order venation random reticulate. Fourth order venation dichotomous and areoles well-developed conform with the *Bursera* (Burseraceae) leaf type. A fragmented compound leaf with four pairs of elliptic-oblong leaflets, acute apex, asymmetrical convex base, first order venation pinnatte, secondary veins brochidodromous, pulvinate petiole, nectary interpetiolar and winged rachis is compared with the leaves of members of *Inga* (Leguminosae:Mimosoideae). *Bursera* is today an important genus restricted to dry tropical flora, while *Inga* has a wider tropical distribution, perhaps suggesting that these fossils formed part of a rain forest that was being selected as climatic condition changed in Central and Southern Mexico, as suggested by their presence in the Oligocene Coatzingo Formation, where dry tropical or chaparral vegetation has been described, and confirmed by its extant distribution.

Keywords: Laguminoase, Burseraceae, *Inga, Bursera*, Eocene.

SS37-O16 (188)

Eocene *Bowenia* (Zamiaceae) macrofossils from far southern latitudes in Australia

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Bowenia is a very distinctive genus of Australian cycad, variously ascribed to the families Zamiaceae, Stangeriaceae or Boweniaceae. It is represented today by two living species, one in rainforest understorey in north-east Queensland and the other in more open savanna vegetation in south-east Queensland. The plants are shrubs with an underground stem, and the long-lived, persistent leaves arise singly from this stem. This is not a genus that would be expected to have a good macrofossil record, given the inherent unlikely addition of its parts to a sedimentary environment. However, macrofossils of all leaflets from the complex bipinnate leaves are known from three Eocene deposits in south-eastern Australia and one in Queensland. Two of these, *B. papillosa* and *B. eocenica*, have been known for several decades, but here we report two new occurrences, dispersed cuticle from the Rundle Oil Shale in Queensland, and numerous well preserved leaflets from Lowana in western Tasmania. The latter represent a new species and also represent the oldest and most southerly distribution of the genus in Australia. Furthermore, we report much better preserved material of *B. eocenica* from Anglesea in Victoria, and note, for the first time, the development of a rudimentary mid-vein in all known specimens of this species, a feature not previously observed in *Bowenia*. We have also examined the diversity of cuticular morphology in the extant species in much greater detail than has been previously recorded, allowing the detailed cuticular morphology of the fossil species to be placed in better context.

SS37-P01 (525)

Late Cretaceous and Paleogene forests and climate in Antarctica: signals from fossil wood

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During the Late Cretaceous and Paleogene Antarctica was covered in forests even though the continent was situated over the South Pole. Global climate data derived from fossils and isotopes suggests that this was a time of warmer climates and higher atmospheric CO_2 than at present. However, there is evidence of climate fluctuations within this period, with warm climates during the mid-Late Cretaceous and cooling during the latest Cretaceous, followed by warm climates during the Paleocene and Eocene. Fossil wood is abundant in the Late Cretaceous and Paleogene marine sequences of Seymour Island, Antarctica. This wood originated from forests that once grew on an active volcanic arc, now represented by the Antarctic Peninsula. By the Late Cretaceous and Paleogene angiosperms (flowering plants) had fully evolved and dominated the canopy of the Antarctic forests, along with many conifer species. Past research has shown that during the Paleogene these forests may have resembled the cool temperate forests of Chile and New Zealand, with taxa such as Araucariaceae, Nothofagaceae and Cunoniaceae. Trees from these forests were transported from the volcanic arc and logs floated as drift wood in adjacent oceans before eventually sinking to the ocean floor where they became covered by marine sediments and subsequently permineralised, resulting in the preservation of cell structure. Tree growth is sensitive to external environmental factors, such as temperature and water availability, thus changes in climate are recorded in the structure of the wood in the form of growth rings and the arrangement of cell anatomy. These features can be analysed to determine climate features, such as annual temperature, rainfall and seasonality. The tree types from the fossil forests can be compared with modern relatives to understand palaeoecology. Fossil wood that has been systematically collected from the Late Cretaceous and Paleogene marine sequences of Seymour Island will be used to reconstruct the climate and ecology of these Antarctic forests in these past greenhouse climates.

Keywords: Antarctic Peninsula, fossil wood, angiosperms, conifers, palaeoclimate.

SS37-P02 (161)

Carbon isotopic analysis of Southern beech (*Nothofagus*) pollen reveals shifts in Antarctic hydrology during the late Eocene

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The Antarctic landscape was mostly ice-free and vegetated with mean temperatures above freezing prior to the E-O boundary (~34 Mya). Cooling and ice-sheet growth in the late Eocene led to conditions that have generally prevailed to the present. Recent palynological data obtained from the SHALDRIL II cores indicate that a significant decrease in plant diversity and abundance had already occurred at ~37 Ma, prior to the boundary. However, uncertainty exists as to why these changes in vegetation occurred. To infer changes in *Nothofagus* ecophysiology we used a spooling-wire device interfaced with an isotope-ratio mass spectrometer to perform carbon isotopic analysis on small quantities of modern and late Eocene *Nothofagus* pollen (20-60 grains per sample) that had been isolated using a micromanipulator. Values of carbon isotope discrimination (Δ) of pollen (range:

16.3-22.5‰) and leaves (range 17.2-23.6‰) from 32 herbarium specimens of 16 *Nothofagus* species from across the Southern Hemisphere are positively correlated (R^2=0.65). These results suggest that Δ of *Nothofagus* pollen is useful for assessing shifts in ratio of intercellular to atmospheric CO_2 concentrations (C_i/C_a), which reflects the proportion of net photosynthetic assimilation and stomatal conductance. Values of Δ from 10 samples of *Nothofagus* pollen from the SHALDRIL II cores range from 17.9-19.5‰ and generally decline through time. These results suggest gradually declining C_i/C_a and thus that increasing aridity contributed to vegetation changes leading up to Antarctic climate deterioration around the E-O boundary.

Keywords: micromanipulation, spooling wire microcombustion, aridity.

SS37-P03 (62)

Palynological analysis from Ligorio Márquez Formation (46º45´ S), Paleogene, Chile

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The blend of phytogeographic elements that characterizes contemporary forests of south-central Chile can be traced back to the ancient Palaeofloras that occupied southern South America during the Paleogene and early Neogene periods, under markedly different climatic and geologic settings from those of the present. Different palaeoclimatic scenarios have been proposed for the Cenozoic, specially at the Paleocene-Eocene thermal maximum (56.3 Ma), recognized as one of the most abrupt global warming events of the past 65 million years; and the Mid Eocene Climatic Optimum, when annual-mean and cold season continental temperatures were substantially warmer than modern, while meridional temperature gradients were greatly reduced. The Ligorio Márquez Formation corresponds to a an Upper Paleocene-Lower Eocene deposit in the south of Chile, located in Patagonia, latitude 46° 45´ S, outcropped in the area of the southern edge of Lago General Carrera. This strata is no more than 60 m thick and it is composed of coal seams and flood plain deposits with abundant plant fossils, which have been the focus of attention in attempting to understand the floristic and climatic history of southern South America during the Paleocene-Eocene. In order to enrich the known floristic history of this site, we have analyzed the palynological records of 23 samples along the section. Palynological analysis showed a high abundance of spores from Pteridophyta and Bryophyta throughout the section, including taxa such as *Polypodiisporites* sp., *Verrucatotriletes* spp., *Polypodiaceoisporites* sp., *Laevigatosporites* sp., *Ischyosporites* sp., *Muerregerisporis* sp., *Clavatriletes* sp., *Chomotriletes minor* and *Cingulatisporites* sp. The pollen assemblage is characterized by Podocarpaceae, Proteaceae and Nothofagaceae families that include *Podocarpus* sp., *Proteacidites* sp., and *Nothofagus fusca* and *menziessi* types. Besides, Palmae, Moraceae, Onagraceae, Loranthaceae and Bombacaceae families are presents, with *Mauritiidites franciscoi franciscoi*, *Momipites africanus*, *Corsinipollenites scabratus*, *Loranthacites* sp. and *Bombacacidites* sp. Acknowledge: FONDECYT 1120215, IMEB P05-002, PFB 23.

Keywords: Southern South America, floristic history, Paleocene-Eocene, *Nothofagus*.

SS37-P04 (331)

A bristlecone pine forest from the early Oligocene of southwestern New Mexico, USA: Evidence for vegetation response to the Eocene-Oligocene transition in interior North America

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The Hermosa and Hillsboro floras of southwestern New Mexico, USA are almost totally dominated by thousands of specimens of foliage and cone scales of *Pinus*. The association of five-needled fascicles lacking persistent bundle sheaths along with cone scales bearing dorsally oriented umbos indicates an affinity with the subsection Balfourianae, which includes the extant bristlecone and foxtail pines. The fossil specimens can be assigned to *Pinus crossii*, which is well known from the late Oligocene Creede flora of Colorado, and elsewhere. Modern representatives of the subsection Balfourinae are endemic to the western U.S. They typically inhabit cold climates at high elevations and are among the world's longest living organisms, some reaching ages of more than 4000 years. The fossil record of this group is known from western American floras as old as Eocene. The almost exclusive dominance of this pine in the Hermosa and Hillsboro floras is unique and indicates a depauperate, cold, subalpine (physiognomically taiga-like) forest. This indicates a colder climate than the more northern Creede flora, which has greater diversity among angiosperms and other conifers. Angiosperms are extremely rare in Hermosa and Hillsboro but include several specimens of *Mahonia*. The coniferous dominance is substantiated by the pollen record, which consists of 90% bisaccate pollen, primarily *Pinus* but also including some *Picea*. Mean annual temperature is estimated at about 0°C and is supported by both physiognomic and nearest-living-relative comparisons. The floras occur in lacustrine shale that was deposited in association with volcanic sediments. This shale uncomformably overlies volcanic sequences representing the eruptive phases of the Emory cauldron. An early Oligocene age for the floras is supported by bracketing dates of 28.1 ± 0.6 Ma and 31.7 Ma for the Hillsboro flora and an age of 33.6 ± 1.0 Ma for Hermosa. This chronology indicates that the Hermosa and Hillsboro floras lived during or immediately following the cooling of the Eocene-Oligocene transition. The floras provide important insight for understanding the response of vegetation to cooling climate at higher elevations in the continental interior of North America. Estimated paleoelevation is about 3000 meters based on comparison with coeval early Oligocene sea level floras and inferred lapse rates. The location of the floras within close proximity to the eroded remnant of the topographic depression of the caldera potentially enhanced cold air drainage and may have exacerbated the cold character of the flora.

Keywords: Hermosa flora, Hillsboro flora, subalpine, paleoelevation.

SS37-P05 (332)

Paleobotanical and pollen evidence from the Antero Formation (Colorado, USA) for climate and floral change during the Eocene-Oligocene transition

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The Antero Formation from central Colorado, USA, provides evidence in combination with the nearby Florissant Formation for better understanding the nature of climate and floral change during the Eocene-Oligocene transition in the Rocky Mountain region. The Antero macrofossil assemblage is known from very small collections that include conifers such as *Abies*, *Picea*, *Pinus* cf. *crossii*, *Chamaecyparis*, and *Sequoia*, and angiosperms strongly dominated by *Cercocarpus* but also including *Mahonia*, *Quercus*, a rosaceous thorn, and others. Associated pollen better documents the

character of the flora and is dominated by conifers including abundant *Pinus*, *Picea* and *Abies* (*A. bracteata*-type), along with less abundant Cupressaceae, *Podocarpus*, *Tsuga* (*T. mertensiana*-type), *Keteleeria*/*Pseudolarix*, and *Pseudotsuga*/*Larix*. The hardwood component is comparatively minor and includes *Ulmus*/*Zelkova* (possibly equivalent to extinct *Cedrelospermum*), *Ostrya*/*Carpinus* (possibly equivalent to extinct *Paracarpinus*/*Asterocarpinus*), *Eucommia*, *Carya*, *Juglans*, *Engelhardtia*-type, *Malus*-type, *Quercus*, *Cardiospermum*, *Sarcobatus*, other Chenopodiaceae, and Gramineae. By contrast, the latest Eocene (34.05 Ma) Florissant Formation has produced a large assemblage of fossil plants including leaves, fruits, and pollen, with a much greater diversity of hardwoods. Florissant has a long history of study and is much better understood. Both the Antero and nearby Florissant plant assemblages accumulated under nearly identical taphonomic conditions within lacustrine basins that formed shale and mudstone in association with volcanic deposition. The precise geochronology of the Antero Formation with respect to the Eocene-Oligocene boundary remains uncertain, although an associated $^{40}Ar/^{39}Ar$ date of 33.8 Ma indicates that Antero is at least in part slightly younger than Florissant and may be coincident with the Eocene-Oligocene boundary. The Antero macrofloral assemblage shares most of its taxa with Florissant (at least 13), although it also shares taxa with the less diverse late Oligocene (27 Ma) Creede flora. The presence of *Pinus* cf. *crossii* foliage, which is not present at Florissant, suggests an affinity with cooler floras such as Creede. The pollen assemblage also shows similarities to Florissant but it lacks the huge diversity of Florissant hardwoods and also has similarity to Creede. Cupresseaceae ("TCT") dominates the pollen assemblage at Florissant but is rare at Antero. The abundance of conifers at Antero indicates that climatic cooling was well underway. Elevation between the sites is comparable, and the difference in floral composition appears to support evidence that the climatic cooling of the Eocene-Oligocene transition occurred between the deposition of the Florissant Formation and the plant-bearing beds of the Antero Formation.

Keywords: palaeobotany, pollen, Florissant.