

**(SS42) Neogene global tectonic and climatic change as drivers in plant evolution:  
linking the palynological, palaeobotanical and molecular records**

**Date:** August 28

**Place:** Room 5234 (oral), Room 6318 (poster)

**Organizers:** Carina Hoorn, Andres Pardo & Alexandre Antonelli

**Contact email address:** M.C.Hoorn@uva.nl

**Purpose:** The Neogene period represents the transition to our modern world, when crucial geographical features such as topographic relief, drainage patterns and oceanic currents were laid out. It also represents the run-up to the 'icehouse' world with final bleeps of a 'greenhouse' during the Middle Miocene (c. 15 Ma) and Middle Pliocene (c. 4 Ma). The combined effects of global tectonic and climatic change was critical for floral and faunal evolution, but also determined present biodiversity patterns, particularly this latter aspect was only identified by scientists in recent years. Interdisciplinary studies that include the geological history, palynology, palaeobotany and molecular phylogeny potentially can offer new insights into our understanding of plant evolution and diversification. In this session we encourage palynologists, palaeobotanists and molecular biologists who work at the interface of their disciplines to present their research on the Neogene evolution of plants and algae in geologically dynamic regions from all over the globe and from both marine and/or continental settings. The insights gained from this type of research are relevant when modeling the impact of future climatic change, but also where it concerns drafting guidelines for conservation policies in regions of high biodiversity.

Oral Presentation

Aug. 28 [AM1] Room: 5234

Chairs: Carina Hoorn, Alexandre Antonelli

9:00-9:20 **[Opening of the Symposium]** SS42-O01

Carina Hoorn, Andres Pardo, Alexandre Antonelli

9:20-10:00 **[Keynote] Understanding the evolution of the Malesian Flora: what the interplay of molecular phylogenies and palynology can offer** [SS42-O02 \(347\)](#)

Robert J Morley

10:00-10:20 **Bayesian estimation of speciation and extinction rates from fossils and molecular phylogenies** [SS42-O03 \(478\)](#)

Daniele Silvestro, Jan Schnitzler, Nicolas Salamin, Lee Hsiang Liow, [Alexandre Antonelli](#)

Aug. 28 [AM2] Room: 5234

Chair: Andres Pardo

10:50-11:10 **Palynology, vegetation and climate of latest Miocene, Pliocene and Early Pleistocene sediments of the Caspian Sea: a detailed study of several outcrop localities in Azerbaijan** [SS42-O04 \(431\)](#)

Keith Richards

11:10-11:30 **Late Cenozoic pollen records of the Qaidam Basin, north Tibetan Plateau and implications for the central Asian aridification** [SS42-O05 \(334\)](#)

[Yunfa Miao](#), Xiaomin Fang, Fuli Wu, Maotang Cai, Chunhui Song, Mark Herrmann

- 11:30-11:50 **Preliminary results from a palynological study of Mio-Pliocene Siwaliks sediments in the eastern Himalaya (Samdrup Jongkhar, Bhutan)** [SS42-O06 \(196\)](#)  
Carina Hoorn, Laurie Barrier, Isabelle Coutand, Guillaume Dupont-Nivet, Djordje Grujic
- 11:50-12:10 **Extended stratigraphy, palynology and depositional environments record the initiation of the Himalayan Gyirong Basin (Neogene China)** [SS42-O07 \(580\)](#)  
Yadong Xu, Kexin Zhang, Guocan Wang, Shangsong Jiang, Guillaume Dupont-Nivet, Carina Hoorn
- Aug. 28 [PM2] Room: 5234  
Chair: Carina Hoorn
- 14:30-14:50 **Landscape changes in northern South America during the Neogene** [SS42-O08 \(435\)](#)  
Ingrid C. Romero, Fátima Leite, Alejandra Restrepo, Carlos Jaramillo
- 14:50-15:10 **Abrupt onset of Patagonian desertification by 11 Ma: insights from the fossil record** [SS42-O09 \(395\)](#)  
Luis Palazzesi, Viviana Barreda, Verónica Guler
- 15:10-15:30 **Timing the land emergence on the Chocó basin, Colombian Pacific (NW South America): micropaleontologic and sedimentologic evidence** [SS42-O10 \(383\)](#)  
Diana Ochoa, Andrés Pardo, Millerlandy Romero, Angelo Plata, Paula López, José-Abel Flores, Carlos Jaramillo, Rosa Navarrete, Sebastián Rosero, Lina Clemencia Restrepo, Carlos Borrero, Clemencia Gómez, Sergio Adrian López
- 15:30-15:50 **Towards a Neogene palynological zonation for Colombian Pacific basins (NW South America)** [SS42-O11 \(396\)](#)  
Andrés Pardo, Diana Ochoa, Angelo Plata, Millerlandy Romero, Silane DaSilva, José-Abel Flores, Francisco Sierra, Alejandra Mejía, Rosa Esther Navarrete, Clemencia Gómez, Sergio Adrián López
- Aug. 28 [PM3] Room: 5234  
Chair: Alexandre Antonelli
- 16:20-16:40 **Palynostratigraphy of the Mid/Late Cretaceous to Cenozoic strata in the Kaikang Trough, Muglad Rift Basin, South Sudan** [SS42-O12 \(1\)](#)  
Omer Babiker Abdel Rahim, Aaron W. Hunter, Jim Cole
- 16:40-17:00 **Geological significances of Late Pliocene - Early Pleistocene palynological assemblages in the Zanda Basin, Tibet (China)** [SS42-O13 \(218\)](#)  
Shang-song Jiang, Shu-yuan Xiang, Ya-dong Xu
- 17:00-17:20 **A flower of *Lunania* Hooker (Salicaceae) preserved in the Miocene amber from Simojovel de Allende, Chiapas (Mexico), as evidence for the long history of this genus** [SS42-O14 \(185\)](#)  
Ana Lilia Hernández-Damián, Laura Calvillo-Canadell, Sergio Rafael Silvestre Cevallos-Ferriz

Chairs: Alexandre Antonelli, Andres Pardo, Carina Hoorn

17:20-17:40 **[Discussion] Bridging the gap. New methods for integrating biostratigraphic and molecular phylogenetic datasets** SS42-O15

Poster Presentation

Aug. 28 [PM1] Room: 6318

13:30-14:30 **Oligocene-Miocene palynofloras from northern South America** [SS42-P01 \(382\)](#)

Diana Ochoa, Andrés Pardo, Millerlandy Romero, Angelo Plata, Silane Da Silva, Francy Carvajal, Jose Abel Flores, Juan Carlos Silva, Sebastian Rosero, Clemencia Gómez, Sergio Adrian Lopez

**Morphological analysis of extant *Serpocaulon* A. R. Sm. (Polypodiaceae J. Presl. & C. Presl.) spores from Colombia (NW South America): a tool for the study of the Cenozoic Neotropical paleobotany** [SS42-P02 \(428\)](#)

Valentina Ramírez-Valencia, David Sanín, Andrés Pardo-Trujillo

**Ladrilleros-Juanchaco: a marine Miocene reference section from the Colombian Pacific** [SS42-P03 \(408\)](#)

Angelo Plata, Andrés Pardo, Diana Ochoa, José-Abel Flores, Francisco Sierro, Alejandra Mejía, Felipe Vallejo, Raul Trejos, Juan Carlos Silva, Clemencia Gómez, Sergio Adrián López

**A palynological study of Neogene fluvial sediments of SW Amazonia (Madre de Dios foreland Basin, Peru) with inferences for paleo-biodiversity studies** [SS42-P04 \(548\)](#)

Jochem Vink, Mélanie Louterbach, Martin Roddaz, Pierre-Olivier Antoine, Laurent Marivaux, Guillaume Billet, Alexandre Antonelli, Carina Hoorn

SS42-O02 (347)

**Understanding the evolution of the Malesian Flora: what the interplay of molecular phylogenies and palynology can offer**

Robert J Morley

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Contrary to earlier beliefs, the Malesian region is not the ‘cradle of the flowering plants’; it became established as a physical entity at the beginning of the Miocene (23 Ma). The palynological record made it clear that rain forests, which circumscribe virtually the entire Malesian Flora, appeared in West Africa well before their establishment in our region. It also was palynology which demonstrated that the Malesian Flora was essentially ‘seeded’ by the Early Tertiary Indian Flora, which aggressively dispersed into the Southeast Asian region following the collision of the Indian Plate with Asia during the Middle Eocene, contradicting then contemporary views which held that the Indian rain forest flora was essentially derived from SE Asia. In the Middle Eocene both India and the Sunda region were in the same climatic zone, and the invasion resulted in the virtual elimination of the previous low diversity Paleocene Sundanian flora. The Miocene establishment of the Malesian Flora, following the collision of the Australian Plate with Sunda, did not result in large scale intermixing of floras but caused a change to a much wetter, rain forest climate across the

region, and the development of the East Asian Monsoon, and that this climatic regime has characterised the region ever since, making it by some measure the *youngest* of the three tropical rain forest blocks. The very high diversity of the present day flora is likely to have developed as a result of a long history of everwet climates within the Bornean core of Sundaland, with lower diversity floras in subequatorial regions where cyclical seasonal climates affected both hemispheres. All this was revealed from palynological studies. Testing many aspects of the development of the flora as proposed from palynology has come largely from molecular studies. The 'Out of India' theory developed to confirm the Indian derivation of many taxon groups; the limited immigration of Australian elements has been confirmed from molecular studies, as has the origin of many Malesian taxon groups, a large number of which date back just to the beginning of the Miocene. Future progress in our understanding of the evolution of the flora of this region will benefit from cooperation with other scientists, especially with those involved in molecular studies.

**Keywords:** Malesian Flora origins, molecular phylogeny.

SS42-O03 (478)

**Bayesian estimation of speciation and extinction rates from fossils and molecular phylogenies**

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Analytical advances in molecular phylogenetics and palaeobiology have provided us with tools to estimate the tempo and mode of biotic evolution. However, most studies have relied on a single source of data: either molecular phylogenies or fossil occurrences. Few attempts have yet been made to compare results based on evidence from both, despite large discrepancies in the patterns recovered for almost all organism groups. This situation might derive from limited interaction between molecular systematists and palaeobiologists, but also from the wide range of methods and assumptions employed, making comparisons statistically difficult. Here we present a new Bayesian framework to estimate speciation and extinction rates based on fossil occurrences. Times of speciation and extinction are estimated from first and last occurrences in the fossil record while modeling the uncertainty on their temporal placement. This information is then used to derive rates of speciation and extinction and their variation through time. The method employs similar statistics and algorithms as those used for deriving such rates from dated molecular phylogenies, making comparisons of results more straightforward for any given taxon. In addition, the method is useful for estimating diversification rates in taxa lacking molecular phylogenetic information, such as extinct lineages. We first perform simulations to evaluate the performance of our new approach, testing the power of the framework in estimating time-varying diversification rates. We then apply the method to mammals, as they have been extensively studied and substantial amounts of both molecular and fossil-occurrence data are currently available. Based on both molecular phylogenies and fossil data we estimate speciation and extinction rates for 1-million-year intervals, and test for significant rate shifts. We compare our results to previously hypothesized links between shifts in mammal diversification, the K/T impact event, and periods of climate change through the Cenozoic. The estimation of mammalian diversification rates using both fossil and molecular data can be confidently done at the species level for many clades. Although our method can be directly applied to palynological data identified to the level of species, in many cases taxonomic uncertainty poses a conspicuous challenge. It may be hence necessary to increase our confidence on species identification of fossil pollen (e.g. by increased use of ESM techniques and image recognition

software); estimate taxon-specific multipliers that translate palynological morphospecies into actual species richness; or modify our approach to estimating plant diversification rates at higher taxonomic levels.

**Keywords:** diversification, evolution, biogeography, bioinformatics, method development.

SS42-O04 (431)

**Palynology, vegetation and climate of latest Miocene, Pliocene and Early Pleistocene sediments of the Caspian Sea: a detailed study of several outcrop localities in Azerbaijan**

Keith Richards

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A detailed palynological study has been made of over 400 outcrop samples from the Kirmaky, Yasamal and Kura Valleys in Azerbaijan. The results give a comprehensive picture of sedimentation, vegetation and climate in the Caspian Sea from the Late Miocene to the beginning of the Pleistocene. Late Miocene sediments contain marine dinocysts, evidence for a connection between the Caspian and Para-Tethyan seas. Latest Miocene sediments are transitional from marine to brackish lacustrine and hypersaline, indicated by frequent hypersaline tolerant algae (*Tasmanites*). The drying of the basin is linked to the Messinian desiccation crisis, during which a deep canyon was formed in the north and central Caspian region. Deposition resumed in the Early Pliocene in an isolated lake basin. These sediments make up the Pliocene Productive Series, which are important for oil and gas production. They are sourced mainly from the palaeo-Volga and palaeo-Kura river systems which deposited very extensive fluvial and deltaic / lacustrine sediments across much of the central Caspian region. Early Pliocene sediments contain very abundant palynofloras, with frequent tree pollen (e.g. Taxodiaceae & *Ulmus*) indicating the presence of localized swamp forest and dry forest vegetation, and a generally warm climate. Shifts in the relative proportions and composition of tree pollen (AP) and various herbs (NAP) e.g. Chenopodiaceae identify a climatic cyclicality, and wet and dry trends in the delta sediments. These are linked to rises and falls in Caspian Sea levels. Highstands are characterized by dilute waters (strong freshwater inflow) and contain frequent algae such as *Pediastrum* and *Botryococcus*. Relative lowstands occur due to reduced run-off and have low salinity dinocyst assemblages including *Spiniferites cruciformis* and *Caspidinium rugosum*. Cycle boundaries are marked by peaks in reworked Mesozoic and Paleozoic palynomorphs and by localized “fungal spikes”. There is no single event that can be linked to the mid (Late) Pliocene warm event (c. 3.3 to 3.0 Ma) but most samples contain frequent warm temperate tree pollen, with deposition around that time occurring in fluvio- lacustrine settings with variable fluvial discharge and salinity (Sabunchi Formation). Latest Pliocene sediments show increasing proportions of NAP, especially Chenopodiaceae, with sedimentation occurring in fluvial to alluvial plain / continental and ephemeral to hypersaline lacustrine settings (Surakhany Formation). The onset of Pleistocene deposition coincides with a renewed marine connection (Akchagyl Formation) with frequent dinocysts (*Lingulodinium*) and cold tolerant pollen types e.g. *Artemisia*.

**Keywords:** Kirmaky, Yasamal, Volga, Kura, Productive Series.

SS42-O05 (334)

**Late Cenozoic pollen records of the Qaidam Basin, north Tibetan Plateau and implications for the central Asian aridification**

Yunfa Miao<sup>1,2</sup>, Xiaomin Fang<sup>2,3</sup>, Fuli Wu<sup>2</sup>, Maotang Cai<sup>2</sup>, Chunhui Song<sup>4</sup>, Mark Herrmann<sup>1</sup>

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The Qaidam Basin is the largest basin at the northern margin of the Tibetan Plateau, central Asia characterized with arid climate. Researches on the Late Cenozoic pollen records from the basin can provide a better understanding of the drying process in the Central Asia and possible linkage with the East Asian monsoonal system. Here, we compiled two cores and one natural section to discuss the aridification process, spanning the early Miocene to the late Pleistocene (ca.18-0.1 Ma). In the Miocene, the pollen results show the conifers dominated in most of the samples, typically including *Picea*, *Pinus*, *Podocarpus*, *Tsuga* and *Cedrus* etc. The other pollen mainly came from shrubs and herbs, such as Chenopodiaceae, *Ephedra*, Asteraceae, *Artemisia*, *Nitraria* and Poaceae etc. The broad-leaved taxa, like *Quercus*, Juglandaceae, Ulmaceae, and Betulaceae were few. Totally, the thermophilic taxa percentages were higher between 18 and 14 Ma and decreased after 14 Ma, fitting well with the Middle Miocene Climatic Optimum between 18~14 Ma and the global climatic cooling after 14 Ma. During the same period, the xerophytic taxa percentages gradually increased and the conifers decreased, suggesting a stably drying process in the Qaidam linked with the gradual weakening of the East Asian summer monsoon driven by the global cooling. During the Pliocene, the conifers of *Picea* and *Pinus* enlarged obviously, the *Cedrus*, *Podocarpus* and *Tsuga* nearly disappeared. Such pollen assemblages imply that the climate became drier and colder than before, correlated with the ice-sheets expansion in the high latitude of the North Hemisphere. During the Pleistocene, the *Picea* and *Pinus* decreased sharply and were mainly replaced by the dry-tolerant grasses, including major *Artemisia*, Chenopodiaceae, Poaceae and Asteraceae etc. The climate became even drier and colder than before. In summary, we argue the Qaidam Basin suffered continuous aridification step by step since the late Cenozoic, which is possibly linked to the weakening of the East Asian summer monsoon, the global cooling and/or the Tibetan Plateau uplift. This work was co-supported by the (973) National Basic Research Program of China (Grant No. 2011CB403000, 2010CB833401) and the NSFC Grants (41172153, 40902015, 41021001, 40920114001).

**Keywords:** pollen, Qaidam Basin, Late Cenozoic, aridification, monsoon.

SS42-O06 (196)

**Preliminary results from a palynological study of Mio-Pliocene Siwaliks sediments in the eastern Himalaya (Samdrup Jongkhar, Bhutan)**

Carina Hoorn<sup>1</sup>, Laurie Barrier<sup>2</sup>, Isabelle Coutand<sup>3</sup>, Guillaume Dupont-Nivet<sup>4</sup>, Djordje Grujic<sup>3</sup>

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The Siwaliks Hills straddle the southern foothills of the Himalayan orogenic system and are

constituted by siliciclastic sediments derived from the erosion of the Himalaya to the north, and deposited during the Mio-Pliocene in the Himalayan foreland basin to the south. These units have been recently uplifted and exposed to the surface by the activation of the Main Frontal Thrust and constitute an excellent record of the Neogene tectonic and climatic evolution in the Himalayan region. Specifically, aboard of the eastern Himalaya, the early Pliocene uplift of a 1600-m-high orographic barrier, the Shillong Plateau, is thought to have altered the regional climate by condensing the monsoon-related moisture derived from the Bay of Bengal along its southern flank, thus creating relatively dryer conditions (compared to pre-Pliocene times) in the central and eastern Bhutanese Himalayan range front. To test this hypothesis we have investigated the sedimentary sequence and palynological record of a 2500-meters-thick Siwalik section located in southeastern Bhutan at Samdrup Jongkhar and dated it by means of paleomagnetic analysis. Our preliminary palynological results show a pollen composition characterized by abundances of grasses and composites and minor amounts of broad leaved forest and conifer taxa. Occasional abundance of ferns further points at episodic increase in local humidity. Pollen taxa such as *Bombacacidites* (Bombacaceae), aff. *Lanagiopollis* (Alangiaceae) and *Neocouperipollis* (Palmae) may represent a proximal tropical forest. We anticipate that, once completed, our study of these organic-rich deposits will allow us to reconstruct the Mio-Pliocene plant composition of eastern Bhutan in relation to paleo-rainfall intensities. This will indicate whether a drying signal, related to the uplift of the Shillong Plateau, is preserved in this sedimentary section or not.

**Keywords:** Palynology, Shillong Plateau, fluvial sediments, monsoon.

SS42-O07 (580)

**Extended stratigraphy, palynology and depositional environments record the initiation of the Himalayan Gyirong Basin (Neogene China)**

Yadong Xu<sup>1</sup>, Kexin Zhang<sup>1</sup>, Guocan Wang<sup>1</sup>, Shangsong Jiang<sup>1</sup>, Guillaume Dupont-Nivet<sup>2,3</sup>, Carina Hoorn<sup>4</sup>

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Here we report new sedimentological and paleontological data from a 603.5m thick Neogene sequence (Woma Section) in the Gyirong Basin, an east-westward extensional basin in the high Himalayas. We document the conglomeratic Danzengzhukang Formation, at the base of the section, and the overlying finer grained Woma Formation that includes a Hipparion fauna. Based on earlier thermochronology and magnetostratigraphic results from this section, we can bracket the depositional age interval most reasonably between 10.2 Ma and 1.7 Ma. Lithology, paleo-current directions and provenance analysis, together with palynological and paleontological data suggest there are 3 distinct depositional environments: (1) An alluvial-fan environment with ESE transport directions (Danzengzhukang Formation, 10.2-7.4 Ma), with in its periphery a warm and humid coniferous- and broad-leaved mixed forests; (2) Lacustrine dominated conditions (Lower Woma Formation, 7.4-3.3 Ma) with WSW transport directions, with locally warm and humid conditions in the low lying areas while input from a new source area suggests the presence of a high-altitude cold and arid deciduous coniferous-leaved forests; (3) A fan delta dominated environment (Upper Woma Formation, 3.3-1.7 Ma) with increased denudation and WSW paleo-currents and a deciduous coniferous and broad-leaved mixed forest suggesting increased climate variability. The data indicate that the Gyirong Basin was under overall warm and humid conditions throughout its history despite changing regional relief associated to tectonism. This is interpreted to reflect the prevalence of the

monsoonal influence on the local basin climate while increased orography contributed to affect more distal pollen sources.

**Keywords:** Tibetan Plateau, sedimentology, palynology, Neogene climate change, tectonism.

SS42-O08 (435)

**Landscape changes in northern South America during the Neogene**

Ingrid C. Romero, Fátima Leite, Alejandra Restrepo, Carlos Jaramillo

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Neotropical rainforests hold one of the highest levels of biodiversity in the world. Orogenic activity and climatic fluctuations have triggered major changes in the landscape by shaping the evolution of their biota during the Neogene. But, how these physical processes have affected plant species composition in neotropical forests? We studied the palynostratigraphy of four Neogene sequences from northern South America located in eastern Colombia and western Venezuela, in which savannas and xerophytic vegetation, respectively, dominate the landscape at present. These sequences reach 8 Km of thickness providing a detailed record of environmental change over the Neogene. One of the most striking findings from our fossil record is the presence of a wet forest during the Miocene opposite to the modern biomes that characterize both areas nowadays. It seems that the expansion of neotropical savannas is a very recent phenomena that started at some point during the Pliocene and produced a continuous reduction in rainforest areal coverage over the past five million years. The dynamics of the landscape are also reflected by two discrete and well-defined flooding events, each one lasting less than one million years, that occurred during the early and middle Miocene. These two events seem to be associated to a continental-scale marine incursion and a large fresh-water lake already reported for northwestern Amazonia.

**Keywords:** Neogene sequence, savannas, tropical rainforest, pollen, Colombia.

SS42-O09 (395)

**Abrupt onset of Patagonian desertification by 11 Ma: insights from the fossil record**

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The southern Andean uplift forced the initial desertification of the eastern Patagonian foreland during the Neogene, giving rise to the largest desert in America. Patagonian landscapes during this changing period have been virtually impossible to reconstruct due to the scarcity of fossil evidence. Here we present the best floristic reconstruction yet attempted during this overwhelming wet-arid transition inferred from fossil pollen grains for the interval 23 to 7 million years ago (Ma). Our results provide constrains of two independent palynological signals by 11 Ma including a 60-fold fossil pollen increase in desert-taxa (joint-pines and amaranths) and an up to 80-fold drop in rainforest-taxa (podocarps and southern beeches). This abrupt and widespread turnover in key climate-sensitive taxa supports the idea that the Andean rain-shadow existed by 11 Ma (Late



Miocene) in the eastern Patagonian foreland. We further demonstrate that the dominance of grasses are not only much younger than previously thought, but also challenge the hypothesis that grasslands had a major, direct influence on the diversification of grazing mammals. Floristic turnovers associated with the Andean uplift will assist in elucidating how plants have responded during one of the world's most important shifts in atmospheric circulation patterns.

**Keywords:** Andean Range, Miocene, pollen grains, southern South America.

SS42-O10 (383)

**Timing the land emergence on the Chocó basin, Colombian Pacific (NW South America): micropaleontologic and sedimentologic evidence**

Diana Ochoa<sup>1</sup>, Andrés Pardo<sup>1</sup>, Millerlandy Romero<sup>1</sup>, Angelo Plata<sup>2</sup>, Paula López<sup>1</sup>, José-Abel Flores<sup>2</sup>, Carlos Jaramillo<sup>3</sup>, Rosa Navarrete<sup>4</sup>, Sebastián Rosero<sup>1</sup>, Lina Clemencia Restrepo<sup>1</sup>, Carlos Borrero<sup>1</sup>, Clemencia Gómez<sup>5</sup>, Sergio Adrian López<sup>5</sup>

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Paleogeographic models built for northern South America traditionally have proposed the presence of a regional marine setting throughout the Miocene along the Colombian Pacific region, whereas shallow waters to more coastal environments have been considered to appear only until the Early Pliocene. This shallowing cycle has been interpreted as the result of a rapid uplifting process due to plate tectonic interaction. As a result, a continuous land bridge across the Americas was formed, allowing the creation of new terrestrial niches and the Great American Biotic Interchange (GABI). To evaluate the timing and evolution of the land emergence process along the Chocó Basin (Colombian Pacific, NW South America), we have studied 9840 ft (~3000 m) of sediments from the Chocó1-ST-S and 1-ST-P wells, which were drilled by the National Hydrocarbon Agency-ANH. In addition, 496 samples for microfossil content, including nannoplankton (154), foraminifera (137) and terrestrial palynomorphs (205), were analyzed. Nannoplanktonic and palynological materials suggest that Chocó-1-ST-P well is not older than the Serravalian (late Middle Miocene). Furthermore, the presence of *Discoaster kugleri* (FO: 11.9 Ma, LO: 11.6 Ma) ascribes an Early Tortonian age to the middle section of the well (4311 ft). Sedimentological analysis reflects a progressive basinal shallowing starting from platform environments under storm action and variable terrigenous influx (base to 4000 ft), passing from fan deltas (4000 to 2000 ft), to low sinuosity fluvial settings (2000 ft to top). Paleoenvironmental changes are also reflected by the microfossil composition, which shifts from marine to terrestrial at 4,047 ft. Our results constitute a sedimentological-micropaleontologic evidence of emerged land for the Colombian Pacific area. This indicates that initial terrestrial settings can be traced back to the Tortonian, thus suggesting the same birth age to the Pacific tropical forest. Previous paleobathymetric data from Opogadó-1, a well located ~250 km to the north, indicated that emersion time was not before than the Messinian (6.3 Ma). Combined data indicates that land emergence was not a coetaneous event throughout the Chocó Basin, but a stepwise process. Further interdisciplinary work is required to precisely constrain the land outgrowth process along the Pacific area and its relation with the regional geological setting.

**Keywords:** Pacific tropical forest, land emersion process, Late Miocene, Chocó basin development.

SS42-O11 (396)

**Towards a Neogene palynological zonation for Colombian Pacific basins (NW South America)**

Andrés Pardo<sup>1</sup>, Diana Ochoa<sup>1</sup>, Angelo Plata<sup>2</sup>, Millerlandy Romero<sup>1</sup>, Silane DaSilva<sup>1</sup>, José-Abel Flores<sup>2</sup>, Francisco Sierro<sup>2</sup>, Alejandra Mejía<sup>2</sup>, Rosa Esther Navarrete<sup>3</sup>, Clemencia Gómez<sup>4</sup>, Sergio Adrián López<sup>4</sup>

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Pollen and spore biostratigraphy have been successfully employed in hydrocarbon exploration in the eastern basins of Colombia (e.g. Llanos, Magdalena and Catatumbo basins). Although non-commercial oil and gas have been recovered from some wells drilled in the Colombian Pacific basins, there are still no attempts to study terrestrial palynomorphs on the westernmost Colombian sequences. This is related to the absence of detailed surface stratigraphic and geologic research due to the dense tropical vegetation and marine origin of the known sections, which traditionally have been considered as barren for terrestrial palynomorphs. We performed a palynological study in 535 samples from 24 surface sections and 4 wells that spanned Cenozoic marine sedimentary sequences along the Colombian Pacific. Our results indicate that several sequences have a rich and diverse association of pollen and spores. About ~43,000 individuals and ~500 morphotypes were recognized. Several pollen markers described for northern South America were identified (e.g. *Palaeosantalaceaeapites cingulatus*, *Fenestrites spinosus*, *Cyatheacidites annulatus*, *Clavainaperturites microclavatus*), while others are absent (e.g. *Grimsdalea magnaclavata*, *Echitriporites cricotriporatiformis*, *Mauritiidites crassibaculatus*, *Cicatricosisporites baculatus*). Based on key zonal events previously defined for the Llanos Basin, we detected zones T-11 to T-18. However, only zones T-12 (Early Miocene), T-15 (Middle Miocene), and T-16 (late Middle Miocene to Late Miocene) were distinctly identified. Detailed review of these data will allow us to build an initial palynological zonation from the early Miocene (23 Ma)-Pliocene for the Colombian Pacific basins. Given that most of the studied sections have precise chronologic information obtained from radiometric dating and marine microfossils (calcareous nannofossils and foraminifers), we will be able to calibrate proposed palynological zones with the geological time scale and to evaluate the synchronicity of main biozonal boundaries. Furthermore, these new palynological data would be useful for (i) establishing regional correlations across basins, (ii) understanding the origin of the high plant biodiversity of western Colombian tropical forests, and (iii) interpreting the relation of the Pacific basins with the Andean uplift and the closure of the Panama Isthmus.

**Keywords:** Biostratigraphic zonation, Miocene-Pliocene pollen, Neogene sedimentary records, Chocó/Tumaco basins, tropical forest evolution.

SS42-O12 (1)

**Palynostratigraphy of the Mid/Late Cretaceous to Cenozoic strata in the Kaikang Trough, Muglad Rift Basin, South Sudan**

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The Muglad Rift Basin has been a source of oil exploration since 1975 and is currently one of the largest petroliferous Interior Rift Basins in the Republics of Sudan and South Sudan. The basin is part of the Central African Rift System (CARS), which developed as a result of the opening of the Central and Southern Atlantic during the ?Late Jurassic-Early Cretaceous, and subsequently underwent three phases of rifting: 1) Early to Mid-Cretaceous (Abu Gabra and Bentiu Formations), 2) Late Cretaceous to Early Cenozoic (Darfur Group and Amal Formation) and 3) the Late Cenozoic (Kordofan Group). Our area of focus, the Kaikang Trough, located in the southern deeper part of the basin, formed either during the development of the three rifting cycles or is older, since it contains more than 13 km of sediments (although maximum drilling has so far reached only 4 km). Previous research on the Kaikang Trough has proved palynology to be a useful tool in studying its stratigraphy. However, lack of information and results from existing wells has resulted in a poor stratigraphical and biostratigraphical record for the trough. This is chiefly due to the clastic lithology and uncertain depositional environment (although thought to be fluvial), and has contributed to reservoir discovery characterised by a “hit and miss” approach. To date, no study has attempted to resolve these issues satisfactorily, with only two exploratory wells drilled through the trough; furthermore these wells have not gone deeper than the Palaeocene and therefore little is known about the early evolution and development of the Kaikang Trough. Using data sampled from four of nine new wells in the centre of the Kaikang Trough, which go deep into the Mid-Upper Cretaceous parts of the basin, a new palynostratigraphic record of the trough, extrapolated across the Muglad Basin, will be established. This will provide a framework from which to work out why some wells are dry, others provide oil shows and others are productive. Using a simple statistical method, spore-pollen grains and related particulate organic matter are examined in order to study the palaeoecology and palaeoclimate, and wherever possible, to reconstruct the prevailing depositional environments that might affect and control the distribution and accumulation of oil in the area. Preliminary analysis of the samples has yielded a diverse palynofloral assemblage belonging to pteridophytic, gymnosperm, and angiosperm groups. Plotted on a range-chart, the identified palynoflora show an age range from the Mid Cretaceous (?Albian-Cenomanian), Late Cretaceous (Turonian-Santonian to ?Campanian-Maastrichtian) and Cenozoic (Paleogene-Neogene). Comparison with relevant palynomorph assemblages in All-Sudan, Egypt, Nigeria and, Africa-South America (ASA) and West Africa- South America (WASA) provinces, confirm the assignment of age.

**Keywords:** palynology, biostratigraphy, palaeoecology Mesozoic, Central African Rift System, All-Sudan.

SS42-O13 (218)

**Geological significances of Late Pliocene - Early Pleistocene palynological assemblages in the Zanda Basin, Tibet (China)**

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The Zanda Basin is a northwest-southeast extensional basin in the Nagri area, southwest of Tibet (China), which formed around 9.6 Ma (Late Miocene). A series of lacustrine, fluvial and alluvial sediments are well preserved in this basin. Here we describe a sedimentary section that is located at 1 km northwest Xiangzi Village, Zanda County. Based on Electron Spin Resonance (ESR) and paleomagnetostratigraphic research the age interval of the Xiangzi Formation is estimated between 2.6 Ma and 1.67 Ma. Following from our palynological study we distinguished 3 palynological zones, 8 characteristic palynological assemblages, and 3 phases of paleoclimatic changes. The proposed subdivision is as follows: From 2.75 - 2.6 Ma, correlating with palynological zone I and

assemblages 1-2, is characterized by *Polypodium*, Gramineae, Fagaceae, and taxa such as *Pinus*, *Podocarpus* and *Cedrus*. This suggests a vegetation typical for warm and damp-humid conditions and composed of conifers and broad-leaved mixed forests. After 2.67 Ma the climate changed to damp-dry; between 2.54 - 2.16 Ma, correlating with palynological zone II and assemblage 3-5, Pinaceae, Juglandaceae and Betulaceae are the main components of the paleo-flora and suggest cool and humid conditions. Deciduous conifer and broad-leaved mixed forests gradually changed into cold deciduous conifer forests, as indicated by the increase in the cold-tolerant tree taxa. Between 2.13 - 1.86 Ma, correlating with palynological zone III and assemblage 6-8, Chenopodiaceae, *Quercus* (deciduous type) and *Artemisia* characterize the paleo-flora. The increase of cold-tolerant bush taxa and drought-tolerant herb taxa suggest a change to cold and arid conditions. The conifers and broad-leaved mixed forest types represented in the pollen spectra are compatible with low altitudes. Compared with the environmental records and the palynological assemblages from adjacent regions, a pattern of regional cooling at 2.6 Ma emerges. After this period the climate of Zanda Basin experienced a general change in palynological composition from cold-tolerant conifers taxa to drought-tolerant herb taxa. The uplift of Qinhai-Tibet Plateau is thought to have had a wide and profound impact on the climate of East Asia.

**Keywords:** Qinghai-Tibetan Plateau, southwest Tibet, palynology, palaeoclimatic changes, Neogene - Quaternary.

SS42-O14 (185)

**A flower of *Lunania* Hooker (Salicaceae) preserved in the Miocene amber from Simojovel de Allende, Chiapas (Mexico), as evidence for the long history of this genus**

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The Miocene amber from Simojovel de Allende (Chiapas, Mexico) is well known for its diverse insect fauna. In recent years plant material has increased the understanding of the flora, especially through the description of flowers. Here we report a small pedicelate, staminate flower, with valvate, widely ovate, punctate, slightly pubescent sepals and lacking petals. The flower has fifteen free stamens with filiform filaments and bitectate, versatile and sub-dorsifixed anthers, and an amorphous pistiloid conform to the *Lunania* Hooker genus. This neotropical genus has 14 species with a single member growing naturally in Mexico, *L. mexicana* Brandegee, Salicaceae, formerly included in Flacourtiaceae, a segregated family without diagnostic function. This new record in Southern Mexico confirms part of the large history of the Low Latitude North American Flora, and may be another example of precursors of the Neotropical flora growing during the Oligocene/Miocene time in México.

**Keywords:** Neogene, Neotropical, reproductive structure, rainforest.

SS42-P01 (382)

**Oligocene-Miocene palynofloras from northern South America**

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The Oligocene-Miocene transition was characterized by a rapid drop on global temperatures, which has been associated with the M1 glaciation and a major coral extinction event. In Colombia, some of the studied Oligocene-Miocene sections are terrestrial and they do not have a precise chronostratigraphic framework. In order to improve the age control of these terrestrial sequences, we have analyzed the palynological record from several sections and drilling-cores in different basins (including the Sinú-San Jacinto, Lower Magdalena, and Cauca-Patía basins, Colombia). Other techniques such as marine micropaleontology, detrital zircon U-Pb analysis and chemostratigraphy, were used as independent chronological techniques. The identified palynological taxa includes *Cicatricosisporites dorogensis*, *Clavatricolpites densiclavatus*, *Concavisimisorites fossulatus*, *Crassiectoapertites colombianus*, *Foveotriletes concavoides*, *Foveotriletes etayoi*, *Horniiella lunarensis*, *Perisyncolporites pokorny*, *Nijssenosporites fossulatus*, and *Retitriletes sommeri*. The same assemblage was previously correlated with the Oligocene-Miocene transition in sediments from oil-producer basins (e.g. Llanos, Magdalena, and Eastern Cordillera). Our results indicate that: i) palynomorphs described in the palynostratigraphic zonation built for the easternmost Colombian basins (i.e. Llanos and Eastern Cordillera) can also be recognized in other areas from northern South America, ii) there was a drop in the accumulated number of morphospecies, which may be closely related to the climatic shifts of the Oligo-Miocene transition. Future research will focus on the evaluation of particular palynological events across basins, in order to produce a biostratigraphic zonation. In addition, further analysis will include information obtained from recent wells drilled by the National Hydrocarbon Agency-ANH in the Colombian Caribbean basins. This new information will allow us to better understand changes in the palynofloral association through time, the timing and evolutionary trends of modern neotropical forests, and their relationship with the Neogene Andes uplift and the Panama Isthmus closure.

**Keywords:** palynology, biostratigraphic zonation, neotropical flora, Oligocene-Miocene transition, Colombia.

SS42-P02 (428)

**Morphological analysis of extant *Serpocaulon* A. R. Sm. (Polypodiaceae J. Presl. & C. Presl.) spores from Colombia (NW South America): a tool for the study of the Cenozoic Neotropical paleobotany**

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In the Cenozoic Neotropical deposits, verrucate monolete spores included in *Polypodiisporites* are abundant, some of them very similar to extant *Serpocaulon*. Therefore, morphologic studies of modern spores could be helpful to discriminate temporal or ecological restricted taxa in the geologic record. *Serpocaulon* is a monophyletic genus within Polypodiaceae, comprised by 42 Neotropical species. The highest diversity of the taxa is found in northern South America, mainly in the Colombian Central Cordillera (21 taxa). Its species inhabit various life zones, from rainforest to páramo. Taxonomy is still not precise, because: a) nomenclatural problems, b) wide geographic distribution c) high species diversity, and d) presence of multiple hybridization events within the genus. In order to increase the taxonomic certainty of *Serpocaulon*, we describe spores from all 21 taxa reported in the Colombian Central Cordillera, using transmitted light and scanning

electron–SEM microscopy. Analyzed specimens were obtained from several regional herbariums. For each species we measured 25 spores in each view (lateral and proximal) and 16 morphological characters were evaluated. Principal Components Analysis (PCA) was used to identify taxa variability. *Serpocaulon* spores are typically monads, heteropolar, bilaterally symmetrical, ellipsoid, sub–ellipsoid to globular in proximal view, and plane–convex to concave–convex in lateral view. All studied taxa have verrucate ornamentation, which varies in size, shape, and distribution. Two basic types of perispores were recognized (thick–folded and thin). Our results suggest that: i) verruca morphology is important for determining most of the species and intrageneric definition, ii) PCA is a useful technique to identify some morphological patterns. Finally, we present four morphological groups, which were suggested in previous molecular studies for *Serpocaulon*.

**Keywords:** microscopy, monolete, verrucae, ferns taxonomy.

SS42-P03 (408)

**Ladrilleros-Juanchaco: a marine Miocene reference section from the Colombian Pacific**

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Tumaco is a forearc basin located in southwestern Colombia. The drilled wells revealed the presence of oil and gas suggesting an important hydrocarbon potential, still unexplored. Geological features and basin evolution remain poorly understood given the few available stratigraphic wells and the poor rock exposures due to dense tropical forest. In the coastal cliffs of the Tumaco basin, we have studied one of the best exposed stratigraphic sequence of the Colombian Pacific: the Ladrilleros-Juanchaco section. This section consist of ~700 m thick marine sediments, composed by organic-rich mudstones with some interbedded turbiditic and contouritic sandstones, with common occurrences of *Zoophycos* and *Nereites* ichnotaxa. Its lower and upper part have the continental (deltaic) influence in the sedimentation becomes evident. The calcareous nannofossil assemblages indicates a Burdigalian-Tortonian (NN4 to NN7) age, based on the presence/absence of taxa such as *Coccolithus miopelagicus*, *Cyclicargolithus floridanus*, *Discoaster deflandrei*, *Sphenolithus abies* gr., *Catinaster coalitus*, *Discoaster signus*, *Discoaster kugleri*, *Helicosphaera ampliapertura*, and *Sphenolithus heteromorphus*. Palynological analysis revealed the presence of a rich assemblage of ~327 pollen and spores morphospecies (~12916 palynomorphs were counted). The assemblage is entirely dominated by pteridophyte and bryophyte spores. Some key taxa identified include *Bombacacidites araracuarensis*, *Clavainaperturites microclavatus*, *Crassoretiriletes vanraadshooveni*, *Cyclusphaera scabrata*, *Echitricolporites mcneillyi*, *Nijssenosporites fossulatus*, *Retipollenites crotonicollumellatus*, *Retiriletes sommeri*, *Rhoipites planipolaris*, and *Striatriletes saccolomoides*. The presence of these taxa can be correlated with T-15 to T-18? biozones (Jaramillo et al., 2011). Further study of the section will be focus on the establishment of an astronomically calibrated chronology pattern based on an integrated high-resolution stratigraphy following the signal provided by calcareous nannofossils, and paleomagnetism tuned with several Earth orbital parameters. After the definition of this astrochronologic framework we will calibrate the terrestrial palynologic biohorizons in order to complete biogeographic, climatic, and oceanographic information for the Neogene of northwestern South America.

**Keywords:** palynology, paleoceanography, cyclostratigraphy, marine biostratigraphy, Miocene sedimentary record.

SS42-P04 (548)

**A palynological study of Neogene fluvial sediments of SW Amazonia (Madre de Dios foreland Basin, Peru) with inferences for paleo-biodiversity studies**

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Western Amazonia has the largest diversity in plant species on Earth. Palynological evidence, however, suggests that the Amazonian Neogene holds even greater amounts of plant taxa. The process of diversity loss is difficult to trace through time and has led to many hypotheses and discussion. In this pilot study we investigated the palynological composition of Neogene fluvial deposits in the Sub-Andean Madre de Dios foreland basin (southeast Peru). We studied the relationship with Neogene pollen spectra documented in other parts of Amazonia and also compared our data with pollen spectra reported from Quaternary fluvial sections. As reference for modern diversity we made an inventory of tree species of different forest plots in the nearby Tambopata National Park. Biostratigraphic markers in the samples suggest an age ranging from Middle Miocene to Pliocene and pollen spectra are either dominated by Poaceae (in combination with *Azolla* and Cyperaceae) or fern spores. These taxa are indicative of vegetation in a humid, fluvial/lacustrine environment. A striking difference with some other Neogene lowland studies is the absence of typical indicators of floodplain forests and swamps such as *Mauritiidites*, *Psilamonocolpites*, *Grimsdalea* (Arecaceae) and *Bombacacidites*. The combined sedimentological and palynological data suggest a high-energy river system and little influence from the lowland rainforest. This is in contrast with the palynologically diverse Neogene fluvio-lacustrine deposits further north, which formed part of the Pebas megafan. In relation to Quaternary pollen spectra from Amazonia, taxa common in fluvial records, such as *Cecropia*/Moraceae, are absent in our Neogene lowland samples. Previous studies found Neogene *Cecropia* only at higher elevations where it might have acted as invasive pioneer in the forest. Our data suggest that these fully fluvial Neogene sediments do not seem to optimally register past rainforest diversity. Nevertheless, we should not discard the possibility that the Late Miocene rainforest in Amazonia was palynologically less diverse due to the influence of coeval climatic cooling. We conclude that to obtain a truthful representation of the paleo-rainforest composition the palynological records from different sedimentary environments ought to be compared.

**Keywords:** Amazon region, Sub-Andean zone, biodiversity, Miocene, palynology.