(SS12) East Asian vegetational responses in the critical climate change events of the Cenozoic

Date: August 29 (poster), 30 (oral)
Place: Room 5233 (oral), Room 6302 (poster)
Organizers: Yusheng (Christopher) Liu & Cheng Quan
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Purpose: It is now clear that during the Cenozic Era, climates have dramatically been changed both in the sea and on land. To name a few, these climatically transitional events in a descending order of geological time include the Paleocene-Eocene Thermal Maximum (PETM, aka Eocene Thermal Maximum1 [ETM1]), Eocene Thermal Maximum2, Early Eocene Climatic Optimum (EECO), Mid Eocene Climatic Optimum, Eocene-Oligocene Transition (EOT), Mid Miocene Climatic Optimum, and Early Pliocene Warming Period. The formation of modern vegetations on Earth has been a product of environmental change and biotic response during the Cenozoic. East Asia occupies an important portion of land in the Northern Hemisphere and is a home to a great number of Tertiary relicts. Therefore, Cenozoic (micro- and mega-) plant remains in East Asia provide essential materials to be studied to better understand how the responses of diverse vegetations to the dramatic climate changes could be. Although much work still remains to be done in East Asia, East Asian Cenozoic Paleobotany has achieved much progress in the past decade. This symposium aims to combine the efforts of paleobotanists and alike worldwide who are interested in the geological history of East Asian vegetations to get insights on the East Asian vegetational responses in the critical climate change events of the Cenozoic.

Oral Presentation

Aug. 30 [AM1] Room: 5233

Chair: Yusheng (Christopher) Liu

9:00-9:20 **Plant remains from the Siwalik successions (Middle Miocene to lower Pleistocene) of Arunachal sub-Himalaya and their bearing on palaeoclimate and phytogeography** SS12-O01 (30)

Subir Bera, Mahasin Ali Khan

9:20-9:40 **Ecostratigraphy of the Subathu Formation of Jammu region, Jammu** SS12-O03 (482)

Yengkhom Raghumani Singh (move to General Session, GS-03)

9:40-10:00 **Justification, validation, and implication of aridity index for paleoclimate** SS12-O02 (425)

Cheng Quan, Yu-Sheng (Chris) Liu, Torsten Utescher

10:00-10:20 **Paleovegetation in response to Neogene climate change in the Hengduan Mountains, SW China** SS12-O04 (500)

Tao Su, Frédéric M.B. Jacques, Yao-Wu Xing, Yong-jiang Huang, Zhe-kun Zhou

Aug. 30 [AM2] Room: 5233

Chair: Cheng Quan

10:50-11:10 **Reconstruction of latest Miocene to Pliocene terrestrial paleoenvironments based on sedimentary facies and pollen assemblages from the Aizu-yanaizu area, Fukushima, northeast Japan** SS12-O05 (206)

Kaori Igarashi, Hiroshi Kurita

11:10-11:30 **Vegetation change across the Eocene-Oligocene Transition (EOT): a case study from southern China** SS12-O06 (294)

Yusheng (Christopher) Liu, Cheng Quan

11:30-11:50 **Vegetation responses in the critical climate change events of the Cenozoic sedimentary successions in the Ganga Basin, India** SS12-O07 (164)

Sudha Gupta, Subir Bera, Manju Banerjee

11:50-12:10 **Late Miocene Fagaceae fruits and leaves from Zhejiang, Eastern China and their palaeoclimatic significance** SS12-O08 (216)

Hui Jia, Bai-nian Sun, Xiang-chuan Li, Liang Xiao

Poster Presentation

Aug. 29 [PM1] Room: 6302

13:30-14:30 **Vegetation and climate of late middle Miocene Konan Flora from Shibetsu City, Hokkaido, Japan** SS12-P01 (365)

Atsufumi Narita, Noriko Hagiwara, Midori Matsumoto, Kazuhiko Uemura, Atsushi Yabe

SS12-O01 (30)

Plant remains from the Siwalik successions (Middle Miocene to lower Pleistocene) of Arunachal sub-Himalaya and their bearing on palaeoclimate and phytogeography

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The Siwalik Group, one of the major sedimentary zones in the Himalayan belt, extends from Jammu in the West to Arunachal Pradesh in the East. In Arunachal Pradesh sedimentation in the Siwalik foredeep continued through Middle Miocene to Lower Pleistocene and has received little attention for palaeobotanical study due to inaccessibility of most of the fossil bearing terrains. The present work is an attempt to fill the lacunae and make a comprehensive study of megafossils in this area for depicting the pattern of floristic changes and corresponding changes of environment since Middle Miocene, identification of exotic taxa migrated from adjoining landmasses of Southeast Asia in the past, ascertaining comprehensive phytostratigraphy with special reference to depositional environment and palaeogeography in the Siwalik strata and estimating change in palaeoatmospheric CO_2 concentration with periodic phases of Himalayan uplift. The fossil leaf assemblage recovered from the Siwalik sediments (Middle Miocene to Lower Pleistocene) has yielded three monocotyledonous and fifty-eight dicotyledonous taxa. Twenty five fossil leaves comparable to modern *Dracontomelum mangiferum* (Anacardiaceae), *Actinodaphne obovata*, *Litsea salicifolia*, *Cinnamomum beghalghota*, *Lindera pulcherrima*, *Lindera bifaria*, *Persea parviflora* (Lauraceae), *Macaranga denticulata*, *Croton caudatus*, *Antidesma ghesaembilla* (Euphorbiaceae), *Dalbergia rimosa*, *Millettia extensa*, *Millettia cineria*, *Dalbergia rimosa* (Fabaceae), *Knema glaucescens* (Myristicaceae), *Quercus lamellosa* (Fagaceae), *Canarium bengalense* (Burseraceae), *Unona discolor* (Annonaceae), *Premna bengalensis* (Verbenaceae), *Eugenia grandis* (Myrtaceae), *Randia longifolia* (Rubiaceae), *Dysoxylum costulatum*, *Aglaia argentea* (Meliaceae) and *Anogeissus*

acuminata, *Combretum chinense* (Combretaceae) and five fossil fruits and seeds comparable to modern *Canarium bengalense* (Burseraceae), *Gynocardia odorata* (Flacourtiaceae), *Shorea assamica* (Dipterocarpaceae), *Bauhinia wallichii*, *Mastertia assamica* (Fabaceae) are new to the Siwalik flora and also to the Neogene flora of India. Analysis of floral assemblage with respect to the distribution pattern of modern equivalent taxa and the physiognomic characters of the fossil leaves, suggests that a tropical evergreen forest was growing in a warm humid climate in the region during deposition in contrast to modern tropical semi-evergreen forests in the area. An increase in deciduous elements in the fossil floral composition is noticed towards the close of the middle Siwalik and the beginning of the upper Siwalik sedimentation. From the stomatal index data an increasing trend of CO_2 concentration is suggested since Middle Miocene. The study further suggests that present day tropical elements might have migrated from Southeast Asian landmasses via upper part of Myanmar through Arunachal Pradesh to northeastern, eastern parts of India including Himalayan regions.

Keywords: palaeovegetation, palaeoenvironment, palaeogeography, plant megafossils, sub-Himalayan Arunachal Pradesh.

SS12-O03 (482)

Ecostratigraphy of the Subathu Formation of Jammu region, Jammu

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The palynological data recovered from the different horizons of the Subathu Formation in Jammu region was analyzed to search age marker palynofossils during the present investigations. On the basis of palynological assemblage of the Subathu Formation has palynostratigraphically been divided into four biozones such as *Homotryblium* spp. assemblage zone, *Spiniferites* spp. Assemblage zone, the Microforaminiferal linings assemblage zone, and the *Pediastrum* spp. Assemblage zone in the ascending order of stratigraphy. On the consideration of the FAD and LAD limits of the age diagnostic taxa, these zones range from Selanian to Ypresian for the *Homotryblium* spp. assemblage zone, Ypresian for *Spiniferites* spp. Assemblage zone, Lutetian for the Microforaminiferal linings assemblage zone, and Post-Lutetian for the *Pediastrum* spp. Assemblage zone in the ascending order of stratigraphy. The Microforaminiferal zone is not made the geological range due to complete absence of age marker species. However, on the consideration of stratigraphic position within this succession of lower zone and upper zone, it is probably considered as Lutetian. On the basis of palynoflora the *Homotryblium*, *Spiniferites*, Microforaminiferal linings assemblage zones has been deposited during transgressive phase i.e. marine environment condition whereas the *Pediastrum* spp. Assemblage zone has been freshwater condition during the Subathu sedimentation regime.

Keywords: FAD, LAD, microforaminiferal linings, transgressive phase, freshwater.

SS12-O02 (425)

Justification, validation, and implication of aridity index for paleoclimate

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In climatology, most variables are unequivocally defined and quantitatively described. These variables, such as temperature and precipitation, can also be quantified from geological proxies in paleoclimate studies. However, there are other climatic factors that, although strongly impacting ecosystems, have been ambiguously delineated and consequently difficult to be applied in paleoclimatology. Among all climatic factors, the aridity (water availability) of climate is one of the main contributors that determine the biome distribution throughout the world, but has various definitions in different fields. As a result, the aridification of the Earth over geologic time has seldom been explored quantitatively, although qualitative estimates of arid climate have been inferred by either the occurrence of some featured sediments, e.g., red beds and evaporites, or the presence of xeric organisms, such as xerophytes. These qualitative indicators, in spite of their effectiveness to some extent, lack a general evaluating criterion to determine the aridity and therefore prevent us from comprehensively understanding the aridification process throughout the geologic time. Alternatively, threshold value of mean annual precipitation (MAP) is employed as the boundary between the humid and arid environments in climatic classification (i.e., 500 mm). This scheme is also widely adopted in modern climatology because of the readily availability of data. However, precipitation alone is evidently inadequate to measure the hydrological conditions of climate. Two other critical factors that influence water balance in biosphere are temperature and evaporation, meanwhile the evaporation is mainly affected by temperature and some other subordinate factors. Then the critical question is, how can we quantitatively evaluate the arid/humid condition of a given region, and compare it with the modern climate under a uniform criterion, by which we explore the geological evolution of aridificaiton? By using modern global climatic data, we examine six previously proposed temperature and precipitation derived aridity indices, and validate the index of Köppen (1923) given by Aridity Index (AI) = MAP/(MAT+33), where MAT is the mean annual temperature. Global aridity condition is then calculated by the new justified index and compared with the global Thornthwaite humidity index (HI), a widely adopted potential evapotranspiration-based indices in describing modern aridity/humidity condition. The justification on aridity indices demonstrates that the AI is the most reliable known PT-base index in hydrological condition evaluation, which is well concordant with the PET-based HI.

Keywords: paleoclimate, aridity index, mean annual temperature, mean annual precipitation.

SS12-O04 (500)

Paleovegetation in response to Neogene climate change in the Hengduan Mountains, SW China

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The Hengduan Mountains, being a southern part of Tibet-Qinghai Plateau, are well known for the abundance of living species. Numerous of plant fossil-bearing basins forming during the Neogene in this region provide opportunities for us to understand the climate history and its influences on the evolution of vegetations. During Miocene, the Hengduan Mountains were mainly covered by

evergreen broadleaf forests. The early Miocene Jianchuan flora in northwestern Yunanan Province is dominated by Fagaceae, Lauraceae and Ulmaceae. The late Miocene Xiaolongtan flora in southeastern Yunnan is dominated by Fabaceae, Fagaceae, Lauraceae and Hamamelidaceae. Fagaceae, Fabaceae, Myrtaceae, Lauraeae and Rosaeae are the most abundant in the late Miocene Lincang flora from western Yunnan Province. During the Pliocene, vegetation changes dramatically and vegetation types are more diverse in the Hengduan Mountains. Deciduous broadleaf forests and evergreen sclerophyllous forests became emerging. Longmen flora and Fudong flora from western Yunnan is characterized by the evergreen sclerophyllous oaks (*Quercus* sect. *Heterobalanus*). In the late Pliocene Mangbang flora from western Yunnan, Betulaceae, Ulmaceae and Fabaceae are the main components. The Pliocene Miyi flora from western Sichuan are dominated by Fagaceae, Lauraceae, Theaceae and Fagaeae. According to paleoclimate reconstructions on Neogene floras in the Hengduan Mountains, the temperature was slightly shifted, and the precipitation was decreased from Miocene to Pliocene. Additionally, the monsoon in the Hengduan Mountains increased gradually during the Neogene. Our results indicate that, vegetations in the Hengduan Mountains were shaped by the climate change, which occurred with the influences of Qianghai-Tibet Uplift during the Neogene. This work is supported by NSFC (No. 31100166, 41030212, 30970206) and 973 Program (No. 2012CB821901).

Keywords: Miocene, palaeobotany, Pliocene, *Quercus*, biodiversity.

SS12-O05 (206)

Reconstruction of latest Miocene to Pliocene terrestrial paleoenvironments based on sedimentary facies and pollen assemblages from the Aizu-yanaizu area, Fukushima, northeast Japan

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The paleoclimatic trend of the Cenozoic is characterized by global cooling as a whole, with several events of temporal warming. The Pliocene is the time of one of those warming that followed the cooling (Messinian crisis) in the latest Miocene. C4 grasses, which use C4 photosynthesis, are considered to have appeared in the late Miocene and diversified through the rest of the Cenozoic. Furthermore, only few previous studies combined results from pollen analysis with sedimentary facies analysis. This study aims to reconstruct latest Miocene to Pliocene terrestrial paleoenvironments based on sedimentary facies and pollen assemblages in the Aizu-yanaizu area, Fukushima Prefecture, northeast Japan. The present forest in the study area is dominated by broad-leaved deciduous trees including *Fagus*, whereas warm elements like evergreen *Quercus* are minor. We conducted geological field surveys, and recognized the sedimentary facies and facies associations to restore the temporal and spatial distribution of depositional systems. Reconstruction of paleovegetation and paleoclimates was intended by pollen analysis of 54 mudstone samples from the latest Miocene － Pliocene Fujitoge and Izumi Formations. Synthetic discussion is given on correlation between the depositional systems and paleoclimates to consider the role of paleoclimates in the basin development. Age control is provided by fission track dating methods of zircon from 5 tuff layers in or nearby the study area. Based on the sedimentary facies analysis, depositional environments of the studied interval changed vertically from sandy braided river to meandering river, to sandy braided river again and finally gravelly braided river. Pollen analysis has revealed a warming period at about 6 Ma that is evidenced by frequent occurrences of pollen of evergreen *Quercus*, *Liquidambar* and *Ilex*. This warming can be correlated to that which followed the Messinian cooling because of the radiometric age of the sediments. The pollen data also showed the detailed herb pollen composition that proves the relatively rich presence of C4 grasses even in the

latest Miocene in the study area. Those include *Polygonum*, Gramineae and Chenopodiaceae. By combining the interpretation of the pollen and sedimentary facies analysis, we propose a model of basin development that a higher rate of tectonic subsidence was the reason of the deposition of the late Pliocene section in the area in spite of the lowered eustacy that is deduced from the pollen record of a cool paleoclimate.

Keywords: paleoclimate, paleovegetation, sedimentary facies analysis, C4 grasses, warming in the Pliocene.

SS12-O06 (294)

Vegetation change across the Eocene-Oligocene Transition (EOT): a case study from southern China

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The Paleogene pollen assemblages from Bose Basin of Guangxi in the subtropical/tropical southwestern China were chosen to demonstrate the vegetation change over the Eocene-Oligocene transition. The Paleogene sediments from Bose Basin have been reported to be presented in continuous outcrop, where the EOT transition may be preserved. Previous studies on the geology and paleontology of this region did not deal with the transitional boundary and any biological and climate changes across it. The present analysis is mainly based on published record from pollen assemblages and in a hope to detect any change in climate and vegetation across the boundary. As macrofossils from the basin have not been studied, the evolution of climate change has to be based exclusively on pollen data. Floristically across the EOT, the abundance of dominant taxa changes, such as the increase in ferns (e.g. *Polypodiaceoisporites*), *Cupuliferoipollenites* and *Fupingopollenites* and decreases of *Quercoidites*, *Ulmipollenites*, and *Alnipollenites*. Conifers seem unchanged across the EOT. As the change in plant taxa appears to be in a minimum, the climate change therefore might not be detected by the application of Coexistence Approach. An ongoing project on re-sampling at the outcrop will re-assess the results.

Keywords: pollen assemblages, EOT, paleoclimate, subtropical-tropical region.

SS12-O07 (164)

Vegetation responses in the critical climate change events of the Cenozoic sedimentary successions in the Ganga Basin, India

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The Ganga basin is an active foreland basin receiving sediments from both the Himalayan orogen and the Indian Peninsula highlands. The basin fills are dominantly Neogene sediments and rest unconformably above Palaeocene to Lower Eocene. The vegetation changes that occurred over time

due to alterations in the climatic and ecological conditions are reflected from the rich, diverse, specific stratigraphic and environment indicator microbiota recovered from four key exploratory wells namely, Puranpur, Matera, Gandak and Raxaul in the basin. The microbiota represents palynomorphs of all the plant groups predominated by the angiosperms. Frequency of occurrence and climatic complex of the palynotaxa identified ten palynostratigraphic zones (GBT I-X) from Palaeocene to Pliocene. The tropical to subtropical climatic complex is the basic component of the assemblages. *Matanomadhiasulcites maximus*, *Lakiapollis ovatus*, the age marker palynotaxa have distinguished the Palaeocene-Eocene sediments. The variable climate and ecology indicator taxa recovered from the Palaeocene–Eocene sediments distinguished 6 palynozones (GBT I–VI). Normapolles group of pollen grains occur in the zones GBT I and IV together with other tropical-Subtropical palynomorphs viz, *Pellicieroipollis*, *Striacolporites* etc. Pollen grains with mangrove plant affinity viz., *Spinizonocolpites*, *Sonneratioipollis* in palynozones GBT II and GBT VI are indicative of coastal environment. The prevalence of some acritarchs, nanofossils in GBT III suggest near shore environment. The representation of subtropical to temperate palynomorphs like *Cupuliferoipollenites*, *Engelhardiadites*, *Juglanspollenites* in GBT III suggest low to moderate altitude topography around the basin. Change in the depositional pattern is marked by the disappearance of the Palaeocene-Eocene marker taxa and abundance of fresh water Oligocene marker taxa viz., *Striatriletes* spp., *Meyeripolis naharkotensis* in palynozone GBT VII. The first appearance of high altitude cool climate plant pollens viz., *Pinuspollenites, Abietineaepollenites* with significant abundance of shallow marine microfossils viz., *Leiosphaeridia*, Dinocyst, *Veryhachium* suggest change of climate and ecology in the basin related to the event of Himalayan orogeny. This palynoassemblage is dated as Early Miocene (GBT VIII). Moderate occurrence of Poaceous pollen together with fungal spores in high frequency in GBT IX suggests abrupt change in the climate. Recurrence of temperate climate indicator taxa in GBT X signifies change of climate towards cool, dry, condition and correlated with the Mid Miocene–Pliocene Himalayan upliftment and also global shift to cool climate in Late Miocene. Palaeogeography of the basin during Tertiary is discussed.

Keywords: palynostratigraphic zones, Tertiary, environment, Himalayan upliftment, palaeogeography.

SS12-O08 (216)

Late Miocene Fagaceae fruits and leaves from Zhejiang, Eastern China and their palaeoclimatic significance

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Neogene tectonic movements led to the formation of many sedimentary basins providing an opportunity for the deposition and preservation of numerous Miocene plant assemblages. In 2005, a well-preserved flora comprising 46 genera was found in a diatomite layer of the Late Miocene Xiananshan Formation in Tiantai County, Zhejiang Province, Eastern China. In the present contribution we present some Fagaceae fossil leaves and fruits collected from this site. The leaf and fruit architecture, microstructure, as well as numerical taxonomy suggest that 17 leaf and fruit species can be recognized. These were assigned to 3 genera, *Quercus* (including *Subgenus Cyclobalanopsis*), *Castanopsis*, and *Castanea*. For most of the fossil species, it was possible to ascertain their Nearest Living Relative species (NLRs). Some of them display at least 90% similarity to one another. This indicates that by the Late Miocene the fossil species of Fagaceae in Eastern China were almost comparable to their corresponding extant Fagaceae species. Based on the number of specimens, *Quercus* was the dominant element in the whole flora. This included both evergreen and deciduous

species, with the former being in the majority. Considering the species and their leaf physiognomy, we infer that the Late Miocene Tiantai flora must have represented the ecotone between subtropical and tropical vegetation, with several temperate elements. By comparing the leaf macro- and micro-structure of the fossil species with their corresponding NLRs, we conducted a palaeoclimatic reconstruction based on overlapping distribution analysis and cuticular characteristics. The result demonstrates that the Late Miocene climate of eastern China was warmer and more humid than today. The stomatal indices of all the Fagaceae leaf species investigated suggests that the atmospheric CO_2 concentration in the Late Miocene was slightly higher than its current level. The result is consistent with independent evidence from stable isotopes of marine foraminifera. The study was supported by the National Natural Science Foundation of China (Grant No. 41172022) and the Specialized Research Fund for Doctoral Program of Higher Education of China (Grant No. 20100211110019).

Keywords: Xiananshan Formation, leaf architecture, cuticle, numerical taxonomy, palaeo-CO_2.

SS12-P01 (365)

Vegetation and climate of late middle Miocene Konan Flora from Shibetsu City, Hokkaido, Japan

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A late middle Miocene megafossil flora (Konan Flora) is preserved in lacustrine deposits in the Konan Tuffaceous Sandstone and Mudstone Member, Bifuka Formation in Shibetsu City, Hokkaido, Japan. We have identified 38 species from 17 families and 24 genera. The flora includes 4 evergreen conifers, 1 perennial herbacous monocot, 33 deciduous dicots, and 2 seeds of yet unknown affinity. Common species include *Fagus palaeojaponica* (48%), *Acer subcarpinifolium*, *A. protojaponicum*, *Picea* sp., *Cercidiphyllum crenatum*, and Betulaceae and Salicaceae. Species diversity of the Konan flora is lower than other Miocene floras of Hokkaido. The pollen assemblage of the Konan flora is represented by broad-leaved, deciduous trees such as *Fagus*, *Alnus*, *Betula*, Ulmaceae, *Juglans-Pterocarya*, and conifers such as *Picea* and Taxodiaceae. The pollen assemblage correlates with the NP-3 (13~6.5 Ma) standard Neogene pollen zone of Japan. The composition of the pollen assemblage is consistent with the megafossil assemblage. The vegetation of the Konan Flora is interpreted as a broad-leaved deciduous and mixed northern hardwood forest, which is common in northern Japan during the late middle Miocene. Compared with other early to late Miocene floras in Japan, the Konan Flora resembles the Mitoku-type flora because of the abundance of *Fagus palaeojaponica* and the presence of modern broad-leaved deciduous trees. However, leaf physiognomy and CLAMP results suggest that the Konan Flora grew in a humid cool-temperate climate which is cooler than those indicated by the middle Middle and Late Miocene floras in Hokkaido. Peculiar features of the Konan Flora (composition and physiognomic characters) might be influenced by the climate change during the Middle Miocene.

Keywords: climate, Konan Flora, megafossil, pollen, vegetation.