

Program and Abstracts



NECLIME Symposium

Nanjing, China, May 27-29, 2012

*Nanjing Institute of Geology and Palaeontology
Chinese Academy of Sciences*

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General Introductions

The second NECLIME Symposium in Asia will be held in Nanjing on May 27-29, 2012. It is co-organized by the Department of Palaeobotany and Palynology, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences (in conjunction with Palynological Society of China and Palaeobotanical Subcommittee of PSC), and NECLIME – the Neogene Climate Evolution in Eurasia Program with the support of Chinese Academy of Sciences.

Scientific Program

- ◆ Palaeoclimate and palaeoenvironmental evolution in the Neogene of Eastern Eurasia, interactions between climate, biosphere, and palaeogeography.
- ◆ Variability and seasonality of precipitation, including monsoonal patterns and the aridification of Central Asia.
- ◆ Identification of palaeoaltitude from the palaeobotanical record.
- ◆ Palaeoclimate and vegetation modeling.
- ◆ Floristic exchange between Europe and Asia.
- ◆ Stratigraphical concepts for E Eurasia

Conference Program

May 26: Arrival and registration

May 27-28: Scientific presentations and discussions

May 29: Field trip nearby Nanjing including geological and historical sites

May 30: Departure from Nanjing

Our symposium will be held in the lecture room, Library, Nanjing Institute of Geology and Palaeontology.

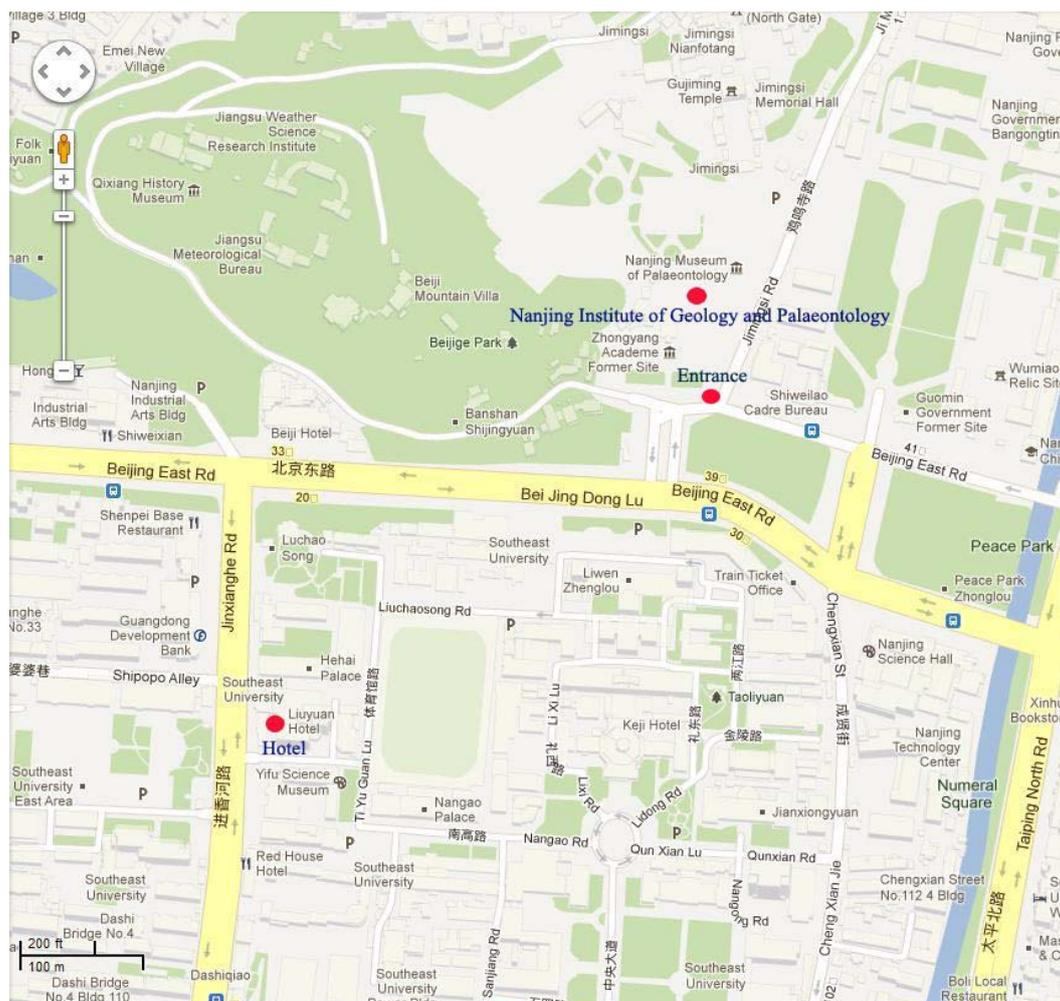
Accommodation

All of the delegates will stay in Liu Yuan Hotel (<http://www.liuyuanhotel.com/>) for accommodation. It is located in the campus of Southeast University, about 600m to the Nanjing Institute of Geology and Palaeontology, CAS (fig.).

A brief resume of the Institute

Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences (NIGPAS), was formally founded on May 7, 1951, with its root in the former Paleontological Section, Institute of Geology (Academia Sinica) and in the Paleontological Group of the Geological Survey of China. It is the only academic institution specialized in invertebrate palaeontology and palaeobotany in China, the largest such research organization in Asia, and one of the leading research institutions of palaeontology and stratigraphy in the world.

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In August 1998, NIGPAS was designated as one of the three pilot institutes in the first phase of the Knowledge Innovation Program, designed to rejuvenate the Chinese Academy of Sciences. In keeping with the goals of this ongoing program, NIGPAS aims to become one of the world leaders in palaeontological and stratigraphical research and education through the improvement of its research infrastructures and better utilization of the palaeontological resources of China. NIGPAS also aims to build a world-class palaeontological library and information centre, a fossil collection and exhibition centre, and a major base for training professionals in palaeontology and stratigraphy.

The institute is engaged in basic and applied basic researches in palaeontology and stratigraphy and in public science communication. It is equipped with modern observational and analytical facilities for studies of fossil and sedimentary strata, a large collection of type specimens and a superb library treasured with long time collection of literature in our specialty. A particular attention is also paid to training next generation of researchers via the graduate studies program for MS, PhD and the postdoctoral program, which are open to applicants throughout China and from other countries.

Program

Saturday, May 26		
All day	Arrival	
14:30-17:30	Registration (Liu Yuan Hotel)	
Sunday, May 27		
08:30-08:50	Registration (Library, Nanjing Institute of Geology and Palaeontology)	
Opening Ceremony --- Chair: Wei-Ming Wang		
09:00 –9:30	Qun Yang	Welcome address of the Institute
	Jun Wang	Welcome address of the Department
	Angela A. Bruch, Torsten Utescher	Welcome address and Introduction to NECLIME
9:30-10:10	Robert Andrew Spicer	[Keynote]: The universal CLAMP calibration: a first look
<i>Coffee break: 10:10 – 10:40</i>		
Session 1 --- Chair: Torsten Utescher and Cheng-Sen Li		
10:40 – 11:05	Zhe-kun Zhou	Neogene floras from Yunnan, SW China and their palaeoclimate reconstruction
10:05 – 11:30	Gengwu Liu	Response of palynofloras to terrestrial Neogene climate events and correlation between marine and terrestrial records in North Hemisphere
11:30 – 11:55	Angela A. Bruch	Early Pleistocene vegetation and climate in Southern Caucasus
<i>Lunch: 11:55– 14:00</i>		
Session 2 --- Chair: Zhe-kun Zhou and Frédéric Jacques		
14:00 – 14:25	Bainian Sun	Fossil plants of Miocene from Ninghai, Zhejiang and their palaeoclimatic significance
14:25 – 14:50	Torsten Utescher	Temperature and precipitation gradients in the Neogene of Eastern Eurasia – where we are now
14:50 – 15:15	Yong-Jiang Huang	Late Pliocene seeds and fruits from southwestern China, and their climatic

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		implications
15:15 – 15:40	Tao Su	Paleoclimate reconstruction of a late Pliocene flora from Longmen, Yongping County, western Yunnan
<i>Coffee break: 15:40 – 16:10</i>		
Session 3 --- Chair: Angela A. Bruch and Yunfa Miao		
16:10 – 16:35	Jun Wang	Vegetational change through the Late Paleozoic Ice-age in North China Block: a case study in Weibei Coalfield
16:35 – 17:00	Gongle Shi	Dipterocarps from the middle Miocene of Southeast China
17:00 – 17:25	Limi Mao	Mangrove biogeography from Palaeocene through Pliocene: palynological and paleontological perspectives
17:25 – 17:50	Li Wang	The first evidence of the Miocene <i>Metasequoia</i> in Yunnan, southwest China and its biological implications
Monday, May 28		
Session 4 --- Chair: Bainian Sun and Robert Andrew Spicer		
09:00 – 09:40	Xiaoming Wang	[Keynote]: Neogene terrestrial mammalian biochronology of Asia -- current status, problems and promises
09:40 – 10: 05	Frédéric Jacques	Paleoelevation of Yunnan in late Miocene
10:05 – 10:30	Jinjin Hu	Changes in stomatal frequency in <i>Quercus pannosa</i> along an elevation gradient in the Himalayas
<i>Coffee break: 10:30 – 10:50</i>		
Session 5 --- Chair: Zihua Tang and Jianguo Li		
10:50 – 11:15	Cheng-Sen Li	The relationship of modern pollen data with climatic parameters in central Qinghai-Tibetan Plateau

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11:15 – 11:40	Torsten Utescher	Recognizing climatic trends in CA analyses by using palynomorph frequency – considerations on data centre and position
11:40 – 12:05	Yunfa Miao	Miocene pollen records of the Qaidam Basin, Northern Tibetan Plateau and implications for the East Asian monsoon evolution
Lunch: 12:05– 14:00		
Session 6 --- Chair: Sangheon Yi and Limi Mao		
14:00 – 14:25	Zihua Tang	Miocene arid Eurasia
14:25 – 14:50	Jianguo Li	Palynological record from a late Cretaceous to Paleogene sequence at southern Qinghai-Xizang plateau and its significance
14:50 – 15:15	Cheng Quan	Eocene intensification of the East Asian monsoon
15:15 – 15:40	Wei-Ming Wang	Stratigraphical concepts for Neogene fossil floras in China
Group photo, Coffee break and Poster Session: 15:40 – 16:50 (each presenter should be ready to give a 5-10 min introduction to the poster)		
Final discussion and synthesis, outlook to future activities --- Chair: Volker Mosbrugger		
16:50 – 17:50	Volker Mosbrugger, Angela A. Bruch, Torsten Utescher	Final discussion and NECLIME perspectives
Tuesday, May 29		
All day	Field trip nearby Nanjing including geological and historical sites	
Wednesday, May 30		
Departure.		

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THE POSTERS		
1	Sangheon Yi, Jang-Jun Bahk	Pliocene–Pleistocene boundary determination in hemipelagic sediment from the Ulleung Basin (East Sea, offshore Korea) inferred from pollen and dinoflagellate cysts
2	Olesya V. Bondarenko	Quantification of Calabrian climate of southern Primory'e using CA analysis
3	Yunfa Miao, Heling Jin, Mark Herrmann, Liangying Sun, Bing Liu	The Holocene cooling or moisture process of the NE Tibetan Plateau–evidence from bryophyte spores of slope deposit, Southeastern margin of the Gonghe Basin
4	Hongjuan Jia, Xiaoguang Qin, Jiaqi Liu, Sangheon Yi	Early to middle Holocene environmental conditions of Lop Nur, western China, inferred from grain-size analyses
5	Hanchao Jiang, Zhongli Ding	Eolian grain-size signature of the Sikouzi lacustrine sediments (Chinese Loess Plateau): Implications for Neogene evolution of the East-Asian winter monsoon
6	Ivan Gabrielyan, Angela A. Bruch, Habib Alimohammadian, Jafar Sabouri, Steffen Scharrer	A new finding of <i>Nelumbo protospeciosa</i> Sap. from the Upper Miocene of Tabriz, NW Iran, and its palaeoecological consequence
7	Chuanbiao Wan, Yewu Sun, Yunfei Xue, Yudong Jin, Xiuyun Qiao, Hongda Teng, Qingyuan Wang, Huanyuan Chi	Neogene pollen assemblages from western Songliang Basin and their paleoclimatic significance
8	Edoardo Martinetto, Arata Momohara, Elena Vassio	Quantitative comparison of a Pliocene vegetation record from Italy with possible East-Asian analogues from the Holocene of Japan
9	Yuanyuan Sun, Zhonghui Liu, Kexin Zhang, Jun Liu, Yuxin He, Bowen Song, Junliang Ji	Cenozoic environmental changes in the Qaidam Basin, northern Tibetan Plateau and a marine transgression event during the Middle Miocene

The Universal CLAMP Calibration: A First Look

J Yang¹, R.A. Spicer^{1,2}, T.E.V. Spicer¹, F.M.B. Jacques³, T. Su³, N.C. Arens⁴, E.M. Kennedy⁵, A.B. Herman⁶, D.C. Steart⁷, G. Srivastava⁸, R.C. Mehrotra⁸, P.J. Valdes⁹, N.C. Mehrotra⁸, Z.-K. Zhou^{3,10}, C.-S. Li¹

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CLAMP (Climate Leaf Analysis Multivariate Program) is a widely applied and robust palaeoclimate proxy based on leaf architecture of woody dicot leaves. It is not universally applicable, however, because of restrictions arising from the current geographically and climatically limited calibration datasets (<http://clamp.ibcas.ac.cn>). Because leaf form is demonstrably convergent in similar climates the assumptions underlying CLAMP are that 1) numerous interacting leaf physiognomic traits influence fitness, 2) natural selection operates towards an optimised ‘engineering solution’ to maximise photosynthetic efficiency despite often conflicting environmental constraints, and 3) this ‘tuning’ operates over geologically short timescales ($\ll 1$ Ma) by the elimination of ill-adapted taxa, migration and selection for novel genotypes arising by mutation or hybridization. However, the generalities of these assumptions have not yet been verified on a global scale.

Until now, leaf form/climate relationships have been investigated using geographically or genetically restricted datasets, and so have been vulnerable to concerns that species evolution and extinction, changes in local environment or species migration might confound an analysis of leaf form and climate. The outcomes of studies geographically restricted, datasets have been contradictory, arguably due to the use of different analytical approaches, non-standardized sampling methods, the inclusion of herbarium-derived data representing large geographical ranges and thus a diversity of climatic conditions, climate records collected over different time intervals, or by incorrect calibration. To date it has not been possible to show unequivocally that leaf form and climate exhibit a coherent relationship across different climate regimes and between vegetation types composed of markedly different species with disparate biogeographic and evolutionary histories.

To test whether foliar physiognomic/climate relationships are universal and consistent across the globe we used a diverse dataset (378 sites) collected using defined protocols from

vegetation encompassing a wide spectrum of species, including sites with highly endemic floras, and areas subjected to Quaternary glaciations but minimally impacted by humans, calibrated against standardised climate data recorded worldwide over a common 30 year interval from a diversity of climate types, we avoid, or at least minimize, spurious regional scale phenomena.

Sites with high physiognomic resemblance plot together, while those with low resemblance plot apart in what is termed 'physiognomic space'. This space is defined using Canonical Correspondence Analysis of a matrix of physiognomic data derived from each of the 378 sites (PHYSGGlobal378) using 31 leaf character states. The climate data (GRIDMetGlobal378_HiRes) we used were based on gridded climate data at 0.16° x 0.16° lat/long resolution interpolated and corrected for the exact site location and altitude.

Mean Annual Temperature (MAT), Coldest Month Mean Temperature (CMMT), Length of Growing Season (LGS), Specific Humidity (SH) and Enthalpy show the strongest coding in leaf form. Variables relating only to precipitation show more complex relationships arising partly from the gridding process and partly because in wet regimes water conservation is not a constraint on leaf form. The strong correlations between leaf form and temperature-related variables show that plants respond to such variables in a universal manner independent of other climate variables, biogeography history or phylogeny. This coherence demonstrates that regional variations seen in univariate analyses such as Leaf Margin Analysis disappear when several leaf characters are scored, implying numerous compensatory roles for leaf architectural features. The highly endemic floras of South Africa, New Zealand and Argentina plot coherently, intermingled with biodiversity hotspots such as Yunnan, China and depauperate vegetation seen in northern Europe that were affected by Quaternary glaciation. The only outliers are sites from Siberia that today experience extreme cold. Such sites are not taxonomically distinct having numerous genera in common with cool temperate sites in Europe and Asia, thus demonstrating that 1) floral composition plays a negligible role in determining leaf physiognomy/climate relationships when the dataset is large enough and 2) the vegetation of previously glaciated regions no longer retain this cold physiognomic signature.

To test the extent to which CLAMP relies on margin characters to derive temperature estimates we removed all such character states from the global analysis reducing the characters scored to 25. We found that even in the absence of all leaf margin information the CLAMP analysis still revealed a strong correlation ($p \ll 0.001$) between foliar form and the temperature-related variables, albeit with increased uncertainty in all cases. Thus it appears that the spectrum of remaining non-margin characters also, collectively, codes for temperature.

Overall this global dataset confirms all the underlying CLAMP assumptions are valid.

Response of palynofloras to terrestrial Neogene climate events and correlation between marine and terrestrial records in North Hemisphere

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Response of palynofloras to the climate changes is the principle for terrestrial paleoclimate reconstruction in palynological research. In northern China previous palynological studies revealed some significant Neogene climate events, e.g. the Early Miocene cool phase, late Early Miocene (to early Middle Miocene) climate optimum (warm), Late Miocene dry episode, Mid-Pliocene warm event and the followed temperature oscillations with declining trend, etc. Pollen floras from Alaska also recorded three warm phases and a dry episode in the Miocene. All these climate events are reflected by abundance changes of different ecologically sensitive types, which we called “index fossils”, in the pollen sequences. Because of no long continuous terrestrial Neogene deposits found in China it is difficult to date and rank those scattered fossil pollen floras. It is therefore also difficult to precisely calibrate and correlate these climate events with the marine records.

Marine oxygen isotope studies of ODP program discovered several well dated Neogene climate events in North Hemisphere, including three Miocene warm phases at ca. 16-15 Ma, 11 Ma and 7 Ma respectively at ODP 588 site of the Alaska Gulf and the Mid-Pliocene warm phase at ca. 3 Ma, the sharp temperature drop at 2.5 Ma from ODP 846 site. An 18 million long pollen sequence from several continuous Neogene sediments from Alaska and Pliocene sediments from North China, afforded us good long pollen sequences for semi-quantitative paleoclimate restorations. By using “Index fossils” Leopold and Liu (1994) produced a temperature climate curve for a Neogene pollen sequence from Nenana of Alaska, which showed three warm episodes in Miocene and can be well correlated with marine record of ODP 588. Using the same method Liu et al. (2002) discovered a warm episode and two cold phases with a declining temperature oscillation in middle to late Pliocene, which can be correlated with the marine stable isotopic curve from ODP site 846. A dry phase reflected by abundant xerophyte pollen in the Late Miocene to Early Pliocene pollen floras from North China (Liu, 1988), eastern Qinghai-Xizang Plateau (Liu, 2001) and Alaska (White et al., 1997) probably can be correlated with the Messinian salinity crisis. These correlations were also supported by other associated fossils and/or radiometric dates.

Keywords: palynology; Neogene; palaeoclimate

Early Pleistocene Vegetation and Climate in Southern Caucasus

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For the reconstruction of Early Pleistocene landscape evolution in the Caucasus the Vorotan basin proved to be a rich area for palaeobotanical and palaeozoological studies. There, lake sediments form huge diatomitic sequences that are perfectly suitable for palaeoenvironmental studies. The highly precise age control of the sites studied so far is based on palaeomagnetic and Ar/Ar dating and enables us to reconstruct the environmental history of the Early Pleistocene between 1.15 and 0.95 Ma. The sedimentation rate for the diatomite is estimated to be about 20-30 cm per 1000 years, which allows for a resolution of about 250 years per sample.

The profiles show a rich and diverse flora and entomofauna. Some parts of the sequences studied in high resolution show clear cyclicity which can be correlated to global climate cycles. The prominent warm phase MIS 31 at 1.07 Ma is well pronounced in the pollen and macroflora record and linked with a major expansion of the forest belt and a diverse mosaic landscape providing a high variety of habitats and resources to early humans. This time of wide spread forest cover lasted for less than 10 000 years. This rich leaf assemblage was the basis of a quantitative climatic analysis based on the Coexistence Approach yielding clearly warmer and more humid conditions than today. Before and afterwards vegetation was dominated by semi-arid steppes and montane meadows, very much similar to today.

Distinct differences between vegetation development during the two interglacial stages MIS 33 and MIS 31 can be used to define a climatic threshold for the development of habitats suitable to early humans in the Armenian highlands. Comparison with pollen data from Western Georgia will shed light on the spatial differentiation of vegetation in this topographically highly variable landscape.

Fossil plants of Miocene from Ninghai, Zhejiang and their palaeoclimatic significance

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Abundant angiosperm fossils collected from the Shengxian Formation of Ninghai in Zhejiang Province were studied in the present paper. The age of the Shengxian Formation is thought to be the late Miocene based on pollen and isotope dating of the underlying basalt. Those fossil plants were called as the Shengxian flora which is consisted of 23 genera based on megafossils plants. The coexistent region of their extant equivalent genera ranges from the altitude of 500m to 1200m within the latitudes from 26°N to 30°N and longitudes from 107°E to 115°E. The concept of the nearest living relatives (NLR) is adopted and applied in this paper by using the assumption that the fossil and its nearest living relative have similar ecological requirements. According to the extant data of above coexist region derived from the climatic data of China, the Miocene palaeoclimate in Ninghai, Zhejiang Province is estimated as the mean annual temperature (MAT) 9.91-19.74C, the difference in temperature between the coldest and warmest month (DT) 18.31-30.68C, the mean temperature of the coldest month (TCM) -3.20-5.19C, the mean temperature of the warmest month (TWM) 16.34-26.44, annual extremely warmest temperature (EWT) 27.99-37.41C, annual extremely coldest temperature (ECT) -6.56-20.16, the mean annual precipitation (MAP) 1117.7-1546.4mm, showing a subtropical mountainous climate.

This work was conducted under the support of National Natural Science Foundation of China (No. 41172022), and Specialized Research Fund for the Doctoral Program of Higher Education (Grant No. 20100211110019).

Key words: fossil plant, Miocene, palaeoclimate, Zhejiang

Temperature and precipitation gradients in the Neogene of Eastern Eurasia – where we are now

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There exist extensive literature resources dealing with the evolution of the monsoon systems in Eastern Eurasia, reconstructed from a variety of proxy data, and on continental drying in the context of uplift of Himalaya and Tibetan Plateau. NECLIME now provides coherent climate data for various Neogene time intervals for the first time to address this question under the perspective of continental climate patterns reconstructed from the palaeobotanical record.

As is known from other continental areas of the Northern Hemisphere the Neogene climate of Eastern Eurasia was more equable when compared to present; temperature and precipitation gradients in general were considerably weaker (e.g., Utescher et al., 2011). Highest anomalies with respect to present-day climate occur in winter temperatures of the high latitudes and rainfall in the continental interior, anomalies in general are minor in the Southeast.

The majority of related studies point out that in the earlier Neogene, seasonality of temperature and precipitation was less distinct (e.g., Liu et al., 2011; Yao et al., 2011). Hence it can be concluded that the Asian monsoon system - today a major guiding factor of the climate in that continental part - had an overall reduced intensity. In the later Neogene, there is evidence for a notable diversification of climate. For Northwest China, drying pulses are reported from the Tortonian (e.g., Wang et al., 2009; Liu et al., 2011), and the Messinian (Tian Shan; Sun, Zhang, 2008). Pliocene records point to an intensification of Winter Monsoon (e.g., Qin et al., 2011). Climate reconstruction from the palaeobotanical record for Southern China is complicated by a mosaic of tectonic blocks with different uplift history thus introducing the altitudinal factor as an additional uncertainty and source of error. Various recent studies concurrently come to the conclusion that during the later Neogene, this continental part was affected more by regional climate dynamics than by global cooling. For Southeast China data point to a late Miocene intensification of the East Asian Monsoon (Yao et al., 2011; NECLIME data set). In the Southwest, Miocene precipitation rates in general were higher than today, pointing to an increased impact of the Indian Monsoon and/or post-Miocene regional uplift processes (e.g., Xia et al., 2009).

Model studies that will considerably improve our understanding of the climate patterns revealed by the proxies are on the way. At the same time, work is in progress to include more well-dated sites in the analysis thus improving the resolution of the proxy data.

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Late Pliocene seeds and fruits from southwestern China, and their climatic implications

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The late Pliocene Fudong Flora from northwestern Yunnan, southwestern China, bears abundant fossil seeds and fruits. The identified taxa include *Ranunculus*, *Antenoron*, *Cucubalus*, *Salix*, *Rubus*, *Aralia*, *Verbena*, *Sambucus*, *Cyperus*, *Scirpus*, *Carex* etc. The fossils of three taxa, *Cucubalus*, *Rubus* and *Sambucus*, are studied in detail. The present *Cucubalus* seeds might represent the first fossil record of this genus, and one of the few fossil records of the fossil-sparse family Caryophyllaceae. The present *Rubus* pyrenes show high morphological diversity. They might represent several species as pyrenes of modern *Rubus* are stable in morphology within the same species based on our survey. This may, to some extent, explain the high species diversity in today's northwestern Yunnan. The present *Sambucus* endocarps represent the southmost fossil record of this genus, and is therefore significant to the past biogeography of *Sambucus*. Coexistence approach is used to quantitatively estimate the palaeoclimate of the late Pliocene Fudong Flora. MAT and MAP yield 12.2-16.8°C and 617-1361 mm, respectively, as compared to 10.2°C and 1023 mm at present. This implies that it was significantly warmer during the late Pliocene than today at Fudong; but the precipitation in this geological past was quite comparable to today's Fudong.

Paleoclimate reconstruction of a late Pliocene flora from Longmen, Yongping County, western Yunnan

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A mega fossil flora from the upper Pliocene Sanying Formation in Longmen village, Yongping County, western Yunnan Province is reported. The Longmen flora consists of ferns, gymnosperms and angiosperms, e.g., *Drynaria*, *Equisetum*, *Cedrus*, *Pinus*, *Lithocarpus*, *Populus*, *Quercus* and *Rhododendron*. Among all specimens, leaves of evergreen sclerophyllous oaks (*Quercus* sect. *Heterobalanus*) are the most abundant. It indicates that the Longmen flora belongs to sclerophyllous evergreen broadleaf forest. Paleoclimate of Longmen flora was reconstructed by Coexistence Approach (CA), Climate-Leaf Multivariate Analysis Program (CLAMP) and Leaf Margin Analysis (LMA). Results of all methods are consistent and support a wet and warm climate in Yongping during the late Pliocene. MAT is 18.9 ± 1.3 °C (CLAMP) and 19.5 ± 1.9 °C (LMA) respectively; MAP is 1723.8 ± 217.7 mm by CLAMP. Our study suggests that, Yongping may have an altitude in the late Pliocene as high as nowadays. In combination to previous palaeoclimate reconstructions of Neogene floras focusing on western and northwestern Yunnan Province, this study supports that, the uplift of Tibet-Qinghai Plateau changed the climate greatly from the Miocene to the Pliocene, and consequently shaped the biodiversity of species and vegetations in western and northwestern Yunnan.

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Keywords: the late Pliocene, palaeobotany, paleoclimate, *Quercus*, CLAMP.

Vegetational change through the Late Paleozoic Ice-age in North China Block: a case study in Weibei Coalfield

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The Permo-Carboniferous may have been the only time in the Earth's history when there were well established floras that experienced a transition from icehouse to greenhouse conditions, and that would have been similar to the one that scientists believe is currently in progress. Understanding the response of floras during the Late Paleozoic icehouse - greenhouse transition could provide meaningful data to help us understand the vegetational changes that may occur in response to the current postulated icehouse - greenhouse climatic change. Based on investigations of stratigraphic sections in the Weibei Coalfield, a typical coal basin in the North China Block, the succession of Late Paleozoic plant macrofossil assemblages were redefined. In combination with all so far available information, the biostratigraphy of the terrestrial deposits in the North China Block were correlated to the IUGS Global Chronostratigraphy. The more precise chronostratigraphic constraints make it possible to more precisely correlate the vegetational successions to the concurrent waxing and waning of the Late Paleozoic ice sheets.

Four floral changeovers (Changeover 1-4) are detected. Changeover 1 occurred at the end of Westphalian, coinciding with the ending of the first ice-age maximum. A pteridosperm-noeggerathialean dominated vegetation was replaced by the pteridosperms - lycopsids assemblage. Changeover 2 went on from the late Stephanian through Sakmarian to Kungurian, and ended by the second glacial maximum. A remarkable floral radiation occurred, and the majority of the typically Cathaysian floral elements were present. Changeover 3 developed at approximately the terminal stages of the Late Paleozoic Ice-age. Early ginkgoaleans and conifers first appeared in the flora. Changeover 4 is clearly recognizable from the Changhsingian, shortly after the ending of the Late Paleozoic glaciations. Cathaysia flora is replaced by peltasperm-dominated, Euramerican and Angaran elements.

New *Dipterocarpus* fruits from the middle Miocene of Southeast China

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Dipterocarpus Gaertner is the type genus of the family Dipterocarpaceae and belongs to the subfamily Dipterocarpoideae. It contains about 70 species distributed in the tropical evergreen forests and savanna woodlands from Sri Lanka to the Philippines, Borneo and Sumbawa. The fossil records of this genus are mostly represented by wood and leaves; the reliability of them is, however, often in doubt. The fruits of *Dipterocarpus*, characterized by their persistent enlarged calyx lobes, the fruit wings, are easily identifiable but very rarely represented in the fossils. In a previous report, we described a fossil species of this genus, *D. zhengae* H.M. Li & G.L. Shi, on the basis of a single fruit wing from the Miocene Fotan Group in Fujian, Southeast China. In the last year, during the field work in the same fossil site, we fortunately discovered some new materials of this fossil species.

The original specimen and the new materials of *Dipterocarpus zhengae* were all collected from the middle part of the Fotan Group. This Group is composed of about three layers of basaltic rocks, in between every two of them with sedimentary deposits such as arenaceous conglomerate rocks, sandstone and mudstone interbedded with lignite and diatomite. The palynostratigraphic study of the sedimentary layers indicated a Miocene, and most probably middle-late Miocene age. The Ar⁴⁰/Ar³⁹ age of the basaltic rocks in Zhangpu under the fossil yielding sedimentary layer is 14.8±0.6 Ma, corresponding to the Langhian stage (middle Miocene).

The new additional specimens of *D. zhengae* include a nearly complete winged fruit with a nut and two enlarged calyx lobes, a compression of a single fruit wing with cuticle preserved, as well as some isolated fruit wing impressions. The nuts are rounded to broadly ovoid in shape, ca. 1.8 cm in diameter, often with a short persistent pedicel. The longer lobes are oblanceolate, with three stout primary veins. The angle between the two enlarged calyx lobes of one fruit is 17° and the other is 20° (two specimens measured). The fruit wings are amphistomatic, with the adaxial and abaxial surfaces generally similar in cuticular structure. The stomata complexes are cyclocytic, randomly arranged, and stomatal pits are fusiform to elliptical.

These new materials further corroborate our previous determination of the type specimen and also corroborate the original conclusion that *Dipterocarpus zhengae* is most similar to the modern *D. gracilis*. The latter is today distributed in Andamans, Chittagong, Burma, Southeast and Peninsular Thailand, Malaysia, Sumatra, West Java, Borneo and the Philippines, often gregarious in seasonal semi-evergreen dipterocarp forests on red soils. *D. zhengae* might inhabit a similar environment as its nearest living relative.

Mangrove biogeography from Palaeocene through Pliocene: palynological and paleontological perspectives

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Mangrove forests are crucial occupiers of the boundary between land and sea, as a key ecosystem along many tropical and subtropical coastlines. The mangrove fossil record of both macrofossils (leaves, wood, flowers, and fruit) and microfossils (pollen) is surprisingly rich. *Nypa* is the earliest of the modern mangrove genera to appear in the fossil record. Late Cretaceous (Maastrichtian) records of *Nypa* are all fossil pollen. Dolianiti (1955) reported *Nypa* fruits from the Palaeocene of Pernambuco, Brazil. Sonneratiaceae play a precursory role in the earliest modern mangrove ecosystem. Recorded first in the Eocene as *Sonneratioxylon* (Ramanujan, 1956; Louvet, 1970, 1973), it is also represented by *Florchuetzia* pollen in the Paleocene of southern France (Gruas-Cavagnetto et al., 1988), in the Eocene of West African (Zaklinskaja, 1978) and in many Neogene (Yamanoi, 1984) and Quaternary tropical localities. The frequent pollen records are explained by its current over-representation reported in modern pollen assemblages (Caratini et al., 1973). Germeraad et al. (1968) and Muller (1978, 1981) discussed the botanical significance of *F. trilobata*, the oldest type, and considered it as an intermediate between the Lythraceae and Sonneratiaceae. It has been suggested as an ancestor of the true *Sonneratia* though it is recorded in the same early Miocene level as the unequivocal *Sonneratia* pollen. Germeraad et al. (1968) found *Florchuetzia* in the assemblages containing *Sonneratia* sp. and *Rhizophora* sp. This suggests that *F. trilobata* was produced by a true, now extinct mangrove plant which was gradually replaced by the modern species towards the end of the Paleogene.

In Rhizophoraceae, fruits and pollen appear simultaneously in the Early Eocene deposits of Western Europe. Muller and Caratini (1975) and Muller (1980) suggested that this pollen-type appeared only in the late Eocene of India whereas Gruas-Cavagnetto et al. (1988) recorded pollen similar to *Rhizophora* or *Kandelia* in the earliest Eocene, i.e. before the well-known London Clay fruit flora, along with the *Palaeobruquiera* and *Ceriops* hypocotyls (Chandler, 1951, 1978; Collinson, 1983). *Bruquiera*-type pollen appears at the same time in the Sparnacian of the Paris Basin (Gruas-Cavagnetto et al., 1980) and in the middle Ilerdian of Southern France (Gruas-Cavagnetto, 1991). The exact phyletic relationship between these precursors and the modern Rhizophoraceae (tribe Rhizophoreae) will probably not be made clear with such a limited set of data. However, convincing similarities between Early Eocene and modern *Ceriops* hypocotyls have been stressed (Wilkinson, 1981, 1983). Thus, ancestors very close to modern genera coexisted in Early Eocene times with other fossils retaining ancestral morphologies which do not exclude a common mangrove-swamp biotope. These earliest finds of Rhizophoreae suggest that the complex, modern mangrove ecosystem had developed in the Earliest Tertiary.

The Eocene/Oligocene boundary crisis appears to herald a beginning of the biogeographic split between the current-day eastern and western provinces of mangrove plants. But while the climatic origins of this major disjunction is not clearly understood, the reassessment of Tertiary paleoclimates suggests that the major cooling events of the middle

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Paleocene, the end of the Eocene and the middle Pliocene were the most likely influences on the evolution of mangrove flora (Plaziat et al., 2001). The global progressive cooling of ocean and atmosphere during late Miocene and early Pliocene times culminated with the first modern glaciation, after 3 Ma. It had certainly induced increased disjunction between the Eastern and the Western mangroves along the Eurafrikan basin, although it did not put obstacles between the opposite sides of the Atlantic Ocean and between the Caribbean and the Pacific shores of Central and South America.

The first evidence of the Miocene *Metasequoia* in Yunnan, southwest China and its biological implications

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Metasequoia has been an ideal plant for palaeoenvironmental and palaeoclimatic reconstructions for it has a long evolutionary history, a wide distribution range, a morphological stasis, and a nearest living relative species. So far, evident *Metasequoia* fossils have not been reported from central and western China. Recently numerous well-preserved fossil *Metasequoia* leafy shoots and female cones were discovered from the middle-upper Miocene deposits near the western slope of Ailao Mountain in central Yunnan, southwest China. This is the southernmost distribution evidence of this genus in its fossil history. The unambiguous attribution of these fossils to *Metasequoia* is mainly based on the shape and decussate arrangement patterns of the leaves and cone scales, as well as the leaf cuticle features. Due to its common occurrence in several layers of strata, the fossil *Metasequoia* must have been a dominant element in the Miocene forest associated with angiosperms such as *Alangium*, *Acer*, and *Bambusoideae* species. The assemblage of the flora most likely represents a swampy and riparian environment, and a warm and humid climate. The migration of *Metasequoia* from north or east China into southwest China might have followed such events: (1) the cooling trend of the Oligocene, (2) the arid zone which stretched across China from west to east during the Paleogene restricted to northwest China around Oligocene/Miocene boundary, and (3) the regression of the Tethys Sea from Yunnan during the late Oligocene. The drying trend during the late Miocene and the Pliocene may cause the extirpation of *Metasequoia* in Yunnan.

Key words: *Metasequoia*, fossil, Miocene, Yunnan, phytogeography, paleoenvironment, paleoclimate

Neogene continental Asian biostratigraphy and geochronology: where we are and where we are heading

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Mammalian biostratigraphy has been and still is the primary means for Cenozoic terrestrial geochronology. This is true for Asia as well, where large basins with long sections archiving abundant fossil mammal remains are the basis for formulating a comprehensive continental chronologic framework. However, abundance of fossils in excellent stratigraphic context has not translated to a uniform, widely-accepted chronologic system in Asia, for reasons of both human (history, methodology, and geopolitics) and nature (unevenness of records, shortage of corroborating dates as from volcanoclastic sediments, and faunal provinciality caused by active tectonism and changing climates).

While the relatively less-developed status of the Asian chronologic system certainly has something to do with the fact that the continent is dominated by developing (or emerging) economies, other human factors remain important, such as limited international communication and a lack of a common framework to set agendas. In an attempt to provide a forum to discuss the feasibility of an Asia-wide land mammal age system, we have organized two international workshops at the Institute of Vertebrate Paleontology and Paleoanthropology in Beijing in 2009 and 2010. A direct product of these workshops is a volume to summarize the state of the art of biochronology for almost all areas of Asia (Wang et al., in press).

Research on local Asian chronologic systems ranges from the cutting edge to undeveloped in some cases, and everything in between. At the finest scale, the Siwalik sequences in Pakistan are methodically assembled into a composite stratigraphic framework with observed superpositional relationships preserved. Age control is well constrained by 47 magnetic sections and high-density sampling of fossil mammals, with consistent resolution of up to 200,000 years or less for 80% of the more than 1,000 fossil localities, and 100,000 years or less for 50% of the localities. Such a remarkable precision is pushing the resolving power in terrestrial sedimentation to the limits (Barry et al., in press), and can rival the resolution of any basin of continental deposits in the world. However, application of such a system to other fossiliferous regions works best within its own biogeographic setting, in this case the Oriental Zoogeographic Province and its equivalent in the geologic past. Cross-province correlation becomes problematic as shared taxa dwindle rapidly as the effect of geographic distance becomes increasingly pronounced.

A Chinese effort in the past 30 years, based on faunas and basins in North China, has achieved prominence. Capitalizing on a long history of study and Chinese tradition of dragon-bone hunting, Qiu Zhanxiang and colleagues have led a renewed effort for a proposal that attempts to inject new rigor into the dialogue (Qiu et al., in press). The evolution of this system was strongly influenced by pre-existing European frameworks, initially as a stage system and more recently increasingly resembling the European Neogene mammal zone (unit) system. In the latest iteration, after extensive debates in the two Beijing workshops, Qiu et al. (in press) adopt a chronostratigraphy-like system following the recommendations of the All-China Stratigraphic Commission, an approach that has not been attempted elsewhere for the continental Neogene. Serious questions still exist both at the conceptual and practical levels.

Resolution for the new Chinese land mammal stage/age system is still relatively low, especially compared to that of the Siwalik sequence. However, given focus on dating observed superposed faunal assemblages in the rich basin deposits of China, a well-dated biostratigraphic framework will emerge and can yield a testable biochronology. The Chinese system has the potential to be widely applicable to much of northern, central, and even western Asia, because of the wide connection and generally similar climate across mid-latitude Asia. Such a system will have to contend with a certain amount of taxon/faunal diachronism as geographic distance and climatic regime across the vast landmass of Asia (such as moisture gradients) become an issue (Mirzaie Atabadi et al., in press). The quest for an Asia-wide chronologic system that has wide applicability to both Palearctic and Oriental provinces remains elusive.

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Palaeoelevation of Yunnan during the late Miocene

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Yunnan Province has a complex geography with altitudes varying from almost sea-level to more than 6000 m. Its Neogene tectonic history is mainly the result of the collision of the Indian and Eurasian plates. This collision resulted in the uplift of the Qinghai-Tibet Plateau and the Himalayas, but also to the uplift of the Hengduan Mountains. Besides, these compressive forces had repercussions on South-East Asian geography. Even if Yunnan occupies an important position between the Qinghai-Tibet Plateau and the Indochina Peninsula, almost nothing is known about its palaeoelevation, in contrast to what have been done in Tibet. In this study, we use information from three fossil leaf assemblages to reconstruct the palaeoelevation of Yunnan during the late Miocene: Lincang, Xiaolongtan and Xianfeng. CLAMP (Climate Leaf Analysis Multivariate Program) links the leaf physiognomy with climatic parameters including the enthalpy at surface. Climate modelling gives the enthalpy at mean sea level. The difference between enthalpy at mean sea level and at surface is proportional to the altitude. During the late Miocene, Xianfeng is at about the same altitude as now (a little over 2000 m) whereas Lincang and Xiaolongtan are at lower altitudes (around 200 m and 500 m) respectively. The Yunnan-Guizhou Plateau to which belongs Xianfeng reached its present elevation; however, South Yunnan underwent uplift since the late Miocene. These results correlate well with the floristic: Leguminosae are an important component of Lincang and Xiaolongtan assemblages whereas Fagaceae are clearly dominant in Xianfeng.

Changes in stomatal frequency in *Quercus pannosa* along an elevation gradient in the Himalayas

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Research into the relationship between atmospheric CO₂ concentration and stomatal frequency (stomatal density, SD or stomatal index, SI) is becoming popular. This relationship can be used as a proxy for the reconstruction of paleo-CO₂ levels and paleo-elevation. However, this relationship is species-specific. Most are positive, with some negative and a few no response. Fossils of *Quercus* sect. *Heterobalanus* are common in Neogene of Hengduan Mountains. They could be suitable potential material for the reconstruction of paleo-CO₂ levels and paleo-elevation. In order to achieve the aim, sun and shade leaf materials of 5 individuals each from 15 sites in different elevations ranging from 2493 m to 4497 m of *Quercus pannosa*, a dominant element of Sclerophyllous forests in the Himalayas and the nearest living relative of *Quercus* sect. *Heterobalanus* fossils, are collected to analyse leaf stomatal frequency. An inverse relationship between stomatal frequency and elevation is found in *Quercus pannosa*, in other word, a positive relationship between stomatal frequency and atmospheric CO₂ concentration. Furthermore, the difference between sun and shade leaves is compared, so as to explore which one is more suitable to apply to paleo-CO₂ reconstruction.

Key words: *Quercus pannosa*; stomatal frequency; sun and shade leaf; paleo-CO₂ levels

The relationship of modern pollen data with climatic parameters in central Qinghai-Tibetan Plateau

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Illustrating the relationships among modern pollen data, vegetation and climate give a better understanding for reconstructing the palaeovegetation and palaeoclimate by using palynomorphs data. In this work, we analyzed 44 surface samples from the Qinghai-Tibetan Plateau and obtained the palynological data. Based on the data, the 5 climatic parameters were reconstructed by the coexistence approach and compared with the 'real' values. In the alpine vegetation of Qinghai-Tibetan Plateau, non-arboreal pollen (NAP) dominated the modern pollen assemblages. Because Asian Summer Monsoon carried arboreal pollen (AP), as exotic pollen (EP, mostly with long-distance transportation), from the southeastern part of Tibetan Plateau to the rest parts northwestwards, about 83km to 1557km in the range based on this study. Obviously, the exotic pollen significantly affected the result of Coexistence Approach (CoA) of mean annual precipitation (MAP), mean annual temperature (MAT), differences of temperature between the coldest and warmest months (DT), and mean temperature of the coldest month (WMCT), and insignificantly of mean temperature of the warmest month (WMWT). It is more reasonable to remove the exotic pollen out of modern pollen assemblages when reconstructing the vegetation and climate by CoA. When excluded the effect of EP, median value of the coexistence interval was still higher than the climatic interpolations of MAP, MAT, WMWT, and WMCT especially at above 4000m altitude area of the plateau. On the plateau, the snowmelt and permafrost improving the insufficient water and low temperature conditions for plants may lead to the disagreements between two sets of climatic data. Conclusively, EP, snowmelt and permafrost should be considered in the reconstruction of past vegetation and climate by CoA, at least, since the Quaternary.

Recognizing climatic trends in CA analyses by using palynomorph frequency – considerations on data centre and position

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As known from a variety of studies using the CA together with microflora climatic resolution obtained often is not quite satisfying. One main reason is the low taxonomic resolution palynomorphs provide when compared to macroflora, in other words, the high taxonomical level at which NLRs are identifiable for a taxon. Another factor is taphonomic condition. While frequent components usually mirror local to regional vegetation (dependent on sediment type) the rare fraction a sample is either explained by low production of the parent plant or by far-distance transport. So far, the CA considers just presence/absence of floristic components in order to avoid any bias caused by taphonomic effects. Applied on microflora, however, this may lead to inconsistencies (local spectrum / transported grains) or loss of signal (smearing of signal / grains are encountered everywhere, though in low quantity).

To overcome these uncertainties and to improve the ability of the CA to detect climatic trends in time series obtained from palynomorph records we introduce here a novel methodology based on probability considerations. The approach takes into account palynomorph frequency in order to define a median position and the standard deviation for each palynoflora. We take into account that the climatic ranges of NLR taxa together with commonness of a component define the standard deviation: if we have a high palynomorph frequency we have a small standard deviation and the other way round.

Miocene pollen records of the Qaidam Basin, Northern Tibetan Plateau and implications for the East Asian monsoon evolution

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Research on the Miocene terrestrial sediments in the east part of the Central Asia can provide a better understanding of the formation and development of the East Asian monsoonal system. The Qaidam Basin is the largest basin in the north margin of the Tibetan Plateau, Central Asia characterized with arid climate (mean annual precipitation <50 mm) in the west and semiarid (mean annual precipitation <400 mm) in the east, very close to the Asian summer monsoon boundary. We selected two sites at these two separate parts to discuss the climate change based on the pollen records. The KC-1 core was drilled to a depth of 3435 m in the west basin, spanning the early to late Miocene (18~5 Ma). 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, Betulaceae are subordinate. Only a few types of algae and fungal spores have been found in some samples. Higher thermophilic taxa percentages decreased continuously, which fits well with the global climatic cooling. During the same period, the xerophytic taxa percentages gradually increased, suggesting a stably drying process in the west Qaidam linked with the gradual weakening of the East Asian Monsoon driven by the global cooling. The Naoge section, with 3075 m thick in the east basin, is also spanning the early to late Miocene (18.4-7.1 Ma) with the high-resolution paleomagnetic dating. The pollen results are similar to the KC-1 results, but with higher percentages of the humid and mesophytic types, for example, *Fupingpollenites*, and Potamogetonaceae are dominated at some samples during the 18~14 Ma and Betulaceae as well as other broad-leaved types occupied the late time. Totally, in the long-term, the pollen at the Naoge section shows a cooling trend but a very slight drying trend. We argue that the precipitation from the East Asia Monsoon has retreated from the west basin gradually during the Miocene, but always can influence the east part. The East Asian monsoon reached its maximum during the Middle Miocene Climatic Optimum and weakening after that time during the Miocene.

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Keywords: Pollen, Qaidam Basin, Miocene, East Asian monsoon

Miocene Arid Eurasia

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The monsoonal systems get dominance in the East Eurasia since the latest Paleogene. In parallel, the central Eurasia becomes a middle-latitude interior arid area, and finally forms a modern-like arid pattern in the late Miocene, but the timing, extent and forcing of the aridification are still not well understood satisfactorily. Palynological evidence from the fluviolacustrine Jingou River section at the south margin of Junggar Basin, NW China, provides the oldest known aridification record in the continental interior, which occurred at the latest Oligocene, as evidenced by significantly decreased pollen influx and diversity, as well as sharply increase of xerophytic herbs and shrubs (*Artemisia* and *Chenopodiaceae*, etc.). Comparison of the available well-dated, pollen-based evidences on aridification shows a stepwise expansion of the arid condition from the Junggar Basin to its adjacent regions. The two major expansions, occurring ~ 14 and 8 Ma, can be well correlated to both the increased global ice volume and the uplift of the Tibetan Plateau. These coincidences imply a combined impact of global climate and regional tectonics on the central Eurasian drying in the Miocene. Late Cenozoic global cooling reduce the strength of hydrologic cycle and increased cold air masses from higher latitudes, while geographic barriers, such as the Tibetan Plateau and Tian Shan, block moisture transportation from neighbouring oceans and induces atmospheric subsidence and relatively infrequent storms over the interior. The epicontinental Paratethys redistribution, influenced by the tectonics and global cooling, also attributes to the aridification.

Palynological record from a late Cretaceous to Paleogene sequence at southern Qinghai-Xizang plateau and its significance

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It has been commonly presumed that the rise of Qinghai-Xizang plateau during late Cenozoic is important for the formation of the climatic pattern of East and even central Asia. However, many aspects of this process still remain obscure, e.g., about its earlier stage or, pre-uplift time. Here we present a palynological study from southern Xizang which represents a good outline of the Indian-Asian collision since late Cretaceous to Oligocene. Since the time of probable collision at late Late Cretaceous, three transgression-regression cycles can be clearly observed, which are ended by a mountainous environment in Oligocene. Together with other evidences from sedimentology and tectonics, three episodes of uplift are implied by clear shifts of palynofacies as well as palynofloras. Though it needs further work for a precise estimation on each of these movements, it can be concluded that the enclosure of the marine environments at Qinghai-Xizang plateau means the modern continental outline of East Asia has been formed since Oligocene and the elevation and size of the plateau have become key factors for the palaeoclimate change there.

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Key words: palaeoclimate; palynology; collision; Qinghai-Xizang plateau

Climatic distribution of Eocene China: planetary wind or monsoon-dominated?

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Proxy-based quantitative estimates of Eocene climate conditions are abundantly available from marine isotope records and floral data. However, the available terrestrial data are mainly from North America and Europe, and only a few are known from East Asia. Previous qualitative studies on Chinese Eocene floras briefly illustrated the zonation of the Eocene climates in China with a planetary wind-dominated arid zone in the central part, i.e., the subtropical highs. But such pattern of climatic distribution is subjected to the quantitative study. Based on analyses on 66 plant assemblages, carefully selected from 37 fossil sites throughout China, we here report the first large-scale quantitative climatic results and discuss the Eocene climatic patterns in China. Our results demonstrate that the Eocene monsoonal climate must have been developed over China, judging from the presence of apparent seasonality of both temperature and precipitation revealed by our quantitative estimation, which appears not to support previously claimed Eocene planetary wind-dominated climate system that is supposed to be accounted for the then arid climate over central China. In addition, the paleoclimatic results from tropical sites in southern China show that the Eocene temperatures in the tropics of Southeast Asia appear cooler than the present, an interesting aspect quite different from the situation of Eocene tropical SST. This might be related to the possible weak Eocene Kuroshio Current in the southwestern Pacific, and/or the significantly enhanced palaeo-winter monsoon from Siberia.

Keywords: Eocene climates; plant fossils; quantitative reconstruction; Eocene monsoon over China; cooler low latitudes.

Stratigraphical concepts for Neogene fossil floras in China

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As a result of substantial geographic variations and environment changes, Neogene fossil floras in China exhibit a great dissimilation over time and space. The important of detailed correlation among the Neogene sequences in the different regions of China is becoming increasing recognition, inasmuch as its large territory with unevenly developed environmental background, and a majority of terrestrial deposits. Recent progress in some regional chronostratigraphic and other related studies have made it possible to confirm the stratigraphical concepts for Neogene fossil floras in China.

The Neogene Global Stratotype Sections and Points (GSSPs) have been mostly established under the effort of the International Commission on Stratigraphy (2009). The Neogene of China is mainly terrestrial with isolated outcrops. Consequently, many studies have concentrated on the detailed evaluation of some available outcrops and core profiles for the transregional correlations with multiapproached methods (CGTRP, 1992; Wang and Deng, 2005; Wu et al., 2006). Under the organization of the National Stratigraphy Committee, combined efforts have been made to establish the Neogene stratigraphic chart of China, mainly based on fossil mammal and palaeomagnetic evidences (National Stratigraphy Committee, 2002; Wang and Deng, 2005).

A comparative study in the regional scale of China will greatly promote the precision in the stratigraphic study. According to the Regional Chronostratigraphic Chart of China, there are Mazegouan and Gaozhuangian Stages in the Pliocene; Baodean, Tunggurian, Shanwangian and Xiejian Stages in the Miocene, which are correlated with Piacenzian, Zanclean, Messinian and Tortonian, Serravallian and Langhian, Burdigalian, and Aquitanian Stages respectively. Efforts were made in determining their stratotype sections and points in the representative profiles in the past years. Some comprehensive approaches including mammalian fossils, pollen grains and spores, paleomagnetic date, etc. have been applied to these profiles (Deng et al., 2003; 2004; 2006; Wang and Deng, 2005). Our study reveals that the lower boundary of Pliocene Mazegouan and Gaozhuangian Stages, and Miocene Xiejian Stage can be determined in the original named profiles, while the lower boundary of Miocene Baodean, Tunggurian and Shanwangian are to be defined in other areas rather than their original named sites.

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Pliocene–Pleistocene boundary determination in hemipelagic sediment from the Ulleung Basin (East Sea, offshore Korea) inferred from pollen and dinoflagellate cysts

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Palynofloral analysis was performed for the first time on sediment from the Ulleung Basin (East Sea, offshore Korea) to locate the Pliocene–Pleistocene boundary, which is very important in determining the depositional age of a stratigraphic unit that contains methane hydrate. Cores from the drill sites UBGH1-9 and UBGH1-10 in the Ulleung Basin produced abundant to common pollen grains and organic-walled dinoflagellate cysts. Age-diagnostic palynomorphs were present in certain intervals: 120–175 mbsf at site UBGH1-9 and 170–205 mbsf at site UBGH1-10. The biostratigraphically meaningful taxa were the pollen genera *Carya*, *Liquidambar*, and *Fagus* and the dinoflagellate cysts *Capillicysta fusca*, *Filisphaera filifera* subsp. *pilosa*, and *Selenopemphix quanta*. The highest stratigraphic occurrence of these pollen taxa in northeast Asia is the late Pliocene, and that of the dinoflagellate cysts is regarded as the late Pliocene in all aquatic areas, especially in the Pacific. The last appearance datum (LAD) of the age indicators in the two cores studied suggests that the Pliocene–Pleistocene boundary is at 120 mbsf at site UBGH1-9 and 170 mbsf at site UBGH1-10.

Quantification of Calabrian climate of southern Primory'e using CA analysis

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The palaeobotanical records from the Suifunskaya Formation of the Pavlovskoe brown coal field (southern Primory'e, Far East of Russia) comprises fossil woods, conifer needles and impressions of angiosperm leaves, fruits and seeds, spores and pollen and thus allows for integrative studies. Traditionally, this formation was considered to be of Pliocene age from the mid-fifties of the last century (Resolution ..., 1958, 1994), though some researchers (Ganeshin, Smirnov, 1960; Ganeshin, 1961; Chemekov, 1962) defined its age as Pliocene – Early Pleistocene. The differing opinions were based on different notions about the Neogene-Quaternary boundary. According to most recent data (Pavlutkin, 2010), the formation is allocated to the Calabrian. The samples considered here were collected from a ca. 15 m thick fluvial succession with alternating clays and sandy gravel. Fossil woods and conifer needles and impressions of angiosperm leaves in each case come from a single level and can be referred to 35 taxa and 39 taxa, respectively (Bondarenko, 2006; Klimova, Feoktistov, 1997; Pavlutkin, 1998). Fruits and seeds belonging to 121 taxa were found at six levels (Pavlutkin et al., 1988; Resolution ..., 1994), microflora originates from a total of 18 levels and yields evidence for 52 taxa (Pavlutkin et al., 1991; Resolution ..., 1994).

According to first results the section reveals two climate cycles with warmer intervals at ca. 15 m and 19.5 m, respectively. Macroflora consistently points to a boreal climate prevailing in the Primory'e during the Calabrian, with cool to moderately warm summers (D type according to Koeppen), with CMT ranging from ca. -13 to -4 °C, WMT from 18 °C to 25 °C, MAT from 4 °C to 11 °C, and MAP commonly above 700 mm. Significantly warmer climate is obtained for depth level 19.4 m. With CMT ranging from ca. -3 °C to -0.5 °C, WMT from 22 °C to 25 °C, MAT from 9.5 °C to 12.8 °C, and MAP of 742–1206 mm, warm temperate conditions are reconstructed (C type climate after Koeppen). The coldest climate is reconstructed from the wood flora at depth level 15.5 m (CMT -8.7–(-3.8) °C; WMT 18.8–19.4 °C; MAT 6.9–7.8 °C; MAP 453–1310 mm). Microfloras provide a good time resolution in the climate record and display more details of the climate cycles. On the other hand, climatic resolution is considerably lower when compared to the data obtained from the macroflora. When macro- and microflora is present at exactly the same level there is mostly overlapping of the resulting coexistence ranges, but data obtained from the mainly local macroflora tend to be at the cold/dry end of the pollen/spore based reconstruction that might reflect climate conditions of a larger region. For a final interpretation of the data studies are in progress.

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The Holocene cooling or moisture process of the NE Tibetan Plateau—evidence from bryophyte spores of slope deposit, Southeastern margin of the Gonghe Basin

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In order to survive hostile environments like on the Tibetan Plateau, the bryophytes and other rare vegetation elements have developed several strategies to adapt to such rough climate. They had to survive strong fluctuations in temperature, rare precipitation, soil depletion and bare rocks especially on slope sediments. In this presentation, we show a Holocene record of spore and pollen data sampled from continuous alpine slope sediments from the KE section, located on the southeastern margin of the semiarid Gonghe basin, NE Tibetan Plateau at an elevation of 3800 m a.s.l. The bryophyte spores including Aytoniaceae, Pottiaceae, Funariaceae, Dicranaceae and other unknown types dominate most of the samples with rich species. These total bryophyte spores show a gradual increasing trend with strong fluctuations. The trend is similar to the summer insolation of the Northern Hemisphere at 40°N expressing changes in temperature and on the other hand shows an out-of-phase relationship with the moisture evolution which is controlled by the Asian summer monsoon. In details, we recognized ten phases with high percentages of bryophyte spores at 10–9.7, 9.4–8.8, 8.5–8.2, 7.7–7.3, 6.8–6.3, 5.8–5.6, 4.5–3.5, 2.3–2.0, 1.5–1.3 and <0.6 cal ka BP. All phases are correlated well with most of the documented cold events found on the Tibetan Plateau. However, the high vegetations are mainly angiosperm from herbs and shrubs with lower percentages, such as Asteraceae (including *Artemisia*, *Acrophylon*, *Anthemis* etc.), Poaceae, Chenopodiaceae, Liliaceae, Cistaceae, and Tamaricaceae. The gymnosperm and fern are very rare in several samples, only *Pinus*, Ephedraceae, Cupressaceae, and Equisetaceae etc. We therefore argue the bryophyte spores as an important proxy for reconstructing the past temperature rather than the moisture changes of semiarid alpine regions on the NE Tibetan Plateau.

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Keywords: Bryophytes, Pollen, NE Tibetan Plateau, Holocene, Temperature Changes

Early to middle Holocene environmental conditions of Lop Nur, western China, inferred from grain-size analyses

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A 6-m-thick stratigraphic section from Loulan (Xinjiang Uyghur Autonomous Region, China), provides the evidence of Holocene climate change in western China. Optical stimulated luminescence dating results show the section deposited from Early to Middle Holocene. Grain size distribution was analyzed in 5-cm intervals. The data indicate that the study area was humid during the early Holocene. A rapid increase in humidity at 7.5 ka BP coincided with previously documented large-scale changes in both atmospheric circulation and sea level. Abrupt, multi-decade to century-scale environmental changes in the middle Holocene may have been caused by solar-induced floods. Strong correlations exist between this record and other terrestrial and marine archives, indicating that the observed pattern of climate change is globally coherent.

Key words: Lop Nur; environmental change; Holocene; grain-size distribution.

Eolian grain-size signature of the Sikouzi lacustrine sediments (Chinese Loess Plateau): Implications for Neogene evolution of the East-Asian winter monsoon

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In order to explore the Neogene evolution of the East-Asian winter monsoon circulation, grain-size analysis was conducted on the Neogene Sikouzi section, Guyuan, Ningxia, China, a relatively monsoon-sensitive region. The results show that most of the particles are fine with the sand-bearing samples ($Md > 63\mu\text{m}$) being less than 6.4%, and that all the grain-size distribution curves of representative samples have a similar pattern to those of eolian dust sediments on the Chinese Loess Plateau. The REE patterns of 8 samples from the Sikouzi section are all characterized by LREE enrichments, relatively flat HREE and slight negative Eu anomaly, similar to those of loess and the average upper continental crust. These lines of evidence point to a wind-blown origin of the Sikouzi fine sediments. Based on previous studies, the 10-70 μm fraction of the Sikouzi sediments is mainly transported by the East-Asian winter monsoon and increase in content of the 10-70 μm reflects strengthening of the winter monsoon. In contrast, sand grains in samples of $Md > 63\mu\text{m}$ are probably brought into the study area by rivers and streams, linking with precipitation enhancement. According to stratigraphic variations in content of various fractions of the Sikouzi grain-size record, the Neogene evolution of the East-Asian monsoon circulation can be divided into three stages. During the period 20.1-12.0 Ma, the 10-70 μm fraction holds the lowest values whereas sand content usually shows high percentages, denoting a weak winter monsoon and a strong summer monsoon. After 12.0 Ma, the 10-70 μm fraction increased substantially and remained at high values while sand content showed a marked decline, indicating that the winter monsoon strengthened dramatically and the summer monsoon declined significantly. From 4.3 to 0.07 Ma, the winter monsoon strengthened further, evidenced by the gradual increase in content of the 10-70 μm fraction. This inference agrees well with the timing of glaciation development in northern hemisphere. During the Early to Middle Miocene, the high values of both Md and sand content mainly distribute in five intervals, 19.8-18.8 Ma, 18.0-17.5 Ma, 16.7-15.6 Ma, 14.3-13.7 Ma and 13.0-12.0 Ma, corresponding to five periods of intense precipitation. 16.7-15.6 Ma is well correlated with the Miocene climatic optimum determined by the well-known Miocene Shanwang biota from eastern China. As for the other four periods, it is speculated that episodic growth of the East Antarctic Ice Sheet possibly shifted atmospheric fronts such as the Intertropical Convergence Zone (ITCZ) and thus carried water vapor further northward, leading to increase in regional precipitation on the northern mid-latitude continent including North China.

Keywords: Wind-blown origin, East-Asian monsoon, grain-size, Neogene, Sikouzi, China.

A new finding of *Nelumbo protospeciosa* Sap. from the Upper Miocene of Tabriz, NW Iran, and its palaeoecological consequence

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Imprints of leaves of *Nelumbo* are quite rare and every new finding always attract the attention of palaeobotanists also due to their effective big sizes, and especially, because *Nelumbo* documents well defined ecological and climatology conditions for the time of their occurrence.

During a field campaign in May of 2009, in the Upper Miocene deposits of Tabriz Basin (Islamic Republic of Iran) imprints of leaves and root fragments of *Nelumbo* with different leaves and other organs of water plants were found by the authors. By the characteristic features (quantity of primary veins, distance between center of leaf and first and following dichotomous branches, roots and rhizomes, etc) the imprints were identified as *Nelumbo protospeciosa* Sap. This is the first *comprehensive* report on a fossil *Nelumbo* species from the Tabriz Basin of NW Iran.

In other regions of Eurasia *N. protospeciosa* is reported from Oligocene of West Europe (France), Pliocene of Beresinka (Ukraine), Lower Miocene of Ekaterininskoe and Shish (West Siberia, Russia), Eocene of Raichikha (Far East, Russia), from Eocene to Pliocene of Kazakhstan (Erzhilansay, Konur-Kura, Toguzken, Altin-Chokusu, Kintikche), etc. Related species were found in Tajikistan (Miocene of Baljuan), Far East of Russia (Cretaceous of Bureinian Tsagayan), South China (Eocene of Changchang). The finding of *N. protospeciosa* enlarged our knowledge about of distribution of this species and for *Nelumbo* generally. The modern relative of *N. protospeciosa* is *Nelumbo nusifera* Gaertn., which today occurs in the delta of Volga river and Far East (Russia), Iran, Afghanistan, China, India, Vietnam, South Japan, Malaysia, Philippines, Australia, etc.

The co-occurrence of other water and near water plants, as well as *Phragmites* sp., *Typha* sp., Monocotyledones sp. indicates that the plants grew where they are preserved. These specimens indicate the subtropical humid climate in the Tabriz Basin during the Upper Miocene.

Pollen and Spore Assemblages from the Neogene in Western Songliang Basin and their Paleoclimatic Characteristics

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The Neogene deposit in the Songliao Basin was developed in the atrophic stage. Since the Upper Cretaceous Mingshui Formation was deposited, the Songliao Basin had been uplifted and eroded. Until Oligocene, it began to be filled gradually in the Yi'an area, north part of the basin. The depositional areas extended southward and westward in the Neogene, therefore the western slope area of the Songliao basin is the most developed area of the Neogene deposit. Due to the poor preservation, most of the Neogene palynomorphs were identified only in the family level, and the assemblage characteristics were obscure.

Based on the new material of Neogene palynomorphs in recent years, two assemblages, i.e. *Momipites coryloides* - *Caryapollenites simplex* - *Celtispollenites* sp. Ass. and *Betulaceipollenites* sp. - *Artemisiaepollenites minor* - *Carpinipites* sp. Ass., are identified separately from the Da'an Formation and the Taikang Formation.

1 *Momipites coryloides* - *Caryapollenites simplex* - *Celtispollenites* sp. Assemblage.

This assemblage is composed of angiosperm pollen (34.4-82.76%), gymnosperm pollen (15.17-64.8%), algae (0-5.51%) and fern spores (0-3.15%). The angiosperm pollen are diverse, including 28 species of 26 genera. Among them, the pollen of the family Juglandaceae, Ulmaceae and Betulaceae are very rich, such as *Caryapollenites simplex* (3.73-23.26%), *Juglanspollenites verus* (2.34-10.35%) and *Momipites coryloides* (0.58-6.89%) in Juglandaceae family, and *Ulmipollenites undulosus* (1.6-14.53%), *Ulmipollenites* sp. (0-13.73%) and *Celtispollenites* sp. (0.79-7.84%) in Ulmaceae family, and the *Carpinipites* sp. (2.84-7.56%) of the Betulaceae family. In addition, *Euphorbiacites marcodurensis* (0-6.89%), *Zelkovaepollenites potonie* (0-4.8%) and *Faguspollenites* sp. (0-4.07%) are common. The gymnosperm pollen are composed of 9 species of 9 genera, dominated by Pinaceae (8.33-52.1%), *Taxodiaceapollenites hiatus* (0.79-19.32%) and *Tsugaepollenites igniculus* (0-12.62%). *Inaperturopollenites dubius* (0-9.66%) is common. Algae fossils including 5 species are dominated by *Botryococcus braunii* (0-3.15%). Ferns spores are composed of 5 species of 4 genera, including *Polypodiaceasporites haardti*.

The above assemblage in the Dan'an Formation shows diverse terrestrial vegetation including aquatic algae. The angiosperms are mainly composed of temperate and north tropical tree of Juglandaceae (*Caryapollenites*, *Juglanspollenites*) and temperate tree of Ulmaceae (*Ulmipollenites*, *Celtispollenites*), Betulaceae (*Alnipollenites*, *Carpinipites*) and Fagaceae (*Quercoidites*, *Faguspollenites*). Some xerocole shrub represented by Zygophyllaceae (*Nitrariadites*) and some aquatic plants such as *Potamogetonacidites*

indicated a warm and humid climate with seasonal draught. Since there are not any tropical elements such as *Dicolpopollis*, *Florshuetzia*, *Lagerstroemia* and *Verrucatosporites* found in this assemblage, the climate might be warm temperate or north subtropical. The vegetation might be mesophytic deciduous broad-leave forest mixed with some evergreen broad-leave trees and conifers.

2 *Betulaceoipollenites* sp. - *Artemisiaepollenites minor* - *Carpinipites* sp. Assemblage

This assemblage bearing in the Taikang Formation consist of angiosperms pollen (33.33-90.45%), gymnosperms pollen (7.87-65.96%), ferns spores (0.44-9.86%) and algae (0-9.33%). The angiosperms pollen in this assemblage are much diverse than those in the privious one, 55 species of 40 genera in total. Juglandaceae, Ulmaceae and Betulaceae are dominant, Rosaceae and Fagaceae are common. They are represented by *Juglanspollenites verus* (1.75-11.24%), *Caryapollenites simplex* (1.41-10.78%) and *Momipites coryloides* (0.7-5.06%) in Juglandaceae, by *Ulmipollenites* sp. (0-10.13%), *Ulmipollenites undulosus* (0-7.19%) and *Celtispollenites* sp. (0.71-5.39%) in Ulmaceae, and by *Carpinipites* sp. (2.11-12.23%), *Betulaceoipollenites* sp. (0.59-6.18%) and *Alnipollenites verus* (0-4.93%) in Betulaceae. *Artemisiaepollenites minor* of the composite family is common. The gymnosperms pollen contain 10 species of 10 genera which are represented by Pinaceae (7.45-58.16%), *Taxodiaceapollenites hiatus* (0.56-5.69%), *Tsugaepollenites igniculus* (0.63-5.67%) and *Inaperturopollenites dubius* (0-4.8%). Ferns spores composed of 6 species of 5 genera are represented by *Polytpodiaceasporites crassicoides* (0-4.93%), *Polytpodiaceasporites haardtii* (0-3.52%) and a few grains of *Deltoidospora* sp., *Punctatisporites* sp., *Botrychium* sp. and *Lycopodiumsporites* sp. Algae fossils including 5 species are dominated by *Pediastrum* sp. (0-4.89%).

This assemblage in the Taikang Formation is similar to that in the Da'an Formation in general. However the content of Rosaceae widely distributed in the temperate and subtropical forest in north hemisphere increased obviously, and the content of *Caryapollenites* which distributed in the north subtropical area reduced slightly. In addition, the content of *Artemisiaepollenites*, a kind of xerocole herb in composite family increases obviously; and other xerocole plants such as *Nitrariadites*, *Ephedripites* and *Chenopodipollis* are common. This indicates that the climate of the Taikang Formation is slightly cooler and drier than that of the Da'an Formation. This climatic change is consistent with the background of Neogene climatic evolution in eastern China.

Quantitative comparison of a Pliocene vegetation record from Italy with possible East-Asian analogues from the Holocene of Japan

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Some modern types of East-Asian vegetation have been indicated as the best analogues for the Neogene zonal vegetation reconstructed in Europe. This assumption was essentially based on the occurrence in Europe of fossil remains of several plant taxa which are now endemic to East Asia (*Cathaya*, *Eucommia*, *Eurya*, *Rehderodendron*, *Pseudolarix*, etc.). However, up to now it has not been possible to compare the reconstructed European palaeovegetation and the modern East-Asian one on the basis of quantitative data. The introduction of the Plant Community Scenario (PCS) approach (Martinetto & Vassio, 2010) and its application to modern fruit and seed deposits in Italy has thrown new light on the interpretation of the vegetation signal locked into carpological assemblages.

We applied the PCS approach simultaneously to carpological assemblages gathered from a Pliocene (ca. 4 Ma) assemblage from North-Western Italy, and Holocene assemblages from central Japan. All of these assemblages were sieved out from fluvial channel-fill sandy deposits and have been interpreted as representative of an Evergreen Broadleaved Forest type of vegetation.

The quantitative information reported into the Italian Pliocene PCS allows to carry out, for the first time, a comparison with the analogous information provided by the Japanese deposit PCSs, and point out the role of several shared floral elements (*Eurya*, *Ficus*, *Meliosma*, *Zanthoxylum*, etc.), as well as the occurrence of non-shared plant taxa, which allow to characterise the European vs. East-Asian assemblages.

The aim of this limited comparative analysis is to show a new way of quantification of the floristic affinity between the European Neogene palaeovegetation and the modern East-Asian analogues. Of course, no general conclusions can be drawn on the basis of such a few case studies, but our preliminary results would suggest that an extension of the analyses, hopefully combined with the sampling of contemporary fruit and seed assemblages in East-Asian environments, could greatly improve our knowledge on the real similarities between the Neogene European vegetation and the Holocene East-Asian one.

Cenozoic environmental changes in the Qaidam Basin, northern Tibetan Plateau and a marine transgression event during the Middle Miocene

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The Tarim Basin still received marine-type sedimentation by the Late Oligocene and since then it was largely disconnected to open sea but occasionally affected by marine transgression events. We are working on a ~50-Myr-long sedimentary section from the Qaidam Basin, northern Tibetan Plateau to reconstruct paleoenvironmental changes and possibly uplift history in this region, primarily with the tools of organic geochemistry and micropaleontology. Surprisingly, we have found foraminifers, nannofossils and marine-type alkenones, which are exclusively produced by marine algae such as *Emiliana huxleyi* and *Gephyrocapsa oceanica*, in the Miocene sediments with an age of ~ 14 Ma. Our results thus imply that a marine transgression event occurred in the Qaidam Basin at ~14 Ma and there is still the existence of a channel that connected the Tarim Basin and the Qaidam Basin at that time. This also implies that the paleoelevation of the Qaidam Basin was not significantly above the sea level at ~14 Ma.

Field Excursions

Excursion site 1: Yangshan Hill Stele

Located at the southwestern slope of the hill, the Yangshan Stele was ordered to quarry by the Emperor Di Zhu of Ming Dynasty for a tablet in memory of his father, the first emperor of the dynasty, Yuanzhang Zhu. But the project has not finished for some reason and the material was left in the hills. The stele was mined from the Qixia Limestone of Early Permian age and, if finished, would be the biggest tablet of the world at that time.



Excursion site 2: Ape man relics of Huludong Hole

Located at the eastern suburb of Nanjing, Huludong hole is the only known fossil site of ape man in Nanjing district. The fossils were discovered by local farmers in 1993, including a skull skeleton and some teeth. Sorts of vertebrate fossils were also found. The hole is a karst cave where a lot of stalagmites were deposited. According to scientific researches, these ancient Nanjing people live in the middle Pleistocene epoch (Wang et al. 2003; attached).



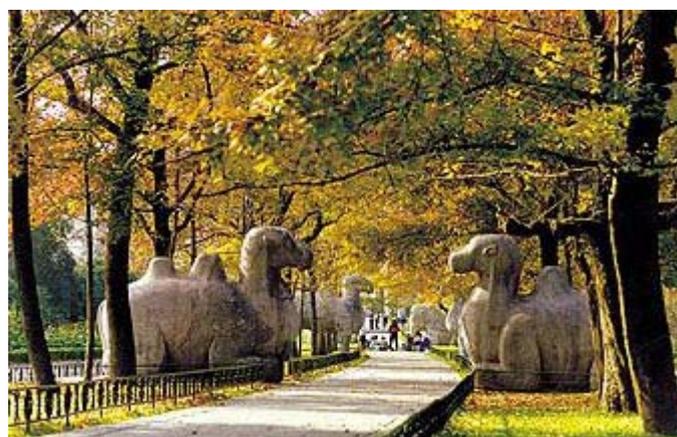
Excursion site 3: Dr. Sun Yat-sen's Mausoleum

Dr. Sun Yat-sen's Mausoleum is situated at the south slope of Zhongshan Mountain (Purple Mountain), covering an area of 133 hectares. Being the first president, Dr. Sun led the famous revolution of 1911 which ended the over-2000-thousand-year-long feudal monarchy and created the Republic of China. After he died, the central government decided to bury him at the capital of Nanjing and built this mausoleum. Besides its special historical significance, the mausoleum is also known by its magnificent architecture and beautiful scenery.



Excursion site 4: Xiaoling Tomb of the Ming Dynasty

Being authorized as the World Cultural Heritage by the UNESCO, the tomb sits at the southern foot of the Purple Mountain, where the first emperor of the Ming Dynasty and his wife, the Empress Ma, were buried. Though suffered from war fires for several times, it is still the biggest royal tomb in Nanjing district as well as the best preserved building of such in China. It is important and rare material for studying ancient architecture, arts, sociality and cultures of China.



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Climate indexes of phytoliths from *Homo erectus*' cave deposits in Nanjing

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Abstract A study on phytoliths and their climate indexes is carried out from *Homo erectus*' cave deposits in Hulu Cave, Nanjing. Evidence shows that phytolith assemblages of the cave deposits are dominated by the cold resistant types with a lower warm index, reflecting an overall cold inclined climate. This possibly connects the cave deposits with glacial climate to a great extent, which is in accordance with the northern fauna revealed by fossil mammals and temperate climate indicated by pollen assemblages. According to the distributional state of the phytoliths and their climate indexes on 4 profiles in the cave, it is revealed that profiles I and II display certain cold/warm, and dry/wet fluctuations; profile III shows a humid and cold condition with the highest humidity in the cave deposits; while profile IV indicates a possible quick accumulating process because of its stable climate indexes except for its bottom and top.

Keywords: climate indexes, phytoliths, Nanjing *Homo erectus*, cave deposits.

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Many related papers have been published since the first report on the discovery of Nanjing hominid crania by Mu et al.^[1], Mu et al.^[1], Xu et al.^[2-4], the Tangshan Archaeological Team^[5] and Dong^[6] have successively studied the Nanjing *Homo erectus*' symbiotic faunas. Mu et al. and Xu et al. considered that the nature of the fauna in the Tangshan area belongs to the Oriental Realm, and this region was usually occupied by *Ailuropoda-Tapirus* fauna in the Pleistocene. However, the typical fossil mammals of this fauna, such as *Ailuropoda*, *Tapirus*, *Megatapirus*, *Elaphodus*, *Capricornis sumatraensis*, etc. have not been found in the Tangshan fauna. Instead, they were replaced by the northern types, such as *Megaloceros pachyosteus* and *Pseudaxis grayi*, which might have migrated from the north, constituting a monotonous northern fauna. The work made by the Tangshan Archaeological Team revealed the similar result^[5], but the comprehensively analyzed result explained by them and Lü et al.^[7] shows that Nanjing *Homo erectus* lived in the warm subtropical or warm inclined temperate environment. In addition, among the 6 species of artiodactyls, 5 are identical with those of

Zhoukoudian. Therefore, Dong^[6] points out that the composition of the Tangshan artiodactyls is closest to that of the Zhoukoudian fauna, and next to that of Hexian fauna^[8]. Pollen analysis shows that the climate feature at that time was temperate, with its temperature lower than the present Nanjing^[9].

In the light of the existing disputes in the study of Nanjing *Homo erectus* and the living environment, this paper aims at offering new evidence on Nanjing *Homo erectus*' living environment as well as climate condition for the related deposits. We try to use the role for climate variations revealed by phytoliths and their climate indexes based on the nature of phytoliths that are favorable in preservation and productive in quantity, to systematically study the phytoliths and their climate indexes on the 4 profiles in the cave, and further compare them with the phytolith result from the simultaneous laterite profile in south China.

1 Profiles in Hulu Cave

Hulu Cave is located in Tangshan, 26 km east of Nanjing. The latitude and longitude of the cave are 32°03' N, 119°02' E. It is about 80 m long, 35 m wide, up to 15 m high. The cave was developed in the Ordovician limestone of Honghuayuan Formation. We measured 4 profiles in the cave and took the samples layer by layer. Profile I is located at the bottom of the cave, belonging to a branch cave in the Hulu Cave, and comprises the lower brown clay layer containing a few fossil mammals, the middle light brown clay layer (fossil-rich layer), the upper brown clay layer, and an overlying calcareous layer with a total thickness of 110—130 cm. Nanjing hominid cranium (Skull I) was excavated from the middle light brown clay layer. Totally 13 samples (Th1-Th13) were collected in ascending order, and each sample covers a thickness about 10 cm. Profile II is outcropped in the corridor from the branch cave to the main cave, 300—600 cm in thickness, and consists chiefly of yellowish brown and brownish yellow sandy and silty clay, a layer of conglomerate cemented by calcium containing some fossil mammals, a grayish yellow patterned silty clay layer, and an overlying calcareous layer and/or stalagmites. Though there are arguments concerning the detailed bed for the second hominid cranium (Skull II), the cranium was heavily cemented at the time of excavation, which is comparable with the conglomerate layer. This is also in accordance with the bed indicated by the farmer who collected it^[10]. We got 53 samples (Th14-Th67) with an interval over 10 cm from the profile. Profile III is located at the east part of the main cave, and is composed of dark or red brown silty clay containing lots of fossil mammals, and an overlying calcareous layer and/or stalagmites. The thickness of the profile is 155 cm, and 7 samples were collected (Th68-Th74) with an interval about 22 cm. Pro-

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file IV is outcropped in the main hall near the exit of the cave, and comprises a brecciated bed consisting of limestone and silty clay, and covered by a calcareous layer and/or stalagmites with over 800 cm in thickness. We took 26 samples (Th75-Th100) in the profile with an interval of about 31 cm.

2 Materials and methods

All together 56 samples were analyzed. Our analytical procedures for phytoliths mainly follow some predecessors' work, which is partly modified at the same time based on the features of soil samples in south China^[11]. Phytoliths with regular forms in 4 slides (22 mm × 22 mm) are identified and counted for each sample. They are mostly originated from Gramineae, and individually from Cyperaceae. The distribution of the phytolith contents in samples is uneven. There are 7 samples with their contents less than 100 grains, while others are generally between 100—350 grains. Phytoliths are classified mainly following Twiss' classification of grass phytoliths^[12,13], including festucoid (poid) phytolith, chloridoid phytolith, panicoid phytolith, elongate phytolith, fan-shaped phytolith and point-shaped phytolith. In addition, we also added the tall saddle phytolith in it, which is common in China.

The climate significance for phytoliths is common understanding for a long time, and has been widely applied in Quaternary research. For example, Lü and Wang^[14,15] used the corresponding analysis method to study the climate reflected by phytoliths in strata based on the phytolith distribution situation in various soil types over China, along with the distribution state of the species ratio with latitudes among the major subfamilies in Gramineae of Japan, while Wu et al.^[16] applied phytolith-climatic factor transfer function to the palaeoenvironment study since the late glacial age. Basically, the principle of phytolith's climatic indication is mainly based on photosynthetic pathways in plants^[12,13,17]. There are three photosynthetic pathways in the land plants, C₃ and C₄ are two common types, and they have a certain corresponding relationship with different environments. C₃ grasses are dominant in moist and cool regions, while C₄ grasses tend to occur in semi-arid to arid, bright and warm regions. However, there are also some exceptions. For instance, Bambusoideae represented by tall saddle phytoliths is a C₃ plant, but mainly distributed in warm regions. In addition, there are also some phytolith types, which show no definite affinity relationship with their parent plants. Therefore, other indirect evidence is needed to ratify their distribution features. Studies on the surface samples have already revealed some distribution roles for certain common phytolith types. For example, the fan-shaped, square and rectangle forms occur mostly in

southeast China, indicating a warm climate; the tall saddle is centered in south China, reflecting the hot and humid condition; the elongate and pointed phytoliths are generally distributed in the north, west and northeast China, indicating a cold climate^[18].

In Twiss' classification of grass phytoliths, the division and classification of festucoid (poid), chloridoid and panicoid phytoliths are mainly following their corresponding climate. Among them, festucoid (poid) phytolith represents C₃ grasses in the moist and cool regions, while chloridoid and panicoid phytoliths mostly indicate C₄ grasses in the warm regions^[12,13]. In order to have an objective and overall reflection of climate features indicated by phytolith assemblages, we divide the phytoliths into two groups, i.e. the cold and warm groups, after comprehensively considering the different photosynthetic pathways in plants, as well as the distribution roles for different phytolith types in the surface samples. The cool group includes festucoid (poid), elongate and point-shaped phytoliths, while the warm one includes, panicoid, fan-shaped and tall saddle phytoliths. We have also included square and rectangle phytoliths in the fan-shaped types, not only because they share the same distributive regions in the surface samples, but also some square and rectangle phytoliths themselves are out of the side view of the fan-shaped types. We can thus calculate the warm index of the phytolith assemblage in strata, i.e. Warm index = Warm group phytoliths / (Warm group phytoliths + Cold group phytoliths).

Additionally, the C₄ grass could be further divided into arid and no arid types based on their demand for soil moisture. The arid grasses produce chloridoid phytoliths, while no arid ones yield panicoid phytoliths. We could thus use their ratio to get the arid index^[12,13] of the phytolith assemblage in strata, i.e. Arid index = Chloridoid phytoliths / (Chloridoid phytoliths + Panicoid phytoliths).

3 Ages of the cave deposits

Chen^[19] first used disequilibrium U-series dating to measure mammals' dental fossils from the fossiliferous bed, and the calcareous layer in the branch cave, and got the age about 300 kaBP which has approached the maximum limitation for the U-series dating; electron spin resonance (ESR) dating of the dental fossils is 350 kaBP on average. Based on the latest thermal ionization mass spectrometry (TIMS) U-series chronological study on the calcareous layers and stalagmites in the Hulu Cave (Table 1), it is now believed that the calcareous layers at the top of Profile I is at least 529 kaBP, and at the top of Profile III is 239 kaBP. The bottoms of stalagmites on top of Profiles II and IV are 463 kaBP and 103 kaBP^[20, 22] respectively. Therefore, ages of the 4 profiles would be older than their top calcareous layers or bottoms of stalagmites.

Table 1 TIMS U-series dates of calcareous layers and stalagmites from profiles in Hulu Cave

Author	Sample position	Age/ka	Measurement place	
Wang et al. (1999)	Bottom of stalagmite on top of profile IV	103 + 17/-15		
	Calcareous layer overlying profile III	239 ± 3.6		
	Bottom of stalagmite on top of profile II	463 + 44/-34		
	Calcareous layer overlying profile I	529 + 32/-27		
Zhou et al. (1999)	Calcareous layer overlying profile I	Sample 1	Dept. of Geology and Geophysics, Univ. of Minnesota, USA	
				530 + 32/-27
				529 + 32/-27
				529 + 53/-39
				539 + 35/-29
				523 + 32/-27
Zhao et al. (2001)	Calcareous layer overlying profile I	Sample 2	Dept. of Earth Sciences, Univ. of Queensland, Australia	
				561+ 54/-42
		Top		571 + 91/-58
		Middle		579 + 67/-44
	Bottom	566 + 82/-51		

4 Results

Phytolith types and climate indexes in the samples are shown in Fig. 1. Samples with phytolith content less than 100 grains are not listed in the figure. We put the phytolith types and climate indexes from the 4 profiles into one diagram mainly out of considering that the above-mentioned TIMS U-series dating result has shown a possible chronological relationship among them on the one hand, and it would also make easy for comparison among the 4 profiles on the other hand. The sample numbers in the figure are correspondent with the sample positions mentioned in the first section. The diagram of phytoliths and climate indexes in the cave deposits shows that all of the 4 profiles are constantly dominated by elongate and point-shaped phytoliths indicating a cold condition. The warm indexes are all lower than 0.5 with the exception of sample TH21 at the lower part of profile II, reflecting an overall cold inclined climate pattern in the cave deposits. The detailed situation varies according to the distribution of the different phytolith types in the profiles.

In profile I, the warm indexes are relatively high at lower and middle parts, while arid indexes are relatively high as a whole, but showing slight fluctuations with a tendency of decrease upward. Additionally, tall saddle phytolith reflecting the warm and humid climatic condition is absent at the lower part of the profile, but continually occurred from the lower middle part (TH6). Despite its very low content, it might be a sign for a slight warming. Meanwhile, this may be also connected with the increasing humidity at the upper part of the profile. In profile II, the warm indexes are all lower except for two samples (TH21 and TH25) at lower part of the profile that are a little higher, in spite of some small fluctuations. Among the samples, the warm index of sample TH21 is the highest, and samples TH35 and TH27 are the lowest in the cave deposits. Arid indexes display obvious fluctua-

tions. They reach 1 in samples TH35 and TH36, which is the highest value of all samples, and are relatively low in samples TH19, TH26, TH31, TH40, TH47, and at the bottom and top of the profile, illustrating the possible dry and wet variations. Two samples in profile III were analyzed, and only one sample contains rich phytoliths. Both elongate phytolith and panicoid phytolith are dominated with outstanding contents. The arid index is only 0.72, reflecting a humid and cold environment with highest humidity in the whole cave deposits. In profile IV, changes in warm indexes are not very distinct, displaying some small fluctuations at the lower part, and a slight warming upward; the arid indexes are also relatively stable, but distinctly decreased at the upper part, reflecting an increase in humidity.

5 Discussion

Although phytolith assemblages from the cave deposits reveal some variation roles, the overall warm indexes are distinctly lower if compared with the phytolith result from the patterned laterite profiles in the lower reaches of the Yangtze River in the corresponding period. We once studied phytoliths from the Middle Pleistocene laterite in Xingzi County of Jiangxi Province, and Xuancheng County of Anhui Province^[11,23], and found that climate cycles revealed by phytolith assemblages in the laterite profiles are more distinct. According to the ESR dating result, the Xuancheng profile are 817—126 ka BP^[24], which is comparable with the deposits in the Hulu Cave. In our recent study on the phytolith climate indexes from the Xuancheng profile, we found that the Middle Pleistocene climates revealed in the laterite profile are not only in accordance with the changes of the oxygen isotope curves from the deep sea, but also their warm indexes which are almost all beyond 0.5. In the cave deposits, the warm indexes are all lower than 0.5 with the exception of sample TH21 in profile II, which reaches 0.62. We can thus confirm that the cave deposits represent an overall

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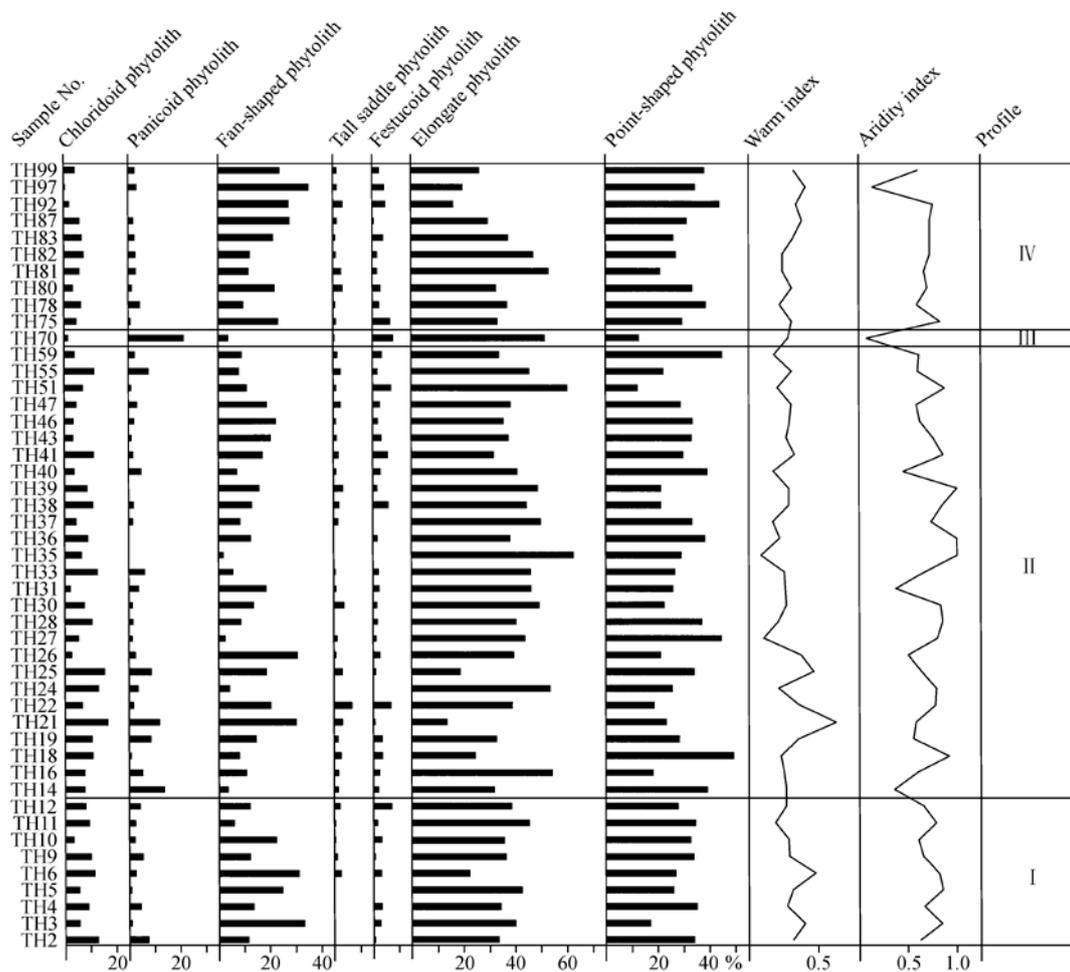


Fig. 1. Phytolith diagram and climate indexes of the 4 profiles in Hulu Cave.

cold inclined climate, which is in accordant with the northern fauna revealed by fossil mammals and temperate climate indicated by pollen assemblages. This makes known that the cave deposits possibly correspond with the glacial climate. The Xuancheng profile is located at 30°54' N, 118°51' E, 1°09' southward than the locality of the Hulu Cave. This might be no doubt a reason for the higher warm indexes on the Xuancheng profile, nevertheless it should not be neglected that the laterite in the south was more possibly formed under the Quaternary interglacial environment^[25].

From the distributional situation of the phytoliths on 4 profiles in the cave, it is revealed that profiles I and II display certain cold/warm, and dry/wet fluctuations; profile III shows a humid and cold condition with the highest humidity in the cave deposits; while profile IV represents a quick accumulating process because of its stable climate indexes except for its bottom and top. Ac-

ording to our current study, climate indexes revealed by phytoliths in the cave are confirmed to be capable of systematically illustrating climate features and a changing process from one aspect. As this is the first study on phytoliths in the cave deposits, further accumulation and refinement of the work will be necessary for more detailed explanation of the data.

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