Explore the Co-evolution of Environment and Life in Geological History: Recent Progress at IVPP Laboratory of Palaeoenvironment

ZHOU Xinying[a,*], WU Yan[a], GE Junyi[a]

a. Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, 100044, Beijing, China

Abstract: The co-evolution of climate-environment and ancient vertebrates fossil human are core topics in the theory of biological evolution. At the micro level, we hope to understand the feeding habits of some important groups of organisms in ancient ecosystems, such as dinosaurs, birds, and mammals, as well as their related feeding behaviors, migration patterns, and ecological niches. This requires a comprehensive analysis of key global climate processes during critical periods, the evolution of terrestrial ecosystems, and their relationship with the origin, evolution, and extinction of ancient fossil fauna. Similarly, changes in global climate and ancient monsoon systems have played important roles in the origin, migration, diffusion and behavioral patterns of ancient human being. The domestication of animals and plants and the origin of agriculture are the most representative examples of the co-evolution of human and ecosystem. The early agricultural society not only adapted to most of the area of the terrestrial ecosystem, but also transformed it into the human ecosystem to a large extent.

Keywords: Global change, Coevolution, Extinction Events, Chronology, Agriculture Origins

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In response to the evolving needs of vertebrate paleontology and paleoanthropology, the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) of the Chinese Academy of Sciences (CAS) made the strategic decision to establish the Paleoenvironment Laboratory in 2013. This initiative aimed to pioneer new interdisciplinary research avenues focusing on the co-evolution of terrestrial ecosystems, the chronology of paleolithic sites, the origins of agriculture, global changes, and human adaptations. Over the past decade, the Paleoenvironment Laboratory has achieved significant progress in constructing instrumental platforms and advancing related disciplines. Here are some notable advancements.

[*] Corresponding author. Email: zhouxinying@ivpp.ac.cn.

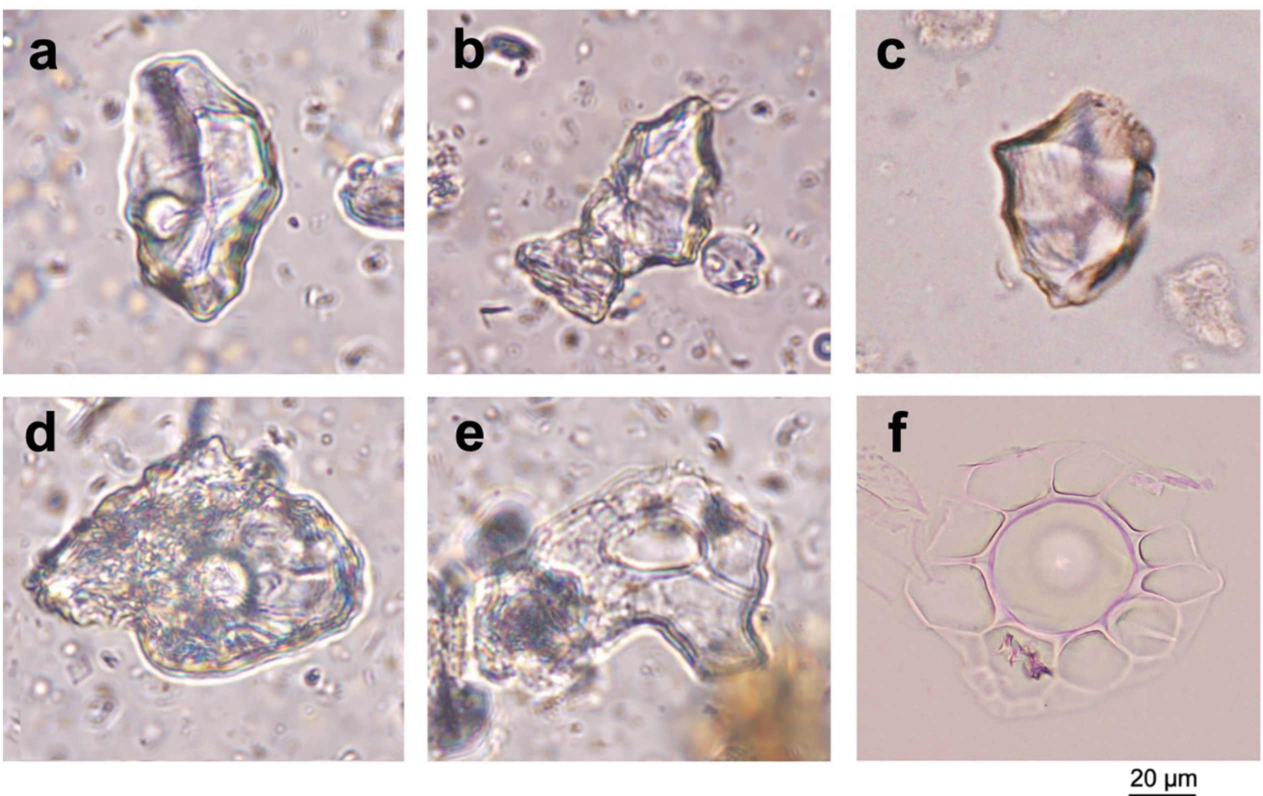
Innovative Methodologies and Paradigms in Paleoenvironmental Research

By continuously exploring new interdisciplinary approaches and research directions, the laboratory has spearheaded innovative methodologies and paradigms in paleoenvironmental research. The integration of epiphyte analysis and geochemical indicators has not only enhanced our understanding of deep-time animal feeding behaviors but has also expanded the boundaries of research in animal feeding evolution and biological and environmental co-evolution.

Through the examination of phytoliths extracted from the tooth attachments of a 100-million-year-old dinosaur (*Equijubus normani*) and the digestive tract of a bird (*Jeholornis prima*), significant insights into the co-evolution of animals and angiosperms have been revealed. This research has shed light on Darwin's hypothesis of the "co-evolution theory of dinosaurs and angiosperms," a longstanding focus of paleontological research. By innovatively integrating phytolith analysis into the study of Mesozoic vertebrate evolution, the team at the Paleoenvironment Laboratory has obtained epiphyte records from ancient animal samples, providing direct evidence for the evolution of dinosaur and early bird feeding habits and their co-evolution with angiosperms.

This groundbreaking research, documented in publications such as those by Wu *et al.* (2023) and Wu *et al.* (2018), represents a significant milestone in the fields of vertebrate paleontology and paleoanthropology. The Paleoenvironment Laboratory at IVPP continues to lead the way in elucidating the complex relationships between ancient ecosystems and the evolution of life forms, paving the path for exciting new discoveries in the field.

Figure 1. Fossil blocky phytoliths with wavy ridgelines from the stomach content of *Jeholornis prima* (IVPP V14978), consistent with the blocky phytoliths in modern magnoliid leaves.



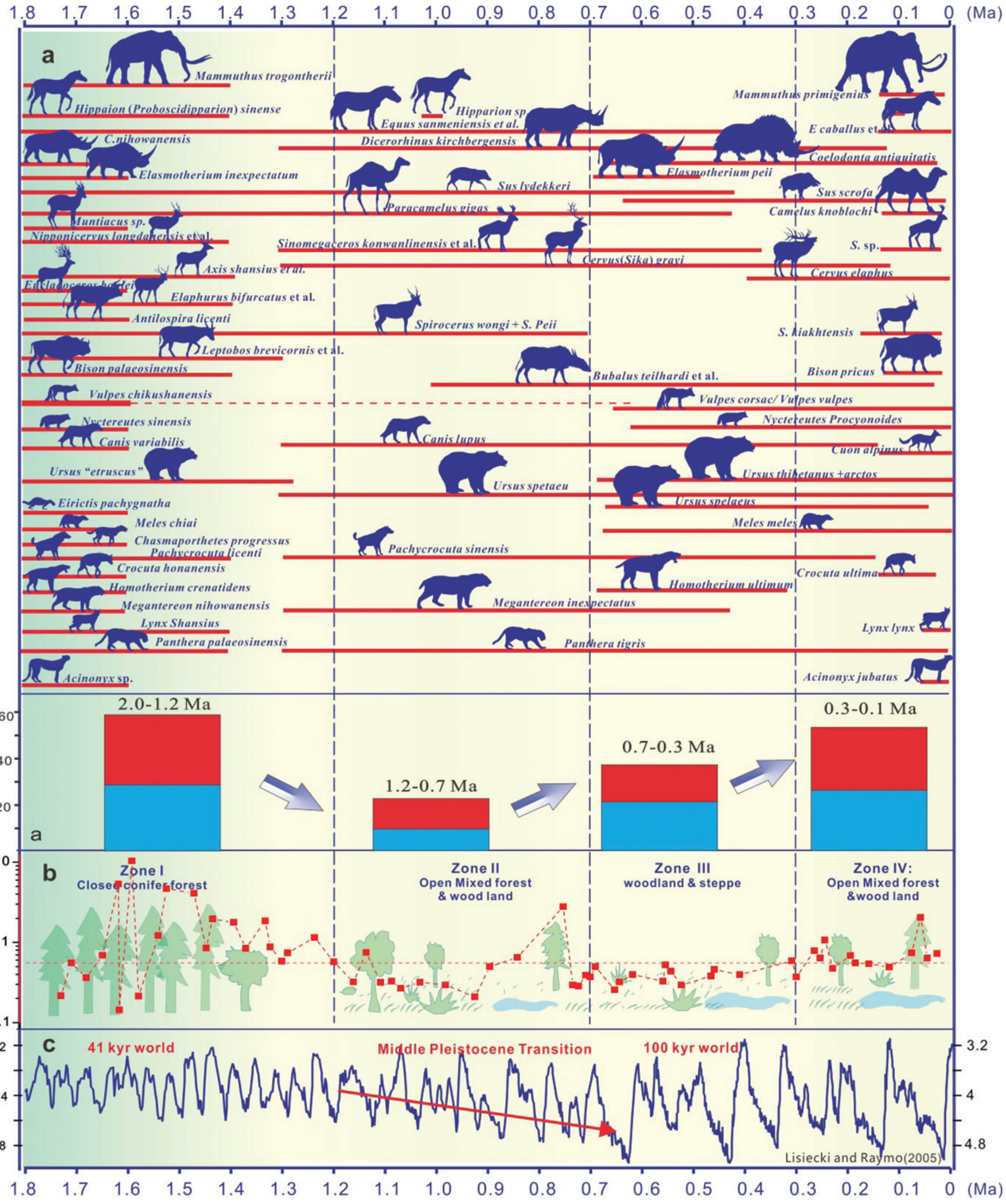


Figure 2. Comparison of co-evolution between mammalian fauna and vegetation ecosystems in the Quaternary of northern China

Evolution of Late Cenozoic Terrestrial Ecosystems and Co-evolution of Mammals

During the late Cenozoic, the global climate underwent major changes including a continued temperature decrease and the initiation of the polar ice caps. This period saw major transformations in the oceans, land, ice caps, carbon cycles, and flora and fauna. Our research focuses on investigating the evolution of late Cenozoic terrestrial ecosystems and the co-evolution of mammals in response to significant global climate changes.

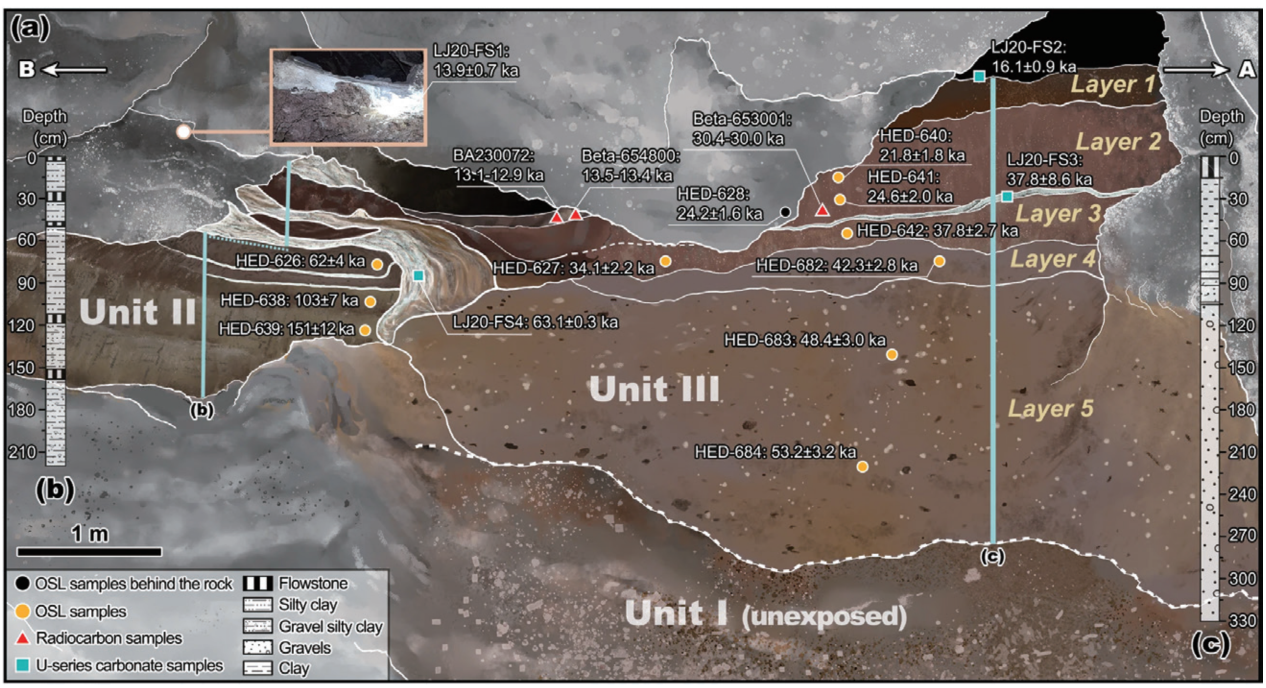
During this pivotal period, characterized by temperature fluctuations and the emergence of polar ice caps, our team delves into the complex interactions that shaped terrestrial environments and affected the evolution of vertebrates, including hominins. Through comprehensive analyses of climate data, including paleontological records, isotopic geochemistry, and sedimentary profiles in regions such as the Altay area of Xinjiang Autonomous Region, Tongxin area of Ningxia Autonomous Region, and boreholes around the Bohai Sea of China, we aim to elucidate the responses of vegetation ecosystems to crucial climatic events like the Miocene Climatic Optimum (MCO) and the Middle Pleistocene climate transition (MPT).

The new studies reveal the transition of terrestrial ecosystems from stable states to high variability during warm/cold periods, underscoring the importance of low-latitude drivers and feedback loops in shaping land-sea climate changes and influencing the co-evolution of global terrestrial ecosystems. By providing essential insights into the evolution of vegetation and climate in East Asia throughout the Cenozoic era, our research establishes crucial temporal and climatic frameworks for understanding the evolutionary trajectories of East Asian fauna. These findings contribute to enhancing our understanding of the interconnected changes in terrestrial ecosystems and marine climates over time (Wang *et al.*, 2023; Wang *et al.*, 2024; Zhou *et al.*, 2018).

New Late Pleistocene Age for the *Homo sapiens* Skeleton from Liujiang, Southern China

As one of the most complete ancient human fossils found in China so far, the age of early modern man "Liujiang Man" has attracted much attention since its discovery in 1958. However, its age has

Figure 3. Stratigraphic and chronological data of Tongtian Rock unearthed by Liujiang People.



always been controversial. The Paleoenvironment Laboratory research team conducted detailed analyses of grain size, macroelement and trace element composition of the sediments preserved in the left femoral bone marrow cavity of Liujiang Man, as well as the sediments from each layer of the cave deposition sequence, to determine the corresponding strata from which Liujiang Man was unearthed.

The results indicate that the age of the second layer of the third sedimentary unit, where Liujiang Man fossils are most likely found, is approximately 20,000 to 30,000 years ago. Based on thorough sampling of the left femur of Liujiang Man and the direct dating of the uranium series, the fossil's age is estimated to be between 23,000 and 21,000 years. This comprehensive work repositions the excavated stratum of Liujiang Man within the global modern human evolutionary sequence, providing key new data for exploring the migration and dispersal patterns of modern humans across Eurasia (Ge *et al.*, 2024).

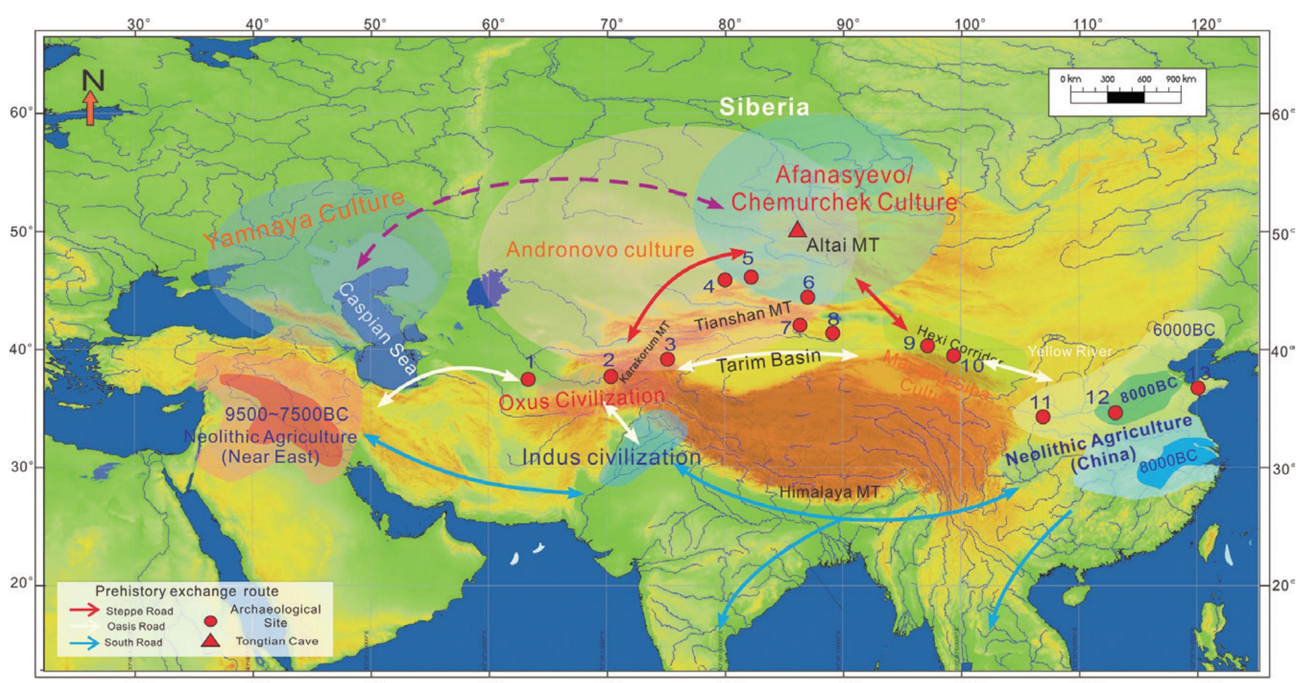
New Evidence of the Pre-Silk Road Civilization Exchange—5200-year-old Common Wheat and Naked Barley Grains from the Altai Mountains

The pre-Silk Road trans-Eurasian civilization exchange is one of the most magnificent events in the history of human social development, which started about three thousand years before the formal opening of the Silk Road. During this time, the exchange of items, ideas, technology, and human genes occurred through the mountains and valleys of Eurasia.

There were three main land routes in the early days of Eurasian exchange: the southern Himalayan route, the oasis in Central Asia to the Tarim basin, and the grassland of North Asia. This study illustrates that crops were being transported across Eurasia to the Altai Mountains around 5200 cal yr BP, which is 1,000 years earlier than previously thought. This finding provides the earliest evidence for the eastward spread of wheat agriculture and highlights the steppe route as a crucial corridor for east-west civilization communication.

As early agricultural populations in western Asia and Iran expanded, common wheat and naked barley reached the foothills of the western Tian Shan Mountains in central Asia around 5,500 cal yr BP. From there, these crops moved through the river valleys

Figure 4. Proposed pathways of cultural exchange at around 5000–4000 cal yr BP, distribution of prehistoric culture groups across mainland Eurasia.



and reached the Altai Mountains by around 5,200 cal yr BP. Subsequently, low-investment prehistoric agropastoralists in the Altai Mountains may have introduced agricultural systems into the Hexi Corridor and the rich river valleys of southern Mongolia. This facilitated the further dispersion of these crops into the areas known as Qinghai Province and Xizang Autonomous Region of China today, and the middle and lower basin of the Yellow River (Zhou *et al.*, 2020).

References

Ge, J., Xing, S., Grün, R. *et al*. (2024). New Late Pleistocene age for the Homo sapiens skeleton from Liujiang southern China. *Nature communications*, 15: 3611.

Wang J., Zhou X., Wang S. *et al*. (2023). C4 expansion of Central Asia in the middle Miocene linked to the strengthening Indian monsoon, *Global and Planetary Change*, 224: 104096.

Wang, J., Zhou, X., Wang, S. *et al*. (2024). Two-stage climate and vegetation change at the East Asian monsoonal margin across the Miocene Climatic Optimum. *Paleoceanography and Paleoclimatology*, 39: e2024PA004894.

Wu Y., Ge Y., Hu H., *et al*. (2023). Intra-gastric phytoliths provide evidence for folivory in basal avialans of the Early Cretaceous Jehol Biota. *Nature communications*, 14: 4558.

Wu Y., You H., Li X. (2018). Dinosaur-associated Poaceae epidermis and phytoliths from the Early Cretaceous of China, *National Science Review*, 5: 721–727.

Zhou X., Yang J., Wang S., *et al*. (2018). Vegetation change and evolutionary response of large mammal fauna during the Mid-Pleistocene Transition in temperate northern East Asia, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 505: 287–294.

Zhou X., Yang J., Xiao G., *et al*. (2023). Megacycles of climate and vegetation in East Asia since 3 Ma, *Catena*, 229:107195.

Zhou, X., Yu, J., Spengler, R.N. *et al*. (2020). 5,200-year-old cereal grains from the eastern Altai Mountains redate the trans-Eurasian crop exchange. *Nature Plants*, 6: 78–87.