

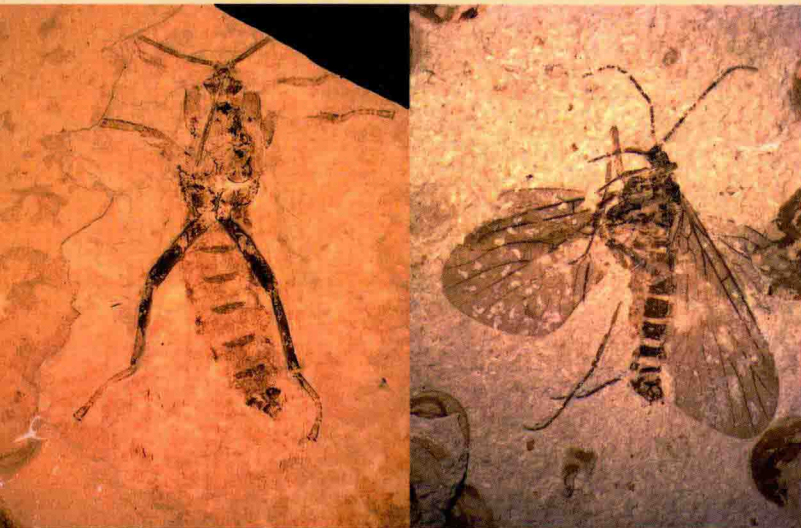
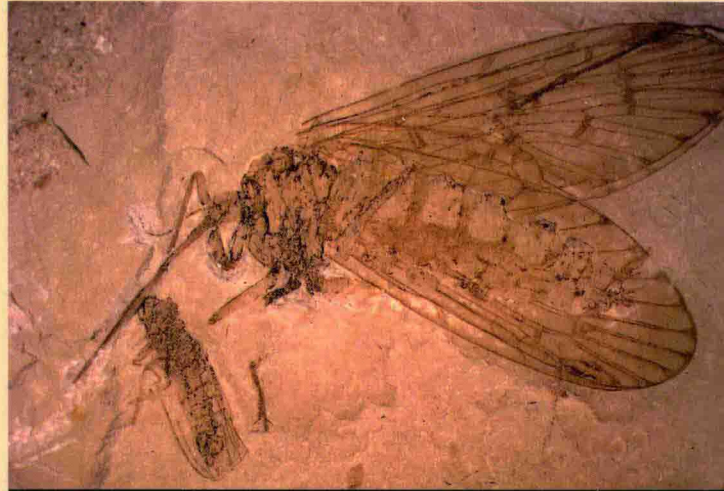
SILENT STORIES

— Insect Fossil Treasures
from Dinosaur Era
of the Northeastern China

**Ren Dong, Shih Chungkun,
Gao Taiping, Yao Yunzhi
and Zhao Yunyun**

English Editor: Shih Chungkun

 Science Press
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Preface



Since the mid 1990's, there have been numerous scientifically important fossil findings from Hebei, Liaoning and Inner Mongolia in China. The studies of these fossils of feathered dinosaurs, pterosaurs, birds, mammals, reptiles, amphibians, insects, and plants have significantly increased our understanding of palaeontology, taxonomy, evolution, ecology and other natural sciences, re-written most text books on these subjects and raised the awareness and interest of the general public globally.

Insects thrived, propagated and served important functions in their ecosystems from the Middle Jurassic to the Early Cretaceous. After sudden death, most likely due to poisonous gas and volcanic ashes, they were fossilized and preserved. Insect fossils, with excellent preservation of amazing details and broad diversity, have been discovered in large numbers from northeastern China. These insect fossils have silent stories to tell us.

Living in the late Mesozoic and preserved in sedimentary rocks, these fossil insects have been studied at the Capital Normal University (CNU) in Beijing, under the leadership of Prof. Ren Dong and Prof. Shih Chungkun. Based on selected specimens from a vast collection of insect and plant fossils, we have reported our findings in the past 10 years—a period of our “foundation building”. At present, we have a 30-member team of professors and graduate students. We have made some progress, but we also realize that more needs to be done and many areas to be upgraded.

Engaging experts from universities and institutions around the world in joint research projects has greatly improved the efficiency and effectiveness of uncovering silent stories from these insect fossils. We have exchanged visits, shared fossil specimens, and conducted joint research work. Synergy, cooperation and mutual learning greatly enhance the outcome. On average, our CNU Team with collaborators publish 30 to 40 SCI papers annually. Based on our reported results and other relevant information in the literature, we put representative insect fossil treasures as the center piece of this book.

Noting that taxonomy is just part of the silent stories, we write this book with three focuses: **natural science** (highlighting entomology, insect morphology, taxonomy, geology, eco-system, pollination, mimicry, etc.), **popular science** of general interest (providing insect-related stories and cultures from China and other countries) and **artistic appreciation** (presenting beauty and elegance of fossil and extant insects as visual art). We have tried our best to achieve a proper balance of these three focal areas.

This book is intended for a broad spectrum of potential readers, such as palaeontologists, entomologists, botanists, biologists, evolutionists, palaeoecologists, fossil collectors, naturalists, insect hobbyists, and students. We hope that readers will have fun reading this book while gaining some knowledge and enjoying the artistic presentations. Although every effort has been made to ensure the accuracy of the information, we will not be surprised that readers will spot mistakes due to our carelessness or ignorance. As such, comments,



suggestions and corrections from readers are highly appreciated.

Standing on the shoulders of academic giants and with support from many scientific and industrial leaders, we value this opportunity to publish this book. We honor pioneering contributions from the following renowned palaeoentomologists: Amadeus W. Grabau, Ping Chi, Hong Youchong, Lin Qibin, Gu Zhiwei and Chang Meemann. We appreciate the support and encouragement from Dr. Liu Xincheng, President of CNU and Dr. He Yikun, former Dean of College of Life Science, respectively. One of us, Dr. Shih, is grateful for the support of Stan Tebbe, Tony Gaskell and Dominique Fournier, former and present Presidents and/or Chief Executive Officers of Paramins or Infineum.

Thanks are due to Dr. Teh Chung Ho for his effort improving the English writing of this book. We also appreciate Jason Shih for providing professional and artistic photos of extant insects and Dr. Ji Shu'an and Dr. Xu Xing for providing fossil animal photos in Chapter 3. This work was supported by the National Natural Science Foundation of China (Nos. 30430100, 40872022), the Nature Science Foundation of Beijing (No. 5082002) and the Scientific Research Key Program (KZ200910028005) and the PHR Project of Beijing Municipal Commission of Education.

Overseas and Chinese collaborators who provided expertise, guidance and dedication are deeply appreciated. In alphabetical order, they are D. S. Aristov, A. V. Bashkuev, Cai Wanzhi, D. L. Dilcher, M. S. Engel, C. L. Hotton, Huang Diyin, A. G. Kirejtshuk, W. Krzemiński, C. C. Labandeira, M. A. Logan, Lu Liwu, Lu Wenhua, V. N. Makarkin, A. Nel, O. Béthoux, J. D. Oswald, Pang Hong, J. F. Petrulevičius, A. Prokin, A. P. Rasnitsyn, J. A. Santiago-Blay, N. D. Sinitshenkova, A. Y. Solodovnikov, S. Y. Storozhenko, P. Vršanský, and Yang Ding.

Representing CNU graduates whose published results are part of the book and current graduate students who participated in the book project but were not chapter coauthors are: Zhang Xiao, Jia Ting, Pan Xiaoxiong, Song Jingjing, Liu Ming, Liu Chenxi, Hao Jianying, Liu Pingjuan, Yang Xiaoguang, Shang Liangjie, Li Yanli, Wang Tiantian, Sun Jianhai, Meng Xiangming, Li Lianmei and Fang Shiwei. We thank them sincerely and deeply.

It has been a humbling experience for all co-authors during the book preparation due to its broad scope, complexity of subject matters, and ever-changing knowledge base from newly discovered fossils and published papers. Thus, we present this book as a “term” report that summarizes results published before March 2010. With regret, many fossil treasures currently under study can not be showcased in this book.

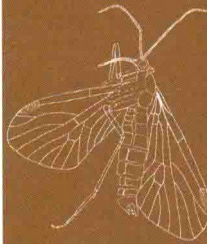
Entering the next phase of “growth and development” for the next five years, the CNU Team will strive to conduct broader-scoped and higher-quality research programs internally and jointly with our current and future collaborators around the world. With CNU’s excellent and vast fossil collection, we welcome and need additional collaborators and expertise to carry out more studies. We expect to apply new and advanced instrument, technology and methodology to gain a far better understanding of these fossils. We hope to update this book in the future to share with readers new fossil treasures and their silent stories.

Science education, knowledge transfer, and research are some key missions of the CNU. This book provides college and graduate students with some general knowledge of natural science. In addition, we hope that teachers of middle and high schools will find this book useful as a reference in natural science in general, and insect fossil, evolution, and eco-systems in particular. We hope some of these young students will be inspired to become future scientists, entomologists or palaeontologists to carry the torch into the future—a bright future for natural sciences.

Shih Chungkun and Ren Dong



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Chapter 1

Introduction



Shih Chungkun and Ren Dong

Silent stories must be told.

Fascinating stories were recorded by fossils of living beings that flourished in the dinosaur era from the Middle Jurassic to the Early Cretaceous about 165 to 130 million years ago (Ma). Leaping across time and space, these fossilized creatures found in the northeastern China have silent stories to tell us.

They lived in a warm, humid, semi-tropical region about 165 to 130 Ma. Lush green plants covering a wide area formed ancient forest. Most of the tall trees were conifers, ginkgos, lycopods and tree ferns. Under the canopy of these plants, mosses (bryophytes), equisetals, ferns (filicales) and seedlings competed with each other for space and for penetrating sunlight. Fallen branches and decaying leaves covered the ground. Nearby, plants grew in marsh area surrounding a large lake. It was a bright sunny morning, hot and humid. Sunbeams cast through dense leaves in the canopy. Beams of light danced as morning fog rising up from the moist ground cover. A breeze brushed leaves and branches in the forest and caressed the plants around the lake. Clouds drifted by, casting shadows below. It was an ideal environment to support active ecological systems (eco-systems)—living systems tested by trial and tribulation over eons.

This was a busy, active and noisy place. A stunning

variety of living beings thrived in these eco-systems. Dinosaurs prowled on the ground or on trees looking for preys. Pterosaurs flew high up looking for preys below. Lizards darted among fallen leaves, branches and debris on the ground, or perched on low plant branches looking for insects while avoiding becoming dinosaur's meal. Primitive mammals, most small sized like mice with some exceptional medium-sized ones, hid and scurried in the undergrowth foraging for food. Birds hopped and flew from branch to branch feeding on seeds, insects, or other small creatures. Some birds even ventured to the lake to catch fish, shrimp or crawfish. A variety of insects buzzed and chirped. Insects, with diverse species and high population, played important roles in these eco-systems such as preys, predators, pollinators, parasites, cleaners, etc. In the lake, small fish swam in large school and large sturgeons moved about majestically. The water was teeming with primitive plants, freshwater conchostracans, shrimps, crawfishes, water lizards, water beetles, water boatmen, backswimmers and various insect naiads and larvae. Mostly by innate imprint and genetic programming while some by learning, these creatures were busy doing what they were used to do: flying, crawling, jumping, swimming, fighting, mating, breeding, feeding, or for some unfortunate individuals, facing sudden death. Occasional shriek and scream signaled alarms, distress calls, or life and death struggles.



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A low dark cloud drifted from west, from what is today's Inner Mongolia, and getting closer and closer. It did not look like the usual clouds. Unaware of the imminent dangers, these creatures continued doing their own routines and minding their own business. This killer cloud, from a volcanic eruption, consisted of very fine ash particles and poisonous gases. The ash cloud had cooled down after traveling such a long distance. Gushing wind, poisonous gas, and ash storm started to blast and drop flying birds, pterosaurs and insects from the sky. A few fell into the lake. Some land creatures as well as leaves, primitive flowers, seeds, branches and other debris were also blown into the lake. Ash particles coated everything and covered everywhere. In the lake, fish, crawfish, conchostracans, lizards, larvae, naiads and water insects were suffocated due to a lack of oxygen. Loud screams and distress calls, attenuated by hollering wind, quickly faded away. This place was filled with silence, only occasional sound from the ash-covered leaves ruffling in the wind.

Some of these unfortunate creatures were covered with very fine ash particles at the bottom of the lake. Devoid of oxygen and out of reach from predators or scavengers, these specimens were entombed in a near sterile condition with little or no bacteria decomposition. After the volcanic ash storm, sediments continued to settle down to the lake bottom. New layers of sediments were formed and the creatures were compressed in between layers.

Sealed in an eternal time capsule, silent, dark and still, these specimens went through successive transformations. Organic matters were replaced by inorganic mineral molecules. Fossilization of these specimens was a long and slow process, which took million years to complete. Until one day in 1994, it was dark no more. A village peasant in Sihetun of Liaoning Province excavated a hillside and dug out a piece of sediment rock. He split the rock, out came a fossilized feathered dinosaur. Many more fossil specimens were discovered since then. Exposed to light and air for the first time after millions of years, these silent fossil specimens surely have fascinating and ancient stories to tell.

1.1 Why “Silent Stories”?

Fast forward 165–130 million years, we are in today's world. In the winter of 1994, a farmer Li Yinfang in Sihetun, Shangyuan, near the Beipiao City split open a slab of rock and found a dinosaur fossil. In 1996, this

fossil was reported as *Sinosauropteryx prima* Ji et Ji, 1996 (meaning the first Chinese dragon feather) (Ji and Ji, 1996). This was the very first dinosaur fossil with protofeathers. In fact, this first feathered dinosaur in the world shocked palaeontologists and rewrote all text books on dinosaurs. Other feathered dinosaurs, e.g. *Microraptor gui* (Xu *et al.*, 2003), *Dilong paradoxus* (Xu *et al.*, 2004), ancient birds, e.g. *Confuciusornis sanctus* (Hou *et al.*, 1995), the first proto-placental mammal, *Eomaia scansoria* (Ji and Yuan, 2002), and the earliest angiosperm plants, e.g. *Archaeofructus liaoningensis* (Sun *et al.*, 1998) and *Archaeofructus sinensis* (Sun *et al.*, 2002) found subsequently in this area have surprised and excited the scientific and palaeontology community around the world ever since. These fossil findings and their scientific implications have been discussed in scientific papers and covered by various news media around the world. Chapter 3 is a brief introduction to these and other fossils of animals and plants.

Many fascinating stories on various northeastern Chinese fossils have been told. But there remain many untold stories about other fossil treasures. For those who are interested in nature, evolution, palaeontology, or just general human-interest knowledge, this book “*Silent Stories*” will provide intrigue insights into an interesting, enchanting ancient world 165 to 130 Ma with a focus on treasures of insect fossils. What types of insects coexisting with feathered dinosaurs, pterosaurs, ancient birds and primitive mammals? How did insects interact with these creatures in these eco-systems? What were the plants in the flora? How did insects interact with plants at that time? To what extent had the insects evolved? What insects survived or became extinct? What was the pollination mutualism between insects and plants in their co-evolution? Insect fossil treasures and their silent stories may be able to answer most of these questions or to lend support to some existing hypotheses.

The purpose of this book is to give a fairly comprehensive survey of the fossil insects existing in the eco-systems during the dinosaur era. This book, focusing on natural science, popular science with general interests, and artistic appreciation is intended for a broad spectrum of readers, for example, palaeontologists, entomologists, botanists, biologists, evolutionists, palaeoecologists, fossil collectors, naturalists, insect hobbyists, students, etc. Specifically, it focuses on 18 orders of insects found in the northeastern China (Chapters 5 to 22), which have received relatively little publicity and attention



Fig. 1.1 Sihetun fossil site with two trenches in August 1999 (Photo by Dr. Shih Chungkun)

in the mass media or popular science publications in comparison to their coexisting feathered dinosaurs, mammals and birds. However, by playing key roles in the eco-systems, these highly diverse insects provide a vast amount of information on climate, habitat, interactions, and evolution—constituting the bulk of the “*Silent Stories*”. Photos of insect fossils and relevant information will be presented to help telling the stories. Although every effort has been made to ensure the accuracy of the information in the book, mistakes and ignorance could have caused errors in its presentation. Therefore, comments, suggestion and corrections from readers are most welcome and highly appreciated.



Fig. 1.2 Huangbanjigou fossil site in August 1999 (Photo by Dr. Shih Chungkun)

1.2 Representative Fossil Sites in the Northeastern China

Fossils are found in a wide area in the northeastern China, especially the western Liaoning, eastern Inner Mongolia and northern Hebei. A major city nearby is the Jinzhou City with a population of about 800 thousand. It takes about 0.5–3 hours driving from Jinzhou to these rather remote fossil sites. There are many important fossil sites in this area. The most notable and most tightly controlled site is Sihetun (Fig. 1.1), Shangyuan near the Beipiao City, a site known for its fossils of birds, feathered dinosaurs, pterosaurs, toads, turtles, lizards, fish, plants, mammals and insects. An on-site museum, built in 2005, has a large collection of fossils while showing sediment layers and excavation. The other important site, not far from Sihetun, is Huangbanjigou

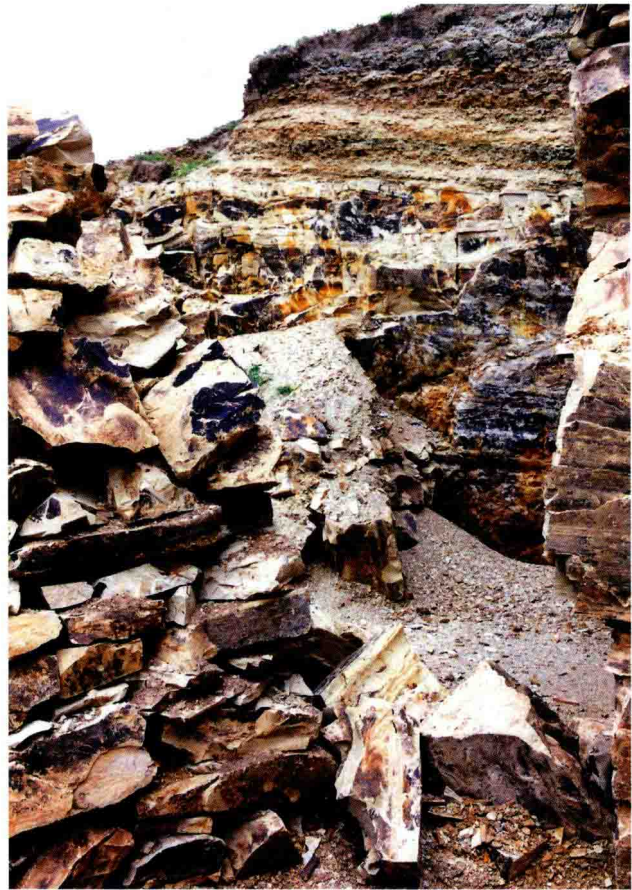


Fig. 1.3 Fossil excavation at Huangbanjigou in August 1999 (Photo by Dr. Shih Chungkun)

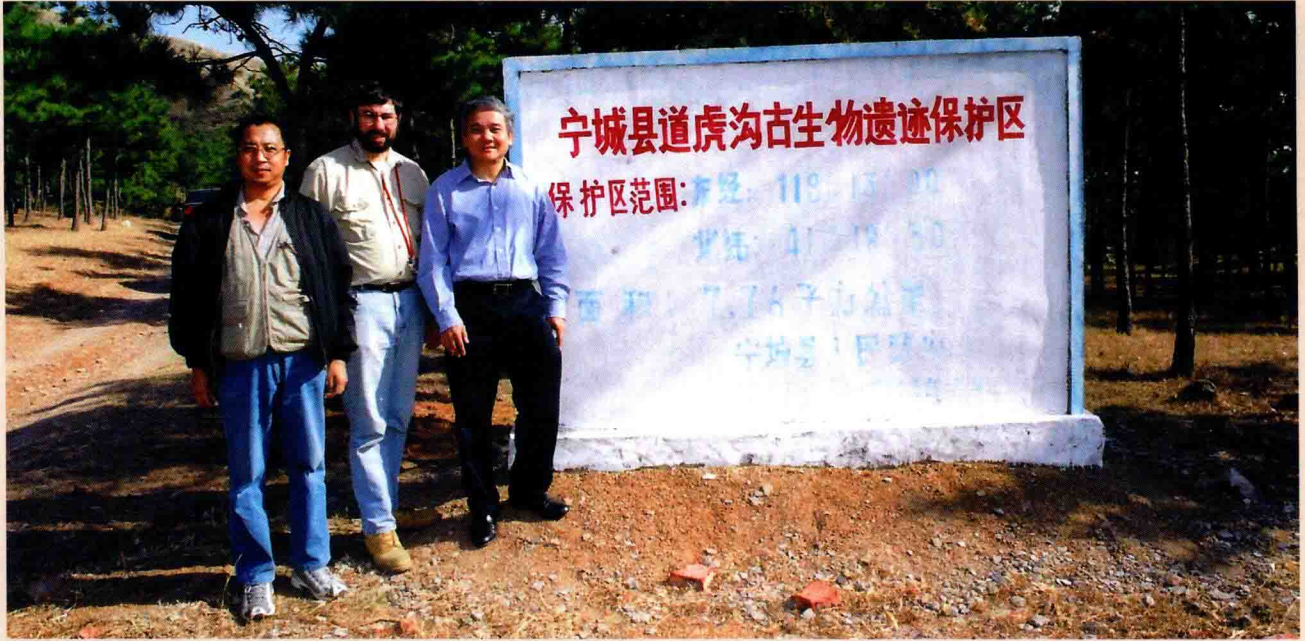


Fig. 1.4 Field trip to Daohugou by Drs. Ren, Labandeira and Shih (from left to right) in October 2005 (Photo by Cai Hongtao)



Fig. 1.5 Daohugou fossil site in October 2005 (Photo by Dr. Shih Chungkun)



Fig. 1.6 Lingyuan fossil site in October 2005 (Photo by Dr. Shih Chungkun)



(Fig. 1.2 and Fig. 1.3) and Jianshangou, Shangyuan near Beipiao for fossils of fish, sturgeons, birds, mammals, insects, angiosperm plants and other plants with very fine clarity and high resolution. Other important sites are: Daohugou of Ningcheng in Inner Mongolia (Fig. 1.4 and Fig. 1.5) for its fossils of conchostracans, plants, insects, salamanders, birds, mammals, dinosaurs and pterosaurs; Lingyuan (Fig. 1.6 and Fig. 1.7) for its fossils of feathered dinosaurs, fish, crawfish, sturgeons, crocodiles, aquatic lizards, insects, birds, angiosperm plants and other plants; Dawangzhangzi of Lingyuan for fossils of plants, birds, and insects; Chaoyang City for its dinosaurs, feathered dinosaurs, birds, plants and insects; Yixian for its fossils of dinosaurs, pterosaurs, lizards, birds, fish, turtles, insects, aquatic lizards, toads, fossilized woods, angiosperm plants and other plants.

At Sihetun site, walls of un-excavated siltstones or mudstones stood tall (Fig. 1.8), while excavated and spent rock matrices without any fossils were tossed to the

side in huge mounds. Walking around the fossil site was like walking around a library, with books lining on all walls. Of course, there were no catalogs, nor maps. But we know that these siltstones may well contain sheets of fossil records with important information. Prying open a siltstone is like opening a rare book—a surprise might pop up anytime and anywhere.

The characteristics and properties of siltstone matrices are different for each site. Generally speaking, Sihetun's matrix is whitish, powdery, very fragile and containing many thin layers. Mudstones from Huangbanjigou and Jianshangou are light yellowish to grayish, clay-like with very fine resolution for the specimens. Lingyuan's matrices are light grayish, containing thin layers, with slightly lower resolution. Ningcheng Daohugou's matrices, light grayish color, contain many tiny fresh water conchostracans. Dawangzhangzi's fossils are dark gray to black color on grayish plates, while Yixian's are grayish, clay-like and very fragile.

Fig. 1.7 Drs. Ren (right) and Labandeira inspecting fossils at Lingyuan in October 2005 (Photo by Dr. Shih Chungkun)





Fig. 1.8 Layers of stratified siltstone at Sihetun standing tall in June 2001 (Photo by Dr. Shih Chungkun)

Sihetun

Sihetun is a small village in Shangyuan, near Beipiao. From Beipiao to Sihetun, it was a 40-minute ride on rough county roads, followed by unpaved roads in August 1999. A majestic poplar tree marked the entrance into this village. The narrow and unpaved road on a dry creek bed was fairly hard to negotiate at times. Villagers' houses were on both sides of the dry creek bed, some behind trees. Quite a few village peasants and kids sit or crouched in the shades in front of their houses, chatting or playing to pass time. Chickens, ducks, geese, and dogs wondered around. Occasionally, a herd of donkeys, sheep, goats, or cattle came by blocking the pass way (Fig. 1.9). Passing the village, the narrow road got more treacherous while moving uphill. Serious road erosion with potholes and steep drops created potential driving hazards. A four-wheel drive vehicle would be much preferred. Below the hilltop, we reached a flat area, surrounded by mounds of white grayish debris from previous fossil excavation.



Fig. 1.9 A herd of sheep sharing pathway to Sihetun (Photo by Dr. Shih Chungkun)



A few deep trenches on the hillside were the actual excavation sites at that time. The stratified siltstone layers marked the wall with layers of different colors and different shades. In June 2001, we visited the Control Office located at the hilltop. From the roof of the Control Office, we had a panorama view of the surrounding hills, the village underneath, the dried creek bed, and patches of farmland (Fig. 1.10). Through some haze, we could see, on a nearby hill, a new fossil site being excavated. They claimed that new species of birds have been found at this new site.

About 2 kilometers to the west of Sihetun, there was a hill, called Xishan (West Hill). The hill was fairly barren with a few trees and not much ground covering bushes or other plants. The rocks on the hill were soft and shale like. In 1970's, geologist came here to survey the hill and told villagers that these rocks were the results of volcanic activity and sediments over million years. Rain eroded the hillside and created a gully. The village kids always came

to Xishan with herds of cattle, sheep and goats to graze the area. They dug these sediment siltstones for fun and found fish, plants and insect impression on the rocks. Out of curiosity, some took them home. In early 1990's, fossil dealers stopped by the village and purchased these fish, insect, plant fossils from kids. In July 1995, a kid found a skeleton fossil on a siltstone plate which looks like a bird. He took the plate home and went to Jianshangou to meet with a dealer. After negotiation, the kid got a payment more than a typical annual household income. Imagine the impact of this news to the village people. Suddenly, they realized that there is a "gold" mine right in their backyard. The village peasants all rushed to the hill and started digging. Fossil dealers came to the village and paid cash for their findings. All of a sudden, "gold" rush was on and the chaotic digging caused serious damage to the site. In 1996, the Liaoning Province government approved the set-up of a natural protection area for the Beipiao Bird Fossil Area and designated Sihetun as the

Fig. 1.10 A panorama view of the area surrounding Sihetun (Photo by Dr. Shih Chungkun)





core area for special protection. In 1997, the Liaoning Geology and Mineral Bureau set up a Natural Protection Control Office for Beipiao Bird Fossil, and designated several sites with a total area of 46.3 square kilometers surrounding Sihetun as a protected and controlled zone for effective management. In 1998, the State Council of the People's Republic of China approved to designate this as a national natural protection area (Zhang, 2002).

Huangbanjigou

Huangbanjigou is a village not far away from Sihetun. It took a car ride of about 20 minutes to get there from Sihetun. Again, the unpaved road to the village followed a dry creek bed packed with small boulders and rocks. There were no road signs. After many turns, the bumpy ride led us into a valley where the village is located. From a distance, we saw the hillside piled up with rubbles and rocks indicating significant excavation at this site (Fig.

1.11). A walkway led us up the hill. A few local farmers carrying picks and shovels happened to walk in front of us. They noticed us as outsiders and hence slowed down. "The new fossils are on the backside of the hill," they told us. We followed them to the excavation site. Compared to what we saw during a previous visit about 22 months ago, it was very obvious that much more debris has been piled up on the hillside. The backside of the hill, which was untouched previously, has been excavated extensively with many holes and debris fields.

Daohugou of Ningcheng

The fossil site is located at the Daohugou village, Shantou Township, Ningcheng County, Inner Mongolia Autonomous Region (Fig. 1.12). Fossils are located in layers many meters below surface. Deep holes all over the fossil site were dug by farmers to reach these fossils. Fossils from this site are easily identified due to the

Fig. 1.11 Huangbanjigou fossil site in June 2001 (Photo by Dr. Shih Chungkun)



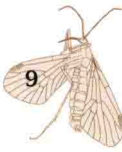


Fig. 1.12 Field trip to Daohugou by Drs. Ren (right) and Shih in October 2005 (Photo by Zhang Lin)

characteristics of many small freshwater conchostracans (*Euestheria* sp.). The palaeoenvironment reconstructed for this locality is a volcanic region with mountain streams and lakes (Ren *et al.*, 2002). Daohugou has provided abundant and diverse insect fauna composed of complete specimens of Ephemeroptera (Huang *et al.*, 2008), Odonata (Zhang *et al.*, 2008), Plecoptera (Liu *et al.*, 2007), Blattodea (Liang *et al.*, 2009), Orthoptera (Li *et al.*, 2007), Heteroptera (Yao *et al.*, 2006), Homoptera (Wang *et al.*, 2007), Neuroptera (Ren, 2002), Raphidioptera (Engel and Ren, 2008), Coleoptera (Tan *et al.*, 2006), Hymenoptera (Shih *et al.*, 2009) and Diptera (Ren and Krzemiński, 2002). In addition, also found are spiders (Seldon *et al.*, 2008), freshwater conchostracans (Zhang *et al.*, 1987), salamanders [*Jeholotriton paradoxus* (Wang, 2000; Gao and Shubin, 2003)], feathered dinosaurs (Xu and Zhang, 2005), pterosaurs (Ji and Yuan, 2002) and *Jeholopterus ningchengensis* Wang, Zhou et Zhang, 2002 (Wang *et al.*, 2002), and mammals

(Ji *et al.*, 2006).

Surrounding Gymnosperm forests were dominated by Ginkgopsida (*Ginkgoites*, *Ginkgo*, *Baiera*, *Czekanowskia*, *Phoenicopsis*), Coniferopsida (*Pityophyllum*, *Rhipidiodendron*, *Elatocladus*, *Schizolepis*, *Podozamites*), Lycopods (*Lycopodites*, *Selaginellites*), Sphenopsida (*Equisetum*), Filicopsida (*Todites*, *Coniopteris*) and Cycadopsida (*Anomozamites*) (Mi *et al.*, 1996). All these palaeontological data were interpreted as indicating humid and warm-temperate climate (Tan and Ren, 2002).

Lingyuan

Lingyuan, the Chinese name means the origin of the Daling River, is located among the Hebei Province, the Liaoning Province and the Inner Mongolia Autonomous Region. It is a low hilly area, mostly covered with sediment siltstones. These matrices contain a lot of fossils from the Late Jurassic to Early Cretaceous. In 1880, *Lycoptera davidi* (a fish) was found here and studied by a French scientist, Mr. Sauvage. In 1920's, Messrs. Weng Wenhao, Tan Xichou and A. W. Grabau studied fossils of fish, conchostracans, insects, and plants from this area and named them the "Jehol Biota". Jehol was set up as a province in 1929; Lingyuan became part of the Jehol Province. However, in 1956, the Jehol Province was eliminated and its area became parts of Inner Mongolia, Hebei and Liaoning. The Lingyuan City became part of the Liaoning Province (Zhang, 2002).

The Jehol Biota, defined as fauna (living beings) consisting of a wide range of creatures in this area, is one of the highly important biotas in the world. The Jehol Biota area, in its broader definition, is expanded to cover a very large geographic area: to the west, Inner Mongolia, Shaanxi, Gansu, Ningxia, and Xinjiang; to the north, Heilongjiang and Russia; and to the east, Liaoning, Korea and Japan.

There are many important fossils found at the Lingyuan fossil site (Fig.1.6). Examples include *Lycoptera* (a fish), *Protosphegus liui* (a sturgeon), *Peipiaosteus pani* (a sturgeon), *Yanosteus longidorsalis* (a sturgeon), *Monjurosuchus splendens* (a crocodile), *Hyphalosaurus lingyuanensis*, *Liaoxiornis delicatus* (a small bird), *Dromaeosauridae* (a feathered dinosaur), and various insects and plants (including one of the earliest angiosperm *Archaeofructus sinensis*, and fossilized woods). To protect the source of these important fossils, the Lingyuan City set up a Fish Fossil Natural Protection Area for Daxinfangzi. In 2000, the Lingyuan City



government asked the Liaoning Geology and Mineral Bureau to survey the fossil sites and set up a Natural Protection Site for an area of 200 square kilometers covering from Daxinfangzi to Fanzhangzi.

Yixian

Yixian is a small city about 30 minutes drive from Jinzhou. Yixian is noted for its Big Buddha Temple with 7 large Buddha statues which are visited and worshipped by many devotees. The other popular tourist site in Yixian is stone Buddha carvings in caves on a mountain side. It is called the Ten Thousand Buddha Cave. These badly eroded and damaged Buddha statues were carved about 800 to 1000 years ago. The limestone was too soft to resist hundreds of years of natural eroding forces of wind and rain. Besides these two famous religious sites,

Yixian, due to the name of Yixian Formation, now is recognized worldwide as a very important fossil site.

Yixian fossil study started in the 1940's. *Manchurochelys manchouensis* (a turtle), *Yabeinosaurus tenuis* (a lizard), and *Lycoptera muroii* (a fish) were three fossil species found in Jingangshan and described by three Japanese scholars, Endosan, Shikamasan and Takaisan, respectively. From 1976 to 1995, many Chinese scientists studied and published fossil specimens found in this area, including conchostracans, insects, fish, and plants. Since 1996, many rare and important fossils were found here, including birds, dinosaurs, feathered dinosaurs, pterosaurs, toads, fossilized woods, angiosperm plants, etc. These fossil specimens gained worldwide recognition and put Yixian on the map as one of the most important fossil sites in the world (Zhang, 2002).



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