

**Tertiary Mammal Faunas of the Lantian Region,
Shaanxi Province**

by

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Introduction

In this chapter, the term "Lantian region" refers to the vicinity of Lantian County, Xian municipality, Lantong and Weinan counties, in addition to their neighboring regions. Six stratigraphic units are recognized in the Tertiary sediments of this region. These are based upon subdivisions established by the Lantian regional survey team from the Institute of Vertebrate Paleontology and Paleoanthropology. Rather numerous fossil vertebrates (predominantly mammalian) have been recovered from these six formations in the Lantian region. Publications resulting from the study of a portions of the paleontological data include Liu and Li, 1963; Young, 1964; Chow, 1964; Xu, 1965; and Li, 1965. The remaining data will be published in the monograph series of this text and will total eight volumes after study by Xiti Zhang, Dongsheng Liu, Renjie Zhai, Yuxuan Xu, Chuankuei Li, Yuqing Li, Banyue Wang, Wenyu Wu, and others.

This chapter describes the mammalian faunas, their correlation, stratigraphic descriptions, and the stratigraphic position and location of the fossil mammal localities.

Stratigraphic data is derived principally from the publication entitled "The Cenozoic of Lantian, Shaanxi" from "Collected Papers from the 1964 Field Conference on the Cenozoic of the Lantian Region, Shaanxi Province," published by the Institute of Vertebrate Paleontology and Paleoanthropology.

Paleontological conclusions and data are all based on an individual taxon's locality and phylogenetic position as reported in the compilation of this series of papers. An exception to this is stratigraphic and locality data derived from papers already published. The authors of this text made conclusions upon the dispersed material from the perspective of faunal nature and stratigraphic position.

I Localities and Stratigraphic Position of the Fossil Mammals from the Tertiary of the Lantian Region

The Tertiary of the Lantian region may be subdivided into six individual depositional units or stratigraphic units (formations), with each formation producing fossil vertebrates. The Early Pliocene (N_2^1) sediments are the most abundant and fossiliferous in the region. Fossils are relatively scarce from other ages (Eocene, Oligocene, and Miocene). A concise description of principal characteristics and fossiliferous units from each formation is conducted from oldest to youngest as follows.

(1) The Lower Tertiary Eocene Honghe Formation (E₂)

The Honghe Formation comprises the lowermost regional Cenozoic sediments that directly overlie Pre-sinian metamorphics and quartzites. Its principal lithologic characteristic is its interbedded purple-red mudstones, sandy mudstones, and fine sandstones with basal conglomerates. Exposures are approximately 200 m thick.

Two fossiliferous units are recognized from this formation. One lies near the river bottom approximately 20 m from the basal gravels, and consists of a purple-red sandy mudstone with blue-green mottling. Produced from this unit is a small tapir, *Breviodon minutus* (Matthew and Granger). The locality (field number 65013) is in the vicinity of Sangyuancun Village, at the middle upper reaches of the Xishuihe River in Lantong County. The other fossiliferous deposit lies near the top of the section and consists of interbedded purple-red sandy mudstones and sandstones. Thicknesses of the interbedded sandstones are approximately 9 m, containing

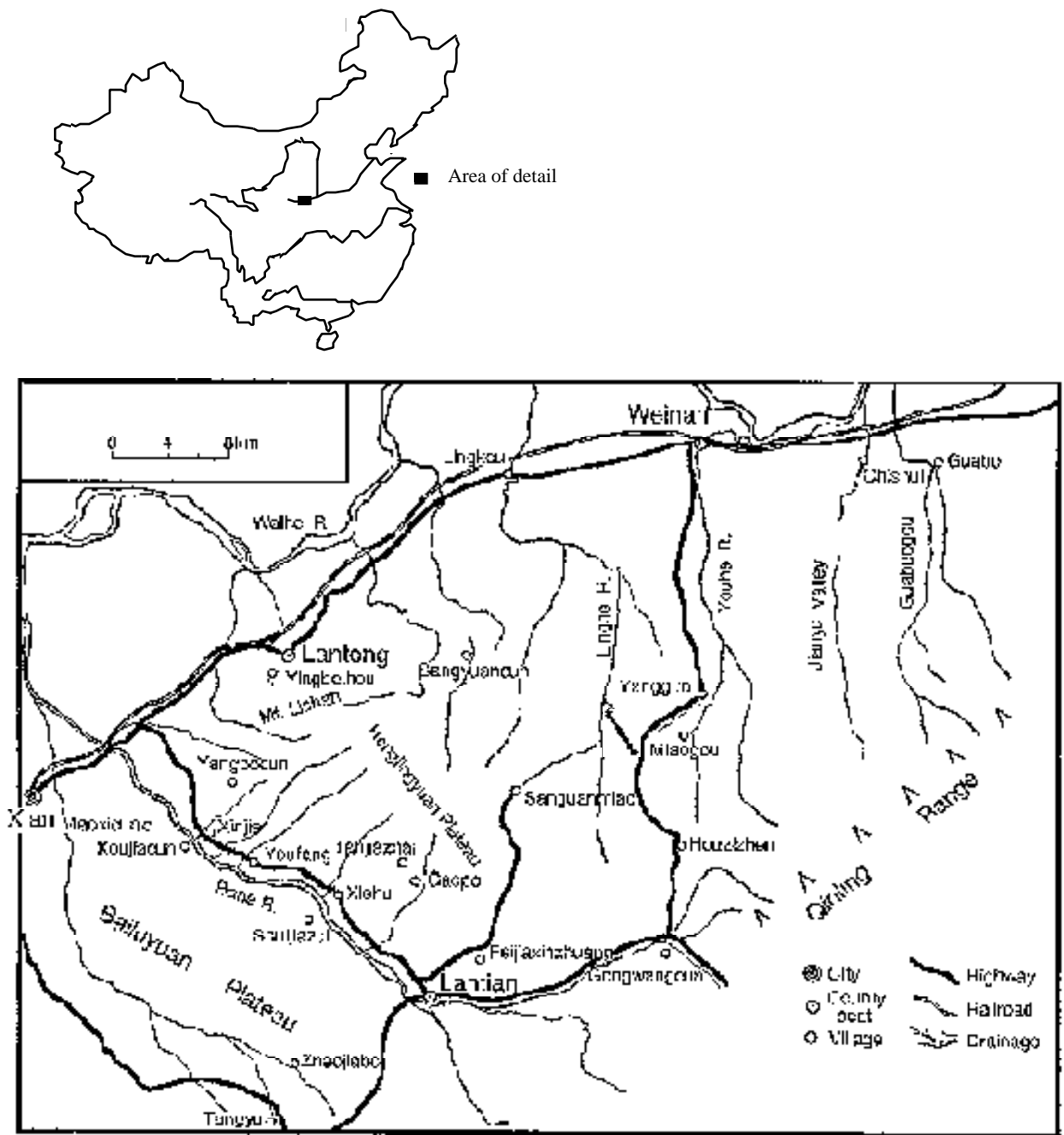


Figure 1. Transportation and communication network in the Lantian region of Shaanxi Province

abundant sandstone concretions and mudballs. Fossils are produced from within the concretions. The fossiliferous unit is approximately 60 m from the top of this section. Both trionychid turtles and brontotheres were collected. The fossil locality (65009) lies beneath Yangpocun Village, in the northeast portion of the Xialuyu Valley, of Hongqingbaogou Arroyo in Northeast Lantong County.

(2) Eocene-Oligocene Bailuyuan Formation (E2-3)

This formation unconformably overlies the Honghe Formation, and is distributed in a belt around the southern, western, and eastern side of Lishan Mountain. The distribution range of this formation is broader than that of the Honghe Formation. Gray-white sandstones dominate the lithology. Three members may be recognized in the Bailuyuan Formation: the upper, middle and lower member. The lower member consists of massive sandstones grading to thinly laminated purple-red mudstones; the middle member consists of interbedded gray-white sandstones and purple-red mudstones; and the upper member is recognized by relatively coarse-grained sandstones grading to purple-red, chocolate colored mudballs or bands with large sandstone concretions. The greatest exposure thickness of this formation in the Lantian region is approximately 400 m. An extremely small amount of fossils has been recovered from two stratigraphic units. One of these units is in the lower member and consists of a gray-white massive sandstone grading to a thinly laminated purple-red mudstone. The fossil material consists of a tapir mandible encased in a sandstone concretion. The locality (65008) lies in the Yangpocun Village vicinity, in the northeast section of the Xialuyu Valley, Hongqingbaogou Arroyo, in northwest Lantong Province. The other fossiliferous horizon lies in the formation's upper member, where material is produced within large sandstone concretions predominantly from mudstones interbedded with white coarse-grained sandstones. Approximately 200 m separates the two fossil horizons, with the higher unit both more fossiliferous and more widely distributed than the lower unit. Fossil localities are listed as follows:

1. Shanyanggou Arroyo (59 S) at Maoxicun Village on the southeast outskirts of the municipality of Xian. In 1959 Dongsheng Liu, Menglin Ding, and others from the Institute of Geology were the first to discover an amynodont mandible in the gray-white sandstones (Xu, 1965). Again in 1963 dentition of the same taxon was recovered from a sandstone concretion at the same locality by the Lantian research team of the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) (Zhang et al., 1964).
2. Xushahegou Arroyo (63705) (on the right bank of the Bahe River across from Maoxicun Village) Xinjie, Lantian. In 1963, the IVPP Lantian research team discovered a skull of the same species of amynodont from the same upper stratigraphic horizon (Zhang et al., 1964).
3. Kangwangou Arroyo, Xiehu, Lantian (64017). A single maxilla from a prosimian primate was lying in the arroyo where it was collected by the Institute of Vertebrate Paleontology and Paleoanthropology in 1964 (Chow, 1964). Judging from the matrix surrounding the specimen, it appears to have been derived from the interbedded white sandstones and purple-red mudstones of the upper member of the Bailuyuan Formation.
4. Gaopocun Village, Shiligou Arroyo, Lantian (64005). This locality was discovered in 1964 by the IVPP Lantian research team. Specimens include a species of lagomorph and a small artiodactyl from the interbedded purple-red mudstones and white sandstones (refer to the following).
5. Gaowangou Arroyo (65017) (Niusimiao) Weinanxian County. The locality was discovered by the IVPP Lantian research team. The complete skull of an amynodont was recovered from a concretion in the white sandstones.

(3) Upper Tertiary Miocene Lengshuigou Formation ($N\frac{2}{1}$)

This formation overlies the Bailuyuan Formation with an angular unconformable contact. Exposures lie at the eastern foot of Lishan Mountain in the middle and upper reaches of the Lingkou and Youhe rivers. Exposures are also found at the southwest foot of Lishan Mountain in all the arroyos and valleys between the Zhoujiahe River at Lantian and Lengshuigou Arroyo. Lithologic character is recognized as gray-yellow and dark yellow muddy sandstones and terra cotta-red or gray-green mottled, red-brown sandy mudstones. The largest exposures are approximately 80 m.

There are four principal but scattered localities in the Lengshuigou Formation, none of which produce abundant fossils. Lithologic character differs between each locality, creating difficulties for stratigraphic correlations. From the perspective of the paleontological data, it appears the four localities may be basically regarded as representing a single stratigraphic unit.

1. Yingbeihoucun Village, Lengshuigou, Lantong (64007). This locality was first discovered by the Department of Geology of Xibe University. In 1964, a systematic excavation of the locality was undertaken by Defen Han and others from IVPP, producing a relatively good collection of fossil mammals. After preliminary diagnosis, the age of the specimens was regarded as Miocene, and older than the Koujiacun Formation (see below); hence, the establishment of the nomenclature "Lengshuigou Formation." Paleontological material is derived from brown-red sandy mudstone-bearing calcareous concretions. Twelve species of fossil mammals are known from the Lengshuigou Formation, including proboscideans, perissodactyls, and artiodactyls (refer to the report by Zhang, Zhai, Li, and Wu in this series of papers). As fossil material here is relatively abundant, it would be possible to conduct further systematic excavations.

2. On the right bank of the Shilihe River (64008) southeast of Niujiakou, Lantian. Here, the IVPP Lantian research team discovered a complete mastodont skull (some damage was incurred at the time of excavation) from a terra cotta-yellow, brown yellow sandstone. Concurrently, a scapula was recovered from a variegated mudstone slightly higher in the section.

3. A roadside locality on the highway southeast of Xinjie, Lantian (64-lan-044). This locality was found in 1964 by a field crew from the Institute of Geology, which was measuring a cross-section at the time. A new species of lagomorph is represented (refer to the paper by Chuankuei Li in this series) in addition to a cervid produced from a yellow sandstone.

4. Zhijiagou Arroyo, Youfang, Lantian (64015). In 1964 a piece of sandstone was collected beneath Getamiao Temple at Zhijiagou, in which there was a small fragmentary skull with partial maxillary dentition, representing a specialized lagomorph (see the paper by Chuankuei Li in this series).

(4) Miocene Koujiacun Formation ($N\frac{3}{1}$)

This formation directly overlies the Lengshuigou Formation with a distinct erosional surface separating the two. In some areas this surface is represented as an angular unconformity. The lithologic character exists as a set of tan-red or tan-yellow mudstones, sandy mudstones, and sandstones. The distribution range of the Koujiacun Formation is equivalent to that of the Lengshuigou Formation. Its thickness is approximately 60 m.

Two stratigraphic units are recognized in this formation. The fossiliferous unit in the upper member is characterized by purple-red and tan-red mudstones. Three localities have been found in

this unit, the first being at Shanyanggou Arroyo (59 S 7) at Maoxicun Village on the outskirts of the city of Xian (the same vicinity as the amplypod from the Bailuyuan Formation) where a *Listriodon* specimen was discovered (Liu and Li, 1963). The second locality is at Gaopocun (64004) by Shilihegou, Lantian, which produced *Lagomeryx* (Young, 1964) The third locality is at Duzhuangcun Village (64016), Tanjiazhai, Xiehu, Lantian, where a small amount of sciurid teeth, undiagnostic to species, were found.

The fossiliferous horizon in the lower member lies in the sandy conglomerate at the base, which produced a gomphothere (see Renjie Zhai in this publication series).

(5) Pliocene Bahe Formation ($N\frac{1}{2}$)

The Bahe Formation is the most extensively distributed set of Tertiary sediments in the region; it is relatively well developed and is the most fossiliferous. Its lithologic character is rather complex, consisting predominantly of orange-yellow conglomerates, sandstones, tan-yellow sandy mudstones, and tan-red mudstones. Lithologic character is inconsistent between each of the cross-sections, as the unit varies in depth of color and grain size. The predominant lithology is a sandy mudstone. It is a relatively thick unit, generally over 300 m.

Relatively abundant fossiliferous horizons occur in the Bahe Formation, with eight occurring in the Baheyuan Loess Plateau region alone. The major localities lie at Damiaogou Arroyo in the Koujiacun vicinity (59 S 10) and in the Shuijiazui region (63702) of Xiehe. Additional localities lie at Shuizigou (64018), Gongwangling, Lantian; Yuanjiagou (64013) and Feijiaxinzhuang in the Majiahe River vicinity; and around the town of Yangguozhen, in Weinan County, where *Hipparion* faunas similar to those in the Bailuyuan Loess Plateau region are found.

Refer to the paper by Liu et al. (this publication series) for a more detailed description of each fossil locality's stratigraphic position and taxonomic list. It is not necessary here to reiterate this information.

(6) Pliocene Lantian Formation ($N\frac{2}{2}$)

This formation is composed of dark red, dark tan clays and tan-yellow sandy conglomerates. The clays contain large amounts of carbonate concretions. After weathering, surficial color changes to gray-yellow or gray-white and the clay units are perched as spongy hummocks.

A distinct erosional surface lies between the Lantian Formation and the underlying Bahe Formation. In this region distribution of the Lantian formation exceeds that of the Bahe Formation, with exposures outcropping in almost all major arroyos and valleys. Sedimentary thickness, however, is modest, generally between 10m and 40 m and reaching nearly 70 m at most.

Although this formation is extensively distributed, distinct in lithologic character, and readily distinguishable in the field, fossil localities are extremely rare and paleontological data is depauperate. The main fossil locality is in the Jiulaopo region (63710 = 59 S 3) on the left bank of the Bahe River in Lantian. Taxa belong predominantly to elements frequently seen in the *Hipparion* fauna (in the broad sense).

II Taxonomic List of Tertiary Mammals and Fossil Localities (or Fossiliferous Units) in the Lantian Region

There are approximately 80 species recognized from 23 known fossil vertebrate localities in Lantian and neighboring regions (including conspecific taxa recovered from different localities). Among them are 6 new genera and 17 new species.

A compilation of "fossil localities"* is hereby conducted based on geologic age (from oldest to youngest) with the age of each "fossil unit" in a single constructed cross-section (from oldest to youngest). Additionally, a vertebrate fossil list (predominantly mammals) is compiled below including those taxa already published upon (five species) and those described in this publication series:

1. Honghe Formation - (Locality 65103) Cangyuancun, Xihe, Lantong

Breviodon minutis ? (Matthew and Granger)

2. Honghe Formation - (65009) Yinbocun, Hongqingbaogou, Xian

Arctotitan hongoensis gen. et sp. nov., cf. *Deperetella* sp.

3. Bailuyuan Formation - (65008) Yinbocun region, Xialuyu, Hongqingbaogou, Lantong.

4. Bailuyuan Formation - (63704) Shanyangou, Maoxicun, Xian.

Sianodon bahoensis Xu, *Sianodon* sp.

5. Bailuyuan Formation - (63705) Xushahegou, Xinjie, Lantian.

Sianodon bahoensis Xu

6. Bailuyuan Formation - (64017) Kangwangou, Xiehe, Lantian.

Lantianius xiehuensis Chow

7. Bailuyuan Formation - (64005) Gaopocun, Shilihegou, Lantian.

Palaeolaginae indet. Artiodactyla indet.

8. Bailuyuan Formation - (64017) Gaowangou, Niusimiao, Weinan.

Amynodon sp., Brontotheriidae indet.

9. Lengshuigou Formation - (64007) Yingbeihoucun, Lengshuigou, Lantong.

Selenolophodon spectabilis (Hopwood) new gen. and new combination,
Hispanotherium lintungensis Zhai sp. nov., *Listriodon lishanensis* Li and Wu sp.
nov., *L.* sp., *Palaeomeryx* sp., ?*Micromeryx* sp., *Palaeotragus* sp.,
Oioceros lishanensis Li and Wu sp. nov., *O.* sp.

10. Lengshuigou Formation - (64008) Right bank of the Shilihe River, southeast of Niujiakou, Lantian.

* Locality numbers are registered under the Institute of Geology or the Institute of Vertebrate Paleontology and Paleoanthropology.

Gomphotherium shensiensis Zhang and Zhai sp. nov.

11. Lengshuigou Formation - (64-Lan-044) Roadside on highway southeast of Xinjie, Lantian.

Alloptox minor Li sp. nov., *Stephanocemas* sp.

12. Lengshuigou Formation - (64015) Zhijiagou, Youfang, Lantian.

Tsananolagus wangi gen. and sp. nov.

13. Koujiacun Formation - (64004) Gaopocun, Shilihe, Lantian.

Platybelodon grangeri Osborn, *Lagomeryx complicidens* Young, Antilopinae gen. and sp. indet.

14. Koujiacun Formation - (59 S 7) Shanyanggou, Maoxicun, neighboring Xian municipality.

Listriodon lantianensis Liu and Li, *Listriodon intermedius* Liu and Li, *L. gigas* Pearson.

15. Koujiacun Formation - (64016) Duzhuangcun, Tanjiazhai, Xiehe, Lantian.

Sciuridae gen. and sp. indet.

16. Bahe Formation lower member - (59 S 10) Damiaogou, Koujiacun, Xian.

Viverridae gen. and sp. indet., *Crocota eximia variabilis* (Zdansky), *Hipparion* sp., *Chleuastochoerus stehlini* Pearson., ?*Tragoreas* sp., *Gazella* cf. *gaudryi* (Schlosser).

17. Bahe Formation Upper Member - (63702) Shuijiazui, Xiehu, Lantian

63702, Unit L4 = Unit 59 S 6: *Tetralophodon exoletus* Hopwood, *Hipparion weihoense* Liu, Li, and Zhai sp. nov., *Hipparion chiai* Liu, Li, and Zhai sp. nov., *Palaeotragus* cf. *decepiens* Bohlin, *Shensispira chowi* Liu, Li, and Zhai gen. and sp. nov., *Antelope* sp., *Gazella* sp. II.

63702, Unit L3: *Testudo sphaerica* Wiman

63702, Unit L2: Emyidae gen. and sp. indet.

63702, Unit L1 = Unit 59 S 5: *Erinaceus* sp., *Tetralophodon exoletus* Hopwood, *Hipparion weihoense* Liu, Li, and Zhai sp. nov., *H. chiai* Liu, Li, and Zhai sp. nov., *H.* cf. *dermatorhinum* Sefve, *Dicerorhinus orientalis* (Schlosser), ?*Brachypotherium* sp., Rhinocerotidae gen. and sp. indet., *Palaeotragus* cf. *decepiens* Bohlin, *Antelope* sp., *Gazella* sp. II.

Unit 59 S 1: *Hipparion chiai* Liu, Li, and Zhai sp. nov.

Unit 59 S 2: *Crocota (Percrocota) macrodonta* Liu, Li, and Zhai sp. nov., *Hipparion* sp.

Unit 59 S 4: *Hipparion* cf. *weihoense* Liu, Li, and Zhai sp. nov., *H. chiai* Liu, Li, and Zhai sp. nov., *Chilotherium gracile* Ringström, *Palaeotragus microdon* (Koken), *Antelope* sp., *Gazella* sp. I.

18. Lantian Formation - (63710 = 59 S 3) Jiulaopo, Xiehu, Lantian.

Hipparion plocodus Sefve, *Dicoryphochoerus medius* Liu, Li, and Zhai sp. nov.,
Chleuastochoerus sp., *Cervavitus* sp., *Gazella gaudryi* (Schlosser).

19. Lantian Formation - (64018) Shuizigou, Gongwangling, Xumiao, Lantian.

Testudo sp., *Hipparion* sp., *Chilotherium habereri* Ringström, *Honnanotherium* sp.,
Cervavitus (*Cervocerus*) *novorossae* Khomenko.

20. Pliocene - (64013) Yuanjiagou, Majiahe, Lantian.

Testudo sp., *Hipparion* sp., Rhinocerotidae gen. and sp. indet., *Cervavitus* (*Cervocerus*)
novorossae Khomenko, ?Cervidae gen. and sp. indet, *Gazella* sp.

21. Pliocene - (63701) Feijiaxinzhuang, Lantian.

Testudo sphaerica Wiman.

22. Pliocene - Zhanghe, Yangguo, Weinan.

Gazella sp.

23. Pliocene - (63713) Lengshuigou, Lantong

Hipparion sp.

III Faunal Characteristics, Age, and Correlation

1. Eocene

It is possible to validate the fossil material derived from the two Lantong localities of Xishuihe (65013) and Hongqingbaogou (65009) in the Honghe Formation. The former locality has produced merely a small amount of isolated teeth belonging to a small species of tapir in the family Perissodactyla. It is not possible to make a more definitive diagnosis due to the fragmentary nature of the material. The second locality has produced two relatively well-preserved teeth that, in size and loph morphology, closely resemble the genus *Breviodon* recently described by L. Radinsky (1965). This taxon is relatively common, but found only in the Chinese Eocene localities of Inner Mongolia; Lushi, Hunan province; and Lunan, Yunnan Province. A direct comparison may be made between the Lantong specimens and those from Lushi (yet to be described). Clearly they are conspecific.

A brontothere specimen consists of an anterior part of a skull representing a new genus and species, which has been described by Banyue Wang as *Arctotitan hongheensis* gen. et sp. nov. (refer to this publication series). This new taxon is extremely large but retains a relatively primitive dentition.

It is possible to make conclusions regarding the stratigraphic nature of the Honghe Formation based upon the occurrence of two species of tapir found in the Lushi Formation, *Breviodon* and *Deperetella*. Hence its age should be regarded as Late Eocene or possibly early Late Eocene, equivalent in age to the Lushi Formation of Henan, or the Irdin Manha Formation in the Erlian region of Inner Mongolia.

2. Fossil mammal units of the Bailuyuan Formation.

Several localities are present in the Bailuyuan Formation. They are principally located in the white sandstones of the upper member. However, as the material is relatively scarce, it is not easy to make a positive correlation. Five species are recognized from this lithologic unit, including *Lantianius xiehuensis* Chow, Palaeolaginae indet., *Sianodon baheensis* Xu, a small artiodactyl, and a skull that has yet to be studied. The age of *Lantianius* was initially regarded by Chow (1964) as possibly being Late Eocene due to its affinity to prosimian primates formerly found in the Late Eocene of North America and Europe. Now, however, as there is a more substantial fossil complex, it is more likely that the age is Early Oligocene. Li (1965) found it difficult to diagnose the age of the lagomorph as the specimen retains merely a single tooth, although he considered the age to be possibly Early Oligocene or slightly older. There is rather more material of *Sianodon*, which has a wide distribution in both China and the rest of Asia. Yubi Xu (this publication series) recognizes the same species found at Lantian in Caijiachong Formation (Early Oligocene) of Qujing, Yunnan Province. A small artiodactyl is represented by a single lower cheek tooth (possibly deciduous) and a piece of astragalus. Its size approaches that of *Archaeomeryx*, and as it is not morphologically readily distinguishable from this taxon, its age appears not to exceed the Early to Middle Oligocene. From the perspective of these few taxa, it is concluded the age of the fossiliferous units in the Bailuyuan Formation is very possibly Oligocene. Stratigraphically, these units may be correlated to the Caijiachong Formation of Qujing, Yunnan, or the Ardyn Obo Formation of the People's Republic of Mongolia.

As stated earlier, paleontological data recovered from the Bailuyuan Formation is derived principally from the white sandstones in the upper member. With regard to the lower member of the formation, only an extremely small amount of data has been recovered which consists of a broken half of a skull, the dentition of which has undergone so much occlusal wear that the teeth are worn flat. The morphology of the skull, dental count, arrangement, and outline strongly suggests that this specimen is a chalicothere, with a size approaching that of the small *Eomoropus*. This clearly is very possibly an Eocene specimen. However, to date there has been no observation of a distinct geologic feature representing an Oligocene-Eocene boundary in this formation. Moreover, the general depositional mode in North China (at Yuanqu, Shanxi and the Xilamulunhe River region at Ulanqab Meng, Inner Mongolia) suggests continuous sedimentation between the Upper Eocene and Lower Oligocene, with no distinct boundary (similar conditions exist in Southern Yunnan Province at Lunan). Additionally, it is possible to distinguish an Upper Eocene stratigraphic unit from a Lower Oligocene unit as there are obvious disparities between the characteristics of the mammalian faunas of these times. This condition characterizes the Bailuyuan Formation as well, such that the production of diagnostic fossils would allow the subdivision of the middle and lower members representing the top of the Eocene from the upper member which is Oligocene.

3. Miocene mammalian faunas of the Lantian Region

In China, the discovery and study of Miocene sediments bearing fossil mammals are extremely rare. The several known relatively significant localities include Tunggur, Inner Mongolia; Shanwang, Lanqu, Shandong; and some others that represent only a single fossiliferous unit (in actuality it is possible these localities are not restricted to a single unit, such as Tunggur, which has yet to be studied sufficiently). Most important are the two fossiliferous strata representing the Miocene of the Lantian region, which may be recognized as two formational units on the basis of lithologic and structural characteristics: the Lengshuigou Formation (lower) and Koujiacun Formation (upper).

The mammalian fossils of the Lengshuigou Formation are typically Miocene. Research undertaken by Xiti Zhang, Renjie Zhai, Yuqing Li, Wenyu Wu, and Chuankuei Li (refer to the following text) recognizes twelve taxa including *Selenolophodon spectabilis* (Hopwood), *Gomphotherium*, *Hispanotherium lintungensis* Zhai, *Listriodon*, *Paleomeryx*, *Oioceros*, *Alloptox*, and *Stephanocemas*. A majority of these taxa occur in the Upper Miocene but are absent in the

Middle Miocene of China and localities outside of China. Of particular interest are the two new species *Listriodon lishanensis* Li and Wu, and *Oioceros lishanensis* Li and Wu which are more primitive than related forms recovered from the Upper Miocene Tunggur Formation (refer to Li and Wu in this publication series). In addition the two species of longirostrine mastodonts and *Hispanotherium* are all more primitive than related taxa from other Chinese and Asian Late Miocene localities (refer to Zhang and Zhai, and Zhai in this publication series). The condition of *Alloptox* is also similar (refer to Li in this publication series), being more primitive than that at Tunggur. Consequently, the age of the Lengshuigou Fauna is undoubtedly older than the Tunggur fauna, appearing to be Middle Miocene. Localities producing fossil mammals of this age (Middle Miocene) have still not been sufficiently described in China, although there is one locality at Dongshabo, Loyang, Henan (Liu and Li, 1963) that has produced *Listriodon*, but the material is too fragmentary for a more complete diagnosis.

There are fewer specimens recovered from the upper section of the Miocene at Lantian than the lower section (Lengshuigou Formation); however, among them are taxa very typical to the Upper Miocene. These include *Platybelodon grangeri* Osborn, which is also recovered from Tunggur, Inner Mongolia, and Kirgizyia, in the Soviet Union (Alexeeva, 1957, P.222). Zhang and Zhai (see this publication series) recognize the specimens from Lantian (locality 64008) to be morphologically consistent with those from Tunggur. Another significant fossil mammal is *Lagomeryx complicidens* Young. Young (1964) believed the age to be Miocene but admitted the possibility that it might be younger than Tunggur. Three species of *Listriodon* are recognized by Liu and Li: *L. gigas* Pearson, *L. lantienensis* Liu and Li, and *L. intermedius* Liu and Li. The age of these taxa encompass both the Middle and the Late Miocene (as the specimens were recovered from the same locality and stratigraphic position there may have been an error). Moreover, they recognized this Miocene ("Koujiacun Formation") stratigraphic unit as "Middle Miocene" (Liu and Li, 1963; p. 303, Table 1). It may be observed from the conditions described above that there is an age discrepancy regarding the Koujiacun Formation (Liu and Li) between those who studied the proboscideans, the cervids, and the suids. Preliminary recognitions are made here based on the position of the Lengshuigou Fauna in the cross-section and its comparison to Tunggur. The age of the Lengshuigou Formation is slightly older than the Tunggur Formation, but there does not appear to be a large disparity between the two, and hence, its age is regarded as Middle Miocene. The Koujiacun Formation is stratigraphically higher and compares more closely to Tunggur. But the fossil content is still too small to determine whether or not the Koujiacun Formation is older than Tunggur. Consequently, it is more likely its age is Late Miocene, which is basically consistent with the proboscidean and cervid data.

4. Pliocene faunas of the Lantian Region*

The most fossiliferous localities, and fossiliferous stratigraphic units in the Lantian region, occur in the Pliocene Bahe and Lantian formations. Moreover, the fossil data from this entire section have been completely studied (refer to Liu, Li, and Zhai in this publication series). It is not necessary to reiterate statements made upon paleoecological characteristics, faunal age, and stratigraphic position of each locality, as these factors have been extensively discussed by the initial workers.

Three distinct fossiliferous horizons may be recognized in the Pliocene at Lantian, and distinguished from the faunas produced from the localities of Koujiacun, Shuijiiazui, and Jiulaopo. This Pliocene mammalian fauna (referred to as the "*Hipparion* fauna" or "Pontian Stage") is the most widely distributed Tertiary fauna in North China (from Hebei Province to Wenquan in the western region of the Xinjiang Autonomous Region). It produces the most vertebrate fossils, displays the greatest taxonomic diversity; and maintains the longest history of research (initiating at

* Translator's note: Now regarded as entirely Miocene.

least in 1885). However, with the exception of a small number of indeterminate localities (such as Ertemte, Inner Mongolia), this set of fossiliferous deposits and its associated fauna share the common appellation "*Hipparion* red clays." Based upon results of research in the Lantian region, it is not only possible to recognize two separate lithologic members of Pliocene "red clays" (in the broad sense "*Hipparion*" red clays) in a single cross-section (Liu et al, 1960; Zhang et al., 1964), but moreover, three "fossiliferous zones" may be recognized (refer to later text). This is a significant addition to Tertiary stratigraphic research in China, as the Lantian data have been derived from basic systematic excavations and detailed stratigraphic work. Each fossiliferous unit is relatively distinct both structurally and lithologically, such that three individual Pliocene "fossil zones" are recognized. The lowest is the lower member of the Bahe Formation, the middle zone is the middle and upper members of the Bahe Formation, and the upper zone consists of the Lantian Formation. Many previous chronostratigraphic positions relating to this fauna are unclear due to large fossil collections mixing various localities. Moreover, although fossil data excavated from the Lantian region is relatively clear, the amount of fossils and taxonomic diversity are not as abundant as could be hoped. Consequently, it is still currently not possible to make a precise diagnosis regarding the age of each fossiliferous unit, or to draw conclusions regarding correlations to the *Hipparion* red clays in other regions of the country.

In their conclusions on Pliocene faunas, initial workers placed emphasis upon two localities. The first was at Lantian, which was previously believed to represent a majority of the taxa from the Early Pliocene (or Pontian Stage) *Hipparion* fauna. Its age, however, appeared to be slightly younger, being middle Pliocene or Late Pliocene (prior to the Nihewan Stage). In this manner, a large majority of the *Hipparion* red clays, extensively distributed in North China, may not be Early Pliocene, but Middle to Late Pliocene. From a sedimentological perspective the sediments representing the Upper Pliocene Lantian Formation are more extensively distributed than the Lower Pliocene Bahe Formation. Pliocene lithologies with a lithologic character comparable to the Lantian Formation at Lantian may be observed from Xian northward to Zhuisu, and from there directly to Lochuan and the Yanan region, Northern Shaanxi Province. Previously, these sedimentary deposits were generally recognized as Lower Pliocene, a viewpoint held not long before the workers of this publication series undertook investigations in the southwestern regions of Shanxi Province. The Upper Pliocene sediments, however, were much more widely distributed than the Lower Pliocene sediments (Chow et al., 1965). Other regions must be visited to conduct sedimentological and paleontological reconnaissance to confirm whether or not this hypothesis is tenable.

In addition, it is apparent through the perspective of faunal analysis to recognize the predominance of dense forest-dwelling taxa in two of the three faunal zones in the Pliocene of Lantian. These forest zones are the upper and lower fossil horizons, with the middle horizon dominated by grassland taxa. It is extremely significant that two phenomena of ecological succession may be recognized in the faunas of a single stratigraphic cross-section.

Among the earliest workers who studied the Pliocene of China (predominantly the early stage) was Schlosser (1903) and more recently Kurten (1952), who distinguished two paleoecological provinces based upon paleogeography: a northern grassland province (eastern Gansu, northern Shaanxi, and northern Shanxi provinces), and a southern dense forest province (southeast Shanxi and Henan provinces). Although it is very possible this condition did exist, it is also very clear that there is a situation that must be confronted wherein at least a portion of animals from different stratigraphic positions have been considered as being derived from the same stratigraphic unit. More attention must be applied to this condition. It is believed here that a grassland to forest succession is more probably the result of orogenic influences, or that is to say the climatic fluctuations that occurred prior to Quaternary glacial stages due to the uplift of the Qinghai-Tibetan Plateau and its neighboring territories which affected North China and other Asian regions beginning in the Late Tertiary.

In summary it is believed here that the undertakings in the Lantian region are a very good start toward the deepening of research into the abundant Pliocene mammalian fossils of China, and that these efforts would greatly benefit the knowledge and solving of numerous related geological and paleontological problems.

IV Preliminary Conclusions

(1) A total of 58 species of mammals are described within this monograph in combination with a portion of literature already published on Tertiary mammals of the Lantian region. This record is composed of 3 species belonging to 3 genera in the Eocene; 3 species belonging to 2 genera in the Oligocene; 18 species belonging to 12 genera in the Miocene, and 34 species belonging to 16 genera in the Pliocene. Among them are 3 new genera and 3 new species in the Eocene and Oligocene, 2 new genera and 9 new species in the Miocene; and 1 new genus and 5 new species in the Pliocene.

(2) The Tertiary continental sediments of the Lantian region comprise the most complete stratigraphic section in addition to producing the most stratigraphic units abundant in fossil mammals recognized to date in the Yellow River valley. A total of six formations bearing Tertiary fossil mammals are found in the region. From oldest to youngest these are listed as: 1) the Early Eocene Honghe Formation; 2) Late Eocene-Early Oligocene Bailuyuan Formation; 3) Middle (?) Miocene Lengshuigou Formation; 4) Late Miocene Koujiacun Formation; 5) Early Pliocene Bahe Formation; and 6) Late Pliocene Lantian Formation. The Pliocene sediments are the most fossiliferous.

(3) There is only a single fossiliferous unit in the Late Eocene Honghe Formation. The fauna from this stratigraphic position is relatively close to those faunas found in the Lushi Formation in Henan, and the Irdin Manho fauna at Erlian, Inner Mongolia.

(4) The Bailuyuan Formation is not very fossiliferous, with all the specimens basically derived from the white sandstones at the top of the formation. The age of this faunal complex is generally equivalent to Ardyn Obo on the Mongolian Plateau region. The age of the lower member of the Bailuyuan Formation may be Eocene, however it is difficult to distinguish it lithologically from the upper member.

(5) Two fossiliferous units are represented in the Miocene: the Lengshuigou Formation in the lower section, and the Koujiacun formation in the upper section. The stratigraphic relationships between these two formations, however, are still not entirely understood. The age of the Koujiacun fauna is relatively clear, and may be correlated to Tunggur, Inner Mongolia which is late Miocene. The Lengshuigou Formation is obviously a bit older, and may be Middle Miocene.

(6) The Pliocene is recognized as the Lower Bahe Formation, which is the most fossiliferous, and the upper Lantian Formation. It is important to note that in the past, the vast majority of Pliocene fossil mammals in China was identified as Early Pliocene regardless of the taxonomic status or stratigraphic position. The condition of the Lantian Formation contradicts this former presumption completely. The sediments of the Lantian Formation are regionally better developed, extensively distributed, and in the broad sense (as they are regarded equivalent to *Hipparion* red clays) are more faunally abundant than the Bahe Formation.

(7) Paleontologists who formerly studied the Early Pliocene or Pontian Stage in China, from the earliest (Schlosser, 1903) to the most recent (Kurten, 1952), subdivided the *Hipparion* faunas of North China into a northern grassland model, or southern dense forest model. The condition of the sediments at Lantian display different paleoecological factors suggesting orogenic changes. Three Pliocene mammalian faunal zones may be recognized at Lantian: the upper and

lower zones constitute predominantly grassland faunas, while the middle zone is dominated by dense forest faunas.

In summary, the significance of Tertiary mammals in the Lantian region lies principally in the relatively complete cross-section. Moreover, each fossil taxon is derived from a relatively diagnostic stratigraphic position. Consequently, this section may be used as a standard not only for stratigraphic and fossil mammal correlations in North China, but for even more expansive regions that contain terrestrial Tertiary systems. Additionally, it may act as an advanced reference point for the clarification of former numerous stratigraphic inconsistencies or ambiguities of fossil localities.

Table 14. Faunal list at Lantian

Age - Fm.	Taxon	Locality
Pliocene	Lantian Fm. Pliocene "upper fossil zone" <i>Hipparion plocodus</i> <i>Hipparion</i> sp. <i>Chilotherium habereri</i> <i>Dicoryphochoerus medius</i> <i>Chleuastochoerus</i> sp. <i>Cervavitus</i> sp. <i>Cervavitus (Cervocerus) novorossiae</i> <i>Honanotherium</i> sp. <i>Testudo</i> sp.	Jiulaopo, Xiehe, Lantian (63710 59 S 3) Shuizigou, Gongwangling, Xumiao, Lantian (64018)
	Bahé Fm. Pliocene "middle fossil zone" <i>Hipparion weihoense</i> <i>H. cf. weihoense</i> <i>H. chiai</i> <i>H. cf. dermatorhinum</i> <i>Hipparion</i> sp. <i>Dicerorhinus orientalis</i> <i>?Brachypotherium</i> sp. Rhinocerotidae indet. <i>Chilotherium gracile</i> <i>Shensispira chowi</i> <i>Antilope</i> sp. I <i>Antilope</i> sp. II <i>Gazella</i> sp. I <i>Gazella</i> sp. II <i>Palaeotragus cf. decipiens</i> <i>P. microdon</i> <i>Tetralophodon exoletus</i> <i>Crocota (Percrocota) macrodonta</i> <i>Erinaceus</i> sp. <i>Testudo sphaerica</i> Emydidae indet.	Shuijiazui, Xiehu, Lantian (63702)
	Pliocene "Lower fossil zone" <i>Hipparion</i> sp. <i>Chleuastochoerus stehlini</i> <i>?Tragoreas</i> sp. <i>Gazella cf. gaudryi</i> <i>Crocota eximia variabilis</i> Viverridae indet.	Damiaogou, Koujiacun, Xian (59 S 10)
Miocene	Koujiacun Fm. <i>Listriodon lantianensis</i> <i>L. intermedius</i> <i>L. gigas</i> <i>Lagomeryx complicidens</i> Antilopinae indet. <i>Platybelodon grangeri</i> Sciuridae indet.	Gaopocun, Shilihe, Lantian (64004) Shanyanggou, Maoxicun, outside Xian (59 S 7) Duzhuangcun, Tanjiazhai, Xiehu, Lantian (64016)
	Lengshuigou Fm. <i>Hispanotherium lintungensis</i> <i>Listriodon lishanensis</i> <i>L.</i> sp. <i>Stephanocemas</i> sp. <i>Palaeomeryx</i> sp. <i>?Micromeryx</i> sp. <i>Oioceros lishanensis</i> <i>O.</i> sp. <i>Paleotragus</i> sp. <i>Selenolophodon spectabilis</i> <i>Gomphotherium shensiensis</i> <i>Alloptox minor</i> <i>Tsaganolagus wangi</i>	Yingbeihoucun, Lengshuigou, Lantong (64007) Right bank of Shilihe, SE of Niujiaokou, Lantian (64008) Hwy. SE of Xinjie, Lantian (64-044) Zhijiagou, Youfang, Lantian (64015)
Oligocene	Bailuyuan Fm. <i>Lantianius xiehuensis</i> <i>Sianodon haheensis</i> <i>S.</i> sp. <i>Amyndodon</i> sp. Brontotheriidae indet. <i>Artiodactyla</i> indet. Palaeolaginae indet.	Gaopogou, Niusimiao, Weinan (64017) Gaopocun, Shiulihe, Lantian (64005) Kangwangou, Xiehe, Lantian, (64017) Xushahagou, Xinjie, Lantian (63705) Shanyanggou, Maoxicun, Xian (67304) Yangpocun vicinity, Xialuyu, Hongqingbaogou, Lantong (65008)
Eocene	Honghe Fm. <i>Arctotitan hongheensis</i> cf. <i>Deperetella</i> sp. <i>Breviodon</i> sp.	Yangpocun, Xialuyu, Hongqingbaogou, Lantong (65009) Sangyuancun, middle-upper reaches of Xishuihe R., Lantong, (65103)

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