The Cenozoic Deposits of the Yunnnan Region

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Introduction

Within the past half-century a large amount of Cenozoic stratigraphic work has been conducted in the Yunnan region associated with the accumulation of abundant data. However, to date, no relatively advanced systematic subdivision of the sediments has been conducted. For several years now the Institute of Vertebrate Paleontology and Paleoanthropology, Academia Sinica (IVPP) has undertaken this task. Collections of vertebrate material have been made prior to and after the establishment of the People's Republic, but the vast majority of material and the systematic analysis of it has been undertaken only since the 1970's. This research provides the basis for the subdivision, correlation, and establishment of a Cenozoic stratigraphic sequence for the Yunnan region, in addition to defining the mammalian faunal characteristics and additional related topics of each geologic age for multidisciplinary research. As a result of this work, substantial revelations have occurred suggesting that research in the Yunnan region is essential for comprehending the Cenozoic stratigraphy of China through the disciplines of Vertebrate Paleontology, Paleoanthropology, and Archaeology.

Cenozoic stratigraphy in the Yunnan region is extremely well developed and comprises six geologic epochs including the Eocene, Oligocene, Miocene, Pliocene, Pleistocene, and Holocene.

This text is arranged by the description of geologic age, and geographic basins from the Lower Tertiary to the Upper Tertiary. A synopsis of Quaternary deposition is summarized as a conclusion.

I Early Tertiary

The Early Tertiary sequence in the Yunnan region is exposed entirely within depositional basins such as Lunan, Chajiachong at Qujing; Luoping, Shizong, and Lijiang. Generally, the surface area of these basins is not extensive and frequently one side of the basin sediments will be in fault contact with the basement rock while on the other side the sediments will overly the basement complex with an unconformable contact, illustrating the structure of a "fault-block basin." Because these basins have been controlled by structural activity, a majority of them are trending north-south or east-west. Sedimentation is principally dominated by continental lacustrine facies such as mudstones, marls, or sandstones, frequently displaying gravel deposits at the base of the section, and generally with a thickness of over 100 meters. The thickest cross-section attains one thousand meters. Later structural movements have modified the sediments through differential deformation and faulting.

The Lower Tertiary of the Yunnan region contains abundant vertebrate fossils comprising four genera that encompass nine species of reptiles, and 29 genera containing 45 species of mammals. The faunal characteristics are fundamentally consistent with those of North China and Inner Mongolia.

A synopsis of the Early Tertiary basins is as follows:

(1) The Lunan Basin

The Lunan Basin of eastern Yunnan represents type localities for the study of Early Tertiary sediments and faunas in southwest China. As early as 1937-1939, C.C. Young and others conducted a geologic reconnaissance and made the first collection of several Early Tertiary mammals in the region. Later, during the interval between 1957-1960, Chengzhi Hu of the Geological Museum and Minchen Chow of IVPP further advanced investigations within the Lunan Basin and made more collections of fossil mammals in addition to discovering more stratigraphic units. In 1970, geologic mapping was conducted in the Lunan region in order to assist in the solving the problems of Cenozoic subdivision and correlation. A field team composed of The Second Regional Brigade of the Yunnan Office of Geology and IVPP conducted detailed research upon the Tertiary sediments and collected fossils from different stratigraphic intervals, in addition to basically clarifying the distribution of Tertiary sediments in the Lunan Basin, and providing an updated subdivision.

The Lunan Basin is located Southeast of the provincial capital Kunming and trends northeast-southwest. Early Tertiary sediments are predominantly exposed within the basin which is surrounded by early Paleozoic carbonates or Permian Limestones. Minor amounts of Quaternary reddish clays, sands, gravels, and paleosols are also distributed in the basin. On the west side of the basin, approximately 800 meters of Early Tertiary sediments are exposed in fault contact with the basement rock. The deposits may be subdivided into two sedimentary packages: the Lumeiba Fm. (Early Eocene) and the Xiaotun Fm. (Early Oligocene). The stratigraphic distribution of the Lumeiba Fm. is relatively extensive and exposures exceed 700 meters. The basal units consist of conglomerates or sandy gravels that are inconsistent in thickness, ranging from 40-50 meters to only 0.5-1 meter. In some regions these units are absent. The lower section of the formation consists of tan to red interbedded sandy mudstones and muddy sandstones that are over 600 meters thick and poorly fossiliferous. The upper section of the formation consists of interbedded gray-white marls, calcareous mudstones, and tan-red sandy mudstones over 100 meters thick that represent the region's principle fossiliferous deposits. There are six to seven fossiliferous subunits in this package. The Xiaotun Fm. is relatively restricted in distribution with an apparent thickness of over 50 meters. Its lithologic characters consist of tan-red interbedded sandy mudstones and muddy sandstones bearing relatively few fossils. There is no conspicuous unconformity between this unit and the underlying Lumeiba Fm.. Because these two formations have undergone structural deformation (principally in the form of fault activity), the sediments have become contorted and fractured, which particularly noticeable in the region of Dayimaban at Anrencun.

Prior workers have expressed numerous hypotheses regarding the age and subdivisions of the Lunan Basin deposits. Deprate (1912) believed the Lunan sediments to be Permian in age. In 1937, C.C. Young and others conducted research upon mammalian fossils from the vicinity of Beixiaoji Village by the city of Lunan where they recorded the presence of *Amynodon*, cf. *mongoliensis*, *Caenolophus minimus*, *Teleolphus* sp., *Deperetella* sp., *Protitanotherium* sp., *Anthrocotheriidae* indet., and turtle. This was the first indication for the age of the Lunan sediments and, in 1939, they wrote that the sediments "could not possibly be considered Permian as previously believed by former workers." Additionally, based upon the best preserved taxa in the collection, *Amynodon* cf. *mongoliensis* and *Caenolophus minimus*, they stated that "these two species are diagnostic taxa for the Late Eocene of Mongolia, therefore, these Early Tertiary sediments within the Lunan Basin may be regarded as Late Eocene. They may possibly be equivalent to the Shara Marun Formation in Inner Mongolia, and the Pengdong Formation of Burma." In 1957 Minchen Chow restudied these specimens, revised, and supplemented the collections with several taxa recording Carnivora indet., *Deperetella* sp., *Lunania youngi*, *Caenolophus medius*, *Amynodon* sp., *Titanotherium* sp., Anthracotheriidae indet., and Chelonia indet. He stated in 1957 that "among these taxa, a majority compare to the type genera and species of the Late Eocene of Inner Mongolia. Their stratigraphic position is probably equivalent to the Late Eocene Inner Mongolian Shara Marun Formation."

In 1958, Minchen Chow conducted research upon another collection in which he listed: Canidae indet., *Parabrontops lunanensis*, *Indricotherium parvum*, *Hyoboops hui*, and *Bothriodon* sp. (Professor Chengzhi Hu, while conducting stratigraphic investigations in eastern Yunnan, made a collection of fossils that he reported as being derived from the upper section of the Lunan sediments). Chow believed that "the Oligocene character of this fauna is extremely conspicuous," and thereupon for the first time suggested "the stratigraphic age of the upper section of the Lunan sediments is Lower Oligocene." He moreover subdivided the sediments into two fossils zones as follows:

Table 1. Subdivision of sediments in the Lunan region from Chow (1958).

	Age	Mammal Zone
Upper Lunan sediments	Early Oligocene	*Parabrontops-Indricotherium* Zone
Lower Lunan sediments	Late Eocene	*Rhinotitan-Amynodon* Zone

In Chow and Hu (1959) studied the brontothere *Dianotitan lunanensis*, where they stated that "after studying the most recent collection of several mammalian fossils, it is clear that, to date, the Lunan Early

Tertiary sediments represent the most complete section of this time period in the South China region, comprising a package that encompasses the Early Eocene through the Early Oligocene with several distinct diachronous vertebrate faunas."

Xu and Qiu (1962) conducted a more advanced and relatively complete discussion of the Lunan faunal characters and ages based upon the descriptions of prior workers and the descriptions of supplemental data provided by themselves. They distinguished two faunas recovered from the section within the Lunan Basin, these being: the fauna from the region of the Lunan County Seat including Creodont indet., *Titanotherium* sp. (*Rhinotitan*?) *Lunania youngi*, *Deperetella* sp., *Teleolophus* sp., *Caenolophus medius*., *Caenolophus* sp. *Amynodon* sp., and Anthracotheriidae gen. et sp. indet. The second fauna is derived from sediments south of the village of Banqiao* that includes Canidae indet., *Eomoropus ulterior*, *Teleolophus medius*, *Amynodon altidens*, sp., cf. *Metamynodon* sp., *Prohyracodon meridionale*, *Prohyracodon progressa*, *Ilianodon lunanensis*, *Indricotherium parvum*, Rhinocerotidae indet., *Eoentelodon yunnanense*, *Probrachyodus panchiaoensis*, *Brachyodus hui*, and Anthracotheriidae indet. They stated that "the taxa from the entire section should be divided into two diachronous faunas, the fauna of the Lunan Formation (those from the vicinity of the Lunan County Seat only) maintains characteristics basically similar to Shara Murun, Inner Mongolia, and should be Early Eocene." Regarding the Anrencun Fauna (from south of Banqiao only), they considered these to represent three suites: the first suite including *Rhinotitan quadridens* sp. nov., *Eomoropus ulterior*, *Amynodon altidens* sp. nov. *Probrachodus panchiaoensis*, *Ilianodon lunanensis*, *Indricotherium parvum*, and *Eoentelodon yunnanensis*. This fauna, they believed, "obviously exceeds the derived mammalian condition generally found in the Late Eocene (for example at Shara Murun and Pengdong) and instead has a complexion attributed to the beginning of the Oligocene. But from another aspect, the fauna also clearly does not display the advanced state generally noted in Early Oligocene mammals (including Artyn Obo, Inner Mongolia and Qujing, Yunnan), and instead maintains characteristics attributed a transition phase between Late Eocene to Early Oligocene mammals. The second suite includes *Parabrontops lunanensis*, cf. *Metamynodon* sp., and *Brachyodus hui*. These animals "are clearly typical of those belonging to the Early Oligocene or even a little younger in time." The third suite includes the taxa *Teleolophus medius*, *Prohyracodon meridionale*, and *Prohyracodon progressa*. These "are typical of forms belonging to the Late Eocene or slightly older, representing relatively conservative or remnant species in the Anrencun Fauna. They further suggested the "Anrencun Fauna is an assemblage typical of the transition phase between the Late Eocene and Early Oligocene, although here it is more appropriate to assign its age to the Early Oligocene.

Tang and Chow (1964) proposed different interpretations regarding the faunal nature of the Anrencun Fauna in their review of the Early Tertiary vertebrates from South China. They believed that the fauna from the upper section of the Anrencun Formation was relatively complicated because "many of the previous fossil collections were made from imprecise stratigraphic horizons with vague locality information," moreover, the asserted "*Parabrontops* specimens were excavated from the whitish calcareous beds in the upper section in the vicinity of Anrencun. *Prohyracodon progressa* and *Eomoropus ulterior* were produced at Xiaoshahe from sediments similar to those that produced *Parabrontops*, being from the base of whitish carbonate concretion bearing sediments. The stratigraphic position of *Prohyracodon meridionale* is even lower, being derived from the reddish muddy sandstones." At the same time, "regarding the fossils themselves, with the exception of *Metamynodon* (?), the vast majority of the collection is typical of the Eocene Stage." And "only *Indricotherium parvum* and *Brachyodus hui* belong in the Oligocene." Due to this they proposed that "the Anrencun Formation may be considered a relatively extensive stratigraphic unit with the Anrencun Fauna encompassing two to three fossil zones, as displayed in Table 2:

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* Formerly spelled Panchiao (WD).

Table 2. Relationships of the Anrencun Group and Lunan Formation from Tang and Chow (1964).

Anrencun Group	*Parabrontops lunanensis* Zone	Oligocene
	Prohyracodon progressa Zone	Late Eocene
	P. meridionale Zone - conformable or partially disconformable	Late Eocene
Lunan Fm.	*Lunania youngi* Zone	Late Eocene

Jiajian Zheng et al. (1970) proposed that the Early Tertiary deposits in the Lunan Basin be designated the 'Lunan Group' and further subdivided into the Meiyi Formation (lower) and the Xiaotun Formation (upper).

Reflecting upon the historical conditions above, it is evident that the Early Tertiary deposits in the Lunan Basin are relatively complex. But because prior workers have conducted an extreme amount of work upon them it is possible here to conclude with relatively comprehensive stratigraphic subdivisions and a statement of the distribution of Early Tertiary sediments in this basin. A synopsis of these preliminary hypothesis is as follows:

Table 3. Fossil mammals from the Late Eocene Lumeiyi Fm., Lunan Co.

Hyracodontidae
- *Caenolophus minimus*
- *C. medius*
- *C.* sp.
- *Teilhardia pretiosa*
- ?*Teilhardia* sp. nov.

Amynodontidae
- *Amynodon* cf. *mongoliensis*
- *A.* sp.
- *A.* spp.
- *A. lunanensis*
- *A. altidens*
- cf. *Paramynodon* sp.
- cf. *Metamynodon* sp.
- Amynodontidae indet.

Indricotheriidae
- *Indricotherium* sp.
- *Juxia* sp.

Rhinocerotidae
- *Prohyracodon meridionale*
- *P. progressa*
- *P.* sp.
- *P.* cf. *orientale*
- *Ilianodon lunanensis*
- ?*Forstercooperia* sp.
- Rhinocerotidae indet.

Lophialetidae
- *Lophialetes expeditus*
- *Breviodon* sp. nov.
- *Rhodopagus pygmaes*

Deperetellidae
- *Teleolophus medius*
- *T.* sp.
- *Deperetella sp.*

Helaletedae
- *Helaletis mongoliensis*
- Helaletidae indet.

Brontotheriidae
- *Protitanotherium* sp.
- *Titanotherium* sp.

Brontotheriidae
- cf. *Metatelmatherium* sp.
- Brontotheriidae gen. et sp. nov.
- *Protitan* cf.*robustus*
- *Rhinotitan quadridens*

Chalicotheriidae
- *Lunania youngi*

Anthracotheriidae
- *Gobiohyus* sp.
- Anthracotheriidae indet.

Entelodontidae
- *Eoentelodon yunnanense*

Mesonychidae
- *Honanodon* sp. nov.

Tillodontidae
- Tillodontidae indet.

Creodonta
- Creodonta indet.

Carnivora
- Felidae gen et sp. indet.
- Carnivora indet.

1. The Late Eocene sediments in the Lunan Basin: It is hereby proposed to adopt the nomenclature "Lumeiyi Fm." of Zheng et al. (1970) to designate the Late Eocene deposits within the Lunan Basin. This will include the nomenclature of past literature such as the "Lunan Formation" and "Lunan Deposits," and will include a large portion of sediments formerly recognized as a portion of the Oligocene Anrencun Group or Banjiao Formation. The Lumeiyi Fm. is characterized by containing numerous gray white marls. The deposits are distributed throughout the entire basin and contain relatively abundant fossils. A majority of these fossils are derived from the Lumeiyi Fm. at Lunan Prefecture and the Anrencun, Da-ke region. The fossil mammals collected from these deposits are documented in Table 3.

The taxa listed above include 29 genera containing 42 species with the majority being typical Late Eocene forms. Therefore, the age of the sediments bearing these fossils should be considered Late Eocene. A majority of the species are equivalent to those at Irdin Manha, Inner Mongolia. Some of the taxa that are produced from the upper sediments are equivalent to those at Shara Murun.

2. Oligocene sediments in the Lunan Basin: It is proposed here to adopt the "Xiaotun Formation" proposed by Zheng et al. (1970) for the nomenclature of the Oligocene deposits in the Lunan basin.

Chow (1958) was the first to diagnose Oligocene sediments in this basin based upon the presence of *Probrachyodus panchiaoensis*, *Brachyodus hui*, Anthracotheriidae indet., *Hyoboops hui*, *Bathriodon* sp., *Indricotherium parvum*, and *Parabrontops lunanensis*. However the precise distribution of the Oligocene sediments was ambiguous. It is precisely because of this ambiguity that a later controversy occurred regarding the subdivision of the Oligocene deposits. In 1970, after Zheng and others conducted relatively detailed and advanced investigations, their preliminary conclusions suggested that a set of tan-red sandy mudstones and muddy sandstones overlay the Lumeiyi Formation. The distribution of this set of sediments is noticeably smaller than that of the Lumeiyi Formation in addition to clearly differing in lithologic character. Within these beds they documented *Gigantamynodon*, providing an Early Oligocene age, and subsequently they erected the Xiaotun Formation. From the aspect of the material currently at hand, despite the relatively small amount of fossils discovered from within the Xiaotun Formation, the *Gigantamynodon* found here is extremely close to *G. giganteus* from Qujing, Yunnan, and clearly possesses the derived characters attributable to Oligocene species of *Gigantamynodon*,. These sediments are correlated to the Inner Mongolian Artyn Obo sediments.

3. The presence of problems: (1) There previously existed several controversies (Xu and Qiu, 1962; Chow and Tang, 1964) with regard to the sediments in the Anrencun-Dayemaban region. From the perspective of current material justifies the presence of the Oligocene Xiaotun Formation in this region. Moreover, there appears to be a stratigraphic unit underlying the Xiaotun unit that is younger than the Late Eocene deposits of the Lumeiyi-Lunan region (note: The relatively stratigraphically higher fossil localities described in the Zheng et al. (1970) all occur in the Anrencun-Dayemaban vicinity). However it is still too difficult to provide a detailed subdivision and diagnostic characters of these relatively higher stratigraphic units because data are currently limited and more advanced work is required.

(2) Since 1957 there have been continuous discoveries of Oligocene fossils from within the basin. These specimens clearly display derived characters attributed to the Oligocene, and it is possible they were derived from the Xiaotun Formation. However, due to the ambiguity of the precise fossil locality, further work is required to confirm whether or not they actually were derived from the Xiaotun Formation.

(2) The Caijiachong Basin at Qujing

The Caijiachong basin is Southwest of Qujing County Seat and isolated by mountain ranges. Extensive Early Tertiary exposures containing abundant vertebrate fossils exist within the basin. This is the only undeniable Oligocene locality in South China. The basin basement complex consists of Carboniferous sandstones and Permian limestones. The Paleogene deposits are situated at the west end of the basin in a fault contact with the basement rock, while on the east side they disconformably overly the basement. Lithologic thickness is over 480 meters and the angle of dip is less than 10° wnw. The most

prominent exposures lie at the northern end of the basin in the Caijiachong-Yangjiachong region. The deposits may be clearly divided from top to bottom into four depositional packages as follows:

1. Basal gravel, calcareous angular conglomerate, with upper section as purple-red massive sandstones and mudstones.

2. Tan-red mudstone grading to gray-green thinly laminated mudstone. After weathering, the mudstones exfoliate spherically and contain fossil fragments. Further up the section are light purple-red massive gray-green mottled marls containing clasts of quartz and limestone.

3. Gray-white, gray-green calcareous mudstones and limestones abundant in fossil vertebrates.

4. Massive limestone, white in color, structureless, and containing the gastropods *Planorbis* and *Parafossarulus*. The top is a thinly laminated "flocculent rock."

Among the four lithologic units described above, the third set of gray-white, gray-green calcareous mudstone and marls is the principle fossil producing unit in the basin. The deposits have undergone compressional fracturing and varying degrees of deformation.

Because collections from the fossiliferous units of the Caijiachong Formation reflect their age relatively clearly, there has been very little dispute for many years now.

In 1932, Professor. Yuelun Wang conducted a geological reconnaissance in Yunnan province and made a collection of several fossil mammals from the Caijiachong region. C.C. Young subsequently studied the material, and listed: Carnivora indet., Rhinocerotidae indet., and *Merycopotamus* sp. Based upon this latter taxon of Anthracothere, C.C. Young considered the age of the lacustrine sediments (or Unit 3) to be Pontian (Lower Pliocene[*]). Later, Colbert (1938) of the American Museum of Natural History believed the age of the Caijiachong Formation to be possibly middle Pliocene or younger than Pontian, based upon the stratigraphic distribution of *Merycopotamus* in India and Burma.

C.C. Young et al. (1939) supplemented the taxonomic list with the following taxa: *Cadurcotherium* cf. *ardynense*, Tragulidae or Cervidae indet. Anthroacotheriidae indet., Chelonia indet., and *Crocodillus* sp. Based upon the first taxon in this list, they revised the age of the Caijiachong deposits to be Early Oligocene, or equivalent to the Artyn Obo deposits of Inner Mongolia. That same year and in a different publication they again reconfirmed this diagnosis adding that they believed the sandstone deposits (or the upper section of Unit 1) underlying the fossil bearing units were Eocene in age and contemporaneous with the Lunan Formation.

Chow (1957) restudied the aforementioned specimens and reidentified the specimen initially assigned to *Merycopotamus* sp. as *Bothriodon* sp. At the same time he also confirmed the Early Oligocene age assigned to the Caijiachong Formation, stating that it is "possible to correlate this formation to Artyn Obo in Inner Mongolia, and the Maoming Series of Guangdong Province (at least partially)."

Xu (1969) conducted research on a new collection of specimens and reorganized the previous material by documenting the entire assemblage as including: Brontotheriidae gen. indet., *Cadurcodon ardynensis*, *Cadurcodon* sp., *Gigantamynodon giganteus*, cf. *Metamynodon* sp., Caenopinae gen. et sp. indet., *Indricotherium* sp., *Bothriodon chowi*, cf. and *Miomeryx* sp.

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[*] Now recognized as Late Miocene (WD).

Later, You et al. (1972) made another supplementary collection of several Oligocene fossils from the gray-white marls at Caijiachong and Yangjaichong. The supplemental taxa include *Indricotherium intermedium* Chiu, and *Gigantamynodon* cf. *giganteus.*

The total assemblage collected to date from the gray-green calcareous mudstones and marls from the Caijiachong-Yangjiachong region is listed below.[**]

Table 4. Faunal list from the Caijiachong Basin.

Brontotheriidae gen. indet	cf. *Metamynodon* sp.
Cadurcodon ardynensis	Caenopinae indet.
C. sp.	*Indricotherium intermedium*
Gigantamynodon giganteus	*I* sp.
G. cf. *giganteus*	*Bothriodon chowi*
G. sp.	cf. *Miomeryx* sp.

Among the aforementioned taxa, the species *C. ardynensis* correlates precisely to the Artyn Obo Formation according to the research of Chow, Xu, Yang, and others in Inner Mongolia. *Gigantamynodon giganteus* is slightly larger than the Artyn Obo species *G. cessator* although they are morphologically similar and are regarded as contemporaneous. The taxon cf. *Metamynodon* sp. is very similar to *Cadurcotherium* from the Oligocene of Western Europe, and *Metamynodon* from the Middle and Lower Oligocene of North America. *Bothriodon chowi* is a relatively smaller individual but shares the same fundamental characters with *B. velaunus* occurring in the European Lower Oligocene deposits of Ronzon, France. *Indricotherium intermedium* approaches *I. intermedium* from the Oligocene of Luoping, Yunnan, but is smaller. It may therefore be concluded from the fossil localities mentioned above that the fauna within the Caijiachong Formation presents an Oligocene complexion, or more precisely Lower Oligocene. There is a set of tan-red mudstones and sandstones in the lower section of the Caijiachong formation that is both relatively extensively distributed and massive. Formerly, Meinian Bian considered these sediments to be Late Eocene in age, or somewhat equivalent to the Lunan Formation. However this set of rocks is conformable with the overlying Caijiachong Formation, and displays lithologic characters exactly like the Xiaotun Formation in the Lunan basin (Early Oligocene), and for this reason they may also be Oligocene in age. In view of the absence of index fossils from these deposits, the precise determination of their stratigraphic age requires more advanced work.

A faunal correlation between the Oligocene localities in Yunnan, Shanxi, and Inner Mongolia is presented in Table 5.

(3) The Lijiang Basin

The Lijiang basin is currently the only verifiable Early Tertiary locality in Northwestern Yunnan Province. It is a north-south trending basin with overlying Quaternary sediments present in its center. The Early Tertiary sediments may be divided into two units. The upper section consisting of the Late Eocene Xiangshan Formation that is only locally exposed within the mountain arroyos of the eastern and southern slopes of Xiangshan mountain, and is present as a lacustrine sedimentary complex composed of brick-red sandy conglomerates, sandy mudstones, and gray-white mudstones. The sediments are not massive, being only 150-200 meters thick. Unconformably underlying these sediments is the "Lijiang Formation." These sediments have been subjected to the affects of strong orogenic activity in western

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[**] See also: Wang, B.Y. and Zhang, Y.P., 1983; New finds of fossils from the Paleogene of Qujing, Yunnan. *Vert. PalAs.* **21**(2), pp. 119-128.

And Wang, B.Y. and Meng. J., 1986; *Eucricetodon* from the Lower Oligocene of Qujing, Yunnan. *Vert. PalAs.* **24**(2), pp. 110-120 (WD)

Table 5. Faunal correlation of South and North China Oligocene localities.

	Lunan, Yunnan	Qujing, Yunnan	Luoping, Yunnan	Yuanqu, Shanxi	Ardyn Obo, In. Mong.
Brontotheriidae					
Brontotheriidae gen. et sp. indet.		x			
Parabrontops gobiensis					x
Titanodectes ingens					x
Embolotherium andrewsi					x
E. grangeri					
Chalicotheriidae					
Schizotherium avitum					x
Helaletidae					
Paracolodon curtus					x
Colodon inceptus					
Amynodontidae					
Cadurcodon ardynensis		x			x
C. sp.		x			
Gigantamynodon giganteus	x	x			
G. cf. *giganteus*		x			
G. sp.		x			
G. cessatar					x
cf. *Metamynodon* sp.					
Caenopinae indet.		x			
Indricotheriidae					
Indricotherium chuchingensis		x			
I. intermedium			x		
I. parvum	x				
I. sp.					
Hypertragulidae					
cf. *Miomeryx* sp.		x			
Miomeryx altaicus	x				x
Lophiomeryx angarae					x
L. gebiae					
Anthracotheriidae					
Anthracotheriidae indet.					x
Bothriodon chowi		x			
Brachyodus hui				x	
Entelodontidae					
Archaeotherium (?) sp.					x

Yunnan and are currently exposed at an altitude of over 2400 meters. Additionally, most localities have undergone compressional deformation due to frequent fault activity. The lithologic character may generally be distinguished from bottom to top as follows. Interbedded purple-red coarse sandstones and mudstones with a small amount of vertebrate fossils. Gray-white calcareous mudstones grading to thinly laminated brick-red mudstones and containing abundant vertebrate fossils, representing the principle fossil bearing unit in this set of deposits. Superimposed upon these are thinly laminated brick-red mudstones that grade to brick-red muddy sandstones and thinly laminated sandstones bearing a few fossils. Underlying these sediments is the Lijiang Formation which is extensively distributed around several localities such as at Lijiang, the high mountain regions east of Heqing, and Xiangshan Mountain at

Lijiang. Its lithologic character consists of a massively bedded limestone breccia. It geologic age predates the Late Eocene.

The Xiangshan Formation within this basin was described by Zhao (1965) as being the gray-white and gray-green calcareous mudstones at the top of the Lijiang Formation. It was in these deposits that he collected several mammalian fossils. In 1972, an IVPP expedition made a second relatively substantial fossil collection from these sediments. The entire assemblage is recorded as follows: *Eoentelodon likiangensis* sp. nov., *Anthracokeryx* sp., *Anthracothema* sp., *Hypertragulidae* gen. et sp. indet., *Breviodon* sp. nov., *Teleolophus* sp., *Depretella* sp., *Lophiodon* sp., *Schlosseria* sp., *Honanodon hebetis*, *Honanodon* sp., Hyaenodontidae indet., Creodonta indet., *Amynodon* sp., *Caenolophus* sp., *Prohyracodon* sp., *Lunania* cf. *youngi*, *Eomoropus* sp., and Brontotheriidae gen. et sp. indet. As these taxa are very close to the Late Eocene faunas at Lunan, Lushi, and Inner Mongolia, there is no doubt that an age assignment of Late Eocene may be provided to the Xianshan Formation.

The Lijiang Formation has been referred to as the "massive limestone breccia" or "Lijiang breccia" as designated by geologists such as Jinglan Feng and others in former years. The "Lijiang Formation" as revised by Jiao (1965) includes the basal section in addition to the massive limestone breccia and the massive red sandstones in the central part of the section. Jinglan Feng and others believed the age of these rocks to possibly be equivalent to the Early Tertiary limestone breccias in eastern Yunnan. Jiao (1965) concurred that their age may be Early Eocene to Paleocene, or may even include some Cretaceous. From observations of the components of each formation this set of rocks and the overlying Xiangshan Formation may be recognized as being extremely different and independent, with the age of the Lijiang formation being pre- Early Eocene. However, to date, as there has been no diagnostic fossil found to diagnose an age, and it is necessary to wait until more advanced work is conducted to provide more evidence.

(4) Other Localities

1. The Shizong Basin at Luoping is located southeast of the Qujing Basin in eastern Yunnan. Specimens from the Cenozoic sediments of this basin are rare. In 1959, when Chow and Xu were studying *Indricotherium* from the Xinjiang Autonomous region, they described a fragment of this genus they referred to as *Indricotherium* sp. recovered from the village of Datong, at Shizong, and assigned it an age of Middle to Late Oligocene. In 1960, an IVPP Yunnan field party collected fragments of *Indricotherium* from an argillaceous lignite by the side of the road at Shizong. Later, Qiu (1962) studied this material noting it as *Indricotherium intermedium* Chiu and Indircotheriinae gen. et sp. indet. Among these, *Indricotherium intermedium* is more derived than *I. parvum*, but more primitive than *I. grangeri*. He estimated the age of the deposits to be either earliest Middle Oligocene or latest Early Oligocene(?). The character of these fossils illustrates the presence of Oligocene sediments in the Shizong region, however more research is required to solve problems concerning the sedimentary distribution and chronologic subdivisions.

2. The Yongsheng Basin at Ninglang is located to the east of the Lijiang Basin. According to the Regional Stratigraphic Chart of Yunnan Province (first draft) and data from the Preliminary Regional Survey of Yunnan Province, there are 800 meters of sediments exposed in this region. The lithologic character at the base consists of gravels and conglomerates. The upper section is a purple-red mudstone grading to shale. Former workers believed the age to be Eocene based upon paleobotanical and invertebrate fossils contained within the sediments. Ostracods include *Cypris decaryi*, and charophytes including *Cyrogona qianjiangensis*, *Obtusochara brevovalis*?, *O. subcylindrica*?, and *Charites* sp. Also documented are angiosperm fruits. From the perspective of the lithologic characteristics of this basin's sediments there appears several similarities with the Lijiang Basin. Moreover the stratigraphic thickness is greater than in the Lijiang Basin. Therefore this region has important implications for the study of Early Tertiary sediments in northwest Yunnan, however a verifiable geologic age must await further research.

II Late Tertiary

The Neogene rocks of Yunnan Province constitute an extensive body of sediments among the Cenozoic deposits of Southwest China. Stratigraphic units containing mammalian fossils are relatively abundant, with their sedimentology dominated by sets of dark colored strata consisting of extensively distributed lake and pond deposits containing lignitic and coal bearing units. Exposures of these sediments display extreme variation of thickness between individual localities. The thickest exposures, such as in the Ailao Mountain region, reach up to 2,000 meters, while the thinnest exposures such as in the Zhenxiong region only attain several tens of meters. Generally the thickness is approximately 200 meters.

Although the Neogene deposits in Yunnan Province are extensively distributed, lithologically easy to distinguish, and contain coal systems, their stratigraphic ages are still extremely provisional as there are inconsistent diagnoses with a majority of localities generally diagnosed as Miocene-Pliocene. The reasons for these conditions are perhaps related to the Quaternary overburden as the majority of the Neogene subdivisions are based upon the data of drill logs from different regions such that interregional correlations are difficult. Some of the preliminary Miocene-Pliocene subdivisions are dependent on lithologic character alone. The majority of sediments that contain thick coal deposits, coal seams, or calcareous shales have been assigned to the Pliocene. Age assignments at several localities are bases upon paleobotanical material such as at Dayao, Kunming, Yuxi, Zhongduan, and Sanying. Others localities base their age assignments upon the presence of invertebrate or vertebrate fossils. In addition to Xiaolongtan, at Kaiyuan, there are cross sections like this at Zhaotong, Yuxi in addition to Shagou and Banguo at Yuanmou.

The type section for Neogene sediments containing relatively abundant vertebrates in Yunnan Province is located at Xiaolongtan, at Kaiyuan, where the "Xiaolongtan Formation" is described. In addition, there are many localities representing the Pliocene, including the "Yanpeng Formation" in the Jianshui region; the "Hotou Formation" in the Kunming region; the "Ciying Formation" in the Qujing region; the "Tuobuka Formation" in the Zhaotong, Tangdan region; the "Miaobalishi Formation," in the Zhenxiong region; the "Jianquancumianyan Formation" in the Zhongdian region, and the "Nasaba Formation" in the Lancang (Mekong River) region. Miocene sediments present in the Zhongdian region are designated the "Shuanghemou Formation," and in the Jianshui region are designated as the "Xiaolongtan Formation," however there are other localities with a generalized Miocene-Pliocene designation such as the "Xiaolongtan Formation" that is referred to at such localities as in the Luxi to Mi-le region, and in the Gejiu to Qiubei region.

A description of the principle region's stratigraphic cross-sections in addition to their fauna, flora, and geologic age correlation is provided as follows.

(1). The Xiaolongtan Basin at Kaiyuan: The Xiaolongtan Basin is situated northwest of Kaiyuan County seat. It contains sediments consisting of a set of gray, gray-white claystones, siltstones, mudstones, brown carbonates and more, with a general thickness of over 600 meters. From top to bottom the section is as follows:

Hetou Formation:

4. Interbedded gray, gray green claystones, siltstones, and sandy conglomerates, containing fossil plants, gastropods, and vertebrates..... 150m

Xiaolongtan Formation:

3. Marls..... 100m
2. Xiaolongtan coal system containing vertebrates 250m
1. Dongjieqiao clays and sandy gravels..... 100m

A preliminary list of the vertebrates from the Xiaolongtan coal system is presented as follows: *Dryopithecus kayuanensis* Woo, *Chleuastochoerus* cf. *stehlini* (Schlosser), *Zygolophodon chinjiensis* (Osborn), *Gomphotherium xiaolongtanensis* Chow and Chang, *G*. cf. *macrognathus* Pilgrim, *Potamochoerus* sp., ? *Hippopotamus* sp., *Rhynchotherium* sp., *Listriodon* sp.

The age of the coal system at Xiaolongtan, Kaiyuan, was considered to be Early Pliocene by C.C. Young et al. (1938) based upon several suid teeth diagnosed as *Chleuastochoerus* cf. *stehlinii*. This taxon may be correlated to the *Hipparion* red clays of North China. For a long time henceforth, the absence of further fossil evidence restricted dispute regarding the stratigraphic subdivision or faunal age. It was not until February of 1956 when colleagues from the Southwestern Geological Office of the Ministry of Geology discovered a set of teeth northwest of the village of Xiaolongtan. This collection of five lower molars was diagnosed as a dryopithecine primate by Rukang Wu who later erected them as *Dryopithecus kaiyuanensis* (Woo 1957, 1958) and which were considered to resemble *Dryopithecus punjabicus* from the Siwaliks of the Indian subcontinent. At that time he diagnosed the age of the Xiaolongtan coal system to be Pontian (Early Pliocene) based upon the co-occurrence of *Tetralophodon* .

The publication "Correlation and Characteristics of the Tertiary and Early Quaternary Mammalian Faunas of South China," (Chow, 1957) discussed the age of the South China Early Pliocene *Dryopithicus* fauna and proposed that, regardless of the individual faunal elements or the entire fauna as a whole, the Kaiyaun mammals were nearly identical to those in the faunas from the upper part of the Lower Siwaliks or the lower part of the Upper Siwaliks of India. Moreover, the suid *Chleuastochaerus* cf. *stehlini* described by Young et al. (1938) also approaches closely, or is conspecific with those from the Siwaliks. For this reason the Kaiyuan fauna was considered a clear correlative to the Siwaliks. There are several characteristic Siwalik taxa found at Kaiyuan that to date have yet to be found in the North China *Hipparion* red clays. Most recent research upon Xiaolongtan specimens indicates a confirmation of the points proposed by Chow (1957), and moreover suggests the age of the Xiaolongtan system to predate the North China Baode Formation and its equivalent *Hipparion* red clays.

In addition to the relatively abundant proboscidean specimens in the Xiaolongtan beds, there are several species of suids. And dissipate the rather fragmentary nature of the specimens, an isolated upper third molar appears relatively close to *Potamochoerus uliginosus* from the Siwaliks of India. Another lower second molar is similar to *P. salinus* from the Siwaliks, and there are upper incisors attributed to several species of *Listriodon*. These are quite distinct from the two species of *Potamochoerus* known from North China.

With regard to the geologic age of the Xiaolongtan system at Kaiyuan, there are many inconsistencies between former hypotheses, with some workers considering it Early Pliocene and others recognizing it as Miocene. A vast majority of workers, however, recognize it as being Late Miocene-Early Pliocene. The fossil mammals from the Xiaolongtan coal system indicate their age correlates to the upper part of the Lower Siwaliks, or the Chinji Formation. Currently, most stratigraphers studying the Siwalik deposits consider the Chinji Formation Late Miocene in age, or equivalent to the Tunggur sediments of Inner Mongolia. Therefore it appears more appropriate to establish the age of the Xialongtang Fauna as Late Miocene based upon the presence of *Listriodon* incisors which is one of the smallest of the species found in China. As this genus has yet to be found in the Pliocene of China, the Xiaolongtan Formation is hereby assigned to the Miocene.

The age of the Hetou Formation in the upper section was discussed by Hu and Hu (1958) in "The Geologic Age of the Hetou Coal System at Xiaolongtan, Kaiyuan." Based upon an antler from the genus *Rusa* discovered in the Hetou coals, they believed the age to be either Late Pliocene or Pleistocene. Currently, the chart published on the Yunnan Regional Stratigraphic Subdivision considers the age of the Hetou Formation to probably be Pleistocene. Naturally, this hypothesis requires more vertebrate fossils for verification.

2. Shagou at Yuanmou: Shagou is situated in the southwest corner of the Yuanmou Basin, with the Shagou Formation present in a sinuous configuration extending from the south to the north of Shagou. The predominant lithology is variegated mudstones, with the lower section as calcareous sediments grading into lignites. At the base are conglomerates. Thirty-five meters of exposure are present.

Vertebrate fossils from Shagou Formation include *Enhydriodon* cf. *falconeri,* ? *Serridentinus* sp., *Dicerorhinus* sp., and *Cervus* sp. Among these taxa, an aquatic mustelid was collected in 1958 by colleagues of the Yunnan Provincial Office of Geology which was subsequently sent to Professor Minchen Chow (Chow, 1961). The other three taxa are specimens documented by Chow, Qiu, and others in a 1961 field report of the Shagou Formation.

The *Enhydriodon* specimen from Shagou was recognized by Chow (1961) as being identical to *Enhydriodon falconeri* Pilgrim produced from the Dhok Pathan Formation in the upper section of the Middle Siwaliks, or Upper Pliocene. Therefore, Chow designated a Late Pliocene age to the Shagou Formation. The remaining taxa are based upon a preliminary diagnosis, and it is possible that these data have become lost. It is not possible to utilize these other taxa for a precise age diagnosis, but from a general perspective it is basically reasonable to equate them to the Dhok Pathan Formation of the Siwaliks.

(3) Banguo Basin: The Banguo Basin is small in scale and located northwest of the Yuanmou Basin. Exceptionally well developed late Cenozoic deposits are present principally represented as fluvio-lacustrine sediments. From top to bottom, exposures exist as follows:

Palang Fm. (Q4) tan-red sandy clays (paleosols).....1.5m

Yuanmou Fm. (Q1) light purplish cross bedded sandstones..... 12.7m

----------Disconformity----------

Shagou Formation (N2/2) fine red, green, light purple variegated mudstones with gravels at the base..... ~35m

The following taxa are produced from within the Shagou Formation of the Banguo Basin: *Stegolophodon banguoensis,* S. aff. *banguoensis, Stegodon primitivum, Stegodon* sp., *Chilotherium yunnanensis,* ? *Hipparion* sp., Hyaenidae indet., *Sus* sp.

The Banguo Basin mammalian fossils were principally collected in 1972 by two field excursions from IVPP in collaboration with colleague Xingyong Zhang of the Yunnan Provincial Museum. These collections were divided mutually between the two institutions. After undergoing study by Liu et al. (1973), and You (1978) it was believed the mammal-bearing varicolored mudstones of the Banguo Basin correlated to the Shagou Formation in the Yuanmou Basin, or were Late Pliocene in age.

(4) Zhaotong Basin: The Zhaotong Basin is situated in the northeast section of Yunnan Province. Previously, the Cenozoic deposits within the basin were subdivided into the two general categories of Upper Tertiary and Quaternary. The Yunnan Regional Stratigraphic Table (first draft) notes the Pliocene System in the Zhaotong region as the Tuobuka Formation, with a lithology consisting of a set of loosely consolidated conglomerates grading to silts, clays, carbonates, and sandstones. The lower section contains ten lignite units, and the upper unit frequently contains limonite zones. Its thickness reaches 120 meters. The section in the Zhaotong region is as follows:

Tuobuka Formation:

8. White ferruginous clays..... ~2.5m
7. Brown-yellow limonite unit.....0.5m
6. Well cemented basalt gravels.....1-4m
5. Black clays 0.5-5m
4. Loosely consolidated small gravels and fine sands.....25m
3. Marls producing *Tulotomoides* sp.....several cm
2. Interbedded clays and fragmentary coals 0.5-1.7m
1. Brown-yellow grading to black and white inconsistent calcareous lignite complex producing *Mastodon* sp.....several cm to 15m

At the end of 1960, Minchen Chow and others noticed a collection of fossil mammals in the Yunnan Provincial Museum collected from Zhaotong County. Preliminary diagnosis (Chow and Zhai, 1962) list the taxa as follows: *Felis* sp., *Equus* cf. *yunnanensis,* Bovidae, *Sus* sp., *Tapirus* sp., *Muntiacus* sp., *Zygolophodon* sp., *Elephas* sp. (cf. *E. hysudricus*), *Stegodon zhaotongensis* Chow and Zhai.

Chow and Zhai (1962) believed the majority of these taxa represent the Late Pliocene to Pleistocene. Among these specimens, the equid consisted only of a single upper molar comparable to *Equus yunnanensis,* an Early Pleistocene taxon of South China (Yunnan and Guangxi Provinces) and Burma. The occurrence of *Zygolophodon* does not postdate the Early Pleistocene. The new species of *Stegodon* may represent the Pliocene to Pleistocene based upon its dental morphology, however because it is relatively large and is morphologically more derived than the Southeast Asian Early Pleistocene *Stegolophodon latidens* (from Burma, India, and other localities), its age cannot predate the Quaternary. A species of true elephant (cf. *Elephas hysudricus*) is rather commonly found in the Early Pleistocene of Southeast Asia. Consequently, from the perspective of the entire fossil assemblage, the age of the Zhaotong fauna appears to be Early Pleistocene and may be correlated to the Yuanmou Equid Fauna of Yunnan (Colbert, 1943; Pei, 1961) and the upper Irawaddy fauna of Burma (Colbert, 1943).

Based upon conclusions of former workers, the age of the Tuobuka Formation at Zhaotong should be considered Early Pleistocene, or equivalent to the Yuanmou Formation. However, because of the paucity of material in addition to the lack of precise locality and stratigraphic data, this assessment must await further verification. Additionally, the authors of this text have received a fragmentary specimen representing *Rynchotherium* from the Zhaotong region, but again, the precise locality and stratigraphic position is unclear. The specimen consists of a broken anterior section of a left lower third molar which, after undergoing study by Minchen Chow and others, is believed unquestionably to belong to *Rynchotherium.* Subsequently, they erected the new species *Rynchotherium huananensis* (Chow and Chang, 1974). Its age is considered Pliocene (see below).

In conclusion, it is possible to demonstrate the presence of Pliocene deposits underlying the Yuanmou Formation in the Zhaotong region. However, due to the deficiency of stratigraphic data it is difficult to establish a boundary, such that the discovery of more material is required to outline a definitive fossil horizon to diagnose its geologic age.

(5) The Yuxi Region: Yuxi is situated in the center of Yunnan Province south of Kunming. The sedimentary exposures of this region exist as follows:

Pliocene:

2. Yellow-red moderate to coarse sands grading to thinly laminated clays …… 5m
1. Light yellow, yellow-gray gravels or sandy gravels ……27m
Miocene
4. Upper unit as gray-white gravels and sands, that downward gradually alter to sandy calcareous clays that grade into lignites ……29-99m
3. Gray-green clays partially grading to calcareous clays and lignites. Produces gastropods …… 5-36m
2. Gray sandy clays grading to sandstones and mudstones, and calcareous mudstones grading to lignites……10-93m
1. Massive lignites, calcareous clays and sandy clays, being thickest in the middle of the basin…… 0-96m

Both vertebrates and plants are produced from the Miocene series. In 1972, while the authors of this text were conducting work in Yunnan Province, colleague Weihua Wang of the Fengyi Songmaopo Coal Mine Geological Investigation Team of Dali County, Yunnan, transmitted a piece of elephant derived from the Yuxi Coal Mine. Preserved is merely the last dental loph which is extremely close to *Zygolophodon chinjiensis* from the Xiaolongtan coal system of Kaiyuan. Therefore, it may be possible that the Yuxi fossil bearing deposits are equivalent to the Xiaolongtan Formation.

(6) The Jianquan-Eryuan Region: Several small Late Tertiary basins are distributed in the Jianquan-Eryuan region of northwest Yunnan Province. To the northwest of Jianquan there exists a set of gray-yellow sands and shales. Approaching the top of the section are gray multistoried marls among which are two to three productive bituminous seams, the thickest of which does not exceed 2.5 meters. This lithologic system is designated the Shuanghemou Formation and is measured as follows:

Shuanghemou Formation
3. Upper section as light gray argillaceous siltstones. Middle section as light yellow massively bedded fine to coarse grained arkose grading to coals. Lower section as light gray thin to moderately laminated argillaceous silts..... 36-118m
2. Deep gray moderately thickly bedded marls producing plants and pelecypods……80m
1. Gray, yellow-brown moderately massive fine to moderate grained calcareous sandstones, and tuffaceous sandstones grading to coals..... 247m

Several species of fossil plants contained within these deposits were diagnosed by Junrong Tao as follows: *Quercus* cf. *relongtanense* Colani, *Phoebe pseudolanceolata* Colani, *Dryophyllum yunnanensis* Colani, *Paliurus* sp., and *Cinnamomum* sp. The age is believed to be Late Miocene.

The Jianquan igneous depositional complex: Also designated the "Jianquan Trachyte Complex." Upper section as gray-green trachytes and trachyte porphyry. Portion of lower section contains gray-white massive tuffaceous sandstones and sandy conglomerates. Plant fossils are produced here, and the geologic age is possibly Early Pliocene.

Sanying Formation: In the Eryuan-Sanying region south of Jianquan there is a set of light gray-green, gray-yellow, pink and other variegated and weakly cemented siltstones and claystones which grade into multistoried lignites. The total thickness is 200-500 m. Fossil plants produced from these deposits were diagnosed by Junrong Tao as follows: *Quercus semicarpifolia* Smith, *Q. spathulata* Seem, *Q. gilliana* R. & W., *Q. monimotricha* H.- M., *Q. pannosa* H.- M. *Acer paxii* Franch, *A. franchetii* Pax, *Populus* sp., *Pinus yunnanensis* Fr., *Abies* sp. The age of these deposits is believed to be Late Pliocene

(7.) Jingyu Basin: The Jingyu Basin is located in the southwest section of Yunnan, west of the Jingyu county seat. Exposures of Cenozoic deposits within the basin are as follows (from Yuzhu You et al. "Investigation on the Jingyu Basin, Yunnan"):

Quaternary: eluvial deposits, slope wash, and alluvial deposits.
Pliocene:
Gray-white sandstones and fine gravely sands grading to purple-red silty mudstones containing coal seams. Basal section as purple-gray conglomerates. >200m
Miocene:
Upper section as gray, gray-white and deep gray sandy mudstones grading to gray siltstones and purple-red sandy mudstones.....>1000m
Middle section as brown, deep gray, and black mudstones and silty mudstones grading to massive calcareous extremely fine to fine sandstones, oil sands, and lignites. Contains fragments of fish, ostracods, gastropods, and plants .....>400m
Lower section as gray, tan-gray massive sandstones, and conglomerates grading to purple mudstones .....~100m

There is another Cenozoic basin just north of the Jingyu Basin called the Jingdong Basin, within which is a set of Tertiary coals and Quaternary diluvial gravels over 100 meters thick. The coal deposits at the mine are reputed to produce black fossil bone.

From the data of the several aforementioned basins, it may be observed that the Neogene of Yunnan may be divided into two stratigraphic units, based upon the mammalian fossils. The Miocene, or more precisely the uppermost Miocene, may be represented by the Xiaolongtan Formation,. The second unit is represented by the Shagou Formation and belongs to the Upper Pliocene.

A general correlation between the Neogene deposits within Yunnan and related sediments within and outside of China may be proposed as in the following table:

Table 6. Correlation of Cenozoic sediments in Yunnan.

		Yunnan	Shaanxi	Correlative formations	India
Pliocene	Upper	Shagou Fm.	Lantian Fm.	Jingle Fm.	Dhok Pathan
	Lower		Bahe Fm.	Baode Fm.	Nagri
Miocene	Upper	Xiaolongtan Fm.	Guanjiacun Fm.	Xiawengshao coal beds (Guizhou) Tunggur, Inner Mong.	Chinji
	Middle		Lengshuigou Fm.	Cixian (Hebei) Puzhen Fm. (Jiangsu) Shanwang Fm. (Shandong), Dongshapo (Henan)	Kamlial
	Lower				

III The Quaternary

The earliest research on the mammalian fossils and subdivision of Quaternary deposits in Yunnan Province was conducted in 1932 in a paper by C.C. Young documenting fossil vertebrates discovered in Yunnan where he described a Middle Pleistocene mammalian fauna from a cave above the Fumin River. Jia (1938) also reported on caves and their deposits at Qiubei, Heqinglong, overlying rivers. Colbert (1940) published on the so-called Makai* mammalian fauna based upon a fossil collection from Yuanmou made by Walter Granger. Colbert believed the deposits within the Yuanmou basin to be Early Pleistocene in age. In a paper from "The Geology of Yuanmou Basin, Yunnan Province," the fluviolacustrine deposits within this basin were designated the "Yuanmou sediments" and were regarded as the type section for South China. However, from the period of 1920 to just prior to 1949 work on the Quaternary of Yunnan slowed to just fragmentary and preliminary phases of research.

After the establishment of the People's Republic of China, workers in the fields of stratigraphy, geomorphology, glaciology, vertebrate paleontology, paleoanthropology, and paleobotany initiated extensive research upon the Quaternary geology of Yunnan.

Intermontaine basins in the Yunnan region are scattered extensively, vary in size and form, are extremely rich in Quaternary sediments, and contain complex lithologies including fluviatile, lacustrine, colluvial, and glacial facies in addition to pyroclastic flows and cave sediments. Fossil discoveries have been made continuously within many of the basin deposits, however there is also a deficiency of fossil evidence in many of the basins creating difficulties for stratigraphic correlation. Therefore, it is only possible to use the principle localities and their representative stratigraphic units as a basis for correlation. Other localities may only be correlated by lithologic character.

Lower Pleistocene

The Early Pleistocene is primarily represented by fluvio-lacustrine deposits. During the beginning of the Pleistocene the entire region of Yunnan inherited lacustrine sedimentation reworked from the Late Tertiary, with most of the sediments consisting of sands, gravels, and clays. A majority of the basins contain low grade lignites. Due to the influence of tectonic oscillation, the basin sediments frequently appear as fining upward cycles. That is to say that some are represented as cyclothems. Those basins known to have these deposits include the Zhaotong Basin, Yuanmou Basin, Erhai Basin, Yongjian Basin, Midu Basin, Lake Shipingyilong, and the region of Yuxiu, in addition to such basins as Baoshan, Longling, Mangshi, Tengchong, Lianghe, and Longquan. At Tengchong, in western Yunnan, the rocks are derived from igneous sources. At Ludian and the Qiaojia region of northeastern Yunnan the deposits are glacially generated, while in Eastern and Southeastern Yunnan there occur isolated cave deposits.

1. The coal-bearing Zhaotong Formation is distributed around Zhaotong and neighboring regions. The Cenozoic cross-sections and fossils produced from these sediments have already been discussed above. The material collected from these deposits has traditionally been subdivided into two sections: the upper section designated as Quaternary, and the lower section designated as Tertiary. The lower Tertiary section is the so-called Tuobuka Formation principally composed of gray-black, gray-white clays grading into multistoried lignite beds in the center of the basin. These sets may reach up to 300 m in thickness and gradually attenuate towards the basin margins. Several mammalian fossils have been collected within the lignite by the Yunnan Provincial Museum that confirm the presence of two geologic ages. The presence of *Equus yunnanensis* and *Stegodon zhaotungensis* suggest an age of Early Quaternary.

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* Read Majie in Pinyin romanization (WD).

Therefore, the previously designated Neogene rocks should be considered partially Lower Pleistocene. However, as the lower section has been confirmed to be Tertiary, further work is required to define the Plio-Pleistocene boundary here. Initially, it appeared as if the Quaternary of the upper section should be Middle to Upper Pleistocene.

2. The Yuanmou Formation of the Yuanmou Basin is typically fluvio-lacustrine and is principally distributed within several locations encompassing the Yuanmou Basin itself, the Banguo Basin, and at Yongren. This formation is composed principally of the regionally eroded basin terrain.

Research upon the Yuanmou Formation has a relatively long history, with much work being conducted in the last half century. In addition, many recent discoveries unearthed over the past several years have deepened the comprehension of these rocks. In the past, the so-called Yuanmou Formation included the Early Pleistocene deposits, the Pliocene Shagou Formation, and the Middle Pleistocene Nabeng Formation. The exact thickness of the Yuanmou Formation is 200 m. Because vertebrate fossils are relatively abundant and exposures are relatively good, the region exposing the Yuanmou Formation may be considered one of the principle Quaternary localities in South China, and may be correlated to the Nihewan Formation of North China. Relatively good exposures of the Yuanmou Formation may be observed southwest of Yuanmou County seat at Yangliu Village, and to the east in the vicinity of Madahai Village. The strata are generally divided into an upper and lower section as follows:

Upper section: Predominantly light purple, gray-white sandstones grading to light purple sandy clays and yellow-green clays bands.

Lower section: Predominantly light purple sandy clays grading to gray-white sandstones and blue-gray clay bands.

Do to the effects of structural movements much of the Yuanmou Formation is dipping generally eastwards 5-10° and is associated with faulting and deformation. There is a disconformable contact with the underlying Shagou Formation (N2/2). The fauna of the Yuanmou Formation was previously recorded by Colbert (1940) to contain six taxa, however in recent years IVPP has successively recovered a large collection of fossil mammals, diagnosed by colleagues Yuzhu You, Guoqin Qi, Hoyi Liu, and Yuerong Pan as containing the following: *Canis yuanmoensis, Equus yunanensis, Vulpes* cf. *chikushanensis, Stegodon yuanmouensis, S. zhaotongensis, S.* sp., *Cynailuris* sp., *Felis tigris, F. pardus, F.* sp., *Sus scrofa, S.* sp., *Muntiacus* cf. *bohlini, Hyaena licenti, H.* sp., *Cervus* sp., *Rhinoceros* cf. *sinensis, R.* sp., *Rusa* sp., and Bovidae indet. In addition to the preceding taxa are fish and trionychid turtles.

3. The Songmaopuo Formation in the Erhai Basin is distributed among such localities as the southwest Erhai Basin, the northern margin of the Youngjian Basin, and the western margin of the Midu Basin. In the region around Songmaopuo, Fengyi, the exposures are generally present as follows:

Upper section: Gray-white, gray-green very fine to fine sandstones and mudstones with many low grade lignites.....8-40 m.
Middle section: Gray-white sandy clays .....25 m.
Lower section: Yellow-brown, gray-green sandy conglomerates.....40-106 m.

Vertebrate fossils are contained in the upper section's mudstones and lignites including[*]: *Stegodon* sp., *Elephas* sp., *Tapirus* sp., and *Bison* cf. *palaeosinensis.*

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[*] Diagnosis from Guoguang Zhao.

In addition to these taxa, an IVPP expedition in 1972 received a molar assigned to *Stegodon preorientalis*[*] from a worker of the Songmaopuo Coal Mine that was reputed to be derived from the lignite beds.

In the past there was controversy regarding the age of the Songmaopuo Formation with some considering it to be Middle or Upper Pleistocene. Guowang Zhao considered it Early Pleistocene based upon its faunal characteristics and primarily the occurrence *Stegodon preorientalis*. From the perspective of current material, this species of elephant does not exists prior to the Quaternary and is extensively distributed among localities of South China, occurring generally in the Early Pleistocene, although occasionally appearing in the Middle Pleistocene. Therefore, it is appropriate the Songmaopuo Formation be assigned to the Early Pleistocene.

At the northern margin of the Yongzhian basin around Hedicun, Yaowang, and other localities, are exposures of a 50 meter set of white, light purple, and pink sandstones and gravels that may be correlated to the Songmaopuo section. The Songmaopuo Formation exposed in western Midu may generally be divided into three sections: The upper section as lignites, the middle section as sandstones, and the lower section as clays, with its greatest thickness reaching up to 480 m. Fossils have been produced here. The Songmaopuo Formation unconformably overlies Jurassic rocks.

4. In western Yunnan each basin contains extensively distributed Early Pleistocene coal-bearing units, but the coal-bearing formations of the Baoshan-Tengchong region are replaced by lacustrine deposits composed of gray, gray-green, gray-black clays and multistoried lignites, with a general thickness of several tens of meters, and at their thickest reach in excess of 300 m. Due to the paucity of vertebrate fossils, the problem of whether or not these sediments represent different geologic ages is a matter for later research.

5. The Luowu moraines are exposed in the northeastern Zhaotong - Qiaojia region of Yunnan and are generally distributed among the higher elevations. The moraines are composed of various gravels that have become infiltrated by clays. The gravels maintain surface abrasion marks. Cobble diameter varies from several centimeters to one meter with deposits varying in thickness from 5-30 m. There is still a problem diagnosing the geologic age of these deposits.

6. The Xigeda Formation is principally distributed along both sides of the Jinshajiang River on the border between northern Yunnan and Sichuan, in addition to the localities of Yongren and Yuanmou. The Xigeda Formation consists of a set of gray, gray-green, and gray-yellow thinly laminated argillaceous silts with a thickness greater than 100 m. The problem of their genesis is relatively complicated as some workers consider them glacial sediments. Wanpo Huang and others believe them to be predominantly fluvial.

7. The Tengchong volcanics are distributed throughout such localities as Tengchong, Lianghe, and Longling in western Yunnan and consist of neutral to basic andesites and basalts, in addition to a small amount of other pyroclastics and carbonates. They reach their maximum thickness in the Tengchong region and may attain 1260 m unconformably overlying the Late Tertiary lacustrine sediments.

II Middle Pleistocene

The Middle Pleistocene deposits of the Yunnan region are mainly represented by sediments including fluvial outwash, piedmont diluvium, and cave deposits, in addition to regions which house eluvial deposits, slope wash, and glacial debris. At the end of the Middle Pleistocene the vast majority of lacustrine basin sedimentation gradually ceased due to tectonic influences. Intensified orogenic effects

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[*] Diagnosis from Yingjun Tang.

combined with sustained and increased erosion caused the widespread deposition of coarse clastics throughout the Yunnan region. This is exemplified in such regions as the piedmonts on the eastern mountains of the Yuanmou Basin where a set of deposits consist predominantly of gravels designated the Shangnafeng Formation; the blocks and gravels within the Anning River Valley; the Panlong River gravels northeast of Kunming; the piedmont gravels on the eastern mountains of the Jingdong Basin in addition to the Erhai Basin, Dongchuan, and other regions, all of which display sediments that are typically composed of coarse clastics. In the regions where there are well developed carbonates, such as in central, eastern, and southeastern Yunnan, the Middle Pleistocene is characterized mostly by cave deposits, calcareous breccias, and sandy clays, in addition to tuffas. Coarse clastics are also the predominant sediments in many of the caves as exemplified by those above the Fumin River, Huahong Cave neighboring Kunming, Shanren Cave, and others in Xichou County. Although there are eluvial and slope wash deposits extensively distributed on the high plateaus and around the margins of each of the basins, they do not possess diagnostic or characteristic lithologies. Isolated occurrences of glacial deposits are present only in the high mountain regions of northwest Yunnan.

1. The Shangnafeng Formation is principally distributed in the Yuanmou Basin and its neighboring regions, consisting of a sequence of fluviolacustrine gravels, sands, and clays. Formerly, the Shangnafeng Formation was considered the top of the Yuanmou Formation. In recent years however this formation has produced continuous and numerous fossil vertebrates. Most important was the discovery of a hominid upper incisor by the Institute of Geology at Danama, Yuanmou, thereupon increasing the importance of this locality. There are, however, workers who still consider these rocks the top of the Yuanmou Formation.

The fauna associated with *Homo erectus yuanmouensis* in the Shangnafeng Formation is as follows: *Arvicola* sp., *Stegodon orientalis, S* sp., *Rhizomys* sp., *Hyaena* sp., *Sus scrofa, Megantereon* sp., *Rusa* sp., *Equus yunnanensis, Cervus* sp., *Rhinoceros* cf. *sinensis, R.* sp., *Gazella* sp., Bovidae indet. This fauna may be correlated with the Yanjinggou fauna of Sichuan and the cave fauna above the Fumin River, both being Middle Pleistocene. The thickness of the Shangnafeng Formation is approximately 100 meters. The sediments are dipping slightly with minor faulting.

Other Middle Pleistocene localities are described by some workers as composed of coarse clastics. Generally speaking the cyclicity of these deposits is not very clear, although they are relatively thick, but not as fossiliferous as the Lower Pleistocene deposits (with the exception of the caves). Other units that may be correlated with the Shangnafeng Formation include the gravels overlying the Songmaopo Formation in the Erhai Basin (formerly considered the upper section of the Songmaopo Formation); those at Tanglangquan in the Anning River Valley, the Panlong River, and the Jingdong Basin. East of the Jingdong Basin on the western slopes of Ailao Mountain are exposures of brown, tan-yellow, and gray gravels which have produced fossil bovids. With the exception of this locality there are almost no records of fossil vertebrates from the other localities.

2. The Heshangdong Formation is principally distributed in central Yunnan in the caves around the Fumin region and consists of sediments composed of calcareous breccias, travertines, and sandy clays. Typical localities are Heshang Cave at Fumin and Huagong Cave in the Kunming vicinity.

The fauna recovered from the Middle Pleistocene Heshangdong Formation in the cave above the Fumin River include the following: *Pongo pygmaeus, Sus* sp., *Macaca* sp., ?*Rusa* sp., *Hystrix* sp., *Muntiacus* sp., *Ursus angustidens,* Ovinae gen. et sp. indet., *Ailurus melanoleuca fovealis,* Bovinae gen. et sp. indet., *Ailurus fulgens, Arctonyx* sp., *Crocuta ultima, Felis* cf. *tigris, F.* cf. *pardus, Lynx* cf. *lynx, Stegodon* sp., *Palaeoloxodon* cf. *namadieus, Megatapirus* cf. *augustus,* and *Rhinoceros* sp.

The fossil mammals discovered from Huahong Cave I, Kunming include: *Hystrix* sp., *Ursus kokens, Felis tigris, Elephas maximus, Tapirus* sp., *Rhinoceros sinensis, Cervus* sp., *Sus* sp., Bovidae indet.

3. The Shanrendong Cave deposits at Gupengjiao, Xichou, are in the vicinity of Xichou county seat which, from the observations of colleagues Zhenxin Yuan and Xingyong Zhang, are composed of yellow-brown travertines, and yellow sandy clays bearing gravels and abundant mammalian fossils listed as follows: *Macacas* sp., *Megatapirus* cf. *augustus, Ursus kokeni, Sus* sp., *Ailurus melanoleuca fouealis,* Bovideae indet., *Crocuta ultima, Stegodon orientalis, Equus* sp., Cervinae indet., *Rhinoceros sinensis, Hystrix* sp.

4. The Lijiang glacial deposits of northwestern Yunnan at Mount Yulongshui, Mount Jushan and other localities consist of boulders, gravels, and sands of the Lijiang Glacial Stage exposed above elevations of 3,000 meters.

(III) Upper Pleistocene

There are two distinct modes of Late Pleistocene sedimentation in the Yunnan Region. These are fluviatile (or fluvio-lacustrine) sediments and cave deposits. But at the top of the high plateaus they exist as eluvial and slope wash deposits, and in the high mountain regions of northwestern Yunnan are partially glacial outwash. Fluvio-lacustrine alluvium is principally represented by the Longjie Formation. Cross-bedded fluvio-lacustrine sediments at Lijiang include the Mujiaqiao gravels and the Jingyuyong level basin sands. Typical cave deposits are represented in Yemao Cave neighboring eastern Kunming.

1. The Longjie Formation is distributed within the Jinshajiang River Valley from Dukou to Wanxian in Sichuan Province, and is composed of thinly laminated dark gray clays, fine gray silts, and gray-yellow silts slightly faulted and attaining a thickness of 130 meters. The Longjie Formation composes terrace III within the Jinsha River valley and frequently terrace II within the Jinsha tributaries (such as in the Longquan River valley and others). The fluvial deposits contain plant fossils.

2. The Mujiaqiao gravels of Lijiang have the greatest distribution in northwest Yunnan Province and consist of fluvio-lacustrine cross-bedded coarse sands, silts, and fine gravels bearing fossils. Contemporaneous sediments may also be observed at Shashihai, Jianquan, Heqing, and other localities. Mammalian taxa documented at Mujiaqiao, Lijiang, include: *Homo sapiens, Bubalus bubalis, Rhinoceros* sp., *Bibos gaurus, Pseudaxis* sp., *Stegodon* sp., *Axis yunnanensis.*

3. The Yemao Cave deposits at Xiaoshiba neighboring eastern Kunming are composed of black sandy clays, red-brown sandy clays and subclays which are finer and more fossiliferous than the Middle Pleistocene deposits. These may be correlated to River Terrace II in the same vicinity. Vertebrate fossils include: *Hystrix* sp., *Felis* sp., *Rhizomys* sp., *Tapirus* sp., *Crocuta ultima, Rhinoceros* sp., *Ursus* sp., *Sus scrofa.* In addition to these taxa are undiagnostic fragments including deer, bovids, sheep, Asian elephant.

4. The Dali glacial deposits are distributed on Mount Yulongshui at Lijiang and in the Mount Laoju region where they consist of Dali Glacial Stage boulders and gravels above elevations of 2,500 meters.

(IV) Holocene

Holocene deposits are present in various forms: fluviatile sediments, piedmont deposits, slope wash, eluvial deposits, glacial deposits, and others. They are present on top of the high plateaus, on slopes, and in the center of basins, are frequently present on both sides as River Terrace I or valley flats. The Holocene deposits in the Yunnan region have not been studied sufficiently. In addition to the absence of advanced and detailed descriptions, are the further absence of subdivisions or correlations. One of the only deposits that has been given consideration is the Palang Formation at Dadunzi, in the Yuanmou Basin. Dadunzi is located five kilometers east of the city of Yuanmou and is a significant Neolithic site. Within the artifact deposit are human limb bones and various species of extant mammals including bear, domestic dog, rodents, lagomorphs, deer, tiger, bovids, and sheep, in addition to fish, birds and other extant animals.

(V) Characteristics and Comparisons of the Quaternary Faunas

The Early Pleistocene faunas of Yunnan may best represented by the assemblages in the Zhaotong and Yuanmou basins. A vast majority of taxa from these localities may be correlated to the Nihewan mammalian fauna. In spite of inconsistencies at the species level, the faunas from North and South China are extremely close. Taxa within the Yuanmou Formation of the Yuanmou Basin (formerly designated either the Makai fauna or the *Equus yunnanensis* fauna), such as *Canis yuanmouensis* and *Equus yunnanensis* are comparable to the Nihewan *Canis chihliensis* and *Equus sanmenensis.* Two elements shared between Nihewan and Yuanmou include *Hyaena licenti* and *Muntiacus bohlini* which are also diagnostic elements for the Early Pleistocene in China. The Yuanmou Formation taxa are also extremely close to the *Gigantopithecus* Fauna from Liucheng, Guangxi Province, with coexisting elements including *Rhinoceros sinensis*, *Equus yunnanensis*, and *Hyaena licenti*. *Stegodon yuanmouensis* and *Stegodon zhaotongensis* are relatively primitive forms of the steogodontine elephants and are characteristic of the Early Pleistocene in the southwest regions of China.

After undergoing study by Minchen Chow and Renjie Zhai, the fauna from the Zhaotong Basin was considered "from a taxonomic perspective to contain a vast majority of species belonging to the Late Pliocene or Pleistocene. The horse fossils, however, are restricted to the Pleistocene and *Zygolophodon* does not occur later than the Early Pleistocene. From the perspective of the entire fauna, the age of the Zhaotong fauna appears to be Early Pleistocene and may be correlated to the *Equus yunnanensis* fauna of Yuanmou or the Upper Irrawaddy fauna of Burma."

The two faunas at Yuanmou and Zhaotong described above both maintain tropical to subtropical characteristics with dense forest taxa constituting the vast majority of elements. This indicates the climate was temperate and humid, or fundamentally similar to that of the three southwest provinces of China today. With regard to specific faunal elements, such as rhinoceroses, pigs, deer, and others, these animals essentially belong to the giant panda-elephant or so-called "*Ailuropoda-Stegodon* fauna." The majority of these taxa currently inhabit the regions of Southeast Asia, and naturally also inhabit southwest China.

The Yuanmou fauna and the Liucheng *Gigantopithecus* fauna are similar but are not exactly the same. Most of the species differ with the exception of three commonly shared taxa. The reasons for this are still unclear, but may be due to either the paucity of material recovered from Yuanmou or to regional variation. A comparison with the Burmese Upper Irrawaddy fauna indicates that, with the exception of the commonly shared *Equus yunnanensis*, other shared taxa are extremely scarce because the Upper Irrawaddy Fauna is actually an Upper Siwalik fauna from India that underwent eastern expansion. This fauna was designated the Siva-Malayan Fauna representing an east Asian Early Pleistocene faunal complex. It is obvious that the Yuanmou fauna is more similar to the *Gigantopithecus* fauna than to the Irrawaddy Fauna.

The Heshang Cave and Shanren Cave faunas both may be considered as belonging to the *Ailuropoda-Stegodon* fauna that is extensively distributed throughout South China and they correspond exactly to the Yanjinggou Fauna of Sichuan Province. Minchen Chow erected the Yanjinggou Fauna as the type assemblage representing the *Ailuropoda-Stegodon* Fauna extensively distributed throughout South China during the Middle Pleistocene. The Mogok Cave deposit in Burma produces a faunal complex that corresponds exactly to the South China cave deposits producing *Stegodon, Ailuropoda, Hystrix*, and others. Together with the corresponding Yanginggou fauna these assemblages constitute a Sino-Malaysian fauna.

Although the giant panda, *Ailuropoda*, is not documented in the Shangnafeng fauna of Yuanmou, a majority of taxa there correspond to the Yanjinggou Fauna including *Stegodon orientalis, Rhinoceros sinensis*, and others. There are relatively diagnostic components of the Shangnafeng fauna such as *Equus yunnanensis* and a saber toothed cat. The presence of *Equus yunnanensis* appears to suggest that the Shangnafeng fauna may be older than the Yanjinggou fauna. However, the possibility that this species may be *Equus sanmenensis* from the North China region may not be ruled out. Making an advanced

definitive and final conclusion must await further discovery of more material. The presence of the saber toothed cat suggests the Shangnafeng fauna to be somewhat older than the Yanjinggou fauna.

The *Ailuropoda-Stegodon* fauna is extensively distributed throughout the southern regions of China. From the perspective of the profuse quantity of material, the fauna is indeed complicated for it extends from the Middle Pleistocene continuously through the Late Pleistocene, and even to the extent of possessing some Early Pleistocene components of the *Gigantopithecus* fauna. The origin of and variation in this assemblage is not very distinct, but as this assemblage does not occur outside the environments of the South China region, there does not appear to be much faunal variation. Secondly, there is insufficient research upon the fossil material itself such that distinguishing geologic age and stratigraphic units are not yet possible based solely on the fossils alone. However there are recognizable developmental phases of hominid fossils which appears to remedy this shortcoming.

The faunas from Qiubeiheiqinglong and Xiaoshibayemao Caves on the eastern outskirts of Kunming are extremely characteristic of the Late Pleistocene *Ailuropoda-Stegodon* fauna. The fossils excavated from Mujiaqiao, Lijiang, comprise a more diagnostic fauna. Although the assemblage contains *Stegodon, Rhinoceros, Bos*, and others that indicate that it belongs to the *Ailuropoda-Stegodon* fauna, the presence of *Axis yunnanensis* makes it a more diagnostic assemblage as the genus *Axis* is recovered from the Pliocene to Early Pleistocene of North China and is unknown from any other region of the country. The presence of the Late Pleistocene *Axis yunnanensis* undoubtedly provides new data for the study of the evolution of this genus. According to the research of Yipu Lin et al., the Lijiang *Stegodon-Axis* fauna, including modern hominids, may be correlated to the Ziyang hominid fauna of Sichuan. It may be correlated outside of China to the *Stegodon-Axis* fauna of Andong, Java (containing the skull of Solo Man). If a comparison is made between the Ziyang and Andong faunas, the Lijiang fauna more closely approaches the Javanese fauna. This is a phenomenon worth further study.

A general temporal arrangement and correlation between the Quaternary faunas within Yunnan to the principle faunas of North China, South China, and neighboring regions is presented below.

Table 7. Correlation chart of Yunnan Pleistocene localities to those in China and Burma.

	Yunnan	South China	North China	Burma
Q_3	Heiqinglong (Qiubei) Lijiang (Yuanmou)	Liujiang Maba Ziyang	Shandingdongsai	Terrace deposits
Q_2	Heshangdong (Fumin) Shangnafeng (Yuanmou)	Yanjinggou	Zhoukoudian Gongwangling	Mogok Cave
Q_1	Yuanmou Zhaotong	Liucheng (*Gigantopithecus* Fauna)	Nihewan	Upper Irrawaddy

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