CHINESE DINOSAUR FAUNAS AND THEIR STRATIGRAPHIC POSITION

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ABSTRACT

The two orders within the class dinosauria, the Saurischia and Ornithischia, arose in the Late Triassic and continued through to the end of the Cretaceous when they went extinct. Dinosaurs roamed the earth for more than 140 million years,as the dominant terrestrial vertebrates of the Mesozoic. They speciated to an enormous degree, evolving and radiating relatively rapidly, and thereby provide evidence for the time periods of the continental sediments that contain them. Dinosaurs are currently one of the more reliable sources for biochronologic diagnosis in the Mesozoic. For example, in the North American Cretaceous, the evolutionary relationships within the Ceratopsia and Hadrosauria are used to distinguish four conformable stratigraphic units.

Within the past several years many Chinese Mesozoic red beds previously considered "unfossiliferous" have recently produced abundant fossils; among them are several large-scaled dinosaurs. This text, while in the process of evaluating the Chinese dinosaur material, will also conduct a classification and analysis of the material, although this paper is still merely an introduction.

THE RHAETO-LIASSIC *LUFENGOSAURIS* FAUNA

The Triassic period is a significant segment of time for the evolutionary history of the vertebrates. In the Late Triassic, such animals as the archaic Labyrinthodontia, the arcosaurian subclass the Thecodontia, and the mammal-like reptiles, were already well past their period of dominance, with the majority withdrawn from this historical stage. The Dinosauria and the new models of primitive mammals emerged as a vanguard, rapidly leading the takeover of the environmental niches from the archaic faunas to attain a flourishing radiation. The dinosaurs had already begun to evolve by the end of the Triassic, and by the Rhaetic stage were extensively distributed throughout each of the world's continents (excluding Antarctica). The predominant bipedal forms at this time were the saurischian Sauropoda and small-scaled Theropoda while the Ornithischia consisted mereley of primitive ornithopods. There are several major dinosaur faunas from this time period produced from the South African Stormberg Series, the upper Keuper Fm. of southern Germany, the North American Newark Supergroup, and the Lower Lufeng Fm. of China. C.C. Young named the dinosaurs contained within the Lower Lufeng Fm. At that time its age was considered Upper Triassic.

The Lufeng Saurischian fauna in Yunnan Province includes: *Pachysuchus imperfectus* Young, *Platyognathus hsuii* Young, *Dibothrosuchus elaphros* Simmons, *Strigosuchus licinus* Simmons, *Microchampsa scutata* Young, *Lufengia youngi* Galton, *Lukosaurus yini* Young, *Sinosaurus triassicus* Young, *Gryposaurus sinensis* Young, *Lufengosaurus huenei* Young, *Yunnanosaurus magnus* Young, *Y. huangi* Young, *Y. robustus* Young, *Tatisaurus oehleri* Simmons, *Kunminia minima* Young, *Bienotherium yunnanensis* Young, *B. elgans* Young, *B. minor* Young, *B. magnum* Chou and Hu, *Lufengia minor* Young, *Oligokyphus sinensis* Young, *Yunnania brevirostre* Cui, *Eozostrodon oehleri, E. heiguopengensis*, and *Sinoconodon rigneyi.* Southwestern China contains other lithologies that are somewhat correlative to the Lower Lufeng Fm.. In Heilicheng, Xichang Co., the lower Yimen Fm. is present; in central Yunnan the Majiahe Fm. is present; and in the Sichuan Basin the Zhenzhuchong Fm. is present. All of these sediments are redbeds. In addition, all of these lithologies contain elements of the *Lufengosaurus* fauna and display either disconformable or conformable contacts with the underlying carbonaceous depositional systems.

There is much controversy about the Triassic-Jurassic paleontological boundary vis à vis the age of the Lufeng fauna, which may be summarized as follows:

1. C.C. Young proposed: "The characteristic Saurischia and Carnosaria contained herein all indicate the Lower Lufeng Fm. to be Upper Triassic." Young frequently suggested that *Lufengosaurus* was similar to the Upper Triassic *Plateosaurus* from Europe, and that the entire faunal character was similar to the fauna of the South African Stormberg Series considered Rhaetic in age.

2. Paleobotanical, palynological, and bivalve biostratigraphers believe it is appropriate to assign the age of the Lower Lufeng Fm. to the Early Jurassic because the underlying carbonaceous layer produces an abundant Rhaeto-Liassic *Dictyophyllum-Clathropteris* flora, and the bivalves from the Lower Lufeng Fm. are represented by such large-scaled forms as *Unio lufengensis* and *Psilunio yipinlangensis* that are considered significant Jurassic indicators. Palynological analysis indicates that the Lower Lufeng *Classopollis* composition equates to the Zhenzhuchong and Qijiang members of the Ziliukai Fm., and that this pollen is also representative of the Early Jurassic. Therefore, through these perspectives, it is advocated that the age of the *Lufengosaurus* fauna in the Lower Lufeng Fm. be regarded as Early Jurassic.

3. Shenfu Sheng et al. believe that through diastrophic and sedimentological perspectives, the Triassic carbonaceous development stage was post-Yinchi movement. There is a hiatus between the Upper and Lower Lufeng Fm. which seems to have developed during the first stage of the Jurassic Yanshan movement, and which in geologic time encompasses the Rhaeto-Liassic. It is thereby proposed that the Lower Lufeng Fm. and its associated fauna be assigned to the Jurassic.

Currently, there are a total of approximately seven orders and 30 genera recorded from the Lufeng Saurischian fauna. Among the assemblage are such taxa as primitive mammals, early ornithischians, and lepidosaurs (pseudosuchians), which, in the history of vertebrate evolution, are all stem elements for future radiations, and all arose in the Late Triassic. The labyrinthodont amphibians and thecodonts are two archaic orders that for the most part underwent extinctions in the Late Triassic, but not at Lufeng. The prosauropods principally existed during the Late Triassic, although Olson and Galton (1976) suggested that several members of the Plateosauridae extended into the Liassic. The type species of one of the mammal-like reptiles, *Oligokyphus*, is found in the Liassic fissure fills of Somerset, England. All of these factors indicate that the Lufeng Saurischian fauna contains elements of both the Rhaetic and Liassic time periods.

Primitive sauropod dinosaurs have been found in both the Lower Lufeng Fm. of central Yunan and in the lower Yimen Fm. of southwest Sichuan. According to Xijin Zhao, these primitive sauropods coexist with prosauropods. Traditionally, quadropedal sauropods were generally believed to have emerged in the Jurassic. Xijin Zhao believes the Lufeng Saurischian fauna should be placed in the Liassic based upon his research on the dinosaurs. The correlation of the Lufeng Saurischian fauna to other global faunas with the same characteristics creates a single animal assemblage that combines taxa from both the Rhaetic and Liassic stages. The Rhaetic is a transitional lithologic horizon lying between the Triassic and Jurassic that contains diagnostic Triassic characters, as well as animals characteristic to the Jurassic. Consequently, there are several workers who believe that the Rhaetic beds represent the terminal stage of Triassic deposition, while other workers believe it to be the commencement of the Jurassic. This text recognizes the hypothesis of Shenfu Sheng et al. to be the most parsimonious through diastrophic and continental deposition research. The Lower Lufeng Fm. that produces the Rhaeto-Liassic *Lufengosaurus* fauna may indeed belong to the Early Jurassic.

THE EARLY TO MIDDLE JURASSIC *SHUNOSAURIS* FAUNA

Due to the deficiency of Early Jurassic terrestrial vertebrates, knowledge regarding the evolution of the Lower Jurassic is principally derived from marine lithologies where relatively well-preserved vertebrates have been discovered. These include ichthyosaurs, plesiosaurs, and crocodiles, as well as several taxa of fish. Current knowledge of Liassic terrestrial vertebrates

discovered in England's marine deposits consists of *Scelidosaurus*. In North America, the Moenave Fm. contains *Protosuchus richardsoni* and fragmentary teeth and bones of titanosaurs. The Australian Wolloon series produces a large Early Jurassic flora with such taxa as *Cladophlebis australis, Taeniopteris spatulata, Otozamites feistmanteli, Neocalamites,* and *Dictyophyllum,* which are found associated with the sauropod *Rhoetosaurus brownei.* In the Kota Fm. of India, a number of dinosaurs including large-scaled sauropods such as *Barapasaurus* have been recovered. South America has also produced sauropods of this age, but whether they are Early or Middle Jurassic is currently not clear.

In the provinces of Yunan, Guizhou, and Sichuan, Mesozoic terrestrial deposits are several thousand meters thick. The Ziliujing Fm. in the Sichuan Basin consists of a set of fluvio-lacustrine sediments, which in some areas, is conformable with the underlying coal-bearing Xujiahe Fm. There are two fresh water bivalve-bearing carbonates that are relatively consistent in distribution and act as extremely good marker beds. In Zigong and Weiyuan counties, the Ziliukai Fm. has been previously divided into five members. These are (stratigraphically from top to bottom): The "Liangaoshan Member,"[*] Daanzhai Member, Maanshan Member, Dongyuemia Member, and Zhenzhuchong Member. Zhengwu Cheng, in 1977, collected a complete prosauropod skeleton from the Zhenzhuchong Member at the Yellow Bed (Huangshiban) Section of Weiyuan. In 1974 the 108th Guizhou Brigade discovered a *Lufengosaurus* fauna in the Zhenzhuchong Member in the Dafangxinchang Basin of Guizhou Province which has subsequently become an important paleontological foundation for solving the correlation problems of the redbeds in these three provinces.

Dinosaurs from the Maanshan Member were collected as early as 1939 by Xinxin Yue, and later identified by C.C. Young. In recent years, Xianhe Zeng has collected several dinosaurs from the Maanshan and Wangaoshan members from such productive regions as Luoquanjing, the Yellow Beds of Weiyuan, and at Huluke. Xinlu He et al. of the Chengdu Geological Institute, in 1970, discovered a dinosaur fauna (yet unstudied) from the lower Shaximiao Fm. at Kaijiangjinji Commune. In 1977, a Sichuan vertebrate paleontological preservation training class collected an exceptionally large-scaled sauropod from the Lower Xiaximiao Fm. in the Dashanpu region of Zigong Co. Previous workers have identified this dinosaur as *Shunosaurus*. A morphological comparison of the dinosaurs from the lithologies mentioned above indicates that they are vastly different from the *Lufengosaurus* fauna in the basal Zhenzhuchong Member, as well as being largely different from the *Mamenchisaurus* fauna of the Upper Xiaximiao Fm. Workers have subsequently designated this Lower Jurassic assemblage the *Shunosaurus* fauna, with taxa including *Sanpasaurus yaoi, Shunosaurus lii, Sinopliosaurus weiyuanensis,* Tritylodontia, Chelonia, *Lepidotus chunkingensis*, *Lepidotus luchowensis*, and *Peipehsuchus teleorhinus.*

Vertebrates from the Ziliukai Fm. express two extremely different faunas. The Saurischian fauna from the Zhenzhuchong Member is a *Lufengosaurus* fauna belonging to the Rhaeto-Liassic. The *Shunosaurus* fauna is restricted to the Maanshan and Liangaoshan Members as is the Lower Xiaximiao Formation's Chungking (Zhongjing) fauna. This fauna was initially regarded to be comparable to the type Early Jurassic, containing *Lepidotes*, and the Teleosaurid, *Peipehsuchus*, as well as common European dinosaur taxa. Tarlo, in 1960, assigned *Sinopliosaurus weiyuanensis* to *Pliosaurus andrewi* of the Oxfordian Stage. A new specimen of *Sinopliosaurus* was discovered in 1978 from the Dongyuemiao Member. The author named the specimen *Bishanopliosaurus youngi* and correlated it to the European *Rhomaleosaurus* of the Liassic Stage.[*] *Shunosaurus* is a large-scaled primitive sauropod. Its diagnostic characters are similar to those of the large

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[*] The comprehensive research team of the Geologic Office of Sichuan, in the Hechanlibi section, is in the process of renaming the deposits equivalent to the Liangaoshan Member as the Xintiangou Fm. It is then to be reassignbed to the Middle Jurassic.

[*] In April of 1979 L.B. Halstead from England visited the PRC and suggested the affinity of *Bishanosaurus* to the European *Rhomaleosaurus.*

sauropods of the Kota Fm. in India. With regard to the age of *Shunosaurus* fauna, Chinese workers believe it may easily be assigned to the Early to Middle Jurassic. The Ziliukai Fm. may also be provisionally assigned to the Lower to Middle Jurassic.[**]

LATE JURASSIC *MAMENCHISAURUS* FAUNA

The Late Jurassic expressed the epitomy of development for the largest of the sauropods, being nearly globally distributed. Currently, the relatively well-known faunas are from the North American Morrison Fm., the East African Tendagaru Fm., the United Kingdoms Oxfordian Stage, and the Portugese Kimmeridgian Stage. In China, the currently known Late Jurassic dinosaur-bearing lithologies are the Hongshan (Red Mountain) Fm. in the Turpan Basin, the Hengtang Fm. of the Gansu Corridor, and the Upper Shaximiao Fm. in the Sichuan Basin, from which the type *Mamenchisaurus* fauna is derived. The principle members of this fauna include *Omeisaurus junghsiensis, O. changshounsis, Mamenchisaurus hochuanensis,* and *M. constructus* representing the sauropods. The theropods are represented by *Szechuanosaurus campi*, *Yangchuanosaurus shangyouensis*, and *Y. magnum*. The stegosaurs are represented by *Chialingosaurus kauni*, and *Tuojiangosaurus multispinus*. The turtles include *Plesiochelys chungkingensis, Plesiochelys radiplicatus,* and *Tienfuchelys tzuyangensis. Ceratodus* sp. is among the fish, and *Hsisosuchus chungkingensis* represents the crocodiles. The Upper Shaximiao Formation's vertebrate fossils are relatively abundant, with its principle elements consisting of the gargantuan *Mamenchisaurus* and *Omeisaurus,* the morphologic diagnostic characters of which are similar to *Diplodocus,* and *Brontosaurus* from the Late Jurassic of North America. The large-scaled theropods, *Yangchuanosaurus* and *Szechuanosaurus* may be compared to the North American and European Late Jurassic *Megalosaurus*. The morphology of the skull and dorsal spines of the stegosaur *Tuojiangosaurus* are similar to the Late Jurassic *Kentrosaurus* from East Africa. Those workers who have studied the large-scaled turtles from the Upper Shaximiao, the Plesiochelyidae, believe they correlate precisely to the Late Jurassic Plesiochelidae of Europe, and that their ages should also be respectively the same. In summary, the age of the current *Mamenchisaurus* fauna can be accurately assigned to the early stage of the Late Jurassic.

THE EARLY CRETACEOUS PTEROSAUR - *PSITTACOSAURUS* FAUNA

Lithologies that produce Early Cretaceous dinosaurs are not globally abundant. The well-known lithologies outside of China consist of the Wealdon Fm. of Europe, the Cloverly Fm. of North America, and the Oshih Fm. of the People's Republic of Mongolia. There are relatively more Early Cretaceous fossil localities in China. Those currently known and relatively well-studied consist of the Qingshan Fm. in Shandong, the Tugulu Group of the Jungar (Tsunggur or Zhunhe) Basin in the Xinjiang Autonomous Region, the Guyang Fm. in the Guyang Basin of Inner Mongolia, and the Napai Fm. in Fusui, Guangxi Province, as described below:

Qingshan Fm.: Distributed in the Jiaodong Co. of Shandong Province, the lithologic characters consist of a green-purple and light red massive volcanoclastic series grading to red and dark purple mudstones with an approximate thickness of 1200 meters. Produced from these lithologies are *Psittacosaurus sinensis, P. youngi,* sauropods, pterosaurs, and the turtle *Peishanemys latipons.* Although the fossils are not numerous, the occurrence of *Psittacosaurus* allows these rocks to be correlated to the Oshih Fm. (Aodesair Group) of the People's Republic of Mongolia. The age of *Psittacosaurus* is currently still considered to be Early Cretaceous.

[**] In January 1979 the "Symposium of Mesozoic Regions in the Sichuan Basin" was convened in which the participants unanimously agreed that members of the Ziliukai Fm. should be subjected to nomenclature revision. However, there were differences in opinion regarding the subdivision diagnosis. From the perspective of the vertebrate fossils, it appears that the upper boundary may be drawn at the top of the Daanshai Member.

Tugulu Group: Exposed north and south of the Tianshan Mountains in Xinjiang, western China, as red-green and variegated striped sandy mudstones, half of the system is subareal, with fluviolacustrine deposits underlying the subareal sediments. Numerous vertebrate fossils are produced from Niaorhe Co., the most abundant taxon being the Jungar pterosaur. C.C. Young et al. named the assemblage the *Dzungaripterus* fauna, which includes *Dzungaripterus weei, Edentosuchus tienshanensis, Noripterus complicidens, Wuerhosaurus homheni, Phaedrolosaurus ilikensis, Kelmayisaurus petrolicus, Tugulosaurus facile,* cf. *Asiatosaurus mongoliensis*, and *Pssitacosaurus* sp. The character of the vertebrate fauna from the Tugulu Group lies between that of the North American Morrison Fm. and the fauna of the Cloverly Fm. The Morrison Fm. is essentially the North American Late Jurassic type dinosaur horizon, is an age somewhat equivalent to the European Kimmeridgian Stage, and contains such taxa as *Brontosaurus, Diplodocus, Stegosaurus,* and *Allosaurus*. The Cloverly and Morrison formations are conformable such that it is difficult to distinguish the two by lithologic character.

J.H. Ostrom believes the Cloverly Fm. to be composed of Early Cretaceous sediments based upon its faunal characteristics. The faunal characteristics of the Tugulu Group compare more closely to the Morrison fauna with such taxa as *Wuerhosaurus homheni* being similar to the North American *Stegosaurus,* and sauropods that are similar to *Camarasaurus.* However, the principle element of the Tugulu Group is *Dzungaripterus*, which C.C. Young presumed to differ from other known pterosaurs, and based upon his analysis of the taxa's derived characters, believed the age should be regarded as Early Cretaceous. The small theropod *Tugulusaurus minjiensis* is similar to *Deinonychus* from the Cloverly Fm. of North America. The presence of *Psittacosaurus* additionally supports the age of the Tugulu Group to be Early Cretaceous.

Napai Fm.: Exposures are in the Napai Basin of Fusui, Guangxi Province, and consist of a series containing purple and red calcareous shales and sandy mudstones representing littoral lacustrine and lacustrine deposits. The lower section's purple-red mudstones and shales produce *Asiatosaurus kwangshiensis, Prodeinodon kwangshiensis,* and *Sinopliosaurus fusuiensis*. The faunal characteristics indicate an affinity with the North China *Psittacosaurus* fauna with its age as Early Cretaceous. Additionally, there are several other scattered Early Cretaceous dinosaur localities and formations such as the Inner Mongolian Hashentuoluocai and Guyang faunas, the Xiaxinminbao fauna of the Gansu Corridor, and several recently discovered dinosaur sites from the Bingou and Fuxin formations in the Chaoyang Co. of western Liaoning Province. However, as this material is fragmentary and as its stratigraphic position is not entirely clear, further research is required.

Shouyong Hu (1964) believed the dinosaurs from Jilantai Co. were produced from two horizons, with the megalosaur *Chilantaisaurus tashuikouensis* derived from the Late Cretaceous, and *C. maortuensis* produced from the Early Cretaceous. This Early Cretaceous dinosaur fauna contains: *Chilantaisaurus maortuensis, Probactrosaurus gobiensis, Probactrosaurus alashanicus, Aspideretes maortuensis,* and others.

A.S. Romer (1956) believed that each member of the Early Cretaceous terrestrial dinosaurs was not too dissimilar from those of the Late Jurassic North American Morrison Fm., and in fact, quite comparable in nature. The Early Cretaceous essentially preserved several forms from the Late Jurassic, but the large-scaled bothrosauropods were beginning to decline. Stegosaurs were the first branch of ornithischian dinosaurs to disappear at this time, going extinct globally. The primitive ornithischians *Iguanodon* and *Hypsilophodon* arose as precursors to the large-scale radiation of the Ornithischia. Several theropods took additional specialized directions of development. The Early Cretaceous dinosaurs, it appears, were situated in a "dormant stage" and compositionally expressed a complicated fauna. As reflected in the assemblage the Tugulu fauna, both archaic and new taxa were coexisting. This, in effect, creates problems when attempting to designate the precise age of Early Cretaceous Dinosaurs, and in the same manner this problem is encountered when attempting to distinguish Early Cretaceous from Late Jurassic dinosaur-bearing

lithologies currently known in China, as exemplified by the Mengyin Group of Shandong Province. The Mengyin Group is distributed throughout Mengyin and Fei Counties, and in the Xintai region consists predominantly of grey-green laminated sandstones interbedded with tuffaceous conglomerates with an approximate thickness of 700 meters. The vertebrates produced from the grey-green sands in the lower and middle sections of the Mengyin Group consist of such taxa as *Euhelopus zdanskyi, Sinamys lens, Sinochelys applanate,* and *Sinamya zdanski*. The plant *Lycoptera* sp. is also found here.

The Mengyin Group has previously been considered to be Early Cretaceous based upon the presence of *Sinamia (Lycoptera)* and *Euhelopus*. C.C. Young, upon his summary of Chinese saurischinas, suggested that the age of *Euhelopus* may be Late Jurassic. Xianhang Liu et al., following their synthesis of *Lycoptera*, also suggested the age of these rocks to be late Jurassic. However, the Early Cretaceous dinosaur faunas contain one characteristic element, the Psittacosauridae. Currently, its occurrence is restricted to Asia, found in such regions as the Qingshan Fm. of Shandong, the Guyang and Lisan formations in the Guyang Basin of Inner Mongolia, the Tugulu Group in the Jungar Basin, the Zhidan Group in the Erduo Basin, Gansu,* and in Hebei, western Liaoning and Ningxia provinces. In addition, there are records in Mongolia from the Wuqi Basin and from Kamchatka, Siberia. *Psittacosaurus* is a primitive genus of Ornithischia that Osborn and Gregory believed to have been related to *Protoceratops*. It appears to have been ancestral to *Protoceratops* and its age is appropriately Early Cretaceous. However, the premaxilla of *Psittacosaurus* is edentulous while *Protoceratops* maintains a premaxilla with a residual dentition. Based upon this feature, the majority of vertebrate paleontologists believe that *Psittacosaurus* cannot be a direct ancestor to *Protoceratops*. C.C. Young (1958), while studying the morphological characteristics of a *Psittacosaurus* from the Qingshan Fm., suggested that the primitive nature of *Psittacosaurus* indicated that it may be a sole surviving element, and that it is conceivable that this group may have arisen at the end of the Jurassic to Early Cretaceous. In summary, more research is required to establish the precise age of *Psittacosaurus*. Currently, it is provisionally regarded as Early Cretaceous. It is certain that the Early Cretaceous dinosaur faunas of the Inner Mongolian Alashan region are stratigraphically higher than the *Psittacosaurus* faunas, as the Inner Mongolian fauna contains primitive hadrosaurs. Shouyong Hu et al. believed its age to be somewhat equivalent to the Albian Stage.

LATE CRETACEOUS TITANOSAUR-HADROSAUR FAUNA

The Late Cretaceous is both the last stage of the dinosaurs as well as an extremely long geological stage. Over half the record of dinosaur taxa lived during this time period. Among the globally well-known Late Cretaceous dinosaur bearing sediments are the North American Lance, Edmonton, and Belly River formations, Asia's Djadokhta and Nemegt formations, and sediments of Madagascar. There are numerous Late Cretaceous dinosaur localities in China (Table I), the most notable being the Wangshi Fm. of Shandong, the Iren Debesu Fm. of Inner Mongolia, the Nanxiong Fm. in Guandong, and the Subashen Fm. in the Tugulu Basin of Xinjiang. More recently, dinosaur discoveries have been made in the Zhenguang Fm. of Qianjiang, Sichuan; the Laijia Fm. of eastern Zhejiang; the Majiacun Fm. in the Xichuan Basin of Henan; and the Jiayin region of Manchuria.

Iren Debesu Fm.: The dinosaurs from the Erlianyanchi region are produced from lacustrine deposits composed of grey-green mudstones and light yellow and red sandstones. When *Ornithomimus asiaticus* was discribed and compared it was believed by C.W. Gilmore to be similar to *Ornithomimus* from North America. It was also his opinion that the Iren Debesu fauna approached the fauna from the Late Cretaceous Belly River Fm. C.P. Berkey and F.K. Morris

* In 1978 the author collected a primitive pterosaur from the lower section of the Zhidan Group at a 15 km stretch of exposures at Qingyang, Gansu, that may be correlated to Late a Jurassic European taxon. The lower section of the Zhidan Group may then probably be assigned to the Jurassic.

suggested the Iren Debesu Fm. to be somewhat equivalent to the Cenomanian Stage. The fauna consists of *Ornithomimus asiaticus, Mandschurosaurus mongoliensis, Bactrosaurus johnsani, Chilantaisaurus tashuikouensis, Alectrosaurus olseni,* and the fossil egg *Oolithes irenensis.*

Wangshi Fm.: The Wangshi Fm. is exposed in the eastern Shandong region in the counties of Laiyang, Jimo, Gaomi, Jiao, Zhucheng, Anqiu, and Zhu. Surface erosion has crept downwards staining the underlying Qingshan Fm. red and creating the deceptive illusion of a conformable contact between a set of red to brick-red thick sands and shales that appear to grade into grey-green sandy mudstone deposits. The thickness is approximately a little over 2000 meters in the Laiyang region with fossils predominantly produced from the middle and upper sandy mudstones. Recorded taxa include *Tsintaosaurus spinorhinus, Tanius sinensis, T. chingkankouensis, Shantungosaurus giganteus, Tyrannosaurus* cf. *rex, Oolithes elongatus, Oolithes spheroides,* and *Oolithes megadermus.* Y.C. Tan suggested the age of the Wangshi Fm. to be rather equivalent to the Iren Debesu Fm. based upon the character of the dinosaurs and pelecypods. C.C. Young (1958) discussed the age of the Laiyang dinosaurs and suggested that "these fossils may all be assigned to the vast category of the Upper Cretaceous, as one genuinely cannot observe anything obvious that would further advance stratigraphic subdivision based upon paleontological data. In this regard, the Wangshi system, which attains the thickness of 2000 meters, represents a single geologic stage." The major element of this fauna, *Tsintaosaurus,* although maintaining certain advanced cranial features, also possesses relatively primitive features in its ischium and pubis. C.C. Young's diagnosis suggested that it approached *Lambeosaurus* from North America. C.Z. Hu believed *Shantungosaurus* produced from the Wangshi Fm. in Douzheng Co. shared many diagnostic characters with *Anatosaurus* and *Edmontosaurus,* both produced from the Edmonton Fm.

The Wangshi Fm. produces abundant fossil eggs that have been studied by M.C. Chow (1951), C.C. Young (1954), and Z.K. Zhao (1979), that may basically be divided into two forms. The elongate eggs from such localities Including Nanxiong, Guangdong, and Ganzhou, Jiangxi, have a consistent morphology and may be compared with the eggs from the Mongolian People's Republic. The other egg type is a spherical form that may possibly be turtle. There appears to be a regular distribution pattern of the fossil eggs from the Wangshi Fm., as thick-shelled eggs are produced from the central secton of the Wangshi Group at Jiangjunding, but above these, at Jingangkou, elongate eggs are predominantly found. Moreover, when Z.K. Zhao studied the microstructure of the eggs, he used them to advance more detailed stratigraphic subdivisions of the Wangshi Fm. The age of the Wangshi Fm. may possibly be equivalent to the ages of the Edmonton or Belly River Fms.

Nanxiong Fm.: The redbeds of the Nanxiong Basin, Guangdong, may be divided into an upper and lower formations, for the lower section of the Nanxiong Fm. produces such forms as dinosaurs, turtles, and fossil eggs. The upper section's Luofozhai member produces Middle to Late Paleocene Amblypoda. The lower unit contains such elements as *Nanhshiungochelys wachingensis, Microhadrosaurus nanshiungensis, Nanshingosaurus brevispinus,* Tyrannosauridae indet., Coelurosauria indet., *Oolithes elongatus, O. spheroidas, O. rugustus,* and *O. nanshingensis.* Fossil preservation in the Nanxiong Fm. is fragmentary, but undoubtedly the Fm. belongs to the Upper Cretaceous based upon the presence of hadrosaurs and tyrannosaurs. C.C. Young conducted detailed research upon the fossil eggs and believed the egg-producing lithologies at Nanxiong and Ganzhou belonged to the upper Upper Cretaceous.

Subashen Fm.: The northern margin of the Tugulu Basin in Xinjiang contains excellent exposures of the Shanshan Group, which is composed of grey, light yellow, and grey-green muddy sandstones, silts, and sandstones. The base is a massive conglomerate that was previously considered Tertiary in age. The grey-green coarse sandstones at the center of the Shanshan Group has produced Dinocerta, which assigns its age to the Paleocene. Discoveries of dinosaurs and fossil eggs from the basal section in 1964 advanced stratigraphic subdivision of the Shanshan

Group indicating the basal section to be Upper Cretaceous and it was subsequently named the Subashen Fm.. It produces animals such as *Shanshanosaurus huoyanshanensis, Nemegtosaurus pachi, Tarbosaurus* sp., *Oolithes spheroides*, and *Mongoliemys turfanensis.* The age of the Subashen Fm. is somewhat equivalent to the Late Cretaceous. The presence of fossil eggs supports this hypothesis. The type of *Nemegtosaurus pachi is* from the Nemegto Fm. of the Mongolian People's Republic (MPR) with its age as Campanian. It may therefore be discerned that the Subashen Fm. is Late Cretaceous based upon the dinosaur fauna, and that it may be correlated to the Sifangtai Fm. of check Songliao; the Nanxiong Fm. of Guangdong; the Wangshi Fm. of Shandong; and the Zhengyang Fm. of Sichuan. Their ages are relatively equivalent to the Upper Nemegto Fm. of the MPR, or Campanian to Maestrictian.

There are numerous Upper Cretaceous dinosaur localities in China, such as in Kansu, Shanxi, Ningxia, Inner Mongolia, and Manchuria. More recently, reports and discoveries have been made in such provinces as Zhejiang, Henan, Anwei, Jiangxi, Hunan, and Sichuan. Fossil eggs have been particularly abundant, expressing their extensive distribution, as well their taxanomic abundance in the late Cretaceous of China. It is just a matter of time before systematic excavations and research of these new regions are undertaken.

In summary, distinctive dinosaur faunas from five stages may be clearly recognized in China according to the current material and assemblage development:

1. The Rhaeto-Liassic prosauropod *Lufengosaurus* fauna
2. The Early-Middle Jurassic sauropod *Shunosaurus* fauna
3. The Late Jurassic sauropod *Mamenchisaurus* fauna
4. The Early Cretaceous *Psittacosaurus*-Pterosauria fauna
5. The Late Cretaceous Titanosaur-Hadrosaur fauna

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Table 1. Correlation chart of Chinese dinosaurs with their stratigraphic positions.

Period	Epoch	Dinosauria	Shandong Lu-dong	Shandong Lu-zhong	Xinjiang Tzun-gur	Xinjiang Tugu-lu	West Gansu	Erduolian Hubei	Ningxia	Inner Mongolia	Sichuan Basin	Maodou Tibet	Lufeng Yunnan	Hunan	Northern Guangdong	Eastern Zhejiang	Eastern Anwei	Western Liaoning	North America	Mongolia	Europe
Triassic	Upper T_3	Prosauropoda																			
Jurassic	Lower J_1	Bothrosauropodidae																			
Jurassic	Middle J_2	Homalosauropodidae																			
Jurassic	Upper J_3	Coelurosauridae																			
Cretaceous	Lower K_1	Megalosauridae																			
Cretaceous	Upper K_2	Tyrannosauridae																			
		Ornithopoda																			
		Hadrosauridae																			
		Stegosauria																			
		Ankylosauria																			
		Ceratopsia																			
		Pachycephalosauria																			
		Titanosauridae — Hadrosauridae	Wangshi Fm. ○●	Wangshi Fm. ○●	Ailikehe Fm. ●	Subashen Fm. ● / Kumutake Fm.			Wulanhuxiao Fm. ●	Erliandabu Fm. (Iren Dabasu) ○●	Guangkou Fm. / Laiguan Fm.	Zongyu Fm.	Shimen Fm.	Dongtang Fm. / Shibajiaping Fm.	Nanxiong Fm. ○●	Laijia Fm. ○● / Shantang Fm.	Xiaoyan Fm. ○ / Qiyuanshan Fm.		Lance / Edmonton / Belly River / Colorado	Upper Nemegt / Lower Nemegt / Djadokhta	Danian / Maestrictian / Senonian / Turonian / Cenomanian
		Psittacosauridae — Pterosauria	Qingshan Fm. ▲	Mengying Group	Tugulu Group ▲	Tugulu Group	Xinminbao Group ▲	Zhidan Group △▲	Dashuigou Fm. ○	Guyin Fm. △▲	Zitang Fm. / Bozi Fm. / Yangting Fm.	Laoran Fm. ▲		Shenwangsan Fm. / Dongtang Fm.		Chaochuan Fm. / Guanto Fm.	Huizhou Fm.	Sunjiawan Fm. / Fuxin Fm. △▲ / Jiufotang Fm.	Cloverly	Dshih	Aptian / Albian / Wealden
		Sauropoda — Mamenchisauridae	Laiyang Fm.		Kalaza Fm. / Qigu Fm.	Kalaza Fm. / Qigu Fm.	Chijinbao Group	Fenfanghe Fm. / Anding Fm.		Lisangou Fm. △ / Wuhai-kouzi Fm.	Penglai-zhen Fm. / Suining Fm. / Upper Xiaximiao Fm.	Kenduo Fm.				Jiande Fm.	Yantang Fm.	Jingangshan Fm. / YixianFm. / Jianchang Fm.	Morrison		Maim
		Sauropoda — *Shuosaurus*			Toudun-he Fm. / Shuixigou Group	Toudun-he Fm. / Shuixigou Group		Zhiluo Fm.			Lower Xiaximiao Fm. / Xintian-gou Fm.	Dabuka Fm.	Upper Lufeng Fm	Tangjiashi Fm.				Tuchengzi Fm. / Lanchi Fm.	Navaho S.S.		Dogger
		Sauropoda — *Lufengosaurus*						Yanan Fm.			Ziliukai Fm.	Daye Fm.	Lower Lufeng Fm	Bajiachong Fm.				Haitangou Fm.	Newark		Lias
					Xiaoquangou Group	Xiaoquangou Group		Yanchang Group			Shunjia-he Fm.	Bagong Fm.	Yiliangping Group					Beipiao Fm.			Rhaetic

Chaya Group / Xiangzhun Group

○ Fossil eggs ● Hadrosauria ▲ Psittacosauria △ *Lycoptera* fauna