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THE CRETACEOUS/TERTIARY BOUNDARY EVENT IN TIBET

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ABSTRACT

The Cretaceous/Tertiary boundary in the Gamba and Tingri regions of Tibet occurs between the Zongshan and Jidula Formations. Arenaceous facies similar to those of the Jidula Formation are widespread in Tibet and Pakistan; collectively, these represent the diachronous deposits of the Latest Cretaceous-Early Tertiary regression. Major faunal changes took place in Tibet during the Late Cretaceous. All of the Cretaceous ammonoids, planktonic and benthonic foraminifera, rudistid and inoceramid bivalves became extinct over the Campanian Maastrichtian interval in a stepwise pattern, with abrupt Late Campanian and Late Maastrichtian extinction events (Tabs. 3, 4). A large number of new taxa appeared during the Danian (Tabs. 3, 4). These faunal changes in the shallow-water marine facies of Tibet demonstrate that this region was not isolated from major global faunal changes taking place in the Cretaceous/Tertiary boundary mass extinction interval.

Key-words: Zongshan Formation; Jidula Formation; Lower Indus Basin; Upper Indus Basin; Zhongba; Tingri; Gamba; extinction; regression; diachronous.

RESUMEN

El límite Cretácico-Terciario en el Tibet, regiones de Gamba y Tingri, se da entre las Formaciones Zongshan y Jidula. Facies arenosas como las de la Formación Jidula están muy extendidas en el Tibet y Pakistan, que en conjunto representan los depósitos diacrónicos de la regresión del Cretácico terminal-Terciario basal. Durante el Cretácico superior se dieron en el Tibet cambios faunísticos principales; todos los ammonites, foraminíferos planctónicos y bentónicos, rudistas e inocerámidos cretácicos se extinguieron durante el intervalo Campaniense-Maastrichtiense siguiendo un modelo pausado, con bruscas extinciones en el Campaniense superior y Maastrichtiense superior (Tbs. 3 y 4). Durante el Daniense aparecieron un amplio número de taxones nuevos. Estos cambios, en ambientes de aguas marinas someras en el Tibet, muestran las relaciones de esta región con los cambios globales de extinción que se dieron en el paso Cretácico-Terciario.

Palabras clave: Formación Zongshan; Formación Jidula; Cuenca del Indo bajo; Cuenca del Indo alto; Zhongba; Tingri; Gamba; Extinción; Regresión; Diacronismo.

INTRODUCTION

Marine Cretaceous and Tertiary strata occur over a wide area in southern Tibet and Gangdise-Nianqingtangula Mountain region (Fig. 1). This has become more evident in recent years as the biostratigraphy of the Himalayan area has been worked out in detail and marine Cretaceous strata were recognised to the north of the Yarlung Zangbo River during the geological investigation of the Qinghai-Xizang (Tibet) Plateau (Zhang, 1981).

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There are important lithologic and environmental differences between the Lastest Cretaceous and Earliest Tertiary deposits. The Cretaceous deposits of Tibet are widespread and exhibit distinct regional facies control. Deep water facies with Cretaceous planktonic micro-fossils have been found along the Yarlung Zangbo River, along this major suture zone between the Indian and Eurasian plates. To the South of the river (suture), Cretaceous strata which belong to the northern margin of the Indian Plate are mainly continental shelf deposits, and contain both benthonic and planktonic fossils in abundance. To the North of the river (suture), the Cretaceous deposits are more complex.

In the Paleogene, the Indian Plate collided with the Eurasian Plate. The sea withdrew totally from Tibet at the end of the Eocene. The Tertiary marine faunas were of shallow water type and assemblages were dominated by bivalves, gastropods, ostracods, and foraminifera.

In Tibet, the boundary between Late Cretaceous and Paleocene marine strata is exposed in Gamba, Tingri, Gyangze and Zhongba (Fig. 1). The K/T boundary in Gamba is comformable and well exposed. It has been studied in detail (Wan, 1987), and is described in this paper.

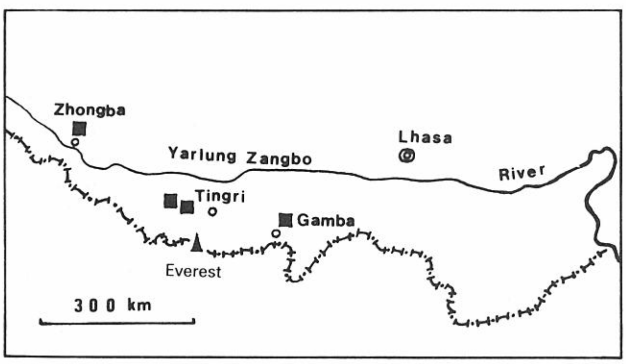

Figure 1. The location of outcrops of Cretaceous/Tertiary Boundary in Tibet.

THE STRATIGRAPHY AND BIOSTRATIGRAPHY OF THE CRETACEOUS/TERTIARY BOUNDARY

The Uppermost Cretaceous unit is the Zongshan Formation, which was established by Mu *et al.* (1973) in the Gamba region. The entire Zongshan Formation is abundantly fossiliferous, yielding ammonoids, bivalves, gastropods, echinoids, corals, ostracods, and foraminifera. The lower unit of this formation is composed of alternating grey limestones and marls, in which companian fossils are contained. According to Wan (1988), two planktonic foraminiferal zones were recognised from the Campanian. The lower part of the Campanian belongs to the *Globotruncrana elevata* Zone. *G. elevata* is dominant and limited to it. Other planktonic foraminifera are *Globotruncana fornicata* Plummer, *G. coronata* Bolli, *G. stuarti* (de Lapparent), *G. bulloides* Vogler, *G. ventricosa* White, *G. linneiana* (d'Orbigny), *G. linneiana tricarinata* (Quereau), *G. stuartiformis* Dalbliez, *Praeglobotruncana anomala* Wan, *Heterohelix globulosa* (Ehrenberg), *H. cordatus* Wan; The Upper Campanian is the *Globotruncana stuartiformis* Zone. Some species of the planktonic foraminifera disappeared before this zone. *Globotruncana stuartiformis, G. stuarti, G. fornicata* and *Heterohelix cordatus* continue into this zone. Only one species of larger foraminifera *Orbitoides tissoti* Schlumberger occurs in the upper part of this zone. In Zhang's unpublished data the dominant ammonoids found in the Zongshan Formation are *Pachydiscus bassae, Menabites pauciturculatus, M. (Delawarella) jeanneti, M. (D) subdelawarensis, Pseudoschloenbachia augusta*, and *Baculites sparsinodosus.* This assemblage can be compared with the *Menabites bouki* and *Anapachydiscus arriborensis* Zones of the Middle Campanian in Madagascar.

The upper unit of the Zongshan Formation is composed of dark grey foraminiferal limestones of Maastrichtian age. All the planktonic foraminifera disappeared here and abundant benthonic larger foraminifera flourished. *Orbitoides tissoti* Schlumberger, *O. media* (d'Archiac), *O. apiculata* Schlumberger, *Omphalocyclus macroporus* (Lamark) and *Lepidorbitoides minor* (Schlumberger) occur in the most parts of the Maastrichtian, only *Orbitoides apiculata*, and *Omphalocyclus macroporus* stil exist upto the end of the Maastrichtian (Tab. 4).

The Cretaceous/Tertiary boundary is well preserved in the Gamba region. The larger foraminifera limestones of the upper Zongshan Formation constitute the uppermost beds of the Upper Cretaceous. No apparent break in stratigraphy or sedimentation was observed between the Latest Cretaceous and Earliest Tertiary. A layer of five meters sandy-limestones at the base of the Jidula Formation contact the Zongshan Formation. It can be readly distinguished by its brown-yellow color and sandy content from the underlying darkgrey lager foraminifera-bearing limestones of the Zongshan Formation. At the bottom of the Jidula Formation all Cretaceous larger foraminifera extincted and Danian foraminifera, ostracods and bivalves began to appear. This fauna will be discussed below.

The Jidula Formation is composed mainly of yellowish-white, indurated homogeneous sandstones, with intercalations of sandy limestones in its middle

Lithological Units	European Stages	Age
Zongpu Formation	Landenian	E_1
Jidula Formation	Danian	
Zongshan Formation	Maastichtian	K_2

Table 1. Stratigraphy between the Cretaceous/Tertiary Boundary of Tibet.

and lower parts. It crops out in the Gamba and Tingri regions. This formation was first recognized at Gamba and referred to the Upper Cretaceous by Wen (1974). The present author, however, has shown that it belongs to the Danian of the Paleocene (Wan, 1987) (Tb.1).

The age of the Jidula Formation provides the key to the location of the Cretaceous/Tertiary boundary. As early as 1907, Hayden referred to these beds as the "Ferruginous Sandstones" and suggested that their age was Early Tertiary. Rao (1964) suggested that they were Paleocene and equivalent to the Ranikot Formation of Pakistan. Wen (1974) correlated the Jidula Formation lithologically with the Pab Sandstones of Pakistan. He suggested that both deposits were of Maastrichtian age.

The present author has delimited the geographical distribution of the Jidula Formation and has recovered a considerable fauna of bivalves, ostracods, and foraminifera in its intercalations of the sandy limestones. A new foraminiferal assemblage was discovered in the collection of the lowermost sample, which is 1.5 meters above the base of the formation, and the samples in the middle intercalation of sandy limestones, in which *Rotalia dukhani* Smout, *R. hensoni* Smout, *Smoutina cruysi* Drooger, *Lokhartia haimei* (Davies), and *Anomalina*, sp. are important elements. *Rotalia dukhani* and *R. hensoni* were originally reported from the Lower Paleocene of the Arabian shore of the Persian Gulf by Smout (1954). *Smoutina cruysi* was discovered in the Plaines Formation of South America, which is of Early Paleocene age (Drooger, 1960). The age of *Anomalina* is not older than Paleocene (Hao *et al.*, 1980). The bivalves found here are *Pholadomya clathrata* Gou, *Mytilus arrialoorensis* Stoliczka, *Laevitrogonia meridiana* (Woods), *Cardium* sp., *Xenocardita* sp., and others. Of these bivalves, *Pholadomya clathrata* is an endemic species similar to the Tertiary species *Pholadomya falconensis* Hodson of the Caribbean area in morphology. *Cardium* is not found in strata older than Paleocene in Asia. Many ostracods have been found in the Jidula Formation. They belong to the following genera: *Bairdoppilata, Neonesidea, Uroleberis, Cytherella, Propontocypris, Brachycythere, Xestoleberis, Hermanites, Phlyctenophora.* Most of these genera are represented in the Tertiary of the Tethys, in which *Uroleberis* is reported from the Paris Basin, Sudan and Pakistan, its age is not older than Paleocene; *Propontocypris* is widespread in the Atlantic and Mediterranean since Paleocene. From an analysis of these three groups, the age of the Jidula Formation seems to be Early Paleocene.

The conclusion by previous authors that the Jidula Formation and the Pab Sandstone of Pakistan were synchronous and of Upper Cretaceous age was made on lithostratigraphic grounds. It did not consider faunal evidence or the fact that the boundary between the calcareous and arenaceous facies, reflecting Late Cretaceous regression, was diachronous. The base of the sandstone facies in the Lower Indus Basin of Pakistan is considerably older than it is in the Gamba region of Tibet (Tab. 2), (Nagappa, 1959; Rao, 1964).

In the Lower Indus Basin, the Pab Sandstone is of Middle Maastrichtian age, and is overlain by the Korara Shale (Kureshy, 1970). The lower part of the Korara Shale is characterized by a microfossil assemblage dominated by species of *Globotruncana* and *Rugoglobigerina*, the most abundant species being *Globotruncana conica* White, *G. stuarti* (de Lapparent), *G. aegyptiaca* Nakkady, *G. contusa* Cushman, *Praeglobotruncana citae* (Bolli), *Pseudoguembelina striata* (Ehrenberg), *Heterohelix reussi* (Cushman), *Pseudotextularia elegans* (Rzehak), *Rugoglobigerina rugosa* Brönnimann, and *R. petaloides* Gandolfi. All these species characterize the Uppermost Maastrichtian in this region. The fauna of the upper part of the Korara Shale is characterized by *Globigerina triloculinoides* Plummer, *G. linaperta* Finlay, and *Globorotalia pseudodulloides* (Plummer), which indicate a Danian age. The Cretaceous/Tertiary boundary occurs here within the Korara Shale (Kureshy, 1970).

Age		Pakistan		Tibet	
		Lower Indus Basin	Upper Indus Basin	Zongba	Tingri & Gamba
E_1	Land.	Ranikot Formation	Ranikot Formation	Jialazi Formation	Zongpu Formation
	Danian				Jidula Formation
		Korara Shale		Sandstone	
K_2	Maastr.	Pab Sandstone	Lumshwal Sandstone	Qubeiya Formation	Zongshan Formation

Table 2. Stratigraphy Correlation of the Cretaceous/Tertiary Boundary between Tibet and Pakistan.

In the Upper Indus Basin, the same sandstone is called the Lumshiwal Sandstone and is of Late Maastrichtian age. The overlying Ranikot formation contains the planktonic foraminifera *Globorotalia* spp., and the larger foraminifera *Miscellanea miscella* (d'Archiac et Haime), *Lockhartia haimei* (Davies), *Operculina canalifera* d'Archiac, and *O. subsalsa* Davies, all of Paleocene age. The Cretaceous/Tertiary boundary occurs at the top of the Lumshiwal Sandstone.

The sandstone facies extends eastwards into Tibet. At Zhongba, the sandstone belongs to the lower part of the Jialazi Formation. Cretaceous ammonoids have been found just below the sandstone and Paleocene foraminifera just above it. An Iridium anomaly was encountered in a thin layer of clay intercalated in the middle of the sandstone (personal communication with Dr. Liu). It possibly correlates with the Iridium anomaly at the Cretaceous/Tertiary boundary recorded elsewhewre. Maastrichtian larger foraminifera *Lepidorbitoides minor* (Schlumberger), *Sulcoperculina* sp. and ammonoids *Sphenodiscus* sp. have been found 3 meters below this layer, and the following Paleocene foraminifera occur 4 meters above it: *Ranikotalia bermudezi* (Palmer), *Lockhartia* sp., *Textularia* sp., *Miliola* sp. Thus, the Cretaceous/Tertiary boundary in Zhongba seems to occur in the middle of the sandstone. Further East, the Jidula sandstone occurs at Gamba and Tingri, and as mentioned previously the Cretaceous-/Tertiary boundary occurs at its base in this region.

In summary, sandstones similar to those of the Jidula Formation are referable to the Middle Maastrichtian in the Lower Indus Basin, and to the Upper Maastrichtian in the Upper Indus Basin. In Zhongba region, the Cretaceous/Tertiary occurs within the sandstone, whereas the sandstone is entirely of Lower Paleocene age in the Gamba and Tingri regions. The age of the sandstone, therefore, become younger and younger along the direction of the regression (Fig. 2).

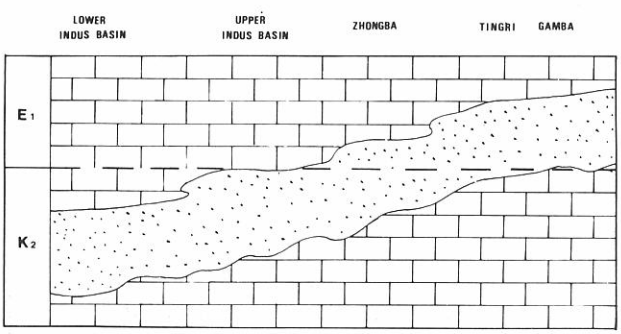

Figure 2. Diagram showing diachronous of the Jidula Sandstone.

THE CRETACEOUS/TERTIARY BOUNDARY EVENT

During the Late Cretaceous, a so-called Himalayan sea existed between the Indian and Eurasian plates. From the Mid-Maastrichtian to Early Danian, this area was characterised by marine oscillations. The broad band of regressive sediments stretching from Pakistan via Tibet to Assam. The end-Cretaceous regression began to occur in the Early Maastrichtian when the sea level fall and a shallow water platform is formed with different procceding in different regions. While the main regression occured from the Middle Maastrichtian to the Early Danian, represented by widespread sandstones. This event is closely related to the Latest Cretaceous global eustatic change, although it took a longer time interval and had the local effect of a general elevation of the region caused by the collision of the Indian Plate against the Eurasian Plate.

As discussed above, this regression is marked by the deposition of arenaceous facies of varying thickness over the entire Himalayan area. The age of the sandstones shows that at the end of the Cretaceous the regression proceeded from both east and west and the sea withdrew towards the Gamba-Tingri Basin (Fig. 3). It caused the ecological effects and recorded the major changes of the marine biota between the Latest Cretaceous and Early Paleocene.

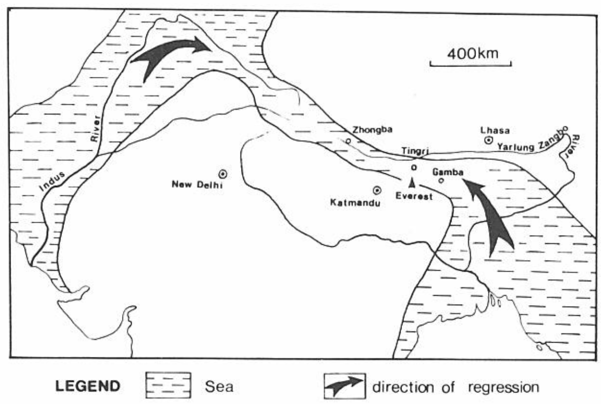

Figure 3. Sketch map showing the regression of late Cretaceous and early Paleocene in Himalayan area.

This regressive phase was followed by the Paleocene transgression, which began in both the Lower Indus and Assam basins and then extended to the Upper Indus Basin. The trasgression did not reach the Gamba-Tingri Basin until the Late Danian. The area covered by the Paleocene sea extended from the Gamba-Tingri Basin westwards to Pakistan and eastwards to Assam.

THE CRETACEOUS/TERTIARY BOUNDARY EXTINCTION

As elsewhere, there was a considerable change in faunas between the Cretaceous and the Tertiary in Tibet. Many elements of the fauna-ammonoids, planktonic foraminifera, larger foraminifera, and inoceramid and rudistid bivalves, disappeared in this

Age		Ammonoids	Planktonic Foraminifera	Larger Foraminifera	Bivalvia
E_1	Danian			Rotalia dukhani R. hensoni Lockhartia haimei Smoutina cruysi	Mytilus arrialoorensis Pholadomya clathrata
	Maastri.	Sphenodiscus sp.		Omphalocyclus macroporus Orbitoides media O. apiculata Lepidorbitoides minor	Bournonia haydeni Praeradiolites sp. Inoceramus sp. Biradiolites sp.
K_2	Campan.	Pachydiscus bassae Menabites pauciturculatus Pseudoschloenbachia augusta Baculites sparsinodosus	Globotruncana stuartiformis G. stuarti G. fornicata G. elevata G. ventricosa Heterohelix globolosa		

Table 3. Change of faunas at the Cretaceous/Tertiary boundary in Tibet.

region towards the end of the Cretaceous. As mentioned above, the end-Cretaceous regression happened in this region lasted for a period of time, and it changed the marine environment to a degree stepwise in nature, so that different marine taxa extincted in order of priority according to their ecological tolerance.

As Table 3 demonstrates, various ammonoids have been found in the Campanian. During the Maastrichtian, ammonoids disappeared except only one species of *Sphenodiscus* found in the Zhongba region. Similarly, planktonic foraminifera are abounndant in the Campanian but are absent from the Maastrichtian. Subsequent to the local extinction of the planktonic taxa, certain elements of the benthos, such as larger foraminifera and bivalves flourished during the Maastrichtian. All these forms, however, became extinct towards the end of the Maastrichtian.

The apparent extinction of the plankton in Tibet was earlier than in most parts of the world due to an environmental change from deeper, outer shelf environments during the Campanian to shallow water platform environments associated with Maastrichtian sea level fall. The benthos continued to flourish during this time.

The changes in biota due to these environmental changes are particularly shown for foraminifera in Table 4. Planktonic foraminifera flourished in the Early Campanian, became reduced in number of species during the Late Campanian, and became largely extinct in the Maastrichtian. Conversely, larger foraminifera flourished in the Maastrichtian, but only *Orbitoides apiculata* and *Omphalocyclus macroporus* were remained upto the very end of the Maastrichtian. They were replaced by new microfaunas in the Danian (Tab. 4).

The extinction of different taxa did not occur all at one time at the very end of the Maastrichtian in Tibet. It actually took place over a long interval from Late Campanian to the end of the Maastrichtian as a series of local extinctions resulting from tectonically and/or eustatically generated changes in water depth. All the Cretaceous taxa became extincted before the end of the Maastrichtian, and none of them cross the Cretaceous/Tertiary boundary. This coincide with the global Cretaceous/Tertiary boundary extinction. Deep water deposits recorded the abrupt boundary extinction, and shallow water sequences also marked this major change of marine biota although it was to a degree stepwise in the proceeding of regression causing environmental changes. The faunal changes in the shallow-water marine facies of Tibet demonstrate that this region was not isolated from major global faunal changes taking place in the Cretaceous/Tertiary boundary mass extinction interval.

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Fossils \ Age	Campanian	Maastrich.	Danian
Rotalia orientalis			x
R. saxorum			x
R. trochidiformis			x
Smoutina corpuscula			x
Lockhartia conditi			x
L. conica			x
L. diversa			x
L. tipperi			x
Keramosphaera tergestina			x
Rotalia dukhani			x
R. hensoni			x
Smoutina cruysi			x
Lockhartia haimei			x
Orbitoides apiculata		x	
Omphalocyclus macroporus		x	
Lepidorbitoides minor		x	
Orbitoides media		x	
O. tissoti	x	x	
Globotruncana stuartiformis	x		
G. stuarti	x		
Heterohelix cordatus	x		
Globotruncana fornicata	x		
G. bulloides	x		
G. elevata	x		
G. ventricosa	x		
G. linneiana	x		
Praeglobotruncana anomala	x		
Heterohelix globolosa	x		
Globotruncana coronata	x		

Table 4. Foraminifera occurence at both sides of the Cretaceous/Tertiary boundary in Tibet.

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