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Late Cretaceous-Early Paleogene Foraminiferal Biostratigraphy in Xishan, Gamba, Southern Tibet, China

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1 Introduction

The Cretaceous/Tertiary (Paleogene) extinction event was a mass extinction event occurring at about 65 million years ago between the Mesozoic Cretaceous and Cenozoic Tertiary, which is the one closest to today among the five major extinction events in the the geological history period (Renne et al., 2013). At the end of the Cretaceous, the proportion of species declined gradually, reaching a peak as the species disappeared closer to the K/T(Pg) boundary, after which 70% of the organisms (including the last dinosaurs and other animal groups) were extinct. The K/T boundary is usually composed of a thin layer of fine clay. So far no one has been able to determine what this layer of soil represents. But the plankton fossils and geochemical evidence on both sides of the boundary indicate that there was a 500,000-year interval between the end of the Cretaceous and the beginning of the third season. It is generally believed that the boundary layer of K/T is caused by the impact of asteroids on the earth, which is rich in iridium. Some scholars also insist that the large amount of iridium in the K/T boundary layer may come from crustal movements such as volcanic activity of the earth itself (Duncan and Pyle, 1988). This is because the earth's interior is also determined to contain a large amount of yttrium. The frequent eruption of volcanoes is that many iridium elements enter the atmosphere and eventually fall to the surface, forming a clay layer (K/T boundary layer) of 2-4 cm 65 million years ago.

The Paleogene records the most significant climatic transition during the Cenozoic, when global climate changed from “green-house” to “ice house” (Zachos et al., 2001). The most pronounced climate event of the Cenozoic happened during the Paleocene/Eocene boundary interval, when the PETM (Paleocene-Eocene Thermal Maximum) took place and caused severe fluctuation of the biosphere, especially in marine settings (Speijer and Schmitz, 1998; Jiang et al., 2018). The Paleocene–Eocene Thermal Maximum (PETM), alternatively “Eocene thermal maximum 1” (ETM1), and formerly known as the “Initial Eocene” or “Late Paleocene Thermal Maximum”, was a time period with more than 8°C warmer global average temperature than today. This climate event began at the time boundary of the Paleogene, between the Paleocene and Eocene geological epochs (Westerhold et al., 2008). The exact age and duration of the event is uncertain but it is estimated to have occurred around 55.5 million years ago (Bowen et al., 2015). During the PETM, thousands of petagrams of carbon were released into the ocean-atmosphere system with attendant changes in the carbon cycle, climate, ocean chemistry, and marine and continental ecosystems. The period of carbon release is thought to have lasted <20 ka, the duration of the whole event was ~200 ka, and the global temperature increase was 5–8°C. Terrestrial and marine or ganisms experienced large shifts in geographic ranges, rapid evolution, and changes in trophic ecology, but few groups suffered major extinctions with the exception of benthic foraminifera. The PETM provides valuable insights into the carbon cycle, climate system, and biotic responses to environmental change that are relevant to long-term future global changes (McInerney and Wing, 2011). These

changes may have contributed to a crisis in the deep-water benthic ecosystems and lead to the extinction of the deep-sea benthic foraminifera, which are the most pronounced indicator of the PETM (Miller et al., 1987; Thomas and Shackleton, 1996). In contrast to the rapid benthic extinction, planktonic foraminifera experienced diversification and progressive faunal turnover started before the BEE from lower Zone P5 to the Early Eocene (Canudo et al., 1995; Pardo et al., 1999; Guasti and Speijer, 2007; Jiang et al., 2018).

Therefore, both Cretaceous/Tertiary (Paleogene) extinction event (Alvarez et al., 1980; Pope et al., 1997; Renne et al., 2013) and PETM (Miller et al., 1987; Canudo et al., 1995; McInerney and Wing, 2011) have always attracted the attention of global geologists. A successive Cretaceous-Paleogene marine stratigraphic sequence developed in southern Tibet, which contains abundant microfossils (Wan, 1990; Li and Wan, 2003 a and b; Li et al., 2003, 2005a and b, 2007, 2009, 2011a and b; Niu et al., 2016; Wang et al., 2017; Zhang and Li, 2017) and thus provides a good condition for us to study K-T boundary and PETM through micropaleontology in this area.

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2 Materials and methods

The Xishan section is located in ~2km west of the town of Gamba, southern Tibet. This section was defined as deposited on the Greater Indian passive continental margin and was mainly composed of foraminifera-bearing limestone, shale and sandstone, which represented the southern Tethyan passive margin succession. Detailed lithostratigraphic studies were made in the field and from thin sections in order to identify depositional and sedimentological changes. For paleontological studies, fifty-one (mainly limestone) samples (No. XS1 to XS51) were collected from the Upper Cretaceous and Lower Paleogene in the Xishan section to recover planktic foraminiferal faunas. Numerous thin sections (especially axial sections of foraminifera) were prepared for taxonomic analysis and were cut in different orientations after visual observations. All thin sections are deposited in the collections of the Fossil Identification Center at the China University of Geosciences (Beijing).

3 Result

Abundant foraminiferal fossils were gained from the Xishan section. About 112 species of 48 foraminiferal genera were identified, which consist 65 species of 36 benthic foraminiferal genera (Cretaceous elements such as *Lepidorbitoides minor*, *L. gangdiscus*, *Omphalocyclus macroporus*, *Omphalocyclus* sp., *Orbitoides medius* et al.; and Paleogene elements such as *Aberisphaera gambanica*, *Alveolina vredenburgi*, *A. Aramaea*, *Assilina dandotica*, *Daviesina danieli*, *D. khatiyahi*, *D. tenuis*, *Glomalveolina levis*, *Keramosphaerinopsis haydeni*, *Lockhartia conditi*, *L. cushmani*, *L. diversa*, *L. haimei*, *L. retiata*, *L. roeae*, *Miscellanites julietta*, *M.minor*, *M. primitivus*, *M. yvettae*, *Orbitosiphon punjabensis*, *Rotalia dukhani*, *Rotorbinella skourensis*, and *Subbotina velascoensis* etc.) and 47 species of 12 planktic foraminiferal genera (such as *Archaeoglobigerina blowi*, *A. cretacea*, *A. bosquensis*, *Globigerinelloides ultramicra*, *Globotruncana arca*, *G. linneiana*, *G. sigali*, *G. lapparenti*, *G. bulloides*, *G. bulloides*, *Globotruncanita stuartiformis*, *G. subspinosa*, *G. stuartiformis*, *Hastigerinoides subdigitata*, and *Whiteinella inornata* etc.).

The division of foraminiferal fossil zones is mainly based on the following literatures as Bolli et al. (1985), BouDagher-Fadel (2008, 2013), Christian and Robert (2009) and Kureshy (1978). Based on the study of marine strata and benthic foraminifera in the Late Cretaceous-Early Paleogene in the study area, 13 foraminiferal biozones were identified in four sedimentary stages: (1) During the first sedimentary stage (Coniacian to Maastrichtian), most of them were formed in deep internal-external shallow sea environment, and the planktonic foraminifera with dragon ridges were the main fauna group in this stage (TLK1 with such index species as *Lockhartia conditi* etc.). (2) In the second sedimentary stage (late Maastrichtian), planktonic foraminifera were almost completely replaced by pre-reef fauna (TLK2 with such main genera as *Lepidorbitoides*, *Omphalocyclus* and *Orbitoides* etc.). (3) In the third sedimentary stage (early Paleocene), after the global extinction at the end of Cretaceous, a global warming began in the Paleocene, and an environment of shallow sea reefs began to reappear. Benthic foraminifera more suitable for living in warm shallow sea environment flourished in this period, which mainly consisted of miliolids and rotaliids benthic foraminifera (such as *Ranikothalia*, *Daviesina* and *Lockhartia*, TP1–4). (4) The fourth sedimentary stage (late Paleocene-early Eocene) is a shallow-sea reef environment. The foraminifera fauna is mainly composed of warm-water benthic foraminifera (such as *Alveolina*, *Assilina* and *Nummulites*, TP5–11).

4 Conclusions

(1) The Upper Cretaceous and Paleogene strata in the Xishan section, Gamba records a diverse, abundant, well-preserved benthic foraminiferal fauna that can be assigned to eleven benthic foraminiferal biozones, including two Cretaceous zones (TLK1 and TLK2) and nine Paleogene zones (TP1–11). Based on the analysis and summary of the benthic foraminifera fossils in the shallow sea sediments of Tibet, this paper preliminarily establishes a high-precision foraminifera biostratigraphy of the Late Cretaceous-Early Paleogene in Xishan, Gamba, southern Tibet.

(2) Base on this foraminiferal biostratigraphy and previous carbon isotope migration data (CIE), K/T(Pg) boundary should be located somewhere between TLK2 and TP1 and the P–E boundary is suggested to be located in TP6, corresponding to the upper part of the standard benthic foraminiferal biozone (SBZ5), rather than the boundary of SBZ4–SBZ5, which is suggested by other scholars.

Keyword: foraminifera biostratigraphy, K/T(Pg) boundary, P/E boundary, Gamba, Tibet

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