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ON THE CATASTROPHIC EVENT MARKERS OF THE PERMIAN-TRIASSIC BOUNDARY IN CHINA

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The Permian-Triassic boundary (PTB) sections in China have been studied in detail in the past decade. The fossil record around the PTB in China clearly shows a sudden biotic change at the PTB, which is associated with a series of event markers, ranging from the base of Triassic to several tens of centimeters upsection. One of the candidates for the PTB stratotype is the Meishan Section, Zhejiang Province, China. Table 1 shows the distribution of $\delta^{13}C$, iridium and microspherules around the PTB of the Meishan Section within a thickness of 35cm.

Traditionally, the Late Permian is viewed as the largest mass extinction in the Phanerozoic, but it still needs to be confirmed if it is a sudden event or a gradual extinction. A statistical analysis based on fossil data at the family level or genera level shows that it is difficult to define a clear line for the mass extinction at the end of the Late Permian.

In the absence of macrofossils right next to the PTB the abrupt negative perturbation of $\delta^{13}C$ values can serve as a good quantitative criterion, indicating a clear horizon for the mass killing of the biotia. The uppermost part of the Upper Permian is still characterized by positive $\delta^{13}C$ values showing relatively rich organic activity in the surrounding environment. The large drop in $\delta^{13}C$ at the base of the Triassic indicates a sudden killing of the biomass (including the macro-organisms and micro-organisms in the ocean). The large $\delta^{13}C$ negative perturbation (about 7 per mil, Table 1) at the base of the Triassic demonstrates the significant distinction between background (normal) extinctions and mass killings in Earth's history, and also the abruptness of the catastrophic event at the end of the Permian. Similar patterns of $\delta^{13}C$ changes have been observed in more than five Chinese PTB sections and in several sections around the world. Therefore, the $\delta^{13}C$ shift can serve as an excellent marker for the catastrophic mass killing event at the PTB.

A thorough reinvestigation of the PTB sediments at the Meishan Section documented a moderate Ir anomaly (Table 2). The iridium data obtained by the preconcentrated NAA method show a peak in the uppermost sanple CG672f. The mean of six samples of the CG672 group equals 0.4×10^{-9}. We feel that these data provide clear evidence that an Ir anomaly occurs in a very thin sublayer of the PTB layer ($<$1cm).

Recently, PTB samples from the Nammal Section, Salt Range, Pakistan, have been analysed by RNAA and preconcentrated NAA methods. The maximum Ir values are 0.37×10^{-9} and 0.6×10^{-9} respectively, agreeing well with the Ir value (0.7×10^{-9}) given by Haq (1987) for the same PTB layer at the Nammal Section. Holser *et al.* (1989) erported an Ir spike (0.165×10^{-9}) at the PTB layer in the Carnic Alps of Austria. The iridium spike can be explained by diagenetic or post-

diagnetic migration of the element, so its occurrence may not be limited to the proper base of the PTB layer.

A variety of microspherules have been discovered in the PTB layers of China. The origin of microspherules in the PTB layers is probably multiple. A large amount of microspherules occur in a thin sublayer of the PTB layer (for example, the peak of microspherules in the Shangsi Section, Meishan Section and Huangshi Section in China) and may serve as an event marker.

The four mentioned event markers (mass killing, large $\delta^{13}C$ shift, Ir anomaly, microspherule peak), which appear in the same PTB layer within several tens of centimeters, illustrate that there was a catastrophic event at the PTB. An extraterrestrial event is very probably the cause of the PTB.

Table 1 The distribution of several event markers around the PTB layer of the Meishan Section

Period	Stage	Sample	Thickness (cm)	Number of analyses	$\delta^{13}C$ Mean	Ir	Microspherules
T	Griesbachian	CG674	8	3	−1.47		
T	Griesbachian	CG673	7	3	−5.27	X	
T	Griesbachian	CG672	6	6	−1.00	X	
T	Griesbachian	CG671	4.5	1	−0.32		Y
P	Changxingian	CG722	6	4	1.90		
P	Changxingian	CG723	3.5	1	1.96		

X. See Table 2 for details; Y. A large amount of microspherules.

Table 2 Ir values at the PTB layer of the Meishan Section based on the Preconcentrated NAA method

Sample	Thickness (cm)	Ir
CG673a	2	0.66×10^{-9}
CG672f	1	$2.02\pm0.38\times10^{-9}$
CG672e	1	$0.125\pm0.019\times10^{-9}$
CG672d	1	$0.062\pm0.011\times10^{-9}$
CG672c	1	$0.048\pm0.016\times10^{-9}$
CG672b	1	$0.041\pm0.011\times10^{-9}$
CG672a	1	$0.056\pm0.008\times10^{-9}$

The stratigraphic location of CG672 and CG673 is shown in Table 1.