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The end-Permian regression in South China and its implication on mass extinction

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ABSTRACT

Records of more than 20 Permian-Triassic Boundary (PTB) sections from South China show that widespread end-Permian regression took place in whole South China. Timing of the low ebb of this regression was pinpointed to the *Clarkina meishanensis* and *Hindeodus changxingensis* zones. Biostratigraphic and paleogeographic studies at conodont zonation level reveal that the Yangtze Carbonate Platform and isolated small carbonate platforms in the Hunan–Guizhou–Guangxi (HGG) Basin experienced sedimentary hiatus during these two zones which lasted about 50–100 kya. Meanwhile the basinal areas, namely the Northern Marginal Basin of Yangtze Platform and the Hunan–Guizhou–Guangxi Basin, have continuous conodont zonation with silicious and ashbed deposits. The basinal areas show two negative $\delta^{13}C$ shifts during the PTB interval from *Clarkina yini* zone to *Isarcicella isarcica* zone, while on the platforms there is usually only one negative shift because the early shift at *C. meishanensis* zone was lost during hiatus. The end-Permian regression and successive rapid transgression taking place at the PTB casted important effects to the pattern and process of the PTB mass extinction. The depositional hiatus hitherto underestimated will necessitate reassessment of some interpretations on the causes and results of that extinction.

1. Introduction and biostratigraphic frame

The end-Permian regression has been reported in many literatures (e.g. Erwin, 1993; Yin et al., 2007 and references therein). However, timing and scope of this regression have not been precisely documented so far, and the causation between the end-Permian regression and mass extinction has only been generally discussed. It is noteworthy that the Eurasian Tethys from Italy, Transcaucasia, Iran, Kashmir to South China remained in Changhsingian highstand system tract while the rest of the world experienced a long term Lopingian sea level drop (Dagys et al., 1979; Yang et al., 1987; Henderson and Baud, 1997; Kozur, 2007; Farabegoli and Perri, 2012). This phenomenon has led to underrating the end-Permian regression in Eurasian Tethys, and its effect in the end-Permian mass extinction has given way to other important factors such as anoxia and volcanism (Wignall and Twichett, 2002; Ogden and Sleep, 2012). However, recent works on more than 20 Permian-Triassic Boundary (PTB) sections from South China have shown that the end-Permian regression took place in the whole South China during a precise period—the *Clarkina meishanensis* zone, that it happened synchronously with a pan-South China volcanism and the main episode of the PTB extinction, and that this event can be correlated with synchronous sections in whole Tethys. This paper will discuss its implications on the extinction at the PTB and re-interpretation of some phenomena related to this regression.

Biostratigraphic frame of this paper is based on Zhang et al. (2009) with reference to Jiang et al. (2007) for Meishan, Zhejiang Province, 2011 for Shangshi, Sichuan Province (Fig. 1). Age calibration of the stratigraphic frame (of Meishan) is based on Shen et al. (2011).

In Iran, a *Clarkina hauschkei* zone was inserted between *C. meishanensis* zone and *C. iranica* + *zhangi* zone (=*C. yini* + *zhangi* zone in South China) (Kozur, 2007). Biostratigraphically it corresponds to an unnamed horizon between Bed 25 (*C. meishanensis* zone) and Bed 24e (*Clarkina yini* zone) of Meishan. Despite careful research around this interval in South China, we have failed to find this *C. hauschkei* zone, although conodont samples of juvenile *meishanensis* or aff. *C. zhejiangensis* did exist at this horizon. *C. hauschkei* was found from Greenland and Iran and had a very short duration (15 kyr according to Kozur, 2007), which may not be enough for an independent zone because adjacent conodont zones are several times longer in duration.

Beds 23a–d belonged to the highstand system tract (HST) of the underlying Changxing Sequence. A type 2 sequence boundary (SB) was assigned at the base of Bed 24e; Beds 24e–26 was attributed to shelf margin system tract (SMST) of the overlying Yinkeng Sequence. The limestone Bed 27 was assigned the transgressive surface (TS), and following it was the transgressive system tract (TST) which brought about the cosmopolitan *Hindeodus parvus* biota (Zhang et al., 1997; Yin and Li, 2000).

2. Stratigraphic records of the end-Permian regression in South China

2.1. Northern Marginal Basin of Yangtze Platform (NMBY, Figs. 2, 3)

The Northern Marginal Basin constitutes the northern slope of Yangtze Carbonate Platform. It is herein represented by six sections, all

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System	Age(Ma)	Sequence		Meishan Bed	Meishan Conodont zonation	Shangsi Bed	Shangsi Conodont zonation
Triassic	252. 10	Yinkeng	TST	29 up	*Isarcicella isarcica*	33 31b	*Isarcicella isarcica*
				28	*Isarcicella staeschei*	31a 30b	*Isarcicella lobata*
				27 c,d	*Hindeodus parvus*	30a 29c	*Hindeodus parvus*
Permian	252. 17		TS	27 a,b	*Clarkina taylorae*	29b	*Clarkina taylorae*
			SMST	26	*Hindeodus changxingensis*	28a	*Hindeodus changxingensis*
	252. 28		SB	25	*Clarkina meishanensis*	27	*Clarkina meishanensis*
		Changxing	HST	24	*Clarkina yini*	26 24	*Clarkina yini*
				23	*Clarkina changxingensis*	23	*Clarkina changxingensis*

Fig. 1. Stratigraphic framework of the Permian-Triassic boundary (PTB) strata in South China. HST = Highstand system tract; SB = Sequence boundary; SMST = Shelf margin system tract; TS = Transgressive surface; TST = Transgression system tract. Biostratigraphic frame is based on Jiang et al. (2007) and Zhang et al. (2009) for Meishan, and Jiang et al. (2011) for Shangsi section. Age calibration of the stratigraphic frame (of Meishan) is based on Shen et al. (2011).

belonging to upper slope SMST deposits, because the deep part of the slope has been cut off by southward thrusts of Qinling Orogen. They are indicated successively from east to west as follows.

2.1.1. Meishan Section, Changxing, Zhejiang Province (Zhang et al., 1997; Mei et al., 1998; Yin et al., 2001; Jiang et al., 2007; Xie et al., 2007; Cao and Zheng, 2009; He et al., 2010)

In the PTB strata of Meishan (Fig. 1), the Type 2 SB is set at the base of Bed 24e (Zhang et al., 1997). Biomarkers of Bed 24e reflect environmental stress (Xie et al., 2007), and in this sub-bed happened the miniaturization of conodonts (Luo et al., 2008) and brachiopods (He et al., 2010). The overlying SMST consists of Beds 24e–26 which is only 0.3 m thick because Meishan is a highly condensed section. Within this interval, essentially in Bed 25, occurred the main episode of PTB mass extinction (Song et al., 2013). Relicts of the extinction in Bed 26 constituted a meager mixed fauna of survivors including remnant foraminifers, pseudotirolitid ammonoids, lilliput brachiopods, and newcomers such as *Hypophiceras*, ancestor clariaids, and hindeodid conodonts. The transgressive surface (TS) is located at the base of a widespread limestone 15–30 cm thick—the Bed 27. *H. parvus* first appeared at 8 cm from the base (Bed 27c). Although highly condensed, so far the conodont zonation is complete and no hiatus of zonal level is known in this section, although some hardground has been found (Cao and Zheng, 2009).

2.1.2. Pingdingshan Section, Chaohu, Anhui Province (Tong and Zhao, 2005)

The Changhsingian is composed of siliceous mudstone of Dalong Formation at Pingdingshan section. Bed 1, siliceous mudstone, yields ammonoids *Pleuronodoceras attenuatum* and *Sinoceltites* sp. of the *Pleuronodoceras* zone of South China. This zone may extend up to *C. yini* zone (Bed 24d of Meishan). Bed 2—yellow clay (2 cm), Bed 3—calcareous shale (11 cm), Bed 4—yellowish brown clay (2 cm), probably of volcanic origin and bearing *C. changxingensis*, *Hindeodus typicalis*; Beds 2–4 probably correspond to Beds 25–26 of Meishan. Bed 5—argillaceous limestone (18 cm) bearing *H. typicalis*; although *H. parvus* has not been found, lithology, thickness and conodont of this bed correspond to Bed 27 of Meishan, implying that the PTB may lie somewhere within it. Bed 6—yellowish green calcareous mudstone (14 cm) yielding *Hindeodus* sp. Beds 7–10—interbeds of calcareous mudstone and argillaceous limestone (0.63 m) with *H. typicalis*, *C. planata*, *C. carinata.* Beds10–11—interbeds of yellowish green shale and argillaceous limestone (1.8 m), with abundant *Ophiceras demissum*, *Lytophiceras* sp., *Claraia griesbachi* and other ammonoid and bivalves of *I. isarcica* zone. It seems that Bed 7 and upwards belong to *I. isarcica* zone. Beds 2–4 belong to SMST, but its conodont zonation has not been clarified.

2.1.3. Huangshi Section, Huangshi, Hubei Province (Xia et al., 2004)

At Huangshi section, HS75–77—black silicalites intercalated by limestones, yielding *Clarkina subcarinata* and *C. wangi*, thus corresponds to the *C. subcarinata* zone of Meishan (Mei et al., 1998). HS78–82 (ca.1.5 m)—interbeds of siliceous shale and limestone, with *C. changxingensis*, *C. deflecta* and *Palaeofusulina* spp., thus corresponding to *C. changxingensis–C. deflecta* zone of Meishan (Mei et al., 1998); HS83-1 to 83-3 (Fig. 2 of Xia et al., 2004) or HS 83-3 to 83-5 (text of Xia et al., 2004), 15 cm limestone yielding *C. yini* and *C. zhangi*, HS83-4 to 84-7 (Fig. 3), 42 cm, interbeds of siliceous shale and limestone yielding *C. meishanensis;* these two belong to *C. yini* and *C. meishanensis* zones respectively. HS84-8 to 84-11, grey siliceous shale intercalated by yellow mudstone (0.3 m) with *C. zhejiangensis*, an index conodont of *H. changxingensis* and *C. tayrolae* zones (Mei et al., 1998; Z.Q. Chen et al., 2009), thus corresponding to the two zones of Meishan. From HS84-12 upward the rocks change into mainly black carbonaceous shale intercalated by thin yellow shales (2.3 m), biostratigraphically corresponding to *H. parvus* zone although this zonal fossil has not been found yet. Further upward is an interbed of dolomitized limestone and mudstone, bearing the Triassic bivalve *Claraia–Ophiceras* assemblage. The PTB strata of Huangshi section belong to deep-water Dalong and Yinkeng Formations, which obscures the lithological boundary between the Changhsingian and overlying Triassic. Beds HS83-1 to 84-11 belong to the SMST (shelf margin system tract) deposit of the Yinkeng Sequence, composed of siliceous argillates intercalated by limestone.

2.1.4. Daxiakou Section, Xingshan, Hubei Province (Zhao et al., in press)

It is located at the northern outlet of the southward twirling Xiakou–Lichuan Bay of Northern Yangtze Basin, and was situated in the siliceous middle ramp during the PTB interval (Fig. 2). The Changhsingian is composed of a lower medium-bedded muddy limestone—Wujiaping Formation (Bed 1) and an upper black mudstone and siliceous shale with minor interbeds of muddy limestone—Dalong Formation (Beds 2–10). Beds 1–7a (2.41 m) yield *C. yini* and represent the highstand system tract (HST) of Changxing Sequence. Bed 7b (0.18 m), shaly deposits with *C. meishanensis.* Beds 8–11b (0.27 m), shaly and volcanic ash beds beginning with the FAD of *C. taylorae. H. changxingensis* was not found here. Since in Shangsi it concurs with *C. taylorae* (Jiang et al., 2011), this interval (8–11b) is tentatively correlated to Beds 27a–b in Meishan D section. Beds 11c–12 mainly consist of micrite and volcanic ash deposits (0.18 m), *H. parvus*, *H. typicalis* and other elements appear in this interval, marking the beginning of Triassic. Beds 13–14 are limestone and volcanic ash beds (0.14 m) witnessing the FAD of *Isarcicella staeschei.* Beds 15–31 (1.65 m) belong to *Isarcicella isarcica* zone; mainly contain limestone and micrite, and yielding a few volcanic ash beds. The fossil zonation of Daxiakou can be completely correlated with that of Meishan.

2.1.5. Ganxi Section, Xuan'en, Hubei Province (Mutwakil et al., 2006; Xia, pers. comm.)

It is situated in the carbonate ramp at the southern margin of Xiakou–Lichuan Bay, nearby Yangtze carbonate platform (Fig. 2, Mutwakil et al., 2006). Here the topmost Dalong Formation, Beds 220–233.3 (mudstone intercalated by limestone, 2.5 m, *C. yini* zone) yields *C. yini*, *C. changxingensis*, *C. zhangi*, and *C. deflecta* and belongs to the HST