A Proposed Area for Study of Accessory Section and Point of Terrestrial Permian-Triassic Boundary

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ABSTRACT: After the establishment of the global stratotype section and point (GSSP) of the Permian-Triassic boundary (PTB), the definition of the accessory section and point (ASP) of the terrestrial Permian-Triassic boundary (TPTB) is now on the agenda. However, all good TPTB sections so far known have the following shortcomings: (1) the exact TPTB horizon is difficult to define paleontologically with high-resolution, and (2) accurate correlation between marine and terrestrial PTBs is hard to attain. In order to enhance the understanding of the nature of the global life crisis in both the marine and terrestrial environments across the Paleozoic-Mesozoic transition, these shortcomings need to be addressed. In western Guizhou and eastern Yunnan, Southwest China, some fossiliferous PTB sections which include marine, paralic and terrestrial are well-developed, allowing bed-to-bed correlation of the PTB sequences. Fortunately, the marine PTB sequence in this area is almost the same as found at the Meishan Section, where the GSSP of the PTB is located, which may provide a reliable auxiliary marker for high-resolution demarcation of the TPTB. These features found in western Guizhou and eastern Yunnan make this area a good place to study the ASP of the TPTB, so we propose to study the ASP of the TPTB in this area.

KEY WORDS: terrestrial Permian-Triassic boundary (TPTB), accessory section and point (ASP), western Guizhou and eastern Yunnan.

The global stratotype section and point (GSSP) of the Permian-Triassic boundary (PTB) was ratified by the IUGS Executive Committee in March, 2001. Thus, the GSSP of the PTB is defined at the base of Bed 27c, at Meishan Section D, Changxing County, Zhejiang Province, China, at the horizon where the conodont Hindeodus paradoxus first appeared (Yin et al., 2001).

With the establishment of the GSSP of the PTB, the accessory section and point (ASP) of the terrestrial Permian-Triassic boundary (TPTB) should be defined as well. Cowie et al. (1986) pointed out that the ASP is especially useful in two clearly different kinds of strata such as the correlation of the new red sandstone and the marine Triassic. The marine bioevents across the Paleozoic-Mesozoic transition have long been researched along with the study of the GSSP of the PTB, but the Paleozoic-Mesozoic life crisis on land is hard to estimate due to the uncertainty of the TPTB. Therefore, high-resolution definition and correlation of the TPTB or the terrestrial Paleozoic-Mesozoic boundary is now on the agenda.

STATUS QUO OF TPTB RESEARCH
Terrestrial deposits of the Permian-Triassic
boundary are widely developed all over the world. The global distribution of the TPTB strata is at least equal to that of the marine PTB. However, the study of the TPTB is not as successful as has been for the marine PTB, and the definition and correlation of the TPTB is more difficult than that for the marine PTB. Some investigators have put forward proposals for the construction of a special time scale (parallel to the existing marine one) for continental deposits (Lucas et al., 1992; Lozovsky, 1991). Accordingly, the search and the establishment of the ASP of the TPTB should be proposed as well. However, studies on the subdivision and correlation of the TPTB sequence and the fauna which featured on land are relatively weak. Until now, few type sections of the TPTB have been proposed.

At present, some scholars are inclined to search for a suitable ASP of the TPTB in South Africa (Lucas et al., 1996). The Permian-Triassic Beaufort Group of Karoo basin in South Africa lies within a large intracratonic retro-arc foreland basin in southwestern Gondwana (Smith, 1995). Many vertebrate fossils were found and have been well studied in this area (Kitching, 1977). The *Cistecephalus* Zone and *Lystrosaurus* Zone in this area correspond to the *Dictyodon* Fauna and *Lystrosaurus* Fauna respectively in Xinjiang, Northwest China (Cheng, 1986; Zhao, 1980). South Africa has become one of the most important areas for the study of the TPTB all over the world, but the study of other kinds of fossils has not been as thorough as that of the vertebrates (D'Engelbronner, 1996). Many difficulties are met when attempts are made to establish correlation between the various regional scales, or to locate the continental tetrapod biozones on the universal stratigraphic scale (Battail, 1995; Shishkin, 1994). Some of the problems which are encountered in global correlation are illustrated with the well-known example of the biozones of the Beaufort Group of Karoo basin in South Africa by Battail (1995).

The Chinese mainland laid in the easterneast part of the Tethys during Pangean time represents one of the most developed areas of terrestrial Permian and Triassic sequences in the world. The terrestrial Permian and Triassic sequences in China are mainly distributed to the north of Kunlun-Qinling Mts. Of these, the Dalongkou Section, Jimsar, Xinjiang is the most exhaustively studied TPTB in China, and its biostratigraphy is well known. The TPTB, which is defined by integrative subdivision of vertebrates, bi-valves, ostracods, plants and palynomorphs can be correlated well between different continents (Zhou et al., 1997; Yang et al., 1988). Event stratigraphic studies, such as magnetostratigraphy (Li et al., 1997), sedimentary events and climate change events (Yang et al., 1992, 1988), have been carried out as well. Clearly, it represents one of the world’s best records of the terrestrial Permian-Triassic transition, and further study of this section could provide more precise correlation to the standard global chronostatigraphic scale and a more detailed understanding of terrestrial biotic changes across the PTB (Lucas et al., 1996). Cheng (1993) and Cheng and Lucas (1993) proposed that the Dalongkou Section be considered as a potential auxiliary (nonmarine) GSSP for the PTB.

Some other areas, such as the Moscow syncline in Russia and the Cis-Ural region in Kazakhstan, the Bowen and Sydney basins in eastern Australia, and the Zechstein basin in Germany and its surrounding countries, developed typical TPTB sections, which have also been well studied.

At present, however, all the preferable TPTB sections in the world have the following shortcomings. (1) The exact TPTB position is hard to define with high-resolution due to sporadic occurrence of vertebrates in only a few beds. As a result, between the definable Permian and the definable Triassic, there are always intervals of several tens of meters of uncertain age. Sometimes, a mixed fauna, which cannot be correlated with the marine GSSP, is found in this interval, and of this fauna, different kinds of fossils have different time ranges, so it is hard to demarcate the exact TPTB at those sections. Therefore, the life crisis on land across the TPTB is hard to estimate. (2) An accurate correlation between marine and terrestrial PTBs is hard to achieve. These two shortcomings hamper the understanding of the global life crisis across the Paleozoic-Mesozoic transition.

If we try to establish the ASP of the TPTB in a wholly continental area, it is difficult to make correlation between marine and continental PTBs. However, if an area contains both marine and terrestrial PTBs connected via paralic facies, there is an opportunity to correlate the different facies directly, and the problems mentioned above might be solved. It appears that we found such an area in western Guizhou and eastern Yunnan, where apparently continuous depositions of fossiliferous PTB strata from
marine via paralic facies to land are very well recorded. The greatest advantage of this area is that the marine PTB sequence is almost the same as is found at the Meishan Section, the GSSP of the PTB, allowing bed-to-bed correlation of the type PTB strata with the marine PTB strata of this area, and thus also with the TPTB strata there. The merits of sections in western Guizhou and eastern Yunnan have made this area a good place to study the ASP of the TPTB.

GENERAL GEOLOGY IN WESTERN GUIZHOU AND EASTERN YUNNAN

The terrestrial strata across the PTB in western Guizhou and eastern Yunnan are composed, in ascending order, of the Late Permian Xuanwei Formation, the Late Permian and Early Triassic Kayitou Formation, and the Early Triassic Dongchuan Formation. Based on detailed study of biostratigraphy, Nanjing Institute of Geology and Palaeontology, Academia Sinica (1980) gave a systematic analysis of the strata in western Guizhou and eastern Yunnan. They attributed the terrestrial coal-bearing strata, with occasional marine interlayers, to the Xuanwei Formation. It is overlain conformably by the Kayitou Formation (or Kayitou beds). The lithology of the Kayitou Formation is almost the same as that of the Xuanwei Formation except that there are no interbedded coal beds. According to fossils such as bivalves, ostracods and palynomorphs, the Kayitou Formation, was attributed either to the earliest stage of the Early Triassic by the research group of Nanjing Institute of Geology and Palaeontology, Academia Sinica (1980), or to the late Late Permian and early Early Triassic (Wang and Yin, 2001). The Dongchuan Formation also overlies conformably the Kayitou Formation. There are obvious differences in color between the Xuanwei Formation, Kayitou Formation and Dongchuan Formation. At the outcrop sections, the gray to gray-green strata belong to the Xuanwei Formation, and the variegated strata belong to the Kayitou Formation, while the red strata belong to the Dongchuan Formation. The nonmarine PTB strata in western Guizhou and eastern Yunnan all belong to these types and so are regionally correlatable with confidence can be well correlated regionally.

There are many excellent PTB sections in western Guizhou and eastern Yunnan which include facies from marine through paralic to terrestrial. This area is an ideal region to study the subdivision and correlation of the PTB strata from marine to terrestrial facies. Based on the stratigraphic study of many sections in western Guizhou and eastern Yunnan from the Late Permian to the Early Triassic, the research group of Nanjing Institute of Geology and Palaeontology, Academia Sinica (1980) drew a sketch map showing the changes of lithofacies and paleogeography of this region during the Permian-Triassic transition (Fig. 1). From this figure, it is evident that not only the marine PTB (clastic facies and carbonate facies) but also the non-marine PTB (paralic facies and terrestrial facies) can be found there. The shoreline during the Changhsingian rarely regressed to the east of the Nayong-Liuzhi line, and the shoreline lay approximately to the east of Shuicheng-Qinglong line at the end of the Permian. By the beginning of the Triassic, the seawater transgressed a little to the west, and the shoreline moved accordingly westward to the Xuanwei-Fuyuan line. Thus the genuine TPTB sections should be found to the west of the Xuanwei-Fuyuan line. All three reported TPTB sections, Laibin Section, Xuanwei, Yunnan (Nanjing Institute of Geology and Palaeontology, Academia Sinica, 1980), Zhejue Section and Chahe Section, Weining, Guizhou (Wang and Yin, 2001), lie in this western area.

SIMILAR BED SEQUENCE ACROSS PTB FROM MARINE TO TERRESTRIAL FACIES IN WESTERN GUIZHOU AND EASTERN YUNNAN

The latest study in western Guizhou and eastern Yunnan reveals a set of TPTB sequences which possess almost the same lithology and event associations as the marine Permian-Triassic boundary stratigraphic set (PTBST) in South China. There are also one or two claystone beds across the TPTB in western Guizhou and eastern Yunnan. The results of X-ray diffraction indicate that the main mineral composition of these claystones are illite-montmorillonite and kaolinite, which are almost the same as the composition of the marine PTB claystones. Zircon, apatite, hexagonal dipyrimal quartz and some other accessory minerals indicative of acidic lava have been found in the TPTB claystones at Chahe Section, Weining of Guizhou Province and Mide Section, Xuanwei of Yunnan Province. Shape parameters (length and width) of the zircons and their total frequencies are recorded. These data show that they are the same as the dirt bands in the coal beds of the Xuanwei Formation, which were considered to be formed by weathe-
ring of volcanic sediments (Zhou and Ren, 1983). In addition, transparent hyaline micro-spherules are occasionally found in the boundary claystones of the two sections. Abundant transparent hyaline micro-spherules and black metallic micro-spherules are also found in the TPTB claystones at Zhejue Section, Weining, Guizhou Province. Transparent hyaline micro-spherules are usually round, clear and transparent. Black metallic micro-spherules are also round, some of which appear teardrop-shaped and some have irregular cracks on their surfaces. Both types of micro-spherules appear to be isotropic under the crossed polars. These characteristics of the micro-spherules indicate that they were formed through quick condensation of molten material. Consequently, it is proposed that the TPTB claystones are the result of volcanism, which coincides with the formation of the marine PTB clayrocks of South China (Yin et al., 1989).

A typical three-layer sequence in ascending order, consisting of claystone (bed 54), muddy siltstone (bed 55) and claystone (bed 56), appears across the TPTB at the Zhejue Section. This kind of TPTB association is also found at the Meishan Section, the type section of the PTBST (Fig. 2) (Peng et al., 2001). The following characteristics are found in the underlying and overlying strata of the terrestrial PTBST. (1) Biostratigraphic aspect: the palynomorph assemblages show clear differences be-

Figure 1. Sketch map of lithofacies and paleogeography from Late Permian (Changhsingian) to Early Triassic in western Guizhou and eastern Yunnan (after Yao et al., 1980).
tween the strata above and below bed 54. Typical members of the Triassic are only abundant in bed 54 and overlying strata. Plant fossils are abundant in beds below bed 54 and are rare in the overlying strata (Wang and Yin, 2001). (2) The susceptibility appears distinctly different below bed 54 compared to the overlying strata, its magnitude continues to increase with height above the boundary (Wang and Yin, 2001). This kind of pattern is almost the same as is found across the marine PTB in South China and so it can be correlated with great accuracy (Peng et al., 2000). (3) The value of $\delta^{13}C_{\text{org}}$ changes abruptly across bed 54 and then recovers. $\delta^{13}C_{\text{org}}$ values are relatively low and stable below bed 54 (−24.51 %) − (−26.98 %) and higher and changeable in the overlying strata (−17.63 %) − (−27.20 %) (Wang and Yin, 2001). These characteristics indicate that the terrestrial PTBST might also represent a high-resolution chronostratigraphic PTB.

The presence of claystone in facies ranging from marine to paraic and terrestrial in western Guizhou and eastern Yunnan provides a reliable auxiliary marker for a high-resolution demarcation of the TPTB. Thus, in this area, there exist the potential for a high-resolution subdivision and correlation of the PTB from marine to terrestrial environments. This can then help us understand the terrestrial and global life crisis across the Paleozoic-Mesozoic transition.

CONCLUSIONS

(1) There are many excellent PTB sections which extend continuously from marine to terrestrial via paralic facies in western Guizhou and eastern Yunnan. This area is one of the ideal regions to study the subdivision and correlation of the PTB from marine to terrestrial environments. Thus, we propose to study the ASP of the TPTB there.

(2) Marked by the PTB claystone beds, with the study of the biostratigraphy and some other event stratigraphic characters such as susceptibility, carbon isotope and radiometric dating across the PTBST, the high-resolution correlation framework of the PTB from marine environment facies via paralic environment facies to terrestrial environment can be set up in western Guizhou and eastern Yunnan. This will help to establish the high-resolution correlation framework of the PTB in South China and over the world.

(3) Establishment of high-resolution chronostratigraphic TPTB in western Guizhou and eastern Yunnan will help us to understand the global life crisis from marine to land across the Paleozoic-Mesozoic transition.

However, the work in this area is preliminary and the further study is necessary. We are appreciative of all cooperation with the research in this area.

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![Diagram](image-url)

Figure 2. Common sequence across PTB from marine to land in Yangtze region and its correlation.
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