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Characteristics of claystones across the terrestrial Permian-Triassic boundary: Evidence from the Chahe section, western Guizhou, South China

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Abstract

X-ray diffraction (XRD), scanning electronic microscopy (SEM) and X-ray fluorescence spectroscopy (XFS) studies were undertaken for claystones and/or mudstones from the Chahe section—a terrestrial Permian-Triassic boundary (TPTB) section. Our results indicate that the compositions of claystones in the Permian-Triassic boundary (PTB) interval (Beds 66f–68) outlined by biostratigraphy are different from claystones and/or mudstones found either below or above the interval of the same section. The clay minerals in the claystones of the PTB interval are mainly composed of illite–montmorillonite interlayers, with a few montmorillonites and chlorites. The other claystones and/or mudstones underlying and overlying the PTB consist of chlorites and/or kaolinites. Some authigenic clastic minerals, such as hexagonal dipyramid quartz and zircons, are only found in claystones in the PTB interval from the Chahe section and some marine PTB sections in western Guizhou and eastern Yunnan, southwestern China. In addition, some elements are present in abnormal concentrations in the claystones of the PTB interval as well. Most important is that we found no spherules in all the claystones studied, indicating no evidence of an extraterrestrial impact during the Permian-Triassic transition. The particular characteristics of the TPTB claystones at the Chahe section indicate their volcanic origin and thus provide a reliable auxiliary event marker for high-resolution demarcation of the TPTB in South China. They are also indicative in the marine PTB claystones in South China. Thus, the PTB claystones can be used as auxiliary markers for high-resolution correlation of the PTB from marine facies to land in South China when direct fossil evidence in the PTB sequence is lacking.

Keywords: Permian-Triassic boundary (PTB); Claystone; Chahe section; South China; X-ray diffraction (XRD); Scanning electronic microscopy (SEM); X-ray fluorescence spectroscopy (XFS)

1. Introduction

Claystones of special origin (for example, volcanism as proposed by Yin et al., 1992, and many others) are highly developed across the marine Permian-Triassic boundary (PTB) in South China. Such claystones are useful for investigation of processes and timing of the PTB mass extinction. Each clay bed across the PTB consists of interbedded illite and mixed illite–montmorillonite interlayers, with subordinate kaolinite occurring locally (Yang et al., 1993). Although the clay beds have been generally regarded to be of volcanic origin due to the presence of high temperature quartz, zeolite and relic tuffaceous textures within the clays (Yin et al., 1992), other scenarios are also possible. The scenario of an impact event associated with the Permian-Triassic transition remains controversial because reports on the Ir anomaly in the PTB claystones are usually inconsistent (see Yin et al., 1992 for review and references cited therein). However, some new evidences, including extraterrestrial fullerenes (Becker et al., 2001), meteoritic debris (Basu et al., 2003) and Fe–Ni–Si grains

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(Kaiho et al., 2001) found in the PTB claystones, support an extraterrestrial origin, although there is still significant debate (Braun et al., 2001; Farley et al., 2001; Buseck, 2002; Koeberl et al., 2002; Erwin, 2003). On the other hand, Zhou et al. (1991) argued that the spherules found in the PTB claystones were of diverse origins, in that sanidine, picotitite and rutile spherules might be related to an impact event, and the apatite and organic spherules may be of biogenic origin, while the ferruginous spherules might be related to both. Whatever the origin of the PTB claystones, they are obviously isochronous and can be correlated regionally in South China (Yang et al., 1993; Peng et al., 2001) and as such are an excellent correlation marker for eventostratigraphy. Zircons are commonly found in the marine PTB claystones, and are useful for age determination of the PTB, although results are sometimes very different due to different testing methods (Renne et al., 1995; Bowring et al., 1998; Mundil et al., 2001, 2004).

Claystones were also found across the terrestrial Permian-Triassic boundary (TPTB) in western Guizhou and eastern Yunnan, southwestern China (Wang and Yin, 2001a,b). A study of the TPTB sections in western Guizhou and eastern Yunnan has revealed a stable set of claystone beds associated with the TPTB sections in the study area. Apart from their special origin by volcanism and/or extraterrestrial collision (Wang and Yin, 2001a,b), of particular interest is the regular vertical (stratigraphical) succession of the TPTB sequence, which is usually characterized by the vertical stacking of a clay and/or mudstone, followed by a muddy siltstone, which in turn is followed by a second clay and/or mudstone bed. This regular succession of claystone beds, which is common to all the marine PTB sections in South China, is similar to the PTB beds at the Meishan section, where it is characterized by two claystone beds (beds 25 and 26) in the lower part, a micrite bed (bed 27) in the middle, and another clay bed (bed 28) in the upper part. Elsewhere, Peng et al. (2001, 2002) have formally named this succession of PTB beds as the Permian-Triassic Boundary Stratigraphic Set (PTBST) in recognition of its stratigraphic persistence and stability across South China and therefore its potential as an alternative marker for recognizing and correlating PTB in both marine and non-marine PTB sections in South China. The concept has proved very useful for defining the PTB position in sections where no definitive biostratigraphic markers, such as the definite first appearance of conodont *Hindeodus parvus* (Kozur et Pjatakova), is available in South China (see Peng et al., 2001 for more details).

2. Geological setting and outline of stratigraphy

The Chahe section is located between the 31 and 32 km milestones of the country road from Heishitou Town to Haila Town, Weining City (Fig. 1). The section includes the upper half of the Upper Permian to lowermost Triassic Xuanwei Formation, the entire lowest Triassic Kayitou Formation (Wang, 2001, 2002) or Kayitou Bed (Nanjing Inst., 1980) and the lower part of the Lower to Middle Triassic Dongchuan Formation (Fig. 2).

2.1. Lithostratigraphy

The Xuanwei Formation is composed of terrestrial clastics (sandstones and siltstones), interbedded with coal beds and/or seams. The Xuanwei Formation is conformably overlain by the Kayitou Formation, which in lithology is almost the same as that of the Xuanwei Formation except that it lacks interbedded coal beds or seams. The Dongchuan Formation, conformably overlying the Kayitou Formation, is dominated by clastic sediments (sandstones and siltstones) of terrestrial origin as well.

There are clear differences in rock color between the Xuanwei, Kayitou and Dongchuan formations in the Chahe section. At the outcrop section, the grey to grey–green strata belong to the Xuanwei Formation, the variegated to the Kayitou Formation, and the purple to the Dongchuan Formation. The non-marine PTB strata in southwestern China all belong to these color types and can be well correlated lithologically and regionally (Peng et al., 2005).

2.2. Biostratigraphy

Only plant fossils and sporomorphs have been found in the Chahe section, western Guizhou (Wang and Yin, 2001a; Peng et al., 2005). Plant fossils are abundant mainly in the Xuanwei Formation, with very few species found in the Kayitou Formation and no intact plants found in the Dongchuan Formation (Fig. 2). Sporomorphs are also abundant in the Xuanwei Formation, but less so in the Kayitou Formation. Until now, no sporomorphs have been found in the Dongchuan Formation (Fig. 2). The PTB in the Chahe section marks the mass decrease of plants and the compositional change of plants from the dominance of Palaeozoic ferns and pteridosperms to the dominance of Mesozoic gymnosperms (Peng et al., 2005).

33 species of 19 genera of fossil plants have been discovered at the Chahe section, distributed in 19 beds from Bed 1 to Bed 69, all belonging to the upper part of the Xuanwei Formation (Nanjing Inst., 1980; Peng et al., 2005). Three plant assemblages have been recognized from the Chahe section, which can be regionally correlated in South China (Nanjing Inst., 1980). The first two assemblages are both composed of filicopsids, pteridosperms, lycopsids and sphenopsids, although the floral diversity decreases afterwards. The third assemblage marks the extinction of the Cathaysian flora. No identifiable plant remains at this stage have been discovered in the Chahe section. Regionally, plant fossils of this stage are also sparse and rare in South China.

The composition of spores and pollen in the Chahe section suggests three distinct evolutionary stages across the