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The Permian–Triassic boundary at Nhi Tao, Vietnam: Evidence for recurrent influx of sulfidic watermasses to a shallow-marine carbonate platform

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Abstract

The Permian–Triassic boundary at Nhi Tao, Cao Bang Province, Vietnam was sampled in a 7.5-m-thick outcrop section at high resolution (~5 cm intervals) for chemostratigraphic and magnetic susceptibility analysis. The section consists entirely of slightly argillaceous limestone representing shallow-marine facies of the Jinxi Platform, one of several large carbonate platforms within the Nanpanjiang Basin, located on the southern margin of the South China Craton. Upper Permian strata (Beds 1–7) are mainly dark-gray, cherty fossiliferous wackestones and packstones containing a diverse open-marine fauna, whereas uppermost Permian and Lower Triassic strata (Beds 9 and higher) are medium-gray calcimicrobial framestones containing rare macrofossils. These facies are separated by a 12-cm-thick oolitic–pisolitic grainstone (Bed 8) that coincides with the disappearance of most Late Permian faunal elements as well as with the first appearance of various geochemical anomalies that continue into the Lower Triassic part of the section. This “Late Permian event horizon” is characterized by (1) an abrupt decline in total organic carbon to near-zero values, (2) the onset of a sustained decline in carbonate $\delta^{13}C$, and (3) the first of eight concentration peaks in pyrite sulfur. Significantly, each sulfide peak is associated with lower pyrite $\delta^{34}S$ values as well as with the *onset* of a negative carbonate $\delta^{13}C$ excursion (or the acceleration of an excursion already in progress). These chemostratigraphic relationships are consistent with multiple episodes of upwelling of sulfidic, ^{34}S- and ^{13}C-depleted deep-ocean waters onto the Jinxi Platform. The first upwelling event was the most intense and caused a drastic reduction in primary productivity and the demise of the Late Permian fauna; subsequent episodes were less intense but may have contributed to a delay in recovery of Early Triassic marine ecosystems. A ten-fold increase in magnetic susceptibility in Bed 9 may record the influx of fine detrital particles following destruction of terrestrial ecosystems and massive soil erosion. The terrestrial signal of the end-Permian catastrophe thus follows the marine signal with a 12-cm lag, which may reflect the time-of-transit of soil-derived particles across the Nanpanjiang Basin, suggesting that the marine and terrestrial crises in the Nhi Tao region occurred more-or-less synchronously. These observations suggest a model in which renewal of

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global-ocean overturn followed a prolonged interval of deep-ocean stagnation during the Late Permian, with upwelling intensity modulated by short-term (~20 kyr) climate cyclicity.

Keywords: Paleoceanography; Event stratigraphy; Upwelling; Geochemistry; Total organic carbon; Major elements; Trace elements; C-isotopes; O-isotopes; Magnetic susceptibility

1. Introduction

The Permian–Triassic boundary (PTB) (251.4±0.3 Ma, Bowring et al., 1998; 252.6±0.2 Ma, Mundil et al., 2004) is characterized by far-reaching changes in global climate, ecosystems, and geochemical cycles. The Late Permian mass extinction, which eliminated ~90% of marine and ~70% of terrestrial species, was the single largest extinction event in the Phanerozoic record and was followed by the widespread appearance of "disaster taxa" (Fig. 1; Raup, 1979; Schubert and Bottjer, 1992; Erwin, 1994; Retallack, 1995; Sepkoski, 1996; Baud et al., 1997; Rampino and Adler, 1998; Bowring et al., 1999; Jin et al., 2000; Benton and Twitchett, 2003). This event was associated with the onset of a pronounced negative shift (from −3 to −8‰) in marine carbonate δ^{13}C values (Baud et al., 1989; Holser et al., 1991; Baud et al., 1996; Jin et al., 2000; Cao et al., 2002; Korte et al., 2004; Payne et al., 2004; Horacek et al., 2007-this volume-a-b) and a correlative excursion in the organic carbon δ^{13}C records of both marine and terrestrial successions (Fig. 1; Hansen et al., 2000; Krull and Retallack, 2000; Krull et al., 2000; Twitchett et al., 2001; de Wit et al., 2002; Sephton et al., 2002). Further, various types of evidence (e.g., redeposited soils, influx of soil-derived organics to marine environments, and changes in stream morphology) have been interpreted to indicate widespread deforestation of land areas and rapid erosion of destabilized soils following the Late Permian mass extinction event (Sephton et al., 2005; Wang and Visscher, 2007-this volume).

Collectively, these observations suggest that the Late Permian event horizon (LPEH) was produced by a major catastrophic event, for which various mechanisms have been proposed (see reviews in Ward, 2000; Erwin et al., 2002; Berner, 2002; Benton, 2003). A case for a bolide impact was built on the basis of extraterrestrial He ratios,

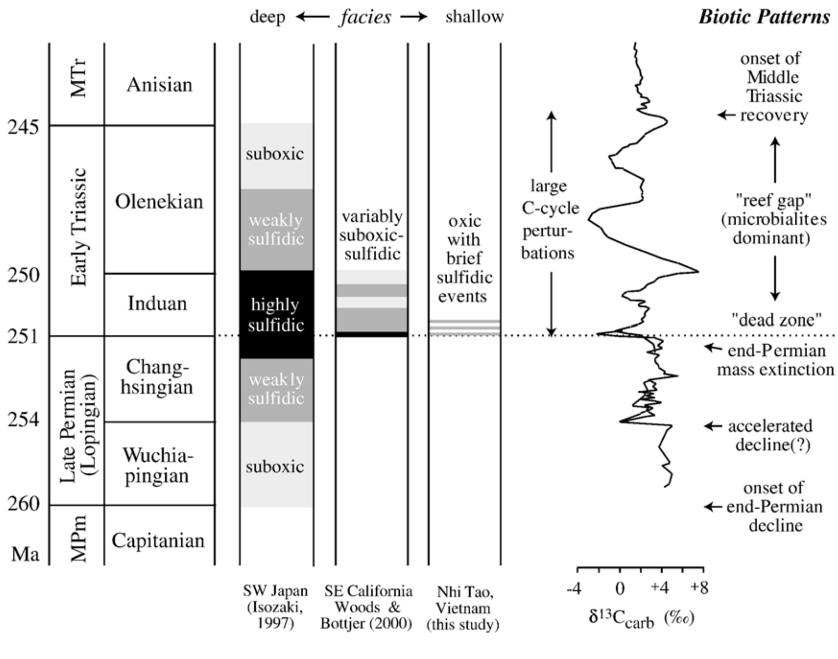

Fig. 1. Generalized depth-dependent redox conditions in Permian–Triassic oceans; based on Isozaki (1997), Woods and Bottjer (2000), and this study. Carbonate δ^{13}C data are for South China sections from Chen et al. (1991), Shao et al. (2000), and Payne et al. (2004). Biotic patterns summarized from Erwin (1994), Erwin et al. (2002) and other sources. Time scale is from Gradstein et al. (2004).