

## THE PERMO-TRIASSIC CRISIS IS PROLONGED, AND THE PTB MASS EXTINCTION IS MULTI-PHASE

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The end-Guadalupian and the Permian-Triassic boundary (PTB) extinctions constitute two phases of a biotic crisis. Following the end-Guadalupian extinction phase, the Paleozoic biota underwent a steady decline through the Lopingian (Late Permian), resulting in their decimation at the PTB level. This trend coincided with the integration of Pangea and related global changes, including the palaeomagnetic shift from a stable reversed superchron to the Permo-Triassic Mixed Superchron (PTMS), double-phase volcanism (Emeishan and Siberia Traps) and the greatest Phanerozoic regression. The extinction at the end of the Guadalupian and that marking the end of the Permian are thus related. The subsequent recovery of the biota occupied the whole of the Early Triassic. Several phases of perturbations in  $\delta^{13}\text{C}_{\text{carb}}$  occurred through a similar period, from the Late Wuchiapingian to the end of the Early Triassic. Therefore, the Permian-Triassic crisis was protracted, and spanned Late Permian and Early Triassic time.

The mass extinction at the Permian-Triassic Boundary (PTB) is said to have been abrupt (at the base of bed 25) and probably caused by an extraterrestrial impact. However, evidence from the Global Stratotype Section and Point (GSSP) of the base of the Induan at Meishan, China, shows that the biotic crisis began prior to bed 25 at which the postulated impact event occurred. Evidence of such a prelude occurs in other sections in South China, and in central and western Tethyan regions. This event is characterized by the extinction of a range of faunas, including corals, deep-water radiolarians, most fusulinids and pseudotiroliitid ammonoids, and many Permian brachiopods. In all sections, this extinction level is usually a few decimeters to meters below that of the main mass extinction in the event beds (25 and 26) at Meishan, and their correlatives elsewhere.

Research advances related to the biotic crisis, molecular fossils and volcanism show that there is a second PTB extinction at bed 28 and its equivalents in South China and Tethys. This is the epilogue of the PTB extinction. Hence, the extinction associated with the PTB occurred in two episodes, the main act (accompanied with the prelude) and the epilogue. The prelude commenced at bed 24, prior to beds 25 and 26 at Meishan and coincided with the end-Permian regression. The main act happened in beds 25 and 26 at Meishan. The epilogue occurred in the late Griesbachian bed 28. The temporal distribution of these episodes constrains the interpretation of mechanisms responsible for the greatest Phanerozoic mass extinction, particularly consideration of the significance of a postulated bolide impact that may have occurred about 25,000 years after the prelude.

The prolonged and multi-phase nature of the Permo-Triassic crisis favors mechanisms of Earth's intrinsic evolution rather than an extraterrestrial catastrophe. The most significant regression in the Phanerozoic, the paleomagnetic disturbance of the PTMS, widespread extensive volcanism, and other events, may all be related, through deep-seated processes that occurred during the integration of Pangea. These combined processes could be responsible for the profound changes in marine, terrestrial and atmospheric environments that resulted in the end-Permian mass extinction. Bolide impact is possible but is neither an adequate nor a necessary explanation of these changes.