

Land-Sea Asynchrony: Revealing the Temporal Discrepancy in Terrestrial and Marine Extinctions at the End of the Permian

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On January 31, 2024, Shu Zhong Shen and his research team published an article in the journal Science Advances titled "The terrestrial end Permian mass extinction in the paleotropics postdates the marine extrapolation." The article investigated the temporal shift of the last Permian mass extinction between land and ocean, focusing mainly on the land and transitional coastal strata in southwestern China. By high-precision zircon U-Pb isotope dating of tuff samples from several key strata, it was revealed that the collapse of terrestrial ecosystems actually began after the mass extinction of marine organisms. The analysis results show that the extinction process of this terrestrial ecosystem is not only later than that of marine ecosystems, but also exhibits significant asynchrony at different latitudes. Research has shown that the extinction of terrestrial organisms began in high latitude areas and gradually expanded to low latitude areas, with the entire extinction process spanning nearly one million years. The possible environmental and biological response mechanisms discussed in the article during the extinction process provide a new geological and temporal framework for understanding one of the most serious biological crises in Earth's history.

1 Analysis of Experimental Data

The study utilized high-precision zircon U-Pb isotope dating technology to analyze tuff samples from different strata in southwestern China. The results indicate a significant temporal difference between terrestrial and marine extinctions. Detailed chronological data confirmed that the collapse of terrestrial ecosystems began after the marine extinction and that this phenomenon was more pronounced in high-latitude regions, gradually extending to low-latitude areas. These data provide new insights into geographical and ecosystem responses, revealing the asynchrony of extinction events at different latitudes.

Figure 2 shows the stratigraphic comparison of different locations in southwestern China (including the Guizhou Basin, Emeishan Igneous Province, and other regions) during the Late Permian Biomass Extinction Event (EPME). This chart reveals the correlation between environmental and biodiversity changes in land and transitional coastal areas by displaying the value changes in each location, the distribution of volcanic ash and organic carbon layers, and the extinction time points of specific plant communities. The stratigraphic records of each section not only display the richness of biodiversity changes, but also reflect the impact of major environmental disturbances such as volcanic activity on ecosystems.

Figure 3 shows the distribution of $^{206}\text{U}/^{238}\text{Pb}$ ages of zircons in tuffs from the land and transitional coastal regions of southwest China. Using the Bayesian MCMC algorithm and weighted mean model, different colored bars and horizontal lines in the figure represent the estimated eruption ages of different samples and their error ranges. From the figure, it can be seen that the age distributions of different samples vary to some extent. These data reflect the volcanic activity history and sedimentary ages of the stratigraphy in the study area during the Late Permian. Specifically, some data from samples MD110217-3 and MD110217-2 were excluded due to nonconformity, highlighting the need for rigorous data screening and quality control when conducting geological chronological analyses.

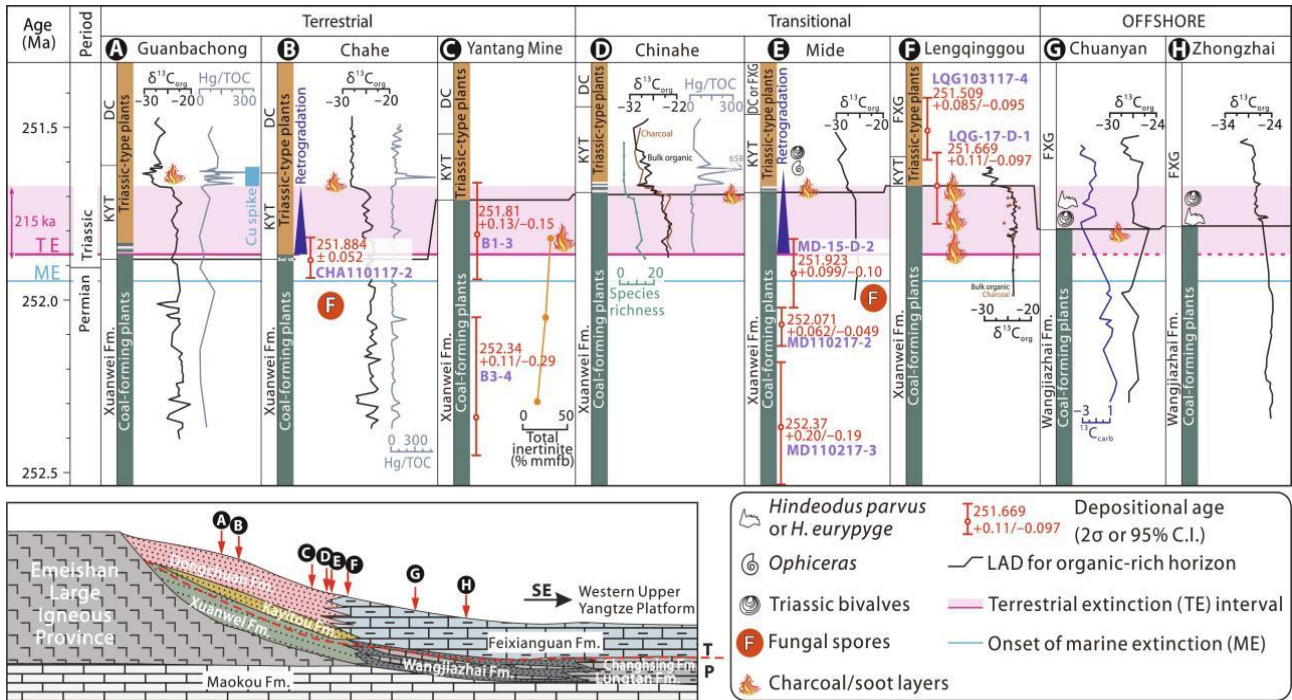


Figure 2 Correlations of the EPME between terrestrial and transitional coastal sections in Southwest China

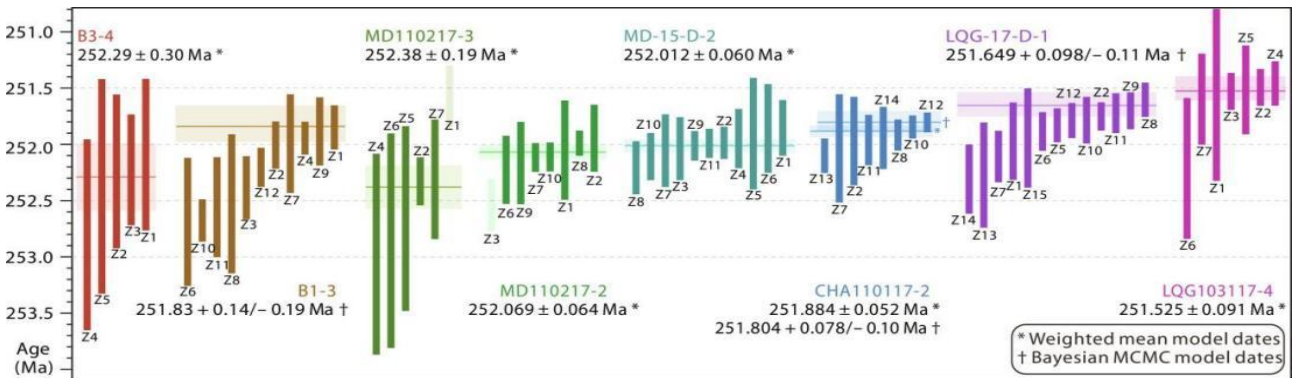


Figure 3 $^{206}\text{U}/^{238}\text{Pb}$ age distribution of analyzed single zircons from tuffs in terrestrial and transitional coastal sections in Southwest China

Figure 5 illustrates the correlation between various strata around the world during the end-Permian mass extinction (EPME). Using high-precision U-Pb geochronology data, the figure details geological and biological events across different regions, from the Sydney Basin in Australia to southern China and the Karoo Basin in South Africa. These data reflect patterns of biological extinction and environmental change in different paleogeographic locations, such as the onset of terrestrial and marine extinctions and changes in plant communities. The precise age comparison of strata records from various regions reveals the synchronicity and regional variability of global extinction events, providing key evidence for understanding global environmental changes during this geological period.

2 Methodological Assessment

The zircon U-Pb isotopic dating technique employed in this study is the high-precision chemical abrasion-isotope dilution-thermal ionization mass spectrometry (CA-ID-TIMS) method, which is widely regarded as one of the most accurate radiometric dating methods in geology. The advantage of this method lies in its ability to provide absolute ages with extremely low errors, which is crucial for studying short time-scale events in Earth's history. The method allows researchers to identify and exclude data biases that may arise from sample impurities, such as extraneous zircons, thereby obtaining more accurate stratigraphic ages.

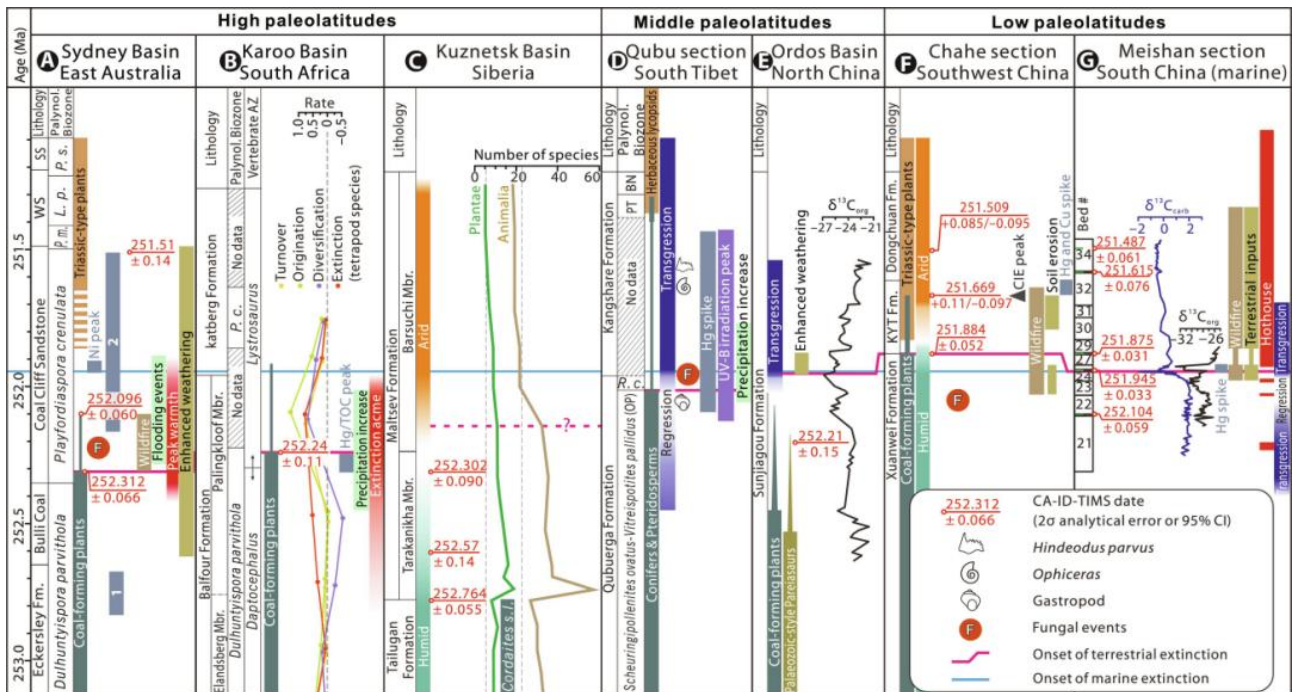


Figure 5 Global correlation of the EPME

However, the limitations of the CA-ID-TIMS technique should also be considered. The selection and processing of samples can affect the geochronological results, particularly when mixed zircons from different sources are present in the samples. Although this technique can provide extremely high dating precision, it requires very high standards for sample quality and condition, which may make it challenging to apply in regions with incomplete stratigraphic records or poor preservation conditions.

3 Review of Research Findings

By conducting high-precision zircon U-Pb geochronological analyses on tuffs from various strata in southwest China, this study revealed a significant temporal discrepancy between terrestrial and marine extinction events. The analysis results indicate that the onset of terrestrial extinction exhibits significant asynchrony across different latitudes and generally occurs later than the onset of marine extinction. Overall, terrestrial extinction began in high-latitude regions and then gradually expanded to lower latitudes over nearly a million years. This time span, compared to marine extinction events, shows that terrestrial ecosystems responded more slowly and diffusely to environmental changes.

4 Conclusions and Significance

This study, through high-precision zircon U-Pb geochronological analyses of tuff samples from the strata of southwest China, has revealed a temporal mismatch and geographic variability between terrestrial and marine extinction events. This finding holds significant scientific importance. It challenges the traditional viewpoint that the end-Permian mass extinction occurred synchronously on land and in the oceans, offering readers a new perspective on the most severe extinction event in Earth's history. The results emphasize the importance of considering geographic and latitudinal factors in global catastrophe studies, as these factors significantly influence how biotic communities respond to and recover from environmental changes.

5 Original Text Reading

Wu Q., Zhang H., Ramezani J., Zhang F.F., Erwin D.H., Feng Z., Shao L.Y., Cai Y.F., Zhang S.H., Xu Y.G., and Shen S.Z., 2024, The terrestrial end-Permian mass extinction in the paleotropics postdates the marine extinction, *Sci. Adv.*, 10(5): eadi7284(2024). DOI:10.1126/sciadv.adi7284

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