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Multiproxy Signals of Vegetation Dynamics, Wildfire activity, and Climate Change across the Permian–Triassic Boundary in the Mahanadi Basin of Lower Gondwana, India

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The Permian–Triassic (P/T) boundary records the most severe biotic crisis in Earth's history, yet terrestrial ecosystem responses in eastern Gondwana remain insufficiently constrained due to limited integration of molecular and isotopic proxy frameworks. This study presents a novel multi-proxy approach combining lipid-molecular indices and $\delta^{13}C$ isotopic analysis with palynology, palynofacies, and fossil charcoal records from borehole TTB-7 (Talcher Coalfield, Mahanadi Basin, India) to resolve floral turnover, organic matter sourcing, depositional conditions, and climatic instability across the P/T transition. The palynoassemblage zones—*Densipollenites magnicorpus* and *Klausipollenites schaubergerii*—establish a latest Permian to early Triassic age, corroborated by regional and inter-Gondwana correlation. Molecular proxy signals reveal mixed lipid sourcing: elevated carbon preference index (CPI) and terrigenous/aquatic ratio (TAR) reflect strong land-plant wax input, while a bimodal n-alkane distribution indicates co-contribution from microbial and terrestrial pools. High amorphous organic matter (AOM) and P_{aq} values suggest transient moderate aquatic–humid depositional conditions during the Permian, followed by intensified organic matter degradation marked by hopanoid enrichment, consistent with enhanced bacterial reworking during the crisis interval. The carbon isotopic ($\delta^{13}C$) values range from –31.2‰ to –21.8‰, capturing a pronounced 9.4‰ negative excursion that, together with molecular turnover and palynofacies restructuring, signals abrupt carbon-cycle perturbation and major climatic shift. The wildfire proxy archive provides the earliest macroscopic charcoal evidence of gymnosperm-affinity vegetation burning in the basin during the Lopingian, with pre-charring fungal colonization implying stressed, drought-prone fuel loads that likely amplified fire activity into the early Triassic. Integrated proxy trajectories support a model of short-lived humid phases in the terminal Permian giving way to rapid aridification, warming, and fire-driven floral collapse in the earliest Triassic, contributing to regional terrestrial ecosystem destabilization in eastern Gondwana.

This work demonstrates the first combined molecular-lipid and $\delta^{13}C$ isotopic stratigraphy across the terrestrial P/T boundary from the Mahanadi Basin, offering new constraints on Gondwanan climate extremes and advancing the application of lipid-molecular and stable isotopic proxies in high-resolution terrestrial paleoclimate reconstruction.