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# Unraveling the Charred Past: Microscopic Insights and Advanced Techniques in Understanding Permian Palaeofires

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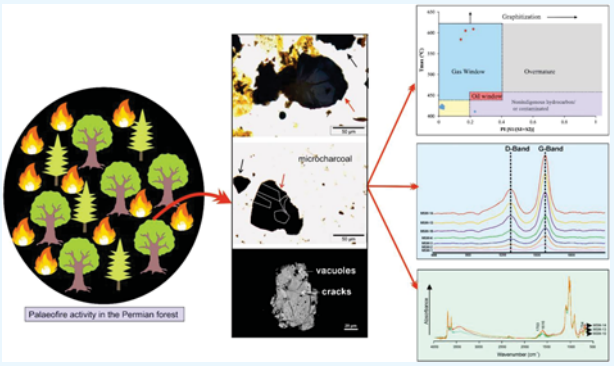
**ABSTRACT:** This study conducts a comprehensive palynofacies and geochemical analysis to characterize organic matter (OM) in shale samples from the Godavari Basin. Palynofacies analysis identified three types of organic matter under transmitted light: translucent organic matter (TrOM), comprising palynomorphs, structured phytoclasts, and degraded organic matter; and two types of opaque phytoclasts/charcoal (CH), distinguished as palaeofire-induced (PAL-CH) and oxidized (OX-CH). The multifaceted approach is applied through Raman spectroscopy, Rock-Eval, and Fourier transform infrared spectroscopy (FTIR) to assess organic carbon's thermal evolution and structural integrity required to substantiate the palynological evidence on microcharcoal. The intensity ratio (ID/IG) ranged from 0.20 to 0.47, indicating varying impacts of thermal events on carbon structures. Higher ID/IG ratios corresponded with samples affected by palaeofires. Additionally, D-FWHM and G-FWHM parameters were analyzed, revealing larger D-FWHM values in thermally matured samples, indicating greater disorder in the carbon structure. The D-FWHM/G-FWHM ratio, exceeding unity, suggested significant structural shifts toward disordered carbon domains. Consequently, the presence of overmaturation of organic matter ranging from 411 to 609 °C indicates the alteration of organic matter due to the impact of heat causing the removal of hydrogen from the samples. FTIR spectroscopy suggests the presence of aromatic and aliphatic deformation due to thermal maturation. This integrated approach combining palaeofire history, Raman spectroscopy, and geochemical analysis provides valuable insights into the palaeofire history and structural evolution of charcoal in the Godavari Basin shales.






## 1. INTRODUCTION

The phenomenon of fire, characterized as a rapid oxidative process, has exerted a substantial impact on terrestrial ecosystems, shaping their dynamics, modification, and evolution from the Late Silurian[1−3] up to Quaternary.[4−7] Palaeofires have been extensively documented in diverse ecosystems of the southern continent during the Late Paleozoic by various researchers.[8−14] Palaeofires, inherently connected to climate conditions, evoke considerable interest from a paleontological perspective and in addressing gaps in our understanding of palaeofires in deep time.[2] Reconstruction methods, including geochemical markers like pyrogenic polycyclic aromatic hydrocarbons (PAHs) and petrological evidence, point to the prevalence of palaeofires.[15]

Utilizing macrocharcoal, a product of vegetation combustion, proves crucial in reconstructing historical palaeofires on Earth.[16] However, the most reliable method remains the identification of macroscopic and microscopic fossil charcoal in clastic sediments.[17−23]

Macroscopic charcoal studies in Permian Indian sediments[13,24−27] reveal associations with coal-bearing strata, indicating the susceptibility of palaeomire systems to burning during severe dry seasons. The repetitive correlation of macroscopic charcoal with Permian coal deposits across Gondwana suggests widespread palaeofire occurrences. High atmospheric oxygen levels may have intensified these events during the Permian.[28,29] Environmental variables and taphonomic processes influence charcoal production, transportation, settling, and percolation, contributing to the complexity of interpreting palaeofire records.[22,30] The initial examination of macroscopic charcoal within Permian sediments of the Indian Gondwana, specifically in the Raniganj Coalfield situated in the Damodar Basin, was conducted by Jasper et al.[24] Noteworthy, Gondwana records from the Damodar Basin (India) and the Paraná Basin (Brazil) demonstrate the prevalence of palaeofires in different sequences and stratigraphic intervals during

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