Illuminating Fossilization Pathways: Diversity of the Minerals involved in Photoluminescence of Early Triassic Shrimps

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Résumé

The Permian-Triassic mass extinction (252 Ma) was the most severe biotic crisis in Earth's history, reshaping marine ecosystems and driving profound evolutionary turnovers (1). Understanding the mechanisms of rediversification following such an event requires both taxonomic and taphonomic insights, which can be gained through the study of exceptional fossil assemblages. This study investigates fossils from the Paris Biota (Idaho, USA; ca 249.1 Ma), a Konservat-Lagerstätte that offers a unique window into the Early Triassic marine recovery (2).
Our research focuses on tened shrimp fossils, and aims to explore their anatomical characteristics, paleo-environments and post-mortem alteration pathways, by establishing a non-invasive methodology for characterizing the physicochemical signatures of the specimens. The development of innovative computational tools to correlate UV-visible spectroscopic point analysis with macro-photoluminescence imaging, applied across a variety of specimens, led to the unexpected discovery of links between mineral luminescence and both histological and morphological characteristics. This approach facilitated a statistical assessment of inter- and intra-specimen variability.

Our findings reveal significant variations in trace element substitutions (including transition metals and rare earth elements) and crystallographic defects across different anatomical features of fossils. Previously undescribed diagnostic patterns were identified, raising questions about their biological significance. Additionally, geochemical signatures correlate with sedimentary matrix composition, indicating a microenvironmental control on fossil preservation.

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Notably, microenvironment-driven differential diagenetic alterations across the specimen's organs enable the distinction of tissue structures that were compressed during compaction, even within the same tissue.

Detailed observations of luminescence characteristics, combined with hypotheses about the burial environment, lead us to propose a taphonomic scenario consistent with these geochemical signatures. This linkage provides insights into the microenvironmental conditions that governed tissue mineralization and refines our understanding of how fossilization processes shaped the preserved record of marine ecosystems following the Permian-Triassic crisis.

(1) "Estimates of the magnitudes of major marine mass extinctions in earth history", Stanley (2016), Proceedings of the National Academy of Sciences
(2) "Unexpected Early Triassic marine ecosystem and the rise of the Modern evolutionary fauna" Brayard, Krumenacker, Botting, Jenks, Bylund, Fara, Vennin, Olivier, Goudemand, Saucède, Charbonnier, Romano, Doguzhaeva, Thuy, Hautmann, Stephen, Thomazo, and Escarguel (2017), Science Advances

Mots-Clés: Data processing, Fossilisation, Luminescence