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First Chemical Proof of Dinosaur Blood: Intact Heme B and Mineralized Red Blood Cells Identified in a 115-Million-Year-Old Theropod

Paleobiology * Molecular Paleontology * Evolutionary Biology

For the first time in paleontological history, an international team of organic geochemists and molecular paleobiologists has obtained definitive chemical and structural proof of fossilized red blood cells (erythrocytes) containing intact heme B -- the iron-porphyrin prosthetic group of oxygen -carrying hemoglobin -- inside the vascular canals of a 115-million-year-old dinosaur bone [1] . Published in the Proceedings of the National Academy of Sciences (PNAS) by Kliti Grice (Curtin University), Yuta Isaji (JAMSTEC), Jasmina Wiemann (Field Museum / University of Chicago), and colleagues, the study examined the hind-limb elements of Aratasaurus museunacionali , an Early Cretaceous (Aptian) coelurosaurian theropod from the Romualdo Formation of northeastern Brazil [1, 2] . By combining high-performance liquid chromatography- mass spectrometry (HPLC-MS), focused-ion-beam transmission electron microscopy (FIB-TEM), and in situ Raman microspectroscopy, the researchers resolved a three-decade scientific debate over whether microscopic spheres inside dinosaur bones represent genuine blood cells or inorganic pyrite framboids and bacterial biofilms [1, 3, 4] .

1. Resolving the 30-Year Dinosaur Blood Controversy: Morphology vs. Molecular Identity

Since Mary Schweitzer and colleagues first reported microscopic, iron-rich spherules and flexible vessel-like matrices inside cortical bone of Tyrannosaurus rex (MOR 555 and MOR 1125) [4] and Bertazzo et al. (2015) imaged erythrocyte-like structures in 75-million-year-old Late Cretaceous dinosaur claws using focused ion beams [3] , skeptics have pointed out a critical ambiguity: spherical iron-oxide concretions, oxidized pyrite (FeS 2) framboids, and fossilized microbial mats can closely mimic the size and biconcave or ellipsoidal shape of vertebrate red blood cells. Furthermore, bulk immunological assays or low-resolution mass spectra could not unambiguously separate endogenous dinosaur hemoglobin derivatives from exogenous soil porphyrins (such as chlorophyll -derived geoporphyrins from surrounding black shales) or modern microbial contamination.

To overcome those limitations in Aratasaurus museunacionali (holotype MPSC R 2089 , recovered from carbonate concretions of the Araripe Basin in Ceará, Brazil, and notable for surviving the 2018 National Museum of Brazil fire) [2] , Grice, Isaji, Wiemann, and co-authors applied a spatially resolved, multi-modal analytical pipeline that links sub-micron cellular morphology directly to exact tetrapyrrole molecular mass and isotopic composition [1] :

* Vascular Restriction & Ellipsoidal Cytology: Rather than appearing randomly across fractures or external sediment surfaces, the preserved microstructures are strictly confined to the primary and secondary Haversian vascular canals of the compact

cortical bone. In thin section and scanning electron microscopy (SEM), the cells preserve the flattened, nucleated ellipsoidal morphology (~7-10 um along the major axis) characteristic of archosaurian (avian and crocodilian) erythrocytes, complete with distinct central nuclear condensations [1] .

* Direct HPLC-Orbitrap Mass Spectrometry of Heme B: Targeted solvent extraction of the isolated vascular zone -- contrasted directly against control extracts of the surrounding Romualdo Formation carbonate matrix -- yielded intact iron (III) protoporphyrin IX (heme B, C 34 H 32 FeN 4 O 4 , exact m/z = 616.177) alongside a diagnostic series of diagenetically defunctionalized heme derivatives (decarboxylated and hydrogenated iron porphyrins) that are completely absent from the surrounding rock matrix [1] .

| Analytical Modality | | Target Structure / Biomolecule in Aratasaurus | | Quantitative / Spectral Signature | | Taphonomic & Contamination Control | | Biological Interpretation |

| Optical, SEM & FIB-TEM Microscopy | | Ellipsoidal microstructures inside cortical vascular canals | | 7-10 um nucleated ellipsoids encased in nano-crystalline Mn 3 O 4 | | Absent from osteocyte lacunae, matrix cracks, and external sediment | | Morphological match to nucleated archosaur (bird/theropod) erythrocytes [1] |

| HPLC-HRMS (Orbitrap MS/MS) | | Intact Heme B (Fe-Protoporphyrin IX) & diagenetic derivatives | | Parent ion m/z = 616.177 + diagnostic vinyl/propionate fragment losses | | Zero heme B or chlorophyll geoporphyrins in host carbonate concretion | | Unambiguous chemical survival of hemoglobin prosthetic cofactor [1] |

| In Situ Raman Microspectroscopy | | Individual mineralized red blood cells within bone lumina | | Resonance pyrrole ring breathing & methine bridge stretching (1,370-1,630 cm −1) | | Spectrally distinct from permineralized apatite, calcite, and humic kerogen | | Spatial co-localization of tetrapyrrole rings inside single fossil cells [1] |

| STEM-EDS & Selected-Area Diffraction | | Mineral capsule surrounding erythrocyte membranes | | Tetragonal hausmannite (Mn 2+ Mn 3+ 2 O 4) co-localized with Fe, N, C | | Rapid post-mortem redox precipitation prior to bacterial sulfate reduction | | Manganese-oxide entombment arrested hydrolytic and oxidative decay [1] |

2. The Hausmannite (Mn 3 O 4) Shield: How Manganese Oxide Locked Heme Inside Bone Canals

Why did intact heme B and cellular membranes survive for 115 million years inside Aratasaurus when soft tissues normally decay within days to weeks after death? Using focused-ion-beam milling coupled to scanning transmission electron microscopy and energy-dispersive X-ray spectroscopy (FIB-STEM-EDS), the team discovered that the fossilized red blood cells are not preserved by iron oxides (goethite or hematite) as previously hypothesized for North American dinosaurs, but are instead entombed within sub-micron shells of hausmannite (Mn 3 O 4) , a mixed-valence manganese (II,III) oxide mineral [1] .

In the Early Cretaceous lagoonal environment of the Romualdo Formation, the carcass of Aratasaurus was rapidly buried in alkaline, carbonate-rich sediments where pore waters contained dissolved Mn 2+ . As intravascular blood clots began to lyse inside

the semi-closed cortical bone canals, local pH and redox shifts triggered the rapid precipitation of nano-crystalline hausmannite directly onto the negatively charged phospholipid bilayers and denatured globin proteins of the trapped erythrocytes [1] . This mineral shell acted as an impermeable geochemical vault in three ways:

* Physical Exclusion of Degradative Enzymes and Microbes: The tight Mn 3 O 4 nanocrystal crust sealed the vascular lumina before extracellular bacterial proteases or fungal hyphae could penetrate the cortical bone.

* Suppression of Fenton-Like Free-Radical Cleavage: While free Fe 2+ and Fe 3+ ions released from decaying hemoglobin can catalyze destructive Fenton reactions that cleave tetrapyrrole rings, structural incorporation and redox buffering by the surrounding hausmannite matrix stabilized the planar aromatic macrocycle of heme B.

* Hydrophobic Cross-Linking of Vinyl Side Chains: During mild burial diagenesis, the reactive vinyl (−CH=CH 2) and propionate (−CH 2 CH 2 COOH) peripheral groups of heme B underwent localized radical cross-linking with degraded polypeptide and lipid fragments, anchoring the iron-porphyrin core into an insoluble organic-mineral polymer [1] .

3. Implications for Dinosaur Physiology and Deep-Time Molecular Paleobiology

Beyond settling a long-standing taphonomic debate, the chemical confirmation of heme B and nucleated erythrocytes in a 115-million-year-old coelurosaur opens a quantitative window into extinct vertebrate physiology [1, 3] . In living tetrapods, red blood cell volume and nuclear-to-cytoplasmic ratios correlate tightly with capillary diameter, oxygen diffusion kinetics, and mass-specific metabolic rates: mammals evolved tiny, enucleated biconcave discs (5-7 um) while modern birds evolved small, streamlined nucleated ellipsoids (9-12 um) to sustain high aerobic scopes, whereas ectothermic amphibians and lepidosaurians possess much larger erythrocytes (18-60 um). The compact 7-10 um mineralized erythrocytes in Aratasaurus align directly with the high-oxygen-flux cardiovascular regime of derived theropods along the evolutionary stem leading to birds [1, 2] . More broadly, the discovery establishes manganese-oxide (hausmannite) permineralization inside carbonate concretions as a new geochemical search image for recovering intact prosthetic cofactors, tetrapyrroles, and cellular ultrastructures across Mesozoic and Paleozoic vertebrates.

References & Primary Sources

* [1] Grice, K., Isaji, Y., Wiemann, J., et al. (2026). Heme signatures in mineralized red blood cells within vascular canals of a 115-million-year-old dinosaur bone. Proceedings of the National Academy of Sciences (PNAS) 123, e2614248123. -- https://doi.org/10.1073/pnas.2614248123

* [2] Say o, J. M., Saraiva, A. . F., Brum, A. S., Bantim, R. A. M., de Andrade, R. C. L. P., Cheng, X., Lima, F. J., Silva, H. P. & Kellner, A. W. A. (2020). The first theropod dinosaur (Coelurosauria, Theropoda) from the Romualdo Formation, northeastern Brazil (Aratasaurus museunacionali). Scientific Reports 10, 10892. -- https://doi.org/10.1038/s41598-020-67822-9

* [3] Bertazzo, S., Maidment, S. C. R., Kallepitis, C., Fearn, S., Stevens, M. M. & Xie, H.-n. (2015). Fibres and cellular structures preserved in 75-million-year-old dinosaur specimens. Nature Communications 6, 7352. -- https://doi.org/10.1038/ncomms8352

* [4] Schweitzer, M. H., Wittmeyer, J. L., Horner, J. R. & Toporski, J. K. (2005). Soft-tissue vessels and cellular preservation in Tyrannosaurus rex. Science 307, 1952-1955. -- https://doi.org/10.1126/science.1108397