Precise imaging technique confirms hemoglobin preservation in dinosaur bone

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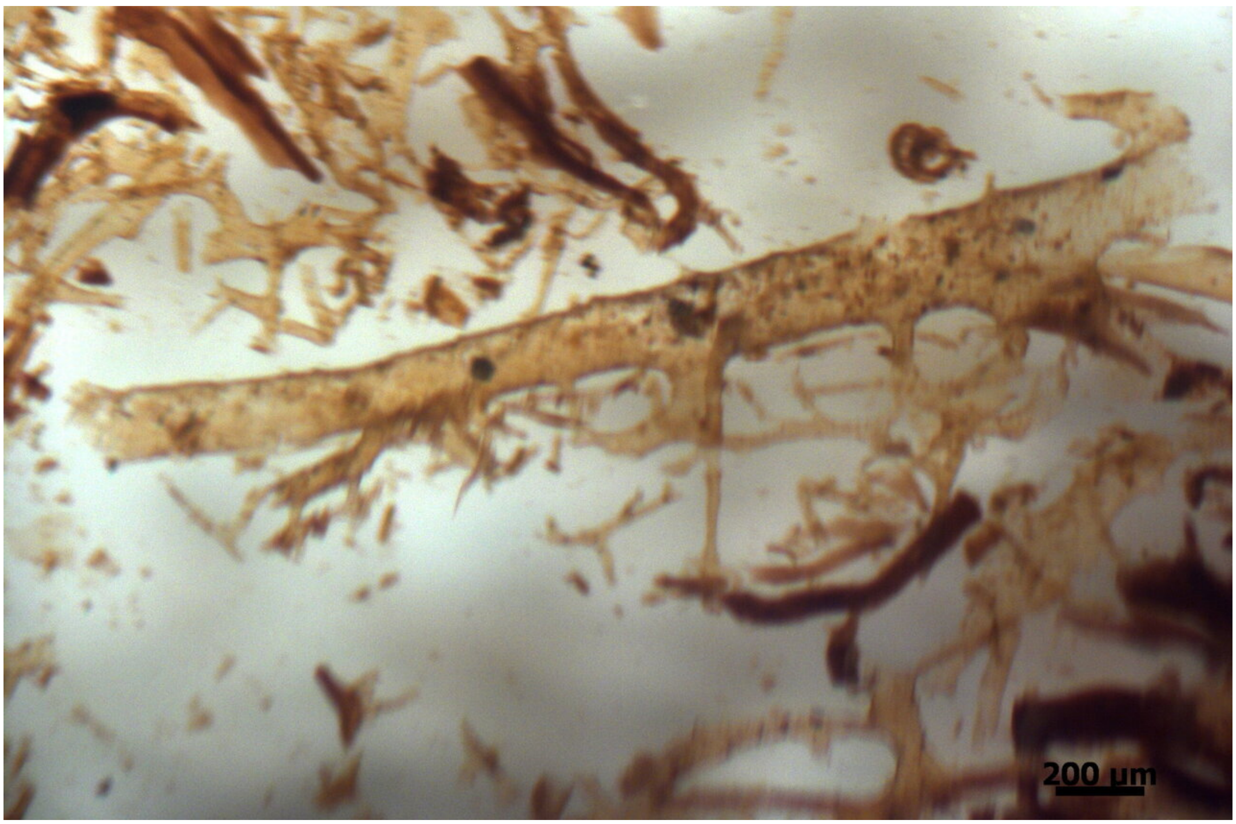

Vessels isolated from Tyrannosaurus cortical bone by demineralization in EDTA. Credit: North Carolina State University

A new study from North Carolina State University identifies vertebrate hemoglobin in bone extracts from two dinosaurs and shows that this molecule is original to those animals. The work also shows how heme, a small molecule that gives hemoglobin the ability to transport oxygen in blood, degrades over time. The study both adds to the body of evidence that biological remains can and do persist across deep time in some fossils and provides further insight into the process of fossilization.

Soft, stretchy tissues recovered from two dinosaurs—Brachylophosaurus canadensis and Tyrannosaurus rex—have been the subject of numerous studies over the last two decades, with researchers using a variety of methods including high resolution imaging, antibody testing and protein sequencing to characterize the remains as biological tissues from the dinosaurs themselves.

In a new study in *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, researchers used Resonance Raman (RR) imaging of the tissues to confirm the presence of both heme bound to globin proteins and heme bound to goethite, a mineral associated with iron oxidization.

"Raman spectroscopy essentially uses light waves to identify a molecule's energetic 'fingerprint,'" says Hans Hallen, professor of physics at NC State and corresponding author of the study. "Resonance Raman, which we use here, takes that process one step further by using light that is already tuned to the molecule of interest—so only that type of molecule will resonate.

"Additionally, that molecule type resonates to give a higher signal level so that its signal 'overwhelms' the signals from other types of molecules," Hallen adds. "This strong signal allows us to find the needle (hemoglobin remnants) in the haystack (messy fossil) to see how this molecule has changed from the functional living state, revealing the chemical changes molecules undergo in deep time."

The researchers used RR to target molecules with a heme-globin bond. They looked at samples from Brachylophosaurus, T. rex, demineralized modern ostrich bone and human blood.

Vessels isolated from B. canadensis cortical bone by demineralization in EDTA. Credit: North Carolina State University

"The signal increase shows that hemoglobin is present, but changes in the signal also allow us to see that as the hemoglobin degrades, goethite may form on the iron within hemoglobin," Hallen says. "We can also pinpoint where the ring-like structure of heme is being damaged. And we saw this process in both modern and ancient samples, so we know that it happens fairly quickly after death."

The results also rule out the possibility of sample contamination.

"Raman spectroscopy will tell you what molecular bonds are present, but molecular bonds aren't exclusive, so those bonds could come from anywhere," says Mary Schweitzer, emeritus professor of biology at NC State and study co-author.

"RR identifies both bonds and structure. So we know that heme is there, and that it is still bound to hemoglobin protein—contaminants like bacteria don't have those specific bonds, so we can say that the molecules are from the animal, or in this case, the dinosaur."

The researchers also point out that understanding how heme degrades and changes over time could help explain how fossilization occurs and why molecules can persist through millions of years.

"While the biggest finding is that we can use RR to show that pieces of hemoglobin can persist for tens of millions of years, we've also gotten some incredible insight into how the molecule has changed," Hallen says. "Goethite is a mineral crystal that is known to be bio-related; that is, it forms from biological action. But we didn't know that it could bind to and stabilize protein fragments."

"Heme has been identified in sediments that are much, much older than dinosaurs, so we know that it persists," Schweitzer says. "Understanding why hemoglobin preserves, and the role that heme plays in the process, is really important if we want to know how these ancient molecules survive through time."

More information: B. J. N. Long et al, Resonance Raman confirms partial haemoglobin preservation in dinosaur remains, *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* (2025). DOI: 10.1098/rspa.2025.0175

Provided by North Carolina State University

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