Can fossil turtle bone apatite be used to reconstruct paleoclimates?

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A significant complication to using the oxygen isotope composition ($\delta^{18}O$) of vertebrate bioapatite in paleoclimate studies is the need to distinguish variation from temporal changes in the $\delta^{18}O$ of surface waters from that due to temperature-dependent fractionation during biomineraliztion. One solution is multiple-taxon comparisons using data from coexisting homeothermic (i.e., mammals) and heterothermic animals. Fossil emydid turtles have been suggested to be potentially useful as functional homeotherms because 1) modern emydids employ behaviors, such as basking, to restrict skeletal growth a narrow temperature range, 2) their aquatic habitat constrains the isotopic variability of dietary inputs, and 3) emydids have a dense fossil record. However, because turtles lack teeth and therefore tooth enamel, sampling must focus on bone, which is potentially more susceptible to diagenetic alteration.

This study examines the $\delta^{18}O$ and carbon isotopic composition ($\delta^{13}C$) of the carbonate ($\delta^{18}O_c$) and phosphate ($\delta^{18}O_p$) fractions of hydroxylapatite from co-occurring emydids and two groups of known heterotherms (crocodilians and gar) from the Paleocene and Eocene of the Clarks Fork Basin, Wyoming. Previous isotopic studies of this area provide an extensive dataset for comparison with the results of this study. Coulometry and X-ray diffraction measurements of bone carbonate content and apatite crystallinity were performed to supplement the isotopic data. Bone and enamel $\delta^{18}O_c$ values measured here exhibit a greater range (16-32‰ VMSOW) than previously observed, suggesting alteration, while the range of $\delta^{18}O_p$ values (9-15‰ VSMOW) is within that predicted by presumably unaltered tooth enamel $\delta^{18}O_c$ from the semi-aquatic mammal *Coryphodon*. While high crystallinity indices (0.28-0.55) and a lack of covariation between $\delta^{18}O_c$ and $\delta^{18}O_p$ suggest alteration of one or both of these components, a strong correlation between intra-individual samples of crocodilian enamel and bone $\delta^{18}O_p$ suggests bone phosphate may be reliable.

References

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Historical perspective: Victor M. Goldschmidt and apatite

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My first published paper, on the crystal structure of apatite and its relation to that of tooth and bone material, was written with the distinguished crystallographer Arnold Beevers. The paper was read to the Mineralogical Society, London, on June 7, 1945 — almost exactly 60 years ago. Our work resulted from Professor Victor M. Goldschmidt's request that we refine the structure of fluor-apatite. While visiting Edinburgh, Goldschmidt gave memorable lectures on how trace elements are selectively captured during the growth of crystals acting as three-dimensional fishing nets of exactly the right size. I believe he expected that — as we found – the size of the fluoride ion was critical to the structure of apatite. The work led to the publication of Beevers and McIntyre (1946) "The atomic structure of fluor-apatite and its relation to that of tooth and bone material" *Mineralogical Magazine*, **27**, 254-257. Most of our instruments (including computers and X-ray cameras) were made by Dr. Beevers' own hands. In addition, I believe that ours were the first colored illustrations published in the *Mineralogical Magazine*. Goldschmidt's interest in apatite was not a passing one. Among his several positions, Goldschmidt was appointed director of the Norwegian government's laboratory for the study of raw materials. He was particularly active in a successful project to extract apatite for use in fertilizer. His outstandingly successful research was terminated by Nazi persecution of the Jews. In 1942, the Norwegian resistance arranged his escape to Britain. When I met him in Edinburgh in 1945, Goldschmidt was in a nursing home. The great scientist appeared to be in his late 80s. In June, 1946, he returned to his beloved Norway, where he died in 1947 at the age of only 59.