Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.25841

Evidence of Double-Medium Diffusion in Trace Element Depth Profiles of Human and Mammoth Enamel

JOHN T FINK[1], MATTHEW J KOHN[1] AND RICHARD L HERVIG[2]

[1]Boise State University
[2]Arizona State University

Diffusion experiments were performed at 23 °C and at 90°C on human and mammoth tooth enamel to determine diffusivities of select rare earth elements (REE) (Sc, Y, La, Pr, Gd, Yb) and other trace elements (Ba, Pb, and U). Enamel consists of nanometer-scale crystals up to ~1 μm in length of carbonated hydroxylapatite [$Ca_5(PO_4, CO_3)(OH, CO_3)$], termed bioapatite. During fossilization, REE and many other trace elements partition strongly into bioapatite, forming either simple profiles consistent with diffusion-adsorption or diffusion-recrystallization mechanisms, or tailed distributions consistent with double-medium diffusion with competing “slow” and “fast” diffusion pathways. These profiles have been used to determine durations of fossilization, yet these interpretations rely on knowledge of the diffusivities of different trace elements, which are not well constrained. We performed diffusion experiments using doped pH-neutral solutions in a commercial sous vide for one week on mammoth enamel at 90°C and for several months at 20°C on human and mammoth enamel. Concentrations were measured at ASU using a Cameca IMS 6f operating in depth profile mode. All trace elements except Ba show “in-diffusion” (concentrations highest on the surface and decreasing inward); Ba shows “out-diffusion” (concentrations lowest on the surface and increasing inward). All trace element profiles are tailed, consistent with double-medium-type diffusion. We interpret “slow” diffusion to represent intra-crystalline diffusion and “fast” diffusion to be inter-crystalline or grain-boundary diffusion. In mammoth enamel, calculated “slow” diffusivities of REE at 23 °C and 90 °C were all about 2-3 x 10^{-16} cm^2/s. “Slow” diffusivities of U, Pb, and Ba were one to two orders of magnitude faster, or about 10^{-15} to 10^{-14} cm^2/s. Calculated “fast” diffusivities in mammoth enamel were about 10^{-13} cm^2/s for REE, 10^{-14} cm^2/s for U and Pb, and 10^{-12} cm^2/s for Ba. Future experiments at 70°C, 52°C, and 36°C will refine the Arrhenius relationship in mammoth enamel and determine the activation energies for many relevant trace elements in the geo- and health sciences.