Survival of eggshell peptides over millions of years in Africa is due to mineral binding

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Protein sequences can complement ancient DNA in reconstructing evolution and phylogeny, and extend the reach of biomolecular studies into deep time. It is a universal truth that proteins survive better than DNA, but for how long can they *really* withstand the combined effect of time and temperature? Claims of intact dinosaur protein sequences are in sharp contrast with the extent of degradation consistently found in closed-system biominerals and predicted by kinetic models. Indeed, the very mechanisms for exceptional survival have not yet been clarified.

Here we use an unprecedented combination of rigorous, multi-analytical testing of the authenticity of ancient protein sequences and computational modelling of protein-mineral interactions. We target ostrich eggshell from sites spanning the last 4 million years in Tanzania and South Africa and we unequivocally demonstrate the survival of peptide sequences in paleontological eggshell which has endured the combined effect of temperature and time for the equivalent of ~ 15 million years at 10°C (thermal age). The peptide sequence surviving consistently in the oldest eggshells is chemically unstable but calculations of the binding energy show that it is strongly bound to the mineral surface. The effect of binding is loss of entropy at the mineral surface, lowering the effective temperature of the local environment, so that the peptides are “frozen” to the surface.

Biomineralising proteins from eggshell, shell and other organic-inorganic biomaterials have the best potential for preservation in the fossil record over geological timescales and can therefore help to answer fundamental questions about the past.