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Exploring the role of DNA-mineral interactions in the long-term preservation of ancient DNA

VEER VIKRAM SINGH[1], RICHARD KIMBER[1], NARESH KUMAR[2] AND STEPHAN M. KRAEMER[1]

[1]University of Vienna

[2]Wageningen University

Presenting Author: veer.vikram.singh@univie.ac.at

The recovery and analysis of ancient DNA (aDNA) has revolutionized our understanding of human evolution. aDNA analysis traditionally relied on the availability of skeletal material, but the recent discovery that ancient human DNA can be extracted from sediments without observable skeletal remains presents new opportunities to expand our geographic and temporal knowledge of our ancient ancestors [1]. However, the geochemical basis and mechanistic understanding of the sedimentary preservation of DNA is still elusive.

Once it enters the environment, DNA is prone to degradation, for example, by nuclease enzymes or by photochemical, and redox processes. In sediments, mineral surfaces offer a wide variety of adsorption sites to the DNA, and adsorption is well known to protect DNA against enzymatic degradation [2]. A recent discovery of 2-million-year-old DNA from sediments suggests that adsorption to mineral surfaces may contribute to long-term DNA protection comparable to the timescale of human evolution [3]. Mechanisms that lead to protection and preservation of DNA on mineral surfaces are not well understood, limiting our ability to utilize this potentially vast source of genetic information effectively. Mineral properties, including surface charge, surface topography, particle size, and crystallinity, influence adsorption processes and could therefore impact DNA protection. However, a systematic approach to elucidate these mineralogical controls is lacking.

This study explores various mineralogical and geochemical controls on aDNA adsorption to mineral surfaces and their effect on DNA preservation. We performed a series of controlled batch experiments to study adsorption kinetics and isotherms of DNA on a range of environmentally relevant minerals, including iron oxides and clays, under varying pH. We then studied the degradation of mineral-bound DNA using DNase I as a model nucleases enzyme to understand the effect of adsorption to minerals on DNA protection. This work aims to identify processes governing the long-term preservation of DNA to enable a more targeted approach to the search and recovery of aDNA from sediments.

References

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