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Unraveling the signature of abiotic organic hazes in Archean sediments – an experimental approach

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Tracing back the earliest stages of biological evolution from the Archean geological record remains a challenging task. While organic matter preserved in Archean metasedimentary rocks can exhibit a high level of elemental and molecular preservation [1], distinguishing abiotic from biotic origins remains difficult. This is in part due to the limited understanding of how both abiotic organic precursors and biological remains evolve during diagenesis and metamorphism of the parent rock [1]. Photochemically produced organic hazes may have been an important source of abiotic organic matter on the Archean Earth, with important implications for early Earth's radiation budget and habitability [2-4]. Yet, their fate during geological burial and potential preservation in the rock record remain poorly constrained. Here, we investigate the morphological and molecular signatures of experimentally synthesized analogs of Archean organic hazes (tholins) under diagenetic conditions. Tholins were synthesized by cold plasma discharge experiments in a range of N_2 - CO_2 - CH_4 atmospheres using the PAMPRE experimental setup [5]. Following syntheses, tholins were subjected to low temperature and pressure conditions typical of diagenesis (50–150°C, 1 kbar) in diamond anvil cells [6]. We then analyzed the experimental products using electron microscopy, deep UV Raman spectroscopy, and scanning transmission X-ray microscopy (STXM) coupled with X-ray absorption near edge structure (XANES) spectroscopy to characterize their morphological and molecular compositions. Our findings provide insights into the potential preservation and detectability of organic haze signatures in Archean rocks, with implications for distinguishing between abiotic organic and biogenic contributions in these sedimentary archives.

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