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Nitrogen in red rocks: a biosignature for Mars exploration?

EVA E. STÜEKEN

University of St Andrews

Presenting Author: ees4@st-andrews.ac.uk

All life as we know it requires nitrogen to form a variety of biomolecules. Due to its unique bonding properties to carbon and its relatively high abundance on planetary surfaces, it is conceivable that nitrogen would also be used in extraterrestrial biochemistries, making it a potential target in the search for past life in ancient sediments on Mars. Most studies of sediment-hosted nitrogen typically target organic-rich strata, which offer the highest potential of finding high levels of organic-bound nitrogen. However, organic-rich sediments have so far not been encountered on the Martian surface, requiring new search strategies for alternative substrates.

Here, I will discuss two recent studies showing that nitrogen can be hosted in oxidized sediments that are nearly devoid of organic matter. The nitrogen may either adsorbed to iron oxides or trapped within phyllosilicate minerals. Data from modern deep-marine iron-manganese crusts and nodules record nitrogen with low isotopic values ($\delta^{15}N$), possibly indicative of local biological ammonium oxidation (nitrification). In contrast, data from Proterozoic siliciclastic red beds show isotopic compositions akin to typical biomass of that age, consistent with transfer of ammonium from organic matter into clay minerals during diagenesis. Red beds associated with microbial mat features (wrinkled bed surfaces) and evaporitic conditions (desiccation cracks) are most N-rich, perhaps indicating that N-retention in diagenetic clays is most efficient where organic matter is directly associated with the clay matrix. The timing of illitization may also play an important role, as ammonium has a similar ionic radius as potassium and is generally known to be retained well in illite clays.

Iron oxides and clays, including illite-smectite clays are present on Mars, as are evaporitic environments that show evidence of past aqueous activity. The nitrogen content and isotopic composition of these strata may be useful astrobiological targets in future missions.