National Aeronautics and Space Administration

FY23 PECASE Award

Investigating the Emergence of Catalysis in Hydrothermal Systems at the Origin of Life

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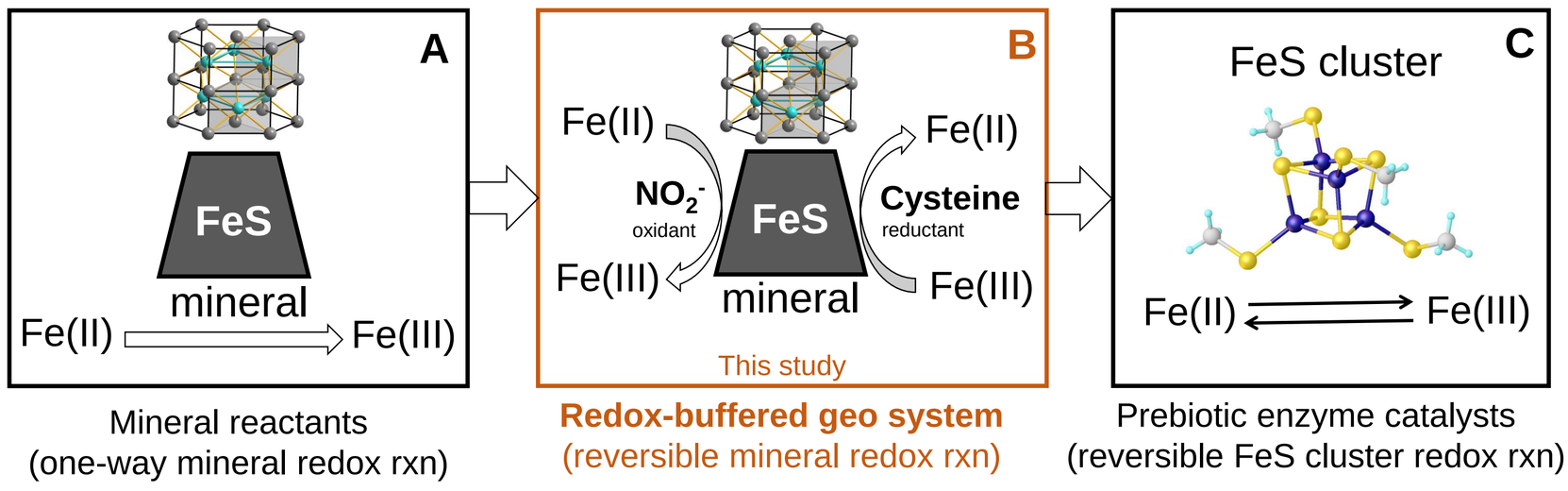
Background: Origin of life (OOL) is the first requirement for life to exist; thus it is important for astrobiology to determine what planetary conditions could have led to life that we might be able to detect with future missions.

Some main questions in OOL include:

- Were minerals precursors to enzymes; if so, how did this transition occur?
- Could minerals have driven proto-metabolic reactions toward the OOL? What geological conditions are required for this?

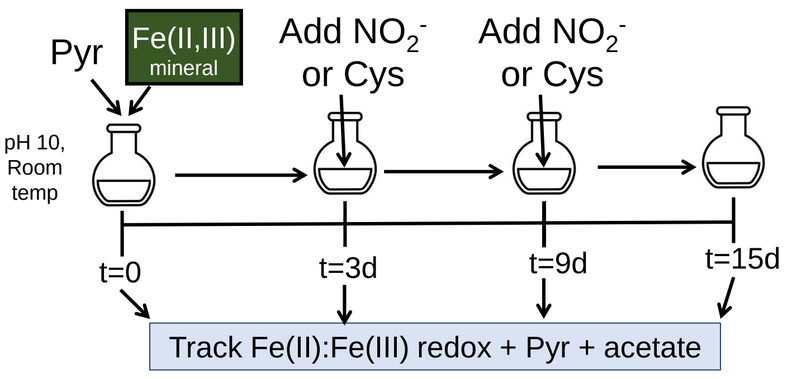
How did the transition from minerals (reactants) to enzymes (catalysts) occur?

We propose: redox-buffered geological systems that could reversibly oxidize and reduce Fe minerals could act as "pseudo-catalysts".

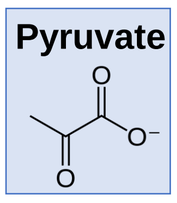


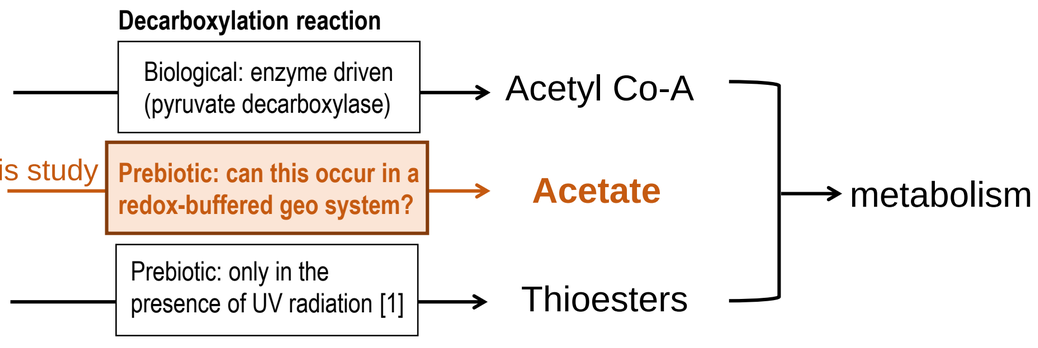
In this study we tested whether an enzyme-driven biotic reaction – **pyruvate decarboxylation** – could also proceed under condition B above. If so, then this is evidence that B could be a transition system between minerals (A) and enzymes (C).

Experimental methods:



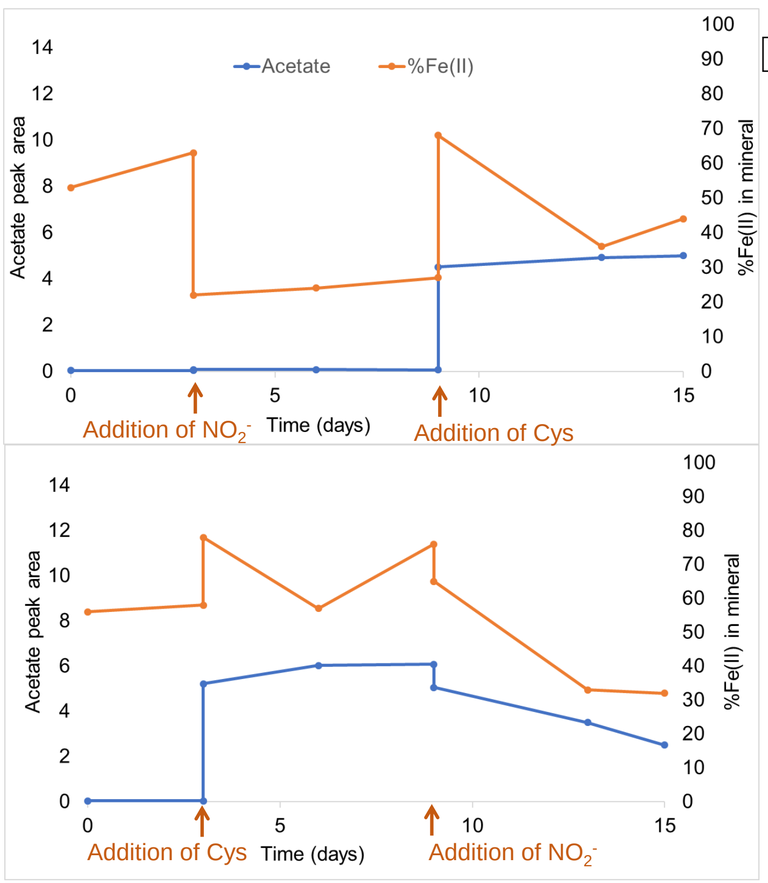
Pyr: a geologically produced prebiotic organic precursor, and an essential biomolecule for metabolism

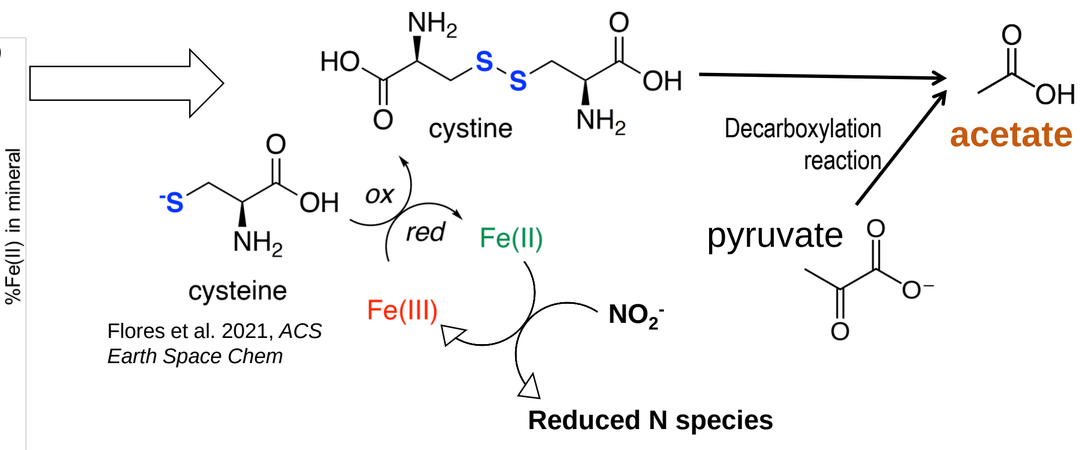




[1] Leqraa et al. Sci Rep 10, 14488 (2020)

Results:





Pyruvate decarboxylation to acetate occurs in the presence of **cysteine and Fe(III),** forming Fe(II), cystine and acetate. **Nitrite** (NO_2^-) re-oxidizes the Fe(II) to Fe(III), allowing the cycle to continue as long as there is a supply of reactants.

Significance to JPL/NASA: We showed that this prebiotic reaction does not require UV light as previously proposed, and can instead occur driven by redox-active iron minerals. **Thus, origin of metabolism could occur on worlds without land - e.g ocean worlds, hydrothermal vents, and exoplanet water worlds; and these would be reasonable places to search for life with future missions.**

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Publications:

Valadez D., Weber J.M., Martinez E., Barge L.M. Redox-buffered systems as a transition to catalysis in a prebiotic iron-mediated organic reaction system. In prep for *Nature Chemistry*

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