# Studying Habitability of Redox-Active Hydrothermal Systems on Earth and Ocean Worlds

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Water-rock interaction and associated hydrothermal systems are significant for understanding how life emerges and sustains on wet rocky planets. There are many possible redox reactions that can yield energy for life in such environments, and hydrothermal redox reactions may also have been significant for the origin of life on Earth. If life exists on ocean worlds like Europa and Enceladus, then chemosynthesis is likely a dominant process, and it is possible that the origin of life also proceeded through carbon-fixing pathways as is thought for Earth. However, the energy regimes of early metabolic reactions on Europa or Enceladus may be significantly different from terrestrial deep ocean biospheres. An additional challenge for simulating geoelectrochemical vent systems of ocean worlds is that hydrothermal environments also host redox-active mineral components, abiotic organic redox chemistry, and geological "fuel cell" behavior that make it difficult to predict exactly what the energetic landscape for redox reactions would be in such a system on another world, or on the early Earth. To investigate the redox properties of mineral systems on ocean worlds, we have developed "planetary test bed reactors", adapting components and methods from fuel cell systems that are normally used for studying redox processes for power applications. These experimental studies will be combined with field studies of active vent sites in the field, utilizing an innovative astrobiology spectroscopy payload to conduct in-situ monitoring of a hydrothermal system in the Pacific Ocean. Synergistic laboratory and field investigations of redox-active geochemical systems can yield insights on the types of life that might live in far-from-equilibrium environments on other worlds, and strategies for how we would approach detecting life in these systems.