ASTROBIOLOGY AT THE WATER-ROCK INTERFACE IN ICY OCEAN WORLDS. S. D. Vance[1*], L. M. Barge[1], R. Hodyss[1], P. V. Johnson[1], M. J. Russell[1], I. Kanik[1], and the NAI Icy Worlds team, [1]Jet Propulsion Laboratory, California Institute of Technology (*svance@jpl.nasa.gov).

Introduction: Astrobiology at water-rock interfaces found on icy bodies such as Europa and Enceladus is the unifying theme of the JPL Icy Worlds team. The NAI funded effort, now heading into its 4th year of 5, is organized into four thematic investigations, led by the main authors of this work.

Investigation I: We are trying to find the mechanisms that enabled life to emerge in an inorganic world at submarine alkaline hydrothermal vents, and by what metabolic pathways [1]. Serpentinization produces both hydrogen and methane. Because our experiments to date have produced little to no methane, we currently consider methane a fuel (along with hydrogen) and a source of carbon but not a waste product. A mineral membrane is considered to have separated the reduced and alkaline hydrothermal fluids at the vent from the relatively oxidized acidulous ocean and thus imposed steep gradients; electrons dropping to external electron acceptors while protons take the counter path through the membrane toward the vent fluid. Life uses the gradients of electrons and protons to drive nanoengines, coupling endergonic reactions with necessarily greater exergonic reactions.

Investigation II: We use laboratory experiments to simulate the geological disequilibrium in hydrothermal systems and determine the role of minerals in harnessing these gradients toward the emergence of metabolism. In the anoxic oceans of the early Earth, hydrothermal systems would have contained abundant reduced / mixed-valence iron hydroxides and other redox active minerals that could drive reactions. We synthesize early Earth hydrothermal minerals, including green rust and iron/nickel sulfides, and test how these may function as reactants or catalysts for organic synthesis and phosphorus chemistry. In the hydrothermal mound, gradients of Eh, pH and temperature would have given rise to different conditions under which prebiotic reactions could occur. We also simulate the growth of hydrothermal chimneys and their functionality as flow-through chemical reactors [2, 3], and feedbacks that might have occurred to drive the emergence of metabolism in a seafloor system on the early Earth or an ocean world [4].

Investigation III: By combining laboratory investigations of chemistry occurring deep in icy ocean worlds with geophysical modeling we examine how, where, and for how long icy ocean worlds might be able to support life. We are developing models of seafloor evolution and habitability under extreme pressures, up to tens of thousands of atmosphere. This includes applying recent breakthroughs in fluid and mineral thermodynamics of Earth's deep carbon cycle to conditions not found on our home planet [5,6]. In the lab, we are measuring fundamental properties of fluids under icy world oceans conditions to enable a new generation of interior models needed for possible planned future missions exploring ocean worlds [7,8,9]. Our recent findings include inventories of redox materials on Europa [10] the possibility for fluids under high pressure ices in the large icy worlds Ganymede, Titan, and Callisto [9,11], and tidal forcing of porous and fluid filled rock as the explanation for the high heat output of Enceladus [12].

Investigation IV: This investigation is shedding light on the evolution of ocean materials expressed on the surfaces of airless icy bodies and exposed to surface temperatures, vacuum, photolysis and radiolysis. Our work illuminates the connections between observables on the surface to the habitability of these past and present aqueous environments. We are experimentally determining the evolution of candidate ocean compositions subjected to freezing, dehydration and radiolysis/photolysis, using Raman and infrared spectroscopies [13,14]. By understanding diagenesis of fluid exposed on the surfaces of icy bodies over a range of predicted ocean compositions, we will enable constraints to be placed on the composition of a subsurface ocean based on the observed surface chemistry. In doing so, we will also enable constraints on the habitability of subsurface oceans.

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