Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-12 Room:A03 Time:May 26 16:45-17:00

Geophysical Controls on the Habitability of Icy Worlds: Focus on Europa

VANCE, Steven[1*] ; HAND, Kevin[1] ; PAPPALARDO, Robert[1]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

Many icy worlds in the solar system are likely to contain inventories of liquid water comparable to Earth's. This meets only one planetary habitability requirement; less is known about whether icy world oceans permit the needed chemical disequilibria. Evidence for sustained internal heat and abundant water on Jupiter's moon Europa suggest life would have had the perceived time necessary to develop there, but sources of electron donors and acceptors critical for habitability have been difficult to assess. Past investigations assumed hydrogen production at the rock-ocean interface scales with the heat input to the rocky interior, and that subsurface weathering and alteration are inconsequential. However, estimates of hydrogen production rates on Earth show that low-temperature hydration of crustal olivine produces substantial hydrogen, on the order of 10^{11} moles yr^{-1}, comparable to the flux from volcanic activity. Here, we estimate global average rates of water-rock reaction on Earth, Mars, and icy worlds in the solar system using the pressure- and temperature-dependent physics of microfracturing in olivine. We predict hydrogen production within Europa's oceanic crust—also potentially applicable to other icy worlds—that are higher than those on Earth, even in the absence of contemporary high-temperature hydrothermal activity. Radiogenic cooling exposes unweathered rocky material progressively over time to ever greater depths. Shallower gradients in pressure and temperature in objects smaller than Earth expose new unaltered rock with an efficiency that scales as the inverse of gravity, so up to 100x more efficiently than Earth. Weathering and alteration of exposed material, mainly by serpentinization, release heat and hydrogen, which are necessary for life. We hypothesize that Europa's ocean could have become reducing during geologically brief periods when hydrogen flux from rapid reweathering far exceeded oxidant flux. thermal-orbital resonance 2 Gyr after Europa's accretion that caused oscillations in mantle heating. Europa's present-day limit of mantle tidal heating would produce volcanic hydrogen (0.6-2x10^{10} moles yr^{-1}) that offsets the low end of estimated production from serpentinization alone (total range 4x10^{8}-5x10^{10} moles yr^{-1}). Evidence for subduction- like behavior in Europa's ice suggests that radiolytic oxidant flux to its ocean is at that high end of the previously estimated range (5x10^{9}-4x10^{11} moles yr^{-1}). These factors make Europa unique among icy worlds for potentially having an oxidizing ocean with a high flux of reductants. Europa is thus a prime candidate for hosting life.

Keywords: Europa, Icy Worlds, Astrobiology, Habitability, Outer Planets, Microfracturing