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HYDROTHERMAL SYSTEMS IN EUROPA AND POSSIBILITY OF WATER ON SIMILAR BODIES AS A BIOLOGICAL PRECURSOR

Abstract

One of the most important precursors to extraterrestrial life is the presence of water in a planet and as such most of the inter-solar remote sensing data centers around testing conditions for water on other planets and natural bodies. In this paper, we examine means for driving hydrothermal activity in extraterrestrial oceans on planets and on satellites that have less than one Earth mass, with implications for sustaining a low level of biological activity over geological timescales. Assuming ocean planets have olivine-dominated lithospheres, a model for cooling-induced thermal cracking shows how variation in planet size and internal thermal energy may drive variation in the dominant type of hydrothermal system—for example, high or low temperature system or chemically driven system. As radiogenic heating diminishes over time, progressive exposure of new rock continues to the current epoch. Where fluid-rock interactions propagate slowly into a deep brittle layer, thermal energy from serpentinization may be the primary cause of hydrothermal activity in small ocean planets. We show that the time-varying hydrostatic head of a tidally forced ice shell may drive hydrothermal fluid flow through the seafloor, which can generate moderate but potentially important heat through viscous interaction with the matrix of porous seafloor rock. Considering all presently known potential ocean planets—Mars, a number of icy satellites, Pluto, and other trans-neptunian objects—and applying Earth-like material properties and cooling rates, we find depths of circulation are more than an order of magnitude greater than in Earth. In Europa and Enceladus, tidal flexing may drive hydrothermal circulation and, in Europa, it may generate heat on the same order as present-day radiogenic heat flux at Earth's surface. In all objects, progressive serpentinization generates heat on a globally averaged basis at a fraction of a percent of present-day radiogenic heating and hydrogen is produced at rates between 109 and 1010 molecules cm-2 s-1. This paper analyzes these possibilities and specifically focuses on Europa and extrapolates the common factors to other similar bodies that may be found and also analyzes their possibility as a biological precursor.