EXAMINING MICROBIAL SURVIVAL DURING INFALL ONTO EUROPA: AN IMPORTANT LIMIT ON THE ORIGIN OF POTENTIAL EUROPAN LIFE.

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Introduction: Previous work shows that transfer of material from Earth to Europa is statistically possible [1 and references therein], opening the question of whether terrestrial biota may have transferred to Europa to populate that world. Transfer of viable organisms is a function of parameters such as ejection shock, radiation exposure, and others, applied across four phases in the transfer process: ejection from the parent body, transport through interplanetary space, infall onto the target world, and biological adaptation [2,3]. If terrestrial biota could survive transport to Europa, then biology on Europa may be either the product of a separate and unrelated origin or they are the descendents of transferred terrestrial organisms. If, however, transfer of viable organisms is impossible, then any biota present on Europa must be the product of a biological origin independent from terrestrial life. We will investigate the survival likelihood of material falling onto Europa.

Infall onto Europa: We will begin by finding the lowest Europan infall velocity for a body of significant mass and compare that value to literature values for impact survival of microbes. We will not consider dust because it does not protect sufficiently against radiation for trans-planetary travel or upon arrival onto the severely irradiated Europan surface [4].

The lowest infall velocity of an impacting body (V_B) occurs in the case of that body approaching Europa from a trailing direction, in a parabolic orbit with perijove equal to Europa's orbital radius from Jupiter:

$$V_B \approx \sqrt{\frac{2\mu_J}{a_E}} - V_E$$

where μ_J is the standard gravitational parameter for Jupiter, a_E is the orbital altitude of Europa with respect to Jupiter, and V_E is the orbital velocity of Europa. Based on the above, the minimum impact velocity at Europa is 5.7 km/s. The maximum velocity scenario occurs for a body approaching Europa's leading face, giving an infall velocity of 33.2 km/s. Since Europa does not possess a substantial atmosphere, impact occurs directly onto the surface without friction-induced heating or deceleration.

Survivability: One-dimensional shock stresses were calculated for basalt projectiles impacting a pure H_2O Europan-surface ice target at the minimum and maximum impact velocities. A density of 0.92 g/cm^3 was assumed for the ice, and the U-u (shock speed – particle speed) hugoniot parameters of Stewart and Ahrens [5] for values of u > 1.59 km/s were used. The U-u equation of state for basalt is from [6]. Results indicate that a terrestrial basalt impactor striking ice will generate a peak shock value of 25.9 GPa at 5.7 km/s and 636 GPa at 33.2 km/s (which would effectively destroy the impactor). Next, we use the minimum value to extract the probability of microbial survival. While several studies exist on the survival of microbes under shock, most of them are geared towards survival in a target rock and study microbe-bearing targets that are not allowed to shear freely. Data do exist on microbe-doped impactors, however [7], and *R. erythropolis* is found to survive at a rate of ~1:10^6 at a peak impact shock pressure of 25.9 GPa. This value may be lower for Europa, however, as peak shock and shear rates will be somewhat higher on impact into ice than for the lower-density agar target used in [7]. Once landed, any surviving microbes will be exposed to ambient radiation of 10-100 Mrad/month. Exposure to 7 Mrad generates survival rates of 1:10^{10} for most microbes, and this dosage accrues between one month at the Europan surface to 7,000 years for burial at 1m depth [4]. Therefore, evidence indicates that infall onto Europa would require a microbial population at a density of about ≥10^6 to retain surviving microbes after impact, and extended survival is strongly limited by ambient radiation flux. If buried at ~1m depth by impact, any surviving microbes would have ~7,000 years or less to propagate in Europa's cryogenic near-surface conditions.

Discussion: Without a velocity-attenuating atmosphere, infall onto Europa results in strong shock. In the low-velocity infall scenario, the likelihood of Europan colonization by terrestrial microbes is governed by the number of microbes present pre-impact (>>10^6 required), burial depth, and the ability of any surviving microbes to adapt to the Europan environment. The likelihood is correspondingly low that any Europan life is related to terrestrial life, transported in the past by meteoritic transfer.

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