INVESTIGATING PORE COMPACTION DEPTH AND THE HABITABILITY POTENTIAL OF ICY MOONS I. Kisvárdai[1], B. D. Pál[1,2] and Á. Kereszturi[2] [1]Eötvös Loránd University, 1117 Budapest, Pázmány Péter sétány 1/A, Hungary, [2]ELKH CSFK, Research Centre for Astronomy and Earth Sciences, 1121 Budapest Konkoly-Thege Miklós út 15-17, Hungary (kisvardaiimre02@gmail.com)

Introduction: Assuming that the structure of our Solar System is similar to that of Exosolar Systems, exomoons may easily outnumber exoplanets. If there is no major difference between their likelihood of being habitable, exomoons would make the largest group of possibly inhabited celestial bodies in the Universe [1]. Building models that estimate the potential of these complex systems being in a habitable state is thus of great importance. In order to construct properly functioning models, first we must investigate the possible life harboring moons of our own Solar System, like the icy moons, such as Europa and Enceladus, which were extensively studied in recent years [2-5].

Geophysical and visual data from the Cassini spacecraftimply the presence of hydrothermal plumes at the bottom of the ocean on Enceladus, which are maintained by tidal heating [6]. These geological structures may have been the origin of life on early Earth due to the intense exothermic interaction between water and rock (serpentinization) on their surface and simple organic molecules in the ocean, which may serve as catalysts of life [7]. We intend to investigate the scale and importance of the possible role of hydrothermal plumes and serpentinization in the emergence of life on icy moons and compare it to the circumstances on Earth.

Pore compaction depth: The porosity (or void fraction) of a material is given by its void volume to total volume ratio, as the following equation [8-9] shows:

$$\phi = \frac{V_{void}}{V_{total}} \quad (1)$$

Starting from the surface, the change in porosity by depth is usually exponential (see Fig. 1.), because the decrease in porosity (the compressibility) is dependent on the porosity itself [8]:

$$\frac{d\phi}{dz} = f(K, \phi, \sigma(z)) \quad (2)$$

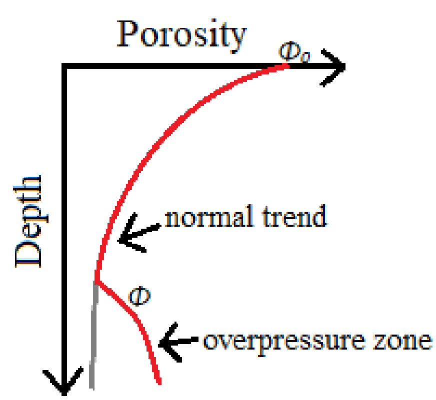

Figure 1: A normal porosity trend, where porosity decreases by depth, except for the overpressure zone.

The rock becomes fully compacted when the porosity reaches 0, and the depth this event occurs is called pore compaction depth [10]. The pore compaction depth varies depending on the rheology of the rock and the pressure (and therefore gravity) [11]. This means, that on a low gravity planet or moon the pore compaction depth is closer to the core, or in some cases may not exist, thus making its core porous.

In the case of Enceladus, Neumann and Kruse (2020) calculated the pore compaction depth for different rheologies and found, that for antigorite and dry olivine it occurs at 60-80 km deep, producing a fully compacted core, which would not be able to create the substantial amount of tidal dissipation inside Enceladus. Following these findings, the composition of the core is most likely wet olivine rock [11].

Pore surface area: In order to approximate the importance of serpentinization in the total endogenic heating of Enceladus, it is necessary to calculate a good estimation of the total pore surface area, which gives the size of the surface on which water-rock interactions can occur [12]. These exothermic reactions on the pore surface of the hydrothermal plumes generate heat, which can support the emergence of life.

Depending on the size of the total surface area, this phenomenon could take place on an even larger scale, than it did on Earth.

Simplified model: Despite considering the interior of Enceladus as a homogenic ice-rock-water mixture, the results for the total pore surface area will remain adequately accurate, because the actual composition of the interior strongly resembles this mixture [13]. Using the compaction trend of this hypothetical homogenic interior, we will be able to give a good estimation of the average compaction by depth and the total pore surface area. Thus, we will be able to estimate the total heat from serpentinization on the icy moon, utilizing the parameters given above and the following chemicalequation [14]:

Mg2SiO4 (forsterite) + MgSiO3 (enstatite) + 2H2O -> Mg3Si2O5(OH)4 (antigorite).

By comparing these results to the conditions on Late-Hadean Earth we will get an illustrative comparison of the probabilities of the emergence of life between a provenly life harboring planet and a possibly habitable or inhabited moon [15].

Summary and perspectives: We aim to consider the composition of Enceladus a homogenic mixture and calculate the pore compaction depth and the total pore surface area of this simplified interior. Using the already available parameters of Enceladus (radius, mass, etc.) we estimate the chance of the emergence of life on an icy moon of our Solar System and compare it to that of the early Earth. With the launch of the James Webb Space Telescope, it will soon be extremely feasible that we can estimate the habitability of celestial bodies like Europa and Enceladus with great simplicity andprecision [16].

In the future, by adjusting the initial parameters to the researched object, this method can be applied to exoplanets and exomoons, which are likely tobecome one of the most rapidly growing fields of astronomy of our decade. Heated by tidal dissipation and serpentinization, exomoons far beyond the conservative habitable zone could have liquid water reservoirs, prerequisites for life.

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