Astrobiological potential of surface features on Europa and pressure calculation for the putative ocean

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Introduction: The Jovian moon, Europa, is currently an interesting astrobiological target as it is considered to have a subsurface water ocean [1], and geothermal heat sources at its bottom. However, only indirect methods can prove information of this internal ocean with the observation of young (50-60 million year-old [2]) surface features. Although the astrobiology potential of the moon has been reported [3][4], in situ measurement would be necessary for further analyzis and proof of possible biosignatures [5]. In order to help investigating astrobiological relevance of Europa, surface features were analyzed regarding to their potential to bear possible (extremophile) life and simple pressure calculation was done for the bottom and the top of the putative global ocean.

Methods: Various surface features were analyzed according to their astrobiological potential (see Table 1.). In fact, the thinner the ice layer, the greater the possibility is to see upcoming material from the interior frozen in the ice [6].

Analogs from Earth were investigated and compared to possibly existing phenomena on Europa – such as submarine volcanism, chemical enrichment and survival of candidate extremophile organisms [7][8]. These analogs may help monitoring the habitability of Europa or even other celectial bodies. One of the well known analogous environments for Europa, however, is the Lake Vostok, in Antarctica, where liquid water underlies a cca. 4 km ice layer.

Simple pressure calculation was done by using Aristotle's hydrostatical law and thus considering the depth and composition [9] of the ocean between reasonable limits. The presence of $MgSO_4$ was suggested from spectroscopic data [9], and calculated in maximum 15 % concentration due to chemical considerations. Density data of clear water and ice are 1000 kg/m^3 and 917 kg/m^3, whereas the density of liquid magnesium sulphate can be up to 1500 kg/m^3. The equatorial surface gravity of Europa is 1,314 m/s^2. Thicknesses of the ice and water layer are commonly used from 2 to 40 and from 80 to 170 kilometres, respectively. Table 2. shows the results for the calculated pressure values.

Results: The surface is visibly "contaminated" with non-ice materials, however the nature of these materials are not yet fully known. Exogenic processes, involving the particles from Jupiter's radiaton, the volcanic sulphur coming from Io and meteoric bombardment are definitely responsible for the non-ice materials on Europa's surface. However, endogenous processes may be also present and cause the typically reddish pigmentation on the ice.

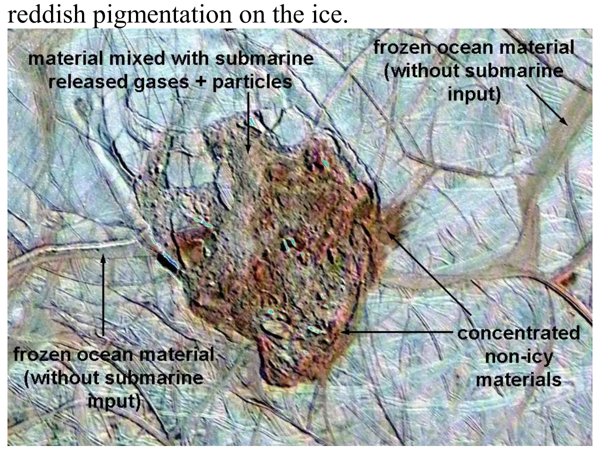

Figure 1. Examples of astrobiological important locations around the 80 km diameter Therea Macula

Analyzing the published results on the interior of Europa, from astrobiological point of view, the most interesting locations are where liquid water, mineral grains with large and reactive surfaces and energy sources are present together. These locations are probably the submarine volcanoes at the bottom of the ocean. As these centers are not accessible for observations today, their characteristics could be analyzed with the most details at chaotic terrains, at the putative surface manifestation of submarine volcanoes.

As the surface is young on a geological time scale, at chaotic terrains the analysis of ice blocks [6] could be used to reconstruct the original thickness [10] during their formation.

The bottom of Europa's ocean might have roughly similar pressure values as Earth has on it's deepest oceanic point, thus astrobiological relevance is shown as living organism (*Halomonas salaria*) have been found thriving under such high pressure (102000 kPa) [11]. Nevertheless, all the analogs from Earth can be considered as extreme environments, but they do have thriving life around – even if it is only bacterial.

Bubble formation may be responsible for the transportation of materials from the bottom of the ocean to the top, or by resurfacing, uprising material may even mix with the ice layer.

Table 1. Astrobiological importance and observational possibilities of different surface structures on Europa

Surface feature type	Astrobiological importance	Proposed detector for the Laplace mission
average plain terrains	composition of sputtered products from Europa helps to estimate the salinity in the ocean	Ion and Neutral Mass Spectrometer
ridges (single, double, multiple)	formed by tidal driven tectonism; separation of tidal driven changes from internally induced	Narrow Angle Camera, Vis-IR Spectrometer
impact craters	might hint subsurface compositional differences, exogenous material influence on surface as large deformed craters might have been in direct contact with the ocean	Vis-IR Spectrometer, Laser altimeter
multiringed palimpsest-like large impact craters	may exhume the bottom layer of the crust or the top of the ocean	Narrow Angle Camera, Ice Penetrating Radar
domes	may show the rising material from below that frozen into the ice, possibly in connection with the submarine volcanoes	Narrow Angle Camera
pits	identify the pit forming process and possible exhumation process, and their connections with ice embedded biomarkers	Narrow Angle Camera, Laser Altimeter
chaotic terrains	exhume subsurface materials and formed by warm rising water plumes from submarine volcanoes, spectral identification of signatures [10, 12] of the deep sea volcanic outputs; regional-scale Europa morphology & topography	Wide and Medium Angle Camera, Vis-IR Spectrometer
pull-apart bands	dark material may contain materials from the ocean, formed by tidal driven tectonism, samples the lower crust, identification of the deep excavated material from the lower ice crust or even the ocean	Vis-IR Spectrometer
troughs	may point to the surface structure, global distribution together with pull-apart bands allow to reconstruct deformation history of the crust that give implication on the distribution of the youngest/oldest regions	Narrow-angle Camera
ridged plains	identification of possible evolutionary sequence form fresh ridges and more uniform old ridges help to reconstruct the chemical and mechanical changes of surface material and the alteration of possible biomarkers	Wide Angle Camera, Narrow Angle Camera, Vis-IR Spectrometer
smooth plains	infrequent low albedo patches also with possible subsurface material on the surface, possible astrobiological relevance is poorly known yet	Narrow Angle Camera, Vis-IR Spectrometer

Table 2. Possible pressure values for the putative ocean for three ice thickness values and for clear or salty water

Ice thickness [km]	Depth of the ocean [km]	Pressure	
		in clear water	in salty water
		under the surface / on the bottom of the ocean [kPa]	
2	80	2409 / 105120	3096 / 113004
25	100	30123 / 131400	38712 / 141255
40	170	48197 / 223380	61939 / 240134

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