Chela-Flores, J. (2010) **Are there habitable ecosystems in Europa and Ganymede?** 3rd Workshop of the Italian Astrobiology Society, "When Darwin meets Copernicus". Duino Castle (Duino-Aurisina, Trieste, Italy), 26 - 28 May.

ARE THERE HABITABLE ECOSYSTEMS IN EUROPA AND GANYMEDE? (*)

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Background: The Galilean satellites have been observed remotely by several flyby missions passing through the Jovian system. Nevertheless, there has been no in situ investigation of the surface materials that may bear relevant biosignatures. Even though planning is going ahead for returning to the Jovian system, we maintain that the ESA funds (facing funding competition) should be guaranteed for a new exploration of the surface of Ganymede in situ, rather than just focusing on Europa alone, even though the presence of a liquid ocean over a silicate core makes Europa a leading candidate for the emergence of life in the Jovian system.

Methods: We restrict our attention to the origin of habitable ecosystems, which is a question in geochemistry, possibly a problem in astrobiology that can be solved in the foreseeable future. The origin of life is a question in chemical evolution, a time-honored pursuit that has been given most attention (Chela-Flores, 2010). Since certain bodies may share a similar geophysical past with the Earth, we should first answer the question: *Can available instrumentation discover habitable ecosystems in geophysical environments similar to the early Earth, where oceans were in contact with a silicate core?* A central piece in this dilemma is the element sulfur (S). A reliable window on the nature of the early terrestrial habitable ecosystems is the Pilbara Craton (Australia), a rich fossiliferous archive of the early steps of evolution. It contains a ~3.47 Ga barite deposit with microfossils of sulfate-reducing bacteria (Shen and Buick, 2004). The large spread in the delta-34S parameter values provides the earliest reliable biomarker from the early Earth. Europa may represent the only other case in the Solar System in which liquid water has been in contact with a silicate core over geologic time in analogy with the early Earth (Bland *et al.,* 2009). It is therefore reasonable to make the following hypothesis: *On Europa the presence of hydrothermal activity at the interface of the silicate core and the ocean can provide a variety of chemicals playing a role in sustaining microbial life at the ocean floor*.

Findings: This hypothesis is subject to experimental tests: The non-ice surficial elements of Europa were found to be widespread, patchy and, most likely, endogenous. We argue that penetrators should be inserted in orbital probes in the future exploration of the Jovian system (Gowen *et al*., 2009). There are alternative views on the effect of space weather on the radiation-induced S-cycles produced on the surficial molecules; but S is common to both interpretations (Carlson *et al*., 1999; McCord *et al*., 1999). The largest known S-fractionations are due to microbial reduction, and not to thermochemical processes. Besides, sulfate abiotic reductions are generally not as large as the biogenic ones (Kiyosu and Krouse, 1990). From experience with a natural population, this type of biota is able to fractionate efficiently S-isotopes up to a delta-34S parameter value of -70 per mil (Wortmann *et al.,* 2001). Dissimilatory sulfate reducers are ubiquitous on Earth, producing the largest fractionations in the sulfur stable isotopes. These microbes are widely distributed in terrestrial anoxic environments. Consequently, they are the most evident candidates for the microorganisms populating a habitable Europan ecosystem. Microbial fractionation of stable S-isotopes argue in favor of penetrators for surveying the surface of not only Europa, but also Ganymede, where surficial sulfur has been detected (McCord *et al.,* 1997). The Europa-Jupiter System Mission (EJSM) intends to explore in the 2020s both of these satellites. Constraining the habitability of Europa is one of its prime goals. The analysis of data retrieved with EJSM on both Jupiter moon surfaces from an orbital platform alone would be subject to assumptions regarding the nature of the icy surfaces; direct measurements of their properties, as the isotopic composition of non-ice elements would yield ground-truth for the orbiter instruments.

Conclusion: According to our hypothesis we predict that penetrators (supplied with mass spectrometry) should yield different results for fractionated sulfur. The icy patches on Europa should give substantial depletions of ^{34}S, while measurements on Ganymede should give significantly lower values for the depletion of ^{34}S. (As Ganymede lacks an ocean-core interface, according to our hypothesis it would not be able to support life.) These diverging results - a large minus delta-34S parameter for Europa, and small minus delta-34S parameter for Ganymede - would provide a clear test for the hypothesis that a habitable ecosystem has emerged on Europa. The test is within reach of available micro-penetrator technology.

References

Bland, M. T. *et al.* (2009) The orbital - thermal evolution and global expansion of Ganymede. Icarus **200**, 207-221.

Carlson, R. W. *et al.* (1999) Sulfuric Acid on Europa and the Radiolytic Sulfur Cycle. Science **286**, 97-99.

Chela-Flores, J. (2010) Instrumentation for the search of habitable ecosystems in the future exploration of Europa and Ganymede. International Journal of Astrobiology, 9 (2), 101-108 (Copyright holder: Cambridge University Press: 2010).
http://www.ictp.it/~chelaf/jcf_IJA_2010.pdf

Gowen, R. *et al.* (2009) Looking for Astrobiological Signatures with Penetrators on Europa. In: *Physical and Engineering Sciences Exploratory Workshops*: Biosignatures on Exoplanets: The Identity Of Life, Mulhouse, France. http://www.ictp.it/~chelaf/ESFsummary.pdf

Kiyosu, Y. and Krouse, H.R. (1990) The role of organic acid in the abiogenic reduction of sulfate and the sulfur isotope effect. Geochemical Journal **24**, 21 - 27.

McCord *et al.* (1997) Organics and Other Molecules in the Surfaces of Callisto and Ganymede. Science 278, 271 - 275.

McCord, T. B. *et al.* (1999) Hydrated salt minerals on Europa s Surface from the Galileo near-infrared mapping spectrometer (NIMS) investigation. J. Geophys. Res. **104**, 11827-11851.

Shen, Y. and Buick, R. (2004) The antiquity of microbial sulfate reduction. *Earth-Science Reviews* **64**, 243-272.

Wortmann, U.G. *et al.* (2001) Hypersulfidic deep biosphere indicates extreme sulfur isotope fractionation during single-step microbial sulfate reduction. Geology **29**, 647 - 650.

(*) The present paper is an improved version of an earlier talk given at the European Geophysical Union General Assembly 2010, Vienna, 7th May 2010. Session: Habitability in the Solar System: Mars, early earth, and the outer planets. Chairpersons: Frances Westall and Francois Raulin, http://www.ictp.it/~chelaf/EGU2010seamless.pdf.