BIOGEOCHEMICAL FINGERPRINTS OF LIFE: FROM POLAR ECOSYSTEMS TO THE GALILEAN MOONS (*)

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Abstract

We highlight two aspects of terrestrial polar regions that are relevant for astrobiology. Firstly, we discuss ecosystems in the McMurdo Dry Valleys of Victoria Land, Antarctica, especially ecosystems in Taylor Valley, where biogenic icy patches are found on both Lake Hoare, as well as on the microbially-produced icy patches of Blood Falls. Secondly, we mention the Canadian Arctic at Ellesmere Island, where sulfur patches are accumulating on glacial ice lying over saline springs that are rich in sulfide and sulfate. All of these ecosystems are appropriate models for possible habitats that will be explored by the European Space Agency JUpiter ICy Moons Explorer (JUICE) mission to the Jovian System. The icy surfaces of Callisto, Ganymede and Europa are amongst JUICE's primary objectives, including the search for biomarkers. The extensive evidence for an ocean over a silicate nucleus makes Europa the leading candidate for the emergence of a second evolutionary pathway of autochthonous life in the Solar System. In future exploration the chemical element sulfur (S) is especially relevant. The earlier Galileo orbital mission (1995-2003) discovered surficial patches of non-ice elements on Europa, including sulfur. They were found to be widespread and, possibly endogenous. There are alternative views on the radiation-induced S-cycles produced on the surficial molecules that are present on the icy surface, but S is common to both interpretations. At present there is no certainty for landing on the icy surface of the Galilean satellites, although NASA has raised the possibility of a Europa lander. However, the tenuous atmospheres of the Galilean satellites can be considered extensions of their surfaces. Chemical elements on the Europa exosphere include SO_2. Its ultimate source must be regions having a young surface, where the upwelling of subsurface material may occur. This suggests the possibility that observed chemical elements in the exo-atmospheres may be from subsurface oceans. Atmospheric spatial resolution has already been done with a Monte Carlo collisionless model. (The atmospheric density has been obtained as a function of altitude.) With this estimate it is likely that the atmospheric S content can be mapped by a neutral mass spectrometer that is available amongst the chosen JUICE instruments. As in the case of the Earth's polar ecosystems, the largest known S-fractionations are due to microbial reduction. This remark provides a test for ecosystem fingerprints. We discuss instrumental issues to ascertain whether measurements of stable S-isotope fractionation of the order of $\delta^{34} > -60$ ‰ are feasible. We pay attention to the JUICE instruments, together with complementary instrumentation that is in principle possible on NASA's suggested lander. To implement the biogeochemical measurements, we argue in favor of already available miniature laser ablation time-of-flight mass spectrometers that are ideal for *in-situ* investigations in planetary space research.

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