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Distinguishing between signatures of past life and nonlife

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Recently chemoautotrophs (microorganisms using inorganic or organic substances as energy source rather than light) have been discussed with special reference to Europa (Chela Flores, 2007). The significance of the presence of sulphur in the Europan ocean, its chemistry and possible role of sulphur reducing bacteria are topics that concern us in the present work. Chemotrophs and phototrophs are abundant in environments where one or more physical, or chemical parameters show values far from the lower or upper limits known for life. We present arguments that militate in favour of microorganisms that in the past and present may have occupied other niches in the Solar System. Some of the possible candidates for life in the Solar System are the extremophiles including chemotrophs, especially sulphur-reducing bacteria (Seckbach and Chela-Flores, 2007).

If there is, or has been, an autochthonous biota on the Jovian satellite the role of sulphur may be similar to what has taken place on earth, especially in the early stages of its geological evolution. It has been emphasized earlier that the sulphur patches on the icy surface of Europa might contain biomarkers that may be accessible to future missions. The early diversification of life on Earth offers some evidence on the reliability of sulphur as a bioindicator. It may be argued that if the plasma from the magnetosphere were responsible for the sulphur distribution, some geologic process has to be invoked to allow for a non-uniform distribution. Sulphur traces on Jupiter's moon Europa detected by the Galileo mission have been conjectured to be endogenic, most likely of cryovolcanic origin, due to their non-uniform distribution in patches (Carlson *et al.* 1999). Effusive cryovolcanism is clearly one possible endogenous source of the non-water-ice constituents of the surface materials (Fagents, 2003). Alternatively, the sulphurous material on the surface may be endogenous and biogenic (Chela-Flores, 2006), a possibility that is subject to testing when we return to Europa, as we endeavour to demonstrate below. We restrict our attention to possible biomarkers that could signal the presence of chemotrophs, especially the presence of sulphur reducers in the ocean beneath the icy surface of Europa.

There is a possibility for returning to Europa, with a mission to the Jupiter System for ESA's Cosmic Vision Programme (2005). In this context, the question of identifying reliable bioindicators is a major priority. We argue that with a data analysis that addresses fluctuations, rather than the mean (Luria and Delbrück, 1943; Nanjundiah, 1999), there are options for approaching the question of selecting the right instrumentation for measuring the more abundant sulphur isotope, in spite of the fact that ^{32}S is isobaric (same m/z) with $^{16}O_2$, which we refer to as the ^{32}S - O_2 ambiguity.

Two technologies are possible in the context of investigating the possible biogenicity of sulphur. With landers, or low-cost penetrators that could first of all be tried out on the Lunar surface (Smith and Gao, 2007), we would be in a position to test the redox state of the Europan ocean. Alternatively, the imprint of the possibly biogenic signature of the surficial sulphur would be retained in the dust cloud that surrounds this singular Jovian satellite (Kruger *et al.*, 2003). The arguments in the present paper militate in favour of mass spectrometry as the instrumentation for future dust detectors in Europan orbit (Taylor *et al.*, 2007): the payloads should however be complemented with additional instrumentation to single out the sulphate reducer biomarkers (such as gas chromatography-mass spectroscopy, GCMS). For this purpose we reconsider the significance of deviations of sulphur anomalies beyond normal (meteoritic) values. In order to undertake such a search for a meaningful biomarker, in the present work we reconsider isotopic anomalies in the light of statistical data analysis. From the fluctuation test we find an exponential dispersion in the bacterial population sampled. The latter will in turn translate itself into an exponential dispersion of the amount of processed isotope ^{32}S over the samples. That would then dominate the mean. These non-gaussian fluctuations that are characteristic of the biogenic origin of the ^{32}S excess will be large, and a more sensitive, indeed, a qualitatively distinct biomarker for the integrated bacterial activity on Europa. The biogenically generated non-gaussianity will show up as the non-vanishing of higher order cumulants. In this context an added advantage will be that the cumulants are semi-invariant, i.e., that they are independent of any additive background bias, for example, a contamination in mass spectrometry by the O_2 that is present on the external low-density atmosphere of Europa. The oxygen molecule is isobaric with ^{32}S, and hence would have been expected to create a disambiguation problem with the present technology from the point of view of resolution and sensitivity. While a fluctuation test is being proposed in the context of future missions to Europa, it may well be appropriate to a laboratory experiment with sulphur-reducing bacteria with the corresponding isotopic fractionation.

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