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Instrumentation for the Detection of Biosignatures on Europa

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Introduction

It has been clear for a long time that the surface of Europa is dominated by water ice (Johnson and McCord, 1971). It has also been equally clear that there is much spectroscopic evidence for the presence of non-ice substances (Delitsky and Lane, 1998). In particular, Galileo Near-Infrared Mapping Spectrometer (NIMS) evidence for the presence of sulfur compounds has been discussed in detail (Carlson et al, 1999, 2002). It had been suggested earlier that the sulfur contamination was due to the implantation of S from the Jovian magnetosphere (Lane et al, 1981). However, based on combined spectral reflectance data from the Solid State Imaging (SSI) experiment, the NIMS and the Ultraviolet Spectrometer (UVS), it has been argued that the non-water ice materials are endogenous in three diverse, but significant terrains (Fanale et al, 1999). Effusive cryovolcanism is clearly one possible endogenous source of the non-water-ice constituents of the surface materials (Fagents, 2003). With the technologies and missions that are currently in the preparation stage, we discuss whether it is possible to clearly pin down the endogenicity of the non-water ice contaminants to cryovolcanism, or whether there are other endogenic factors, including biogenicity.

Core

Of all the biogenic elements, S has the most relevant isotopic fractionation in the present context: Once the primordial planetary mantle material (for example, on the Earth), or satellite internal silicate nucleus (for example, on Europa) had entered their corresponding geochemical cycles, their initial isotope mixtures began to be redistributed. The Earth upper mantle and crust are believed to reflect broadly the isotopic distribution patterns of chondritic meteorites (Libby, 1971).

Modeling of Europa suggests that a type of chondrites carry sufficient amount of water (13.35%), carbon compounds (2.46%) and sulfur (3.25%) to stand as a good model of the planetesimals that gave rise to the proto-Europa. The meteorite in question is petrographic type-2 carbonaceous chondrite of chemical class CM, i.e., similar to the prototypical Mighei meteorite (Cronin and Chang, 1993). This shows that in an ice-ocean model of Europa (Oro et al, 1992), collisions with the proto-satellite planetesimals of this composition would have carried with them sufficient amounts of water to account for an ocean on Europa (up to 7 % of the mass of the satellite). Other models have been discussed during the last decade independently (Kargel et al, 1999). There would have been also sufficient carbon input for eventually inducing a substantial biota.

The redistribution of the primordial isotopic mixtures can be followed up in terms of the appropriate parameter, namely the ’delta-parameter’ (Schidlowski et al, 1983): (delta^{34}S). The relevant terms are the dominant sulfur isotope (^{32}S) and the next in abundance (^{34}S). This suggests that focusing on S might be more reliable for estimating biological effects (if any) on Europa. In contrast to the isotopes of hydrogen, carbon or nitrogen, meteorites (as well as the Moon fines, breccias and fine-grained basalts retrieved by the Apollo missions) show a (delta^{34}S) parameter with a relatively narrow distribution range that is (in the case of meteorites) of about $2^{o}/_{oo}$ relative to the standard Canyon Diablo Meteorite (CDM), (Kaplan, 1975). The measurements of isotopic ratios of the biogenic elements were not considered during the Galileo Mission. Fortunately, they are in principle measurable in a future mission to Europa.

Some arguments militate in favor of focusing on spectrometry measurements in situ. There are very clear signals associated with sulfate-reducing bacteria living in reducing environments. Dissimilatory sulfate reduction releases hydrogen sulfide with associated turnover rates of sulfur unlike the significantly much smaller assimilation processes. The consequence of this biochemical cycle is that the dissimilatory sulfur reducers are responsible for the well-observed large scale interconversion of sulfur between oxidized and reduced reservoirs in lacustrian, marine or oceanic environments. For instance, seawater sulfate has a (delta^{34}S) parameter value of $+20^{o}/_{oo}$, in sharp contrast with, for instance, insoluble sulfide in marine environments, where the (delta^{34}S) parameter can reach values of less than $-40^{o}/_{oo}$(Schidlowski et al, 1983). On the other hand, one could not rule out possible sources of sulfur from Europan deep oceanic vents, where there may be bacterial ecosystems similar to those existing around the Earth’s deep-sea hot springs (Oro et al, 1992). Such an environment has the potential to raise sulfur and its compounds to the Europan icy surface, due to strong thermal and dynamical linkages with the ocean beneath. This phenomenon is suggested by the fluid dynamics of the ocean and its impact on the geologic record of the frozen surface (Thomson and Delaney, 2001). Since mercaptan production is sufficiently abundant in lacustrian anoxic environments, according to our recent data (Del Negro et al., 2005), sulfur bacteria cannot in principle be ruled out as a source of the stains of the icy surface of Europa.

Conclusion

We have attempted to show that with the appropriate physical technique (mass spectrometry), the interaction between the icy surface and the buried ocean beneath is likely to provide a reliable geochemical biosignature on the icy shell itself. Surficial sulfur contamination from an endogenous microbial community would be expected to differ sharply from a signal arising from sulfur surface contaminants that were deposited by cryovolcanism.

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