STRATEGIES FOR DETECTING BIOLOGICAL MOLECULES ON TITAN.

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Introduction: Saturn's moon Titan has all the ingredients needed to produce "life as we know it". Titan's dense atmosphere of N_2 and CH_4 supports a rich organic photochemistry, producing a suite of carbon, hydrogen, and nitrogen containing products ($C_xH_yN_z$), which eventually settle onto its surface. Once on the surface, the products of Titan's photochemistry may react with liquid water to produce a range of biomolecules, such as amino acids [1].

Thus, Titan provides a natural laboratory for studying the products of prebiotic chemistry. If given enough time, it is even possible that life arose on Titan and persisted for a short interval before its habitat froze. It is thus crucial that we develop a plan to collect the results of these natural experiments. In this work, we examine the ideal locales to search for evidence of biological molecules on Titan. We then suggest mission scenarios to test the hypothesis that the first steps towards life have already occurred there.

Geologic settings for aqueous chemistry: Liquid water is both a crucial source of oxygen and a useful solvent for the creation of biomolecules on Titan's surface. Thus, if we wish to identify biological molecules on Titan, we need to determine where to find evidence for past liquid water there. We are most likely to find these environments on Titan in two distinct geological settings: (1) cryovolcanic lava flows and (2) melt in impact craters.

Cryovolcanos. On Titan, lavas are generally referred to as cryolavas, since they involve the eruption of substances that are considered volatiles on the surface of Earth (e.g. water). One feature thought to be volcanic in origin is the region formerly known as Sotra Facula. However, unless this region represents a persistent hot spot, it is unlikely that the lava remained liquid long enough to produce complex, biological molecules. The flow lobes at Sotra Facula are tens of meter thick [2], and so would be expected to cool over relatively short timescales (~1 yr). In addition, if these lava flows have a peritectic composition close to that of pure ammonia dihydrate, they would erupt at a temperature of ~176 K. This would significantly impact reaction rates. A reaction that takes a few days to complete in the lab at 253 K would take a few hundred years to complete at 176 K [3]. Thus, aqueous chemistry in cryolavas may not have sufficient time or energy to produce more complicated, biological molecules.

Impact craters. A better target may therefore be impact craters. When a comet or asteroid impacts a planet, energy becomes available to melt its surface, with melt production increasing with crater size [4]. Once melted by the impact, any liquid water generated will begin to cool to the ambient temperature of ~94 K. O'Brien et al. [5] found freezing timescales of $\sim 10^2$-10^3 yr for a 15-km-diameter crater, and $\sim 10^3$-10^4 yr for a 150-km-diameter crater. These lifetimes are considerably longer than those for lava flows, allowing more time for aqueous chemistry to proceed. Impact melt is also likely to be emplaced at temperatures higher than the liquidus. This could increase the temperature of the melt above the freezing point of water, accelerating the chemistry occurring there.

We therefore judge that the best targets for observing the products of aqueous chemistry on Titan are the floors of large, relatively unweathered impact craters. These will contain the largest amount of impact melt, and that melt will be easier to access with a spacecraft. There is topography data for seven craters on Titan with $D > 75$ km. Of these, the two least degraded craters are Sinlap and Selk. The largest impact crater on Titan – Menrva – also remains a high priority for future exploration given the amount of impact melt expected in such a large crater.

Identifying biological molecules on Titan: To identify biological molecules on Titan, it will be necessary to obtain more detailed data than is currently available from the Cassini-Huygens mission. Reflectance spectra of common biological molecules demonstrate that an orbital spectrometer would have difficulty identifying their spectral features, given the limited number of atmospheric windows available on Titan. A more effective approach would be to send a lander equipped with a gas chromatograph and/or mass spectrometer capable of identifying a wide range of biological molecules [6]. Given the non-uniformity of impact melt exposures in the floor of a weathered impact crater, the ideal lander would be mobile, allowing it to identify locations where impact melt deposits have been exposed through erosion and/or mass wasting.

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