SEARCHING FOR MARTIAN BIO-INDICATORS AND EXTANT LIFE USING SPACECRAFT.

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Introduction: Current environmental conditions at the surface of Mars are hostile to "life as we know it", but the near subsurface may well provide sufficient shielding to harbor simple life forms. This discussion focuses on methane – which can be produced either abiotically or by microbial life – and possible geological or biological sources for that methane in the subsurface.

Follow the Methane: The detection of methane in the Martian atmosphere is important because the gas has a lifetime of only centuries before dissociation, and thus must have been relatively recently released. Methane has been detected by Earth-based telescopes at the ppm level. Repeated seasonal variations, at the ppb level, have been measured by the SAM instrument on the Curiosity rover. These variations may indicate a seasonally-varying generation, or seasonal variations in planetary conditions such as temperature or wind that could promote release from the subsurface [1].

The sources of methane have not yet been localized. However the ExoMars Trace Gas Orbiter (TGO), currently orbiting Mars, has the potential to locate areas of enhanced methane concentration on a scale of a few hundred km^2. In addition, this spacecraft may detect other trace hydrocarbon gas species [2]. The ratios of these gases could be used to help differentiate between biological and geological origins for any methane detected.

Follow the Geology. The localization of methane concentrations near specific geological features can potentially indicate the source and origin of this gas.

Abiotic Methane: Methane can be produced abiotically by serpentinization/Fischer-Tropsch Type (FTT) reactions [1,3]. If such reactions have occurred or are occurring at depth on Mars, the gas could migrate to the surface thru fractures and be released to the atmosphere. Large-scale, recent fracture systems, such as those at Cerberus Fossae, could be sources of gas release, and other potential release locations could be reactivated faults, such as those along the dichotomy or those associated with large impacts [1]. If orbital measurements detect recurring methane concentrations near such fracture systems. and in regions where serpentinization/FTT reactions might occur, abiotically generated methane could be indicated.

Clathrates: Large amounts of methane can be bound in the crystal structure of water ice, forming clathrates. Warming of this material, and/or pressure changes, can release this methane [1,4]. Mars undergoes cycles in which water ice sublimes in summer and refreezes in winter. Evidence of seasonal ice loss has been documented at the Martian poles. If areas of enhanced methane concentration are shown to correspond to areas of ongoing ice loss, clathrate breakdown may be the current source of both the gas and its seasonal variations. The origin of methane trapped in the ice could be either abiotic or biogenic.

Mud Volcanoes: On Earth, low-temperature sediment- and fluid-expulsion features – known as mud volcanoes – are common on the ocean floor and in onshore areas of hydrocarbon enrichment [5]. Mud volcanoes are a significant source of Earth's atmospheric methane. In addition, living microbes have been brought from depth in the mud and fluids erupted by many of these features. On Mars, more than 18,000 km-scale structures, with morphologies and geologic settings suggestive of mud volcanoes, have been mapped in southern Acidalia Planitia [6]. While these structures are estimated to have been formed in the early Amazonian, they may comprise a large number of paths for gas expulsion from the subsurface. If Acidalia Planitia is identified as a significant source region for methane release, these features could rate careful investigation in the search for extant Martian life.

Next Steps: This strategy builds on current observations of methane in the Martian atmosphere, studies of geological features on the planet, and the expected capabilities of the ExoMars TGO to detect methane and other hydrocarbons. Although making the distinction between abiotic and biotic methane will be challenging [7], even abiotic methane could serve as a nutrient for non-methane-producing life-forms, and so the localization of methane release sites could point to habitable areas within which life may occur.

Actually locating extant life in promising areas will likely necessitate a rover with km-scale mobility and instruments to quantify hydrocarbon gases and assess chemical bio-indicators. Such a life detection mission will also require a level of sterilization previously employed only on the Viking landers [8]. Nobody said this would be easy.

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