MARTIAN BIOSIGNATURES: TANTALIZING EVIDENCE WITHIN MARTIAN METEORITES.
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The Astrobiology Roadmap [1] notes that for evidence of life within a terrestrial or extraterrestrial sample selected biosignatures must be present within the sample. It must also be recognized that these biosignatures must have a spatial relationship within the sample. Catagories of biosignatures may include: cellular and extracellular morphologies, biogenic fabrics in rocks, bio-organic molecular structures, chirality, biogenic minerals, biogenic stable isotope patterns in minerals and organic compounds, and atmospheric gases [1,9]

Greater than 70 meteorites have been recognized as Martian in origin. These Martian samples offer an opportunity to study the history of Mars and any biogenic processes that have occurred on the red planet because they essentially span the age of the planet from 0.165 to 4.1Ga. However, only four or five of these 70+ Martian meteorites are suitable for study because they display the least amount of terrestrial contamination. Recognition [2,3,4,] that the Martian meteorites EETA 79001, Nakhla and Y000593 [5] contained indigenous organic matter from Mars showed the presence of reduced C on Mars, something the Viking 1 and 2's GC-MS instruments failed to detect in the 1970s [6].

The 1996 announcement by McKay et al. [7] that ALH84001 may contain features which could be interpreted as having a biogenic origin generated considerable excitement and criticism along with establishing the Astrobiology Program within NASA. The discovery that the >4.1+ Ga old Martian meteorite contained 3.9 Ga old carbonate globules formed at temperatures between 25^{o}-30^{o}C offered the first opportunity to study carbonates formed from subsurface fluids that had been present on early Mars. The carbonates contained magnetites of unusual morphologies, sizes and compositions [8] associated with reduced carbon components previously shown to be indigenous to Mars [3,6]. Further studies revealed these magnetites could not have been formed by either thermal decomposition or shock processes operating on iron-bearing carbonates [8]. The ALH84001 meteorite, formed in the first 600 million years on Mars when the planet had a magnetic field, and the subsequent recognition that the younger Nakhla and Yamato 000593 samples (~1.3 Ga formation ages showing aqueous alteration processes 500 to 700 million years after formation) along with the Shergotty meteorite (formation age of 165 ma) offer unique opportunities to examine the evolution of Mars' hydrosphere, atmosphere and possible biosphere over time. Despite the 20 years of intense study on ALH84001 by the world's scientific community, the original scientific evidence presented by McKay et al. [7] has not been refuted and still stands today. The biosignature criticism is on the interpretation of the data.

In 2001, Gibson et al. [10] reviewed the requirements for acceptance of life on the Earth and noted eight criteria are required. For geological samples to be accepted as possible representative of early life on the earth, a majority of the following criteria must be known: The geologic context of the sample, the age and history of the sample, any cellular morphologies present within the sample, associated biofilms and microbial colonies present within the sample, the sample contain representative biominerals or evidence of chemical disequilibria, the isotopic signatures of the biogenic elements are compatible with biogenic activity, there are significant organic biomarkers or components present in the sample, and finally, the features are indigenous to the sample.

For ALH84001, we know the sample is from Mars [10]. Specifically the oxygen isotopic composition of the silicates is identical to other meteorites known to be from Mars along with trapped samples of the Martian atmosphere. The crystallization age of the ALH84001 silicates is 4.09 Ga. The carbonates were formed at 3.9 Ga and represents a period during the Noachian epoch on Mars during which both the oldest extant Martian surfaces were formed, and perhaps the earliest global ocean existed. During this period of Martian history, the early Mars magnetic field was still present. Within the ALH84001 carbonates, Nakhla and Y000593 biomorphs with segmented structures are present [5,10].

The presence of indigenous organic or reduced carbon, of which PAHs (polycyclic aromatic hydrocarbons) are a subset, is spatially associated with the ALH84001 carbonate globules. Isotopic signatures of this reduced carbon are well within the ranges accepted for biogenic fractionation on Earth. Observations of rare biofilms-like morphologies within ALH84001 carbonate globules, as well as within aqueously altered zones in other Martian meteorites such as the Nakhla, Shergotty and Yamato 000593 are additional evidence [4,5, 10]. The reduced carbon phases have been shown to be associated with the secondary alteration phases (i.e. iddingsite clays) within the samples. After careful examination of the biomorphs in these meteorites, we conclude that they are indigenous features within the ALH84001, Nakhla, and Yamato 000593 Martian meteorites [5,10] and have been associated with the Martian groundwaters..

When comparing the criteria required for recognition of life in a geological sample with features observed in selected Martian meteorites, a majority of the criteria are met. Still since these samples are extraterrestrial (i.e. Martian), caution must be taken to positively identify signatures of life in these samples and the possibility of contamination cannot be ruled out.

References:

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