Life Detection With Minimal Assumptions – Setting an Abiotic Background. A. Steele[1] [1]Carnegie Institution of Washington, Geophysical Laboratory, 5251 Broad Branch Rd, Washington DC, 20015. asteele@ciw.edu

The simplest form of extraterrestrial life detection with minimal assumptions on the nature of the organism or a potential "alien biochemistry" to be detected, is to understand the possible abiotic organic chemical reactions given the context of the samples and look for perturbations to that signal. More precisely, life chooses only a few of the many known organic chemicals produced by abiotic processes. Therefore anomalous deviations from predicted abiological yields of organic chemicals under given conditions may be the easiest life detection protocol. The assumptions are minimal; life is carbon based and it chooses only a subset of possible abiotic chemicals available (Steele et al., 2006). An example would be the organic chemistry responsible for the inventory of organics in the Murchison meteorite and abiotic processes such as the Miller-Urey reaction and Fischer – Tropsch (FTT) synthesis. In the case of the Murchison meteorite, it appears that all possible isomers of a particular carbon number or compound are present but only a very limited subset of these molecules used by terrestrial biology (Schmidt-Koplin 2010). In the case of FTT as chain length increases, yield decreases and although analysis of the products this is subject to analytical problems, mainly volatile loss, the kinetics of this reaction are very well understood and predictable. Life on the other hand tends to use ~ C17 to C31 alkanes and produce an odd even preference that is not present in FTT products (Donnelly, 1989). A final and perhaps extreme example of this philosophy is that if terrestrial life uses A,T,C,G and U for information storage a Martian organism may use L.M.N.O and P. Again the probability is that life will choose only a few of the possible choices of, in this case, purine and pyrimidine isomers. Therefore, knowing the abiotic reactions are possible in a certain context provides a baseline value from which any anomalous concentrations of organics that may be a 'biosignature' can be detected.

This strategy depends on several key points for implementation.

1) An understanding of possible abiotic chemistry undertaken in Mars environments (including meteoritic infall) and the preservation / diagensis of that signal with time.
2) A clear understanding of the geological context in which measurements are made.
3) A multidisciplinary and multi-measurement approach with convergent data sets from each measurement.
4) Commitment to a null hypothesis that all observations are treated as non-life signatures until a wealth of evidence exists to falsify this hypothesis.
5) Clear operating guidelines and peer review of results and data. It is after all the community and not a single investigator or measurement that will ultimately define a positive "Life Detected" result.

While apparently biased towards the detection of molecular biosignatures, the invocation of a null hypothesis demands similar rigorous examination of data from the detection of possible mineral, isotopic or morphological biosignatures.

Setting an abiotic signature for Mars

If, as stated, the detection of life from organic molecules requires an understanding of the abiotic Martian organic inventory then what is our current understanding of Martian organic chemistry. To the first order the answer to this question is that while there are tantalizing glimpses and debate on both landed mission data (Viking) and Mars meteorite data currently there is no uncontested detection of a reduced carbon phase on Mars.

ALH84001 - In the debate to understand whether relic Martian life is present in ALH84001, significant research has been conducted to understand the presence and provenance of organic materials, specifically polyaromatic hydrocarbons (PAHs) in this meteorite (Bada et al., 1998; Becker et al., 1999; McKay et al., 1996). Steele et al., (2000) showed the presence of contaminating terrestrial organisms in the meteorite. Carbon isotope analysis (δC^{13} and C^{14}) shows that there is a high temperature phase of carbon, that comprised approximately 20% of the carbon in the meteorite (~240 ppm), both within the carbonate globules and the host pyroxene of ALH84001 that is indigenous to the meteorite (Jull et al., 1998). Using C-XANES, Flynn et al., (1998), showed the presence of C-C, C=C and possibly C-H bonds in both carbonate and magnetite. Bada et al., (1998) showed that a range of biologic amino acids exist in ALH84001 most, but perhaps not all, of which could be explained by terrestrial contamination. Organic contaminants have been detected ALH84001 (Becker et al., 1999; Jull et al., 1998; Steele et al., 2000; Stephan et al., 2003). Becker et al. (1999) found that only a small proportion (~1%) of the indigenous organic carbon in ALH84001 is accounted for as PAHs and amino acids. The rest is present as a high temperature released macromolecular phase that is postulated to have originated from meteoritic infall to Mars (Becker et al., 1999).

Steele et al., (2008) found polyaromatic macromolecular carbon species (MMC) as well as graphite in intimate association with magnetite in both ALH84001 and terrestrial mantle derived carbonate globules from samples collected from the Svalbard Bockfjorden Volcanic Complex (BVC). The authors demonstrate that MMC synthesis appeared to be associated with known abiotic reactions within the Fe-C-O system and that MMC was produced during precipitation of the carbonate globules and potentially also through thermal decomposition of siderite (Koziol 2004; McCollom, 2003; Treiman, 2003; Zolotov and Shock, 1998; Zolotov and Shock, 2000, Steele et al., 2008). By inference to a terrestrial analogue of mantle origin (BVC), these results appear to represent an explanation of the presence of indigenous organic material in ALH84001 and potentially indicative of an abiotic macromolecular carbon synthesis mechanism on Mars.

Nakhla - The presence of organic substances in Nakhla and other meteorites (e.g. polycyclic aromatic hydrocarbons, amino acids and aliphatic hydrocarbons) has previously been demonstrated, suggesting that the abundance of these substances may partially be indigenous and partially a result of contamination from their respective terrestrial environments (Bada *et al*., 1998; Wright *et al*., 1998; Glavin *et al*., 1999, Flynn *et al*., 1999, Toporski and Steele 2004). Jull *et al*., (2000) argued through δC^{13} and C^{14} data that 75% of the carbon inventory in Nakhla was Martian in origin, with terrestrial contamination representing the other 25%. Polycyclic aromatic hydrocarbons, amino acids, and aliphatic hydrocarbons have been detected in Nakhla (Glavin *et al*., 1999; Flynn *et al.*, 1999). Sephton et al., (2002) showed the presence of benzene, toluene, C2 alkyl benzene and benzonitrile in pyrosylates of the Nakhla meteorite that have a carbon isotope distribution similar to the Murchison meteorite. Due to this similarity these compounds are attributed to meteoritic infall to Mars.

Glavin *et al.* (1999) concluded that most of the amino acids in Nakhla were derived from terrestrial sources, probably bacteria. Toporski and Steele (2004) showed the presence of terrestrial organisms throughout a depth profile of the Nakhla meteorite.

Other Martian meteorites

Using stepped combustion Grady et al., (2004) showed the presence of a high temperature phase of carbon (released between 600 and 1000^{o}C) that the authors claim is a crystalline carbon phase indigenous to the meteorite. This work follows on from previous observations and represents a consistent data set over 12 Martian meteorites (Wright et al., 1989, 1992; Grady et al., 1997)

Biotic Carbon

McKay et al., (1996) postulated that the distribution of polyaromatic hydrocarbons in ALH 84001 was one line of evidence (from 4) that showed possible relic biogenic activity in this meteorite. Since this study, the group has extended the claim of life to Nakhla (within iddingsite that is indigenous to the meteorite), Shergotty and unpublished data on NWA 998 (Gibson et al., 2001).

Organics Detected on Mars

Loes Ten Kate (2010) completed an excellent review on the current state of in-situ investigations for Martian organic material. Navarro-Gonzalez (2010) has recently reinterpreted the Viking GCMS detection of chloromethane as organic matter degraded by perchlorate during pyrolysis.

A further interesting aspect of the discovery of iron and potentially stoney meteorites on Mars (Schroeder et al., 2008) is that most iron meteorites consist of a significant proportion of graphitic carbon (Deines and Wickman, 1975). The isotopic signature of which can vary from -4.8 to -24.1 ‰ (Deines and Wickman 1975).

In impact terrains the likely residue of any carbon species in the impactor or impacted terrain is also probably graphitic as evidenced from lunar experience (Steele et al., 2010). However, this does not preclude survival of more volatile species (Ross 2006, Chyba 1989). Separating meteoritic and indigenous Martian carbon may prove challenging for SAM give the similarity of carbon speciation and isotope signature between potential Martian organic material and the Murchison meteorite for example (Sephton et al., 2002). Carbon isotope signals that are used to discriminate terrestrial life are also very similar to that reported for indigenous Martian organic material (Grady et al., 2004 and references therein).

Conclusion

With these studies we have a tantalizing glimpse of the processes that could produce organic chemical and life signatures on Mars; abiotic chemistry, meteoritic infall (non indigenous abiotic chemistry) and possibly life. The life detection philosophy outlined in this abstract is robust and has minimal assumptions about the nature of ET life and furthermore, will allow accurate deconvolution of different carbon pools (abiotic V biotic etc). While the Mars program and community regard the finding of life as of paramount importance, the lack of life on Mars would beg the question "why ?" and what is unique about the earth to allow life to start here. N would equal 2. Therefore the search for life on Mars is a search for our own beginnings.

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