BEAGLE 2 AND THE SEARCH FOR ORGANIC COMPOUNDS ON MARS USING GAP.

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Abstract. A fundamental challenge for the future exploration of Mars is to locate and study the organic materials that must inevitably reside on the planet. The failure of the *Viking* GC-MS instrument to detect organic compounds at the very surface of Mars [1], along with results from the *Viking* Biology experiments which suggest a chemically active surface [e.g. 2], has resulted in virtually the wholesale acceptance of the idea that a combination of UV irradiation and chemical oxidation destroys organics on Mars. And yet organic compounds are continually being added to the surface from micrometeorites, meteorites, cometary impacts, etc., [e.g. 3] and atmospheric processes conspire to produce simple compounds such as H_2CO and CH_4 [4]. Furthermore, even in purely abiological terms, Mars as an entity must have the capacity to process and produce organic compounds through the operation of geological phenomena. These facts, coupled with the improvement, since *Viking* times (i.e. the late 1970s !), in our understanding of the biology of Earth means that the new realism amongst scientists is that martian organic chemistry, and in particular its potential to support a martian biochemistry, is worth reappraising. Thus, future missions to Mars should explicitly go and seek evidence of organic materials, in order to provide evidence with which to contemplate the past (or present?) existence of life on the planet. Whilst sample-return remains the ideal of most geochemists (including organic geochemists, biochemists, etc.) the safe and unadulterated return of such materials to Earth is clearly a technologically demanding task. The ubiquitous presence of biology on Earth makes the prospect of (instantaneous) contamination very real. Furthermore, if extensive quarantine procedures are necessary, perhaps coupled with appropriate sterilisation of the samples, the chances of scientists getting the material they require into their laboratories may be remote. In contrast, making the measurements on Mars itself, whilst daunting at first glance, may be the most satisfactory way of achieving the desired goals. Success in this case rests on being able to devise appropriate methods of cleanliness for the space hardware which will ultimately travel to Mars – this involves not just sterilisation, but also the characterisation and removal (as far as possible) of potential contaminants [5].

Beagle 2 is one such mission which aims to explore the surface of Mars [6,7], being part of the ESA *Mars Express* program [8], which will be launched in 2003. *Beagle 2* is unashamedly an exobiology mission; however, it is not intended to go and find evidence for extant life. Rather, it contains a suite of instruments which together will collect evidence about those surface and sub-surface conditions on Mars that are important in an exobiological context. One of the key experiments is to search for “organic compounds” (sensu lato). This will be done using the Gas Analysis Package (GAP) and will, amongst other things, involve analysis of solid materials from both the surface and some depth within the regolith, and cored from rocks. These materials will be analysed using the well-known technique of stepped combustion [9,10]. In this way, *all* forms of carbon will be analysed both quantitatively and for their stable isotopic compositions (i.e. $^{13}C/^{12}C$, with results being referenced, in situ on Mars, to appropriate standard materials and thereby given as $\delta^{13}C_{PDB}$ values expressed as usual in ‰).

Whilst the search for organic compounds will be one of the key objectives of GAP, the instrument has a much more extensive capability. In general terms GAP is designed to make quantitative and stable isotopic measurements of gases such as H_2, N_2, O_2 and CO_2. The system can also process and determine some of the noble gases (Ne, Ar and Xe) as well as anticipated trace constituents such as CH_4. GAP operates in one of two ways, either analysing gases directly (such as those present in the atmosphere, or which can be liberated from samples by heating), or producing appropriate analyte gases (e.g. CO_2) by chemical processing (e.g. conversion of organic compounds to CO_2 by oxidation). In this way GAP is tremendously flexible, being able to investigate processes of atmospheric evolution, circulation and cycling, the nature of gases trapped in rocks and soils, low-temperature geochemistry, fluid processes, organic chemistry, formation temperatures, rock ages, surface exposure durations, etc.

At the heart of the GAP system is a 6 cm-radius magnetic sector mass spectrometer, which operates in both a dynamic and static mode (i.e. continuously pumped and isolated respectively). The mass spectrometer includes seven ion beam detectors. The main unit is a triple-collector array for the determination of N_2 (m/z 28, 29 and 30), O_2 (m/z 32, 33 and 34), and CO_2 (m/z 44, 45 and 46). A spur in the flight tube of the instrument includes a double-collector for measurement of D/H ratios (H_2^+ and HD^+ at m/z 2 and 3 respectively). Further detectors, mounted on the low- and high-mass side of the triple-collector, comprises pulse-counting electron multipliers for measurements of trace gases. When operated dynamically the mass spectrometer should be able to measure stable isotope ratios to high degrees of precision and accuracy (±0.1‰ when expressed as a δ-value). In contrast the static operation will allow high levels of sensitivity albeit with lower precision of the isotopic measurements.

As an illustration of instrument performance note that when *Viking* test equipment was used to analyse two different Antarctic soils [11] each containing 300 ppm carbon, they were determined to have about 5 and 0.01 ppm C as organic carbon. Had materials of equivalent character been analysed on Mars by *Viking* the latter of these would not have yielded any carbon above background, even though a significant fraction of the 300 ppm total carbon may have been non-pyrolytically degradable organic matter [see 12]. Laboratory analyses of carbon in SNC meteorites by a system similar to GAP is regularly used to measure carbon contents of 250 ppm, or less, from a few milligrams of sample [e.g. 13, 14]. Thus GAP should provide meaningful data from samples where *Viking* would have detected nothing. The mass spectrometer on GAP has been designed to measure, quantitatively and isotopically, nanogram quantities of carbon in any form. For a 50-100 mg-sized sample (the target for Beagle 2 operations on Mars) this translates to a detection limit for carbon of 0.02-0.01 ppm. This represents a very significant advance on previous in situ investigations of Mars, and opens up the possibility of a serious reappraisal of the presence of organic materials on the planet.

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