ORGANIC CARBON EXISTS IN MARS METEORITES: WHERE IS IT ON THE MARTIAN SURFACE?

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The search for organic carbon on Mars has been a major challenge. The first attempt was the Viking GC-MS *in situ* experiment which gave inconclusive results at two sites on Mars [1]. After the discovery that the SNC meteorites were from Mars [2], [3-5] reported C isotopic compositional information which suggested a reduced C component present in the Martian meteorites. [6 & 7] reported the presence of reduced C components (i.e., polycyclic aromatic hydrocarbons) associated with the carbonate globules in ALH84001. Jull et al. [8] noted in Nakhla there was an acid insoluble C component present with more than 75% of its C lacking any ^{14}C, which is modern-day terrestrial carbon. This C fraction was believed to be either indigenous martian or ancient meteoritic carbon. Fisk et al. [9, 10] have shown textural evidence along with C-enriched areas within fractures in Nakhla and ALH84001. Westall et al. [11] have shown the presence of a large irregular fragment of organic material completely embedded within a chip of ALH84001.

Interior samples from the Nakhla SNC made available by the British Museum of Natural History, were analyzed. Petrographic examination [12] of Nakhla showed evidence of fractures (~0.5 µm wide) filled with dark brown to black dendritic material with characteristics similar to those observed by [10]. Iddingsite is also present along fractures in olivine. Fracture filling and dendritic material was examined by SEM-EDX, TEM-EDX, Focused Electron Beam microscopy, Laser Raman Spectroscopy, Nano-SIMS Ion Micro-probe, and Stepped-Combustion Static Mass Spectrometry. Observations from the first three techniques are discussed in [12 and 13].

Nano-SIMS Ion Microprobe studies of the C-bearing fractures, containing the optically dark dendritic material, show direct correlation between C^- and CN^- abundances. Ion abundances for epoxy are distinct from those of the dendritic material[12] .

Laser Raman Spectrometry was utilized to examine the optically dark dendritic material prior to stepped- combustion [13]. Samples of the epoxy were examined along with the 100 - 150 µm diameter cores. Individual 3 - 5 µm size regions within the cores were analyzed in the 1000 - 2000 wavenumber (cm-1) region. Bands observed include: 1868, 1705, 1500, 1450, 1435, 1385, 1350, 1267, 1147, 1076 and 1045 wavenumber (cm-1). This was the first report of an apparent complex mixture of carbonaceous components associated with Nakhla dendritic material and iddingsite.

Stepped Combustion Static Mass Spectrometry analysis is capable of distinguishing different C- and N-bearing components present along with their C and N isotopic compositions. Analysis of epoxy blanks along with cored samples bearing the opaque carbonaceous-rich materials were analyzed. Three distinct components were detected in Nakhla [13]. A low-temperature C component released below 300°C was predominately terrestrial contamination with an isotopic composition of –22 to –24‰. A reduced C-bearing component with isotopic compositions of -16.1‰ to -18.4‰ to -20.2‰ to -19.4 ‰ was measured for the 400°, 450°, 500° and 550°C temperature intervals, resp. Possible presence of a pre-terrestrial secondary carbonate with an isotopic composition of >+5‰ was released at T > 550°C, but this phase is also similar to operational blanks. The isotopic composition of the reduced C-component was identical to values -18 to -20‰ reported by [8] and [14]. However, our C analysis is the first isotopic measurement of directly imaged high molecular weight carbonaceous components in Nakhla. Previous measurements were from bulk Nahkla samples with no direct observation of the C-bearing phases. N isotopic composition associated with the reduced C-component was ~+5‰.

[12, 13] were the first reports correlating fracture-fill material in Nakhla, iddingsite and optically dark dendritic material, with reduced carbonaceous components. The source of these components can be interpreted as produced by different possible processes: (a) C introduced during a carbonaceous-rich impactor on Mars 600,000 to 700,000 years ago [15] -- this impact may have produced the fractures in Nakhla where iddingsite resides; or, (b) these C-bearing components may be products of biogenic activity and introduced by ground-water into the fracture features in Nakhla [16]. We have also recently identified carbon-rich grains and crack filling material in the Nakhlite Yamato000593 recovered from Antarctica by the Japanese Polar Program.

The lack of identified carbon in the Viking data is commonly attributed to a superoxident that may be present in the uppermost martian regolith [eg.16]. Strong UV exposure also has been shown to decompose and destroy organic carbon relatively rapidly [17]. In the case of ALH84001 and the Nakhlites, the organic carbon may be protected from both the proposed super-oxidizing agent and UV light exposure by a modest (a few meters) pre-ejection burial depth. All of these meteorites show some sign of aqueous alteration, perhaps by ground water or from short-lived lakes. However, the lack of major aqueous alteration and the presence of mainly ferrous iron show that most of their residence time on Mars was not spent in an environment which was significantly oxidizing. The presence of organic carbon in these meteorites also shows that the regions containing the carbon were never significantly exposed to surface UV light. Our interpretation is that organic carbon may not be uncommon in rocks and regolith near the surface of Mars samples. The best place to look may be in crack fillings in rocks and other places where water flowed but which are protected from direct sunlight. The origin of the carbon remain enigmatic, but the meteorite data give encouragement to further robotic exploration for organics on Mars.

References:

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