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An abiotic Organic Synthesis Mechanism on Mars

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Carbonate minerals in Martian meteorites and in particular ALH84001 bear witness to the processing of volatile and biologically relevant compounds (CO_2, H_2O) on Mars. In the debate to understand whether relic Martian life is present in ALH84001, significant research has been conducted to understand the presence of organic materials and specifically polyaromatic hydrocarbons (PAHs) in this meteorite. The initial finding of PAHs helped spark the debate as to the presence of a possible Martian biota. However, whilst there is debate on the provenance of PAHs in the meteorite there is a pool of macromolecular carbon (MMC) both within the carbonate globules and the host pyroxene that is indigenous to the meteorite. The nature, provenance and formation mechanism of both these pool of MMC remains unknown. Although in the case of MMC within the carbonate globules both biogenic and meteoritic infall have been suggested.

We report on the use of confocal micro-Raman imaging spectroscopy analysis coupled with 3-D montage light microscopy and scanning electron microscopy (SEM) of a number of carbonate globules, diffuse carbonates and features within the bulk rock. Analysis was conducted on fresh fracture surfaces throughout 5 allocations of ALH84001 that constitute a complete depth profile of the meteorite. To understand further the mechanism of formation of the carbonate globules and to confirm any observations on a terrestrial analogue, studies were undertaken on carbonate globules contained in xenoliths from the Bockfjord Volcanic Complex (BVC) on Svalbard, similar in mineralogy to those found in ALH84001. In many of the ALH 84001 globules MMC is associated with magnetite both in the rims and around small magnetite particles inside fresh internal carbonate surfaces.

MMC in ALH 84001 varies from very ordered (almost pure graphite) to very disordered (similar to IDPs). The vast majority of MMC found in ALH 84001 is relatively amorphous, with crystalline graphite occurring in two localities among the matrix magnetite assemblages analyzed. Indigenous MMC, which may include PAHs, have been found within ALH 84001. PAHs have also been detected in the MMC/graphitic component of carbonaceous chondrites and IDPs using the same techniques as applied to ALH 84001 by the McKay et al team i.e. two step laser ablation mass spectrometry. Raman spectroscopic analyses of similar material (i.e. carbonaceous chondrites and IDPs) show a peak distribution of MMC similar to that found in this study. We conclude therefore, that the PAHs originally found in ALH 84001 by McKay et al. in 1996 are related to the pool of carbon analyzed in this study. The Raman peak distribution in ALH 84001 shows broad peaks at both $\sim$1600 and 1350 cm^{-1}(G and D band) that are indicative of MMC and not of poorly crystalline or crystalline graphite. It has been shown that this peak distribution does not indicate a biological or abiological origin for MMC, however, the peak distribution of graphite and poorly ordered graphite are significantly different from kerogen or MMC.

We conclude that the carbonaceous material detected in our study is composed of MMC containing a range of compounds including polyaromatic species and that the D and G band Raman peak distribution of MMC is similar to that found in carbonaceous chondrites and IDPs. The presence of MMC within carbonate globules in lherzolite xenoliths from BVC suggests that macromolecular carbonaceous material can be generated during carbonate deposition within mantle rocks on Earth. Thermodynamic calculations and experimental data on the thermal breakdown of siderite show that PAHs, graphite, and MMC are produced. Although a thermal decomposition of siderite origin for PAHs in ALH 84001 is alluring, the studies on BVC show that magnetite and carbonates associated with MMC can form during primary development of the globules.