

An In-Situ Organic Molecular Study of the Matrices of a Primitive CR2 Chondrite Meteorite Hills 00426

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Introduction: Carbonaceous chondrites (CC) retain organic matter of varying formation environments i.e. the interstellar media; solar nebula; parent body processing. These molecules retain unique records of their origins and subsequent evolutionary journey's [1-4]. CR chondrites are of particular value in recent years, retaining rare organics of extreme isotopic enrichments pertained to formation within cold molecular clouds and/or the outer protoplanetary disk (Nanoglobules) [5]. Meteorite Hills (MET) 00426 underwent significantly less aqueous alteration than other members of its group like Queen Alexandra Range (QUE) 99177, retaining a higher degree of O-bearing pre-solar grains, ferromagnesium silicates, isotopically anomalous pre-solar signatures and amino acids than typically recorded in CC [1, 7-9]. MET 00426's carbonaceous material also exhibits a low degree of crystallinity indicating low thermal processing [6, 8]. These studies suggest a very primitive matrix, retaining signatures of early nebula processing [1-8].

Previous studies have focused on defining organic morphologies, textural and contextual relationships within MET 00426 matrix through in-situ analyses predominately using the transmission electron microscope (TEM) [7-8, 10]. These studies identified relationships with carbon rich material and nanoglobules in association with phyllosilicates, oxysulphide and in rare cases tochilinite grains [7-10]. A recent study by Le Guillou and Brearely (2014) suggested MET 00426's spatial distribution relationships between carbon rich regions and hydrated inorganics supports a current interstellar theory which suggests nanoglobules become trapped within ice on IDP's and/or other pre solar carriers. These materials later become incorporated into meteorites. The ice melts, mobilizing these organic materials into cracks and boundaries. Understanding this relationship and refining our primitive organic evolutionary knowledge requires an understanding of insoluble and soluble organic spatial distribution. Preliminary geochemical studies on MET 00426 have used Raman and Auger probe spectroscopy [11-12], however no study thus far has chemically classified distinct molecular speciation spatial relationships or produced a comprehensive organic molecular classification of MET 00426's insoluble and soluble organic material due to technical limitations.

Experimental and Results: We carried out in-situ chemical, isotopic and contextual analyses of ~20-50 μm matrix regions pressed into Au foil utilizing an optically flat sapphire window. These regions were randomly selected across whole rock to reduce the effect of bias results. No chemical treatments i.e. epoxy, were utilized during the prep process, enhancing the chemical classification of our primitive sample.

Samples were then initially characterized with non-destructive ultraviolet (UV) microscopy, showing spatial distribution of IOM. We then chemically mapped and obtained spectral data of whole and intact molecular species at the ~2 μm scale using the two-step laser mass spectrometry ($\mu\text{L}^2\text{MS}$) at Johnson Space Centre. This provided spatial distribution relationships of whole insoluble and soluble organic species across the matrix regions studied.

Subsequent study measures isotopic images at high spatial resolution (<200 nm pixel dimension) for ^{12}C , ^{13}C , ^{16}O , $^{12}\text{C}^{14}\text{N}$, $^{12}\text{C}^{15}\text{N}$ & ^{28}Si using the NanoSIMS 50 with a focused 16 keV Cs^+ primary ion beam. Due to the primitive nature of the sample, this provided speciation relationships with chemical information aiding to refine our understanding of the primitive relationships of organic species.

Finally, samples are coated with 2 nm of Pt to reduced surface charging for contextual mineralogical analysis utilizing energy dispersive x-ray spectroscopy (EDX) to correlate chemical species with carbonaceous textural relationships previously discussed in literature.

Discussion: A significant enrichment of nanoglobules were observed, indicating primitive organic origins as supported through previous literature [9, 13]. Associated isotopic signatures presented results observed in our previous study of QUE99177 [13], exhibiting rare anomalies consistent with outer regions of the protosolar disk and/or within pre-solar molecular clouds [5]. Primitive O-enriched organic species were observed in association with MET 00426's nanoglobules, consistent with primitive chemistries. Our study has produced a comprehensive chemical classification of MET 00426's organic molecular species and their contextual spatial distribution relationships within the matrix.

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