SIGNIFICANCE OF PRIMORDIAL MATRIX IN MUKUNDPURA CARBONACEOUS CHONDRITE (CM2).

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Introduction: Carbonaceous chondrites (CC) generally retain their original chemical, isotopic and mineral characteristics since the time of formation of our solar system. Therefore, these groups of meteorites might be helpful for understanding the earliest processes and events which have occurred during evolutionary pathway in the early solar system. The retrieved meteorite sample (weight ~ 2.23 kg) in recent past (fall on 6th June 2017 at around 05:15 hrs IST) from the Mukundpura village (N26°52′52.5″; E75°39′53.9″), Bhankrota, Jaipur, Rajasthan was registered and curated at the National Meteorite Repository (NMR), GSI, Kolkata. The Mukundpura meteorite is a member of the rare group of carbonaceous chondrites, which constitute only about 4.6% of the meteorite falls on earth [1]. Detailed morphometric, petrographic, mineral chemical, whole rock geochemistry and Laser Raman Spectroscopic (LRS) analysis of Mukundpura meteorite suggests it is a carbonaceous chondrite (CM) of petrologic type II [2,3,4 and 5].

Methodology and Results: Mineral chemical data were acquired by CAMECA SX-100 electron microprobe (EDS + WDS) analyser at the EPMA Laboratory, GSI, Kolkata. An accelerating voltage of 15 - 20 kV and beam current of 12-15 nA with ~ 1 µm beam diameter were used in all cases (analysis of 14 elements including S with X-PHI mode). These data were corrected internally (PAP) and a set of natural standards was used to control analysis results, with synthetic standards being used for Mn and Ti. Semi-quantitative SEM – EDS studies were carried out at the Palaeontology Division, GSI, Kolkata by using Carl-Zeiss Oxford Instruments (Model No. EVO - 40), having SEM HV (Heat Voltage) ~ 20 kV, beam intensity ~ 15 – 20 and beam spot size ~ 0.3 – 1 µm.

Petrographically Mukundpura meteorite is characterized by largely altered, rounded to sub-rounded chondrules (size varies from ~ 50 µm to 250 µm), aggregate of carbonate ($CaCO_3$) grains, phosphates, different types of sulphides, metals (Fe-Ni), some angular mineral fragments and fine grained clasts set within a dark coloured, finer grained matrix (Figure 1). The matrix constitutes nearly 70 volume % of the sample, and matrix : chondrules/clasts is ~ 70 : 30. The polygonal, angular to sub-angular fragments, measuring upto ~ 1 cm in length giving the sample a brecciated appearance in hand specimen.

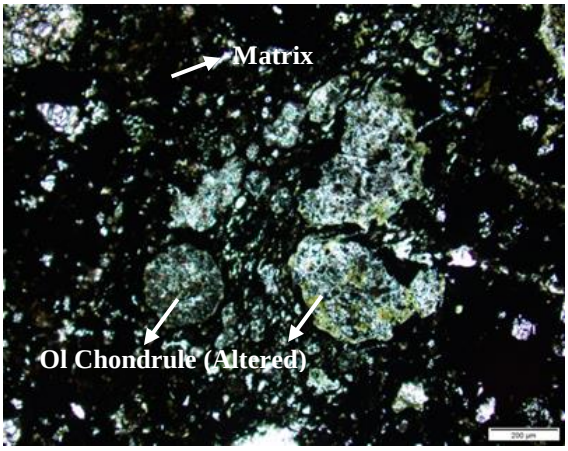


Figure 1: Photomicrograph (under PPL) showing mostly altered (serpentinized) chondrules, trails of finer grained aggregates (mostly tochilinite) surrounding the chondrules, set in a translucent matrix.

The matrix is relatively fine grained, dark colored and mostly composed of serpentine, tochilinite, other phyllosilicates, some poorly or partly characterized phases (PCPs) and Amoeboid Olivine Aggregates (AOAs). Both discrete and aggregates of irregular shaped carbonate (calcite) grains are present within the matrix. Often, these carbonate grains are surrounded by thin bands of magnetite, Fe-Ni sulphides, FeS (troilite) and Fe-Ni metal phases along its boundaries. Detailed petrographic and mineral chemical (aided by EPMA and SEM) studies reveal the occurrence of largely altered, rounded to sub-rounded chondrules, aggregate of carbonate grains, some angular mineral fragments / clasts and fine grained clasts set within a highly altered, dark, serpentine-tochilinite dominated matrix in Mukundpura carbonaceous chondrite. Several clasts with discernible boundaries couldn't be compositionally segregated from the host matrix (Figure 2), referred as Fine Grained Rim (FGR). The matrix is primarily composed of abundant phyllosilicates, tiny olivine grains (10 – 50 µm), "Poorly Characterized Phases" (PCPs), Amoeboid Olivine Aggregates (AOAs) and calcite ($CaCO_3$). The matrix is sulphur (S) rich and it ranges from 2.36 to 19.22 wt.% as revealed by EPMA data. Tochilinite (SiO_2 – 24.75, Al_2O_3 – 2.26, MgO – 16.29, FeO – 39.77, NiO – 1.25 in wt.%) in matrix is commonly associated with serpentine ± calcite ± Fe-Ni sulphides.

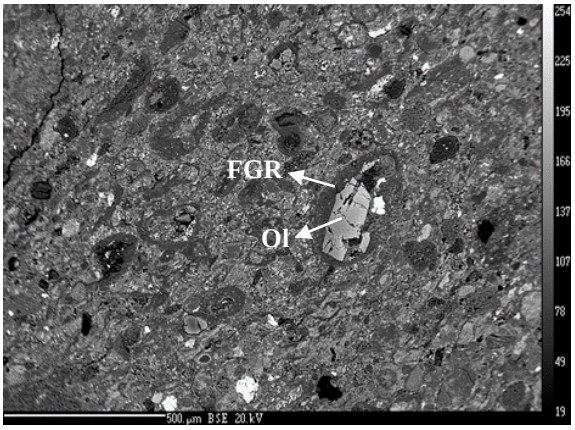


Figure 2: Relict olivine clast rimmed by finer aggregates (FGR) in BSE image.

Sulphur (S) in tochilinite, ranging from 2 to 5 wt.% is revealed by Energy Dispersive Spectra (EDS). The matrix component strongly varies in S-content (1.18-9.62 atomic wt.%), and it is reflected in SEM/BSE images in grey and brighter shades (Figure 3). Rare traces of refractory Calcium Aluminium Inclusions (CAIs) are observed in matrix as revealed from mineral chemical data (Ca = 18.99, Si = 17.96, Al = 12.62, Mg = 4.28, Ti = 1.54 and O = 43.42 in atomic wt.%).

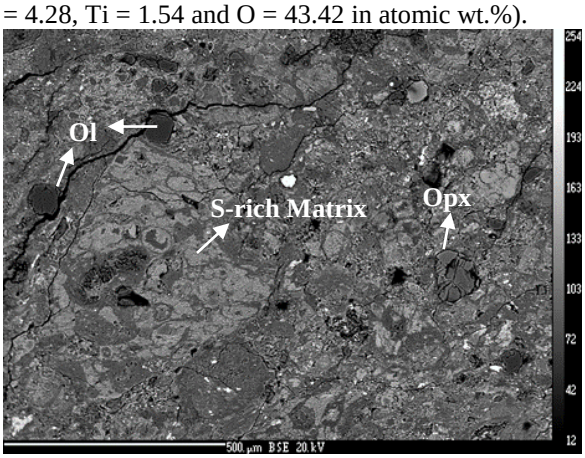
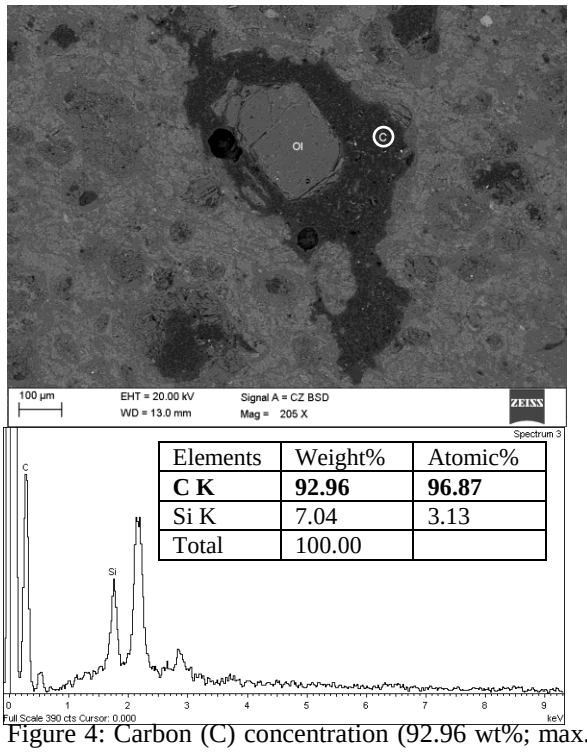


Figure 3: Relict olivine and orthopyroxene clasts in serpentine, tochilinite dominated matrix. Note the colour sheds of matrix (S-bearing portions are in brighter tone compared to grey colored matrix) (BSE image).

Moreover, SEM – EDS studies reveal that the carbon (C) concentration in the matrix varies from 4.77 – 92.96 wt.% (Figure 4), probably contributed by primordial organic components. Variation in carbon (C) concentrations (4.77-16.94 wt.%) in the matrix component from point-to-point analysis are also documented.



Elements	Weight%	Atomic%
C K	**92.96**	**96.87**
Si K	7.04	3.13
Total	100.00	

Figure 4: Carbon (C) concentration (92.96 wt%; max.) in the matrix (pint analysis # c) (in SEM-EDS).

Discussion: Abundance of secondary minerals (phyllosilicates), PCP clasts, AOAs and carbonates in matrix suggest Mukundpura meteorite has undergone aqueous alteration.This type of meteorite (CM) is rare, primitive and contains organic compounds (carbonaceous material). Most importantly it also contains water-bearing mineral phases (phyllosilicates) which is the direct evidence of presence of water in the solar system. Detailed study on this particular meteorite sample might lead to the window of finding of life on planet earth. It belongs to the CM Group of carbonaceous chondrites, with petrologic type 2, believed in having the most pristine primordial carbonaceous matter recovered from space that might carry important clues about the origin of life.

References: [1] *GSI CHQ e-News Volume 48*, 1, January – June 2017, 3-5. [2] Ray D. and Shukla A.D. (2018) *Planetary and Space Science 151*, 149–154. [3] Shukla A.D. et al. (2018) *81st Met. Soc.* (LPI Contrib. No. 2067), Abstract # 6112. [4] Rudraswami, N.G. et al. (2018) *Geoscience Frontiers 30*, 1-10. [5] Tripathi R.P. et al. (2018) *Current Science* 114(1), 214-217.