MINERALOGY AND SPECTROSCOPY (VNIR AND FTIR) OF MUKUNDPURA CM2:MORE INSIGHTS INTO THE AQUEOUS ACTIVITY AND POST ACCRETION HISTORY

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Introduction: The mineralogy of CM2 chondrites is very intriguing due to the higher phyllosilicate content (~70-80 vol%) in their matrix. Additionally, with the fine-grained nature of the matrix and difficulty in identifying crystalline and amorphous phases, the mineralogy of CM2 chondrites remains poorly constrained. Thus, using XRD for identification and quantification of phases is very useful for precise mineralogical characterisation. The VNIR and FTIR studies further facilitate proper identification of hydrous phases and therefore provide insights into the aqueous process occuring in the parent asteroids of the early Solar System. Laboratory studies of CM chondrites have further applications in linking remotely acquired spectra from the primitive asteroid targets during Hyabusa 2 (Ryugu) and OSIRIS REx (Bennu) missions. In this study, we examine the mineralogy and spectral characters of a newly fallen meteorite Mukundpura CM2 (June 6, 2017) and conduct phase identification, quantification and precise characterisation of the hydrated minerals vis-a-vis the extent and mineralogy of the alteration.

Results and Discussion: Preliminary petrography of Mukundpura CM2 has been previously described elsewhere [1]. The most striking features of the matrix are occurrences of variegated clasts with distinct FeO-enriched rims. Otherwise, flaky serpentine is also common and appears to grow either from the clast boundary or within the clast interior. The matrix serpentine includes Mg-rich (with more or less stoichiometric composition), intermediate Fe (FeO ~22-30 wt%) and high Fe (FeO ~38-45 wt%) types. The Mukundpura matrix corresponds well within the known field of CM phyllosilicate. However, there is a slight deviation in serpentine solid solution probably due to lack of crystallinity of many phases in the matrix. The calculated MAI (Mineralogical Alteration Index) is 0.42 [2]. The FeO/SiO_2 and S/SiO_2 of high-Fe bearing clasts range between 1.46-2.42 and 0.08-0.53 respectively [3]. XRD of bulk samples reveal majority of Mg and Fe serpentine and minor calcite in the marix. The Visible Near Infrared (VNIR) spectrum of Mukundpura CM2 shows distinct absorption bands near 0.72, 0.91, 1.12, 1.94 and 2.24 µm. Mixed-valence serpentine-group phyllosilicates are the strongest contributors to the absorption band around 0.72 µm [4]. This serpentine-group along with their Fe rich varieties is likely to be responsible for the absorption near 0.91 µm. The broad absorption band centered at 1.12 µm may be related by the presence of forsteritic olivine in chondrules or within the matrix [1]. The broad absorption feature centered at around 1.94 µm is attributed to the combination of H-O-H bend with the OH stretches of the water molecules attached to the phyllosilicates [5]. The absorption feature around 2.24 µm is related to the presence of serpentine minerals. The prominent absorption features of the FTIR spectrum of the Mukundpura CM2 shows a sharp absorption band around 1000 cm^{-1}, peaking at 985 cm^{-1}, an absorption band centred at about 633 cm^{-1}, followed by a small peak at 579 cm^{-1}; a broad absorption band around 450 cm^{-1} with distinct peaks at 445 cm^{-1}, 454 $cm^{-1}$and 461 $cm^{-1}$and shoulders at 406 cm^{-1}, 419 cm^{-1}, 502 cm^{-1}, 546 cm^{-1} and 564 cm^{-1}; two separate absorption bands centred at 1629 cm^{-1} and 1423 cm^{-1} and a broad absorption band between 2900-3700 cm^{-1}. The sharp, single-peak nature of the absorption around 1000 cm^{-1} suggests that the Si-O stretch vibrations primarily represent saponite [6]. This, along with the lower frequency of the peak centred at 985 cm^{-1}, shows the lack of any signature of highly crystalline phases like olivine or pyroxene in this band. The absorption band between 600 and 700 cm^{-1}, centred at 633 cm^{-1}, can be attributed to the OH-librations of the phyllosilicates. The narrow absorption band centred at 1423 cm^{-1}can be attributed to υ3 asymmetric stretch of calcite. The υ2 and υ4 IR active bands of calcite are supposed to be at 879 and 680 cm^{-1}, respectively [7]. The other narrow absorption band centred at 1629 cm^{-1} can be assigned to the bending vibrations in H_2O attached to the phyllosilicates. The broad absorption band between 2900 cm^{-1} and 3700 cm^{-1} is due to the OH-stretch in the H_2O molecules attached to the minerals as well as in the hydroxyl ions of the phyllosilicates.

Summary: Our integrated mineralogic and spectroscopic data suggests Mukundpura CM2 experienced modest degree of aqueous alteration. Matrix clasts suffered varied extents of aqueous alteration inducing formation of crystalline and amorphous phyllosilicates in matrix. The intermix of Mg-Fe serpentine and "Fe-rimed" clasts suggests pervasive aqueous alteration is likely achieved locally. However, presence of anhydrous silicate clasts and relict chondrules suggest that the alteration is incomplete or possibility of incorporation of variously altered clast and correspond to the variability of geochemical conditions during the aqueous alteration preferably aftermath the accretion of the parent body.

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