Aqueous alteration characteristics of Mukundpura (CM2) chondrite

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Introduction: Hydrated minerals are commonly found in the Carbonaceous Chondrite (CC) due to high content of H_2O (up to 10 wt%) [1]. Aqueous alteration of silicates of CM (Mighei type) chondrite groups produces various hydrous phyllosilicates, serpentines, poorly crystallised phases in the matrices and also in the chondrule mesostasis [2]. Aqueous activities commonly attributed to formation of other minerals also include carbonates and oxides. Though the timing of alteration (pre or post accretion) and place of alteration (nebular or asteroidal) are not fully understood yet, it is imperative to study the nature and textures of secondary minerals to offer new insights on aqueous alteration, processes involving mixing of clasts and to assess relative timing. Mukundpura is a new CC fall in India (June 6, 2017) and classified as CM2 [3,4]. Petrography, mineralogy and cosmogenic radionuclide results are reported elsewhere in this volume [5,6]. Hence, we report the alteration characteristics of chondrule, mesostasis and different clasts in the matrices in order to understand the aqueous histories of this new fall.

Analytical Techniques: Mineral compositions and X-ray mapping were carried out using JEOL IT300 scanning electron microscope (20kV, 0.6 nA) equipped with OXFORD EDS and Cameca SX 100 electron microprobe (15 kV, 15nA) equipped with three vertical WDS respectively. EDS and WDS elemental X-ray mapping were conducted using higher sample current (70 nA) to achieve higher counts.

Results: A few relict chondrule appears to be forsteritic-rich (Fo>98 mol%). However, the mesostatis of chondrules suffers aqueous alteration. Individual clasts are fayalitic (Fo ~50 mol%). The matrix of Mukundpura is dominantly comprised of different mineral clasts and poorly crystallised phases. The most common occurrences of hydrous clasts include typical subrounded to rounded shaped Fe -poor core (FeO ~21-32 wt%) with a distinct Fe-rich rim (FeO ~49-61 wt%). A few of the hydrous clasts look heavily aqueous altered. Fayalitic olivine mineral clasts look apparently fresh. Interestingly in one instance apatite occurs as a rim of a rounded hydrous clast. One relatively large forsteritic chondrule (>2 mm) typical shows rounded, fresh forsterite grains (10-250 µm) with altered mesostasis is examined further test the alteration pathway. EPMA line scan across the chondrule and surrounding rim shows differential elemental enrichment and depletions, e.g. hydrous accretionary rim sector is charaterised by variable Fe-enrichment (FeO ~18- 44 wt%). The chondrule mesostasis is also relatively Fe-rich (FeO ~24-30 wt%) as compared to forsterite grains. Minor Al_2O_3 (2-7 wt%) is also present. Pure calcite grains also occur as isolated grains.

Discussion: Mukundpura appears as Calcium-Aluminium-Inclusion (CAI)-poor, clast-rich CM2. The proportion of matrix is also high (~70-80vol%). The high aqueous activity may induce dissolution of majority of CAI, alteration of chondrules and matrices to various degrees. The petrographic feature of apatite (occur as reaction rim) clearly suggests the migration of P and Ca from some Fe-Ni and CAI bearing sources, respectively. This texture definitely suggests that fluid is involved for this migration and formation, thereafter. Sometimes apatite formation is also related to fluid assisted metamorphism. Concentric inward growth texture of hydrous clast is also considered as an additional evidence for migration of fluids or testifies substantial aqueous activities. Some smooth, rounded edges clast probably implies at least some degree of transportation or abrasion prior to final incorporation. Based on the occurrences of heterogenous clasts associated with varying degree of alteration, it is difficult to find any clue on the timing of the aqueous alteration. The probable explanations could be aqueous alteration might have occurred after mixing or aqueous alteration could have taken place prior to mixing.

Conclusion: Our study suggests Mukundpura experienced multiple and complex aqueous alteration processes. The occurrence of apatite probably relates with different stages of fluid evolution. The heterogeous clasts may correspond to independent history of aqueous alteration activity. Further studies are in progress.

References: [1] Kerridge J.F. (1985). *Geochim. Cosmochim. Acta* 49: 1707-1714. [2] Lee M.R. and Lindgren P. *Meteorit. Planet. Sci.* 51:1003-1021. [3] Meteoritical Bulletin no. 107 (2018) *MAPS* (in preparation). [4] Ray D. and Shukla A.D. (2018). *Planet. Space Sci*. 151:149-154. [5] Ray D. and Shukla A.D. (2018) this conference. [6] Shukla A.D. et al. (2018) this conference.