Merrilite Rim around the Phyllosilicate clast in Mukundpura Carbonecous Chondrite (CM2) Meteorite

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Introduction: The CM2 type of meteorites have been investigated for understanding the asteroidal aqueous alteration processes. The alteration processes induce formation of secondary and hydrous minerals like phyllosilicates, calcites, poorly charachterized phases and phosphates [1,2]. The occurrences of phosphate minerals has been generally postulated due to fluid assisted metasomatism on the parent body[3]. Earlier studies introduced that the Mukundpura carbonaceous chondritehas been classified as CM2 chondrite and its alteration records are primarily discussed based on nature and abundance of phyllosilicates and carbonates in matrix [4,5] . In this study, we discuss the mineralogy, formation process of phosphate mineral phases, uniquely occurred within a phyllosilicate clast, with an aim to understand aqueous alteration history in Mukundpura CM2, the recent meteorite fall in India.

Analytical Techniques: Mineral compositions and X-ray mapping were carried out using three epoxy mounted thick sections . For imaging and semiquantitave (EDS) and quantitative (WDS) analyses, a JEOL IT300 scanning electron microscope with an OXFORD EDS operated at 20 keV 500pA and a Cameca SX 100 electron microprobe with operation biasing voltage of 15 kV, 15nA with 2 μm beam diameter have been used .

Results: In the studied thick sections, all the chondrule and the matrix of the meteorite are highly altered except a few isolated chondrule appears to be survived as a relict clast and fayalitic in composition. The matrix includes mainly clast of phyllosilicates or poorly crystallised phases(PCP) along with presence of minor calcite, dolomite (rare) . Interstingly, one of the studied sections hosts an altered chondrule ~100 μm size and is surrounded by Ca-P rich fine-grained rim. The rim width also varies from 4 to 10 μm in size. Under X-ray mapping, it appears that the Ca-P layer is not homogeneous in nature. The EPMA elemental analysis shows CaO 50-42 % & P_2O_5 30-25.6%. Na_2O 1.8 to 3.2 %, MgO 1.5-4.4%, FeO 4-7 % and MnO 0.19 to 0.37%, SO_2 ~1 %, Cr_2O_3 600 -1000 ppm. The phyllosilicates and calcite are common near the fracture zone of the rim. The elemental analysis within the fracture zone shows CaO 28-38 % & P_2O_5 16-24%, Na_2O 1.5 to 2.2 %, MgO 6-10%, SiO_2 9-16% . FeO 7-14 %, MnO 0.2 to 0.3% and SO_2 ~1-3 %. The matrix is predominantly Fe (2-14% FeO), Mn rich merrilite (0.3 -2.6% MnO). The chondrule at the interior is altered and compositionally akin to Cr- rich phyllosilicates. The EPMA analysis also shows that phyllosilicates in the matrix are phosphorus rich (upto 7.5 % of P_2O_5), while the PCP are relatively depleted in P_2O_5 (0.1-0.2 %). The calcite is also occasionally foundenriched with phosphorus (P_2O_5 0.4-1.1 %).

Discussion: Based on SEM study, it appears that Mukundpura is depleted in CAI (Calcium-Aluminium-Inclusion) , clast-rich CM2 with a highly altered matrix rich chondrite. The occurrences of phosphorus phases in terms of phosphate at reaction rim clearly suggests the migration of P and Ca from some Fe-Ni and CAI bearing phases. The X-ray maping and EPMA analysis show the presence of Na, Mg, Fe in phosphate, whereas Cl and F are apparently absent. Based on the chemical analysis, the rim formation the phosphate mineral resembles merrilite in composition. The phosphate mineral are secondary product which can be formed due to interaction of fluid which led to migration of elements and formation, thereafter. Apart from this the phosphate mineral also can be formed by fluid assisted metamorphism. In our studied sections of the Mukundpura the concentric inward growth texture of hydrous clast can be also considered as an additional evidence for migration of fluids or testifies substantial aqueous activities. The width of the rim is very small size (4-10 μm) and attributed to be formed by metamorphic process[6]. Based on chemical anlysis and textural characters, it can be postulated that during the alteration process Ca, P, Na migrated to form the fine-grained Ca-P rich rim [7] . The Ca-P mineral phases are associated with $CaCO_3$ grains outside the Ca-P rim. It is to be noted that the concentration of P and S increased in the phyllosilicates which may be due to the fluid interaction processes of Fe-Ni-S-P with the matrix

Conclusion: Our study suggests that Mukundpura experienced complex aqueous alteration processes. The presence of phosphate (Merrilite) mineral is formed due to the low temperature alteration processes .

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