The degree of aqueous alteration of nine CM chondrites estimated from mineralogy and chemical variations of matrix.

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Introduction:

CM chondrites have undergone prevailed aqueous alteration in the parent asteroids and the alteration changed mineralogy of water-bearing C-type asteroids [1-2]. Although most CM chondrites are classified as peteologic type 2, the degree of aqueous alteration varies widely. In the previous studies, classification schemes of CM chondrites were proposed by McSween [3] and Rubin [4]. The two schemes classify the same meteorite differently such as Nogoya. In this study we used the some schemes for new nine samples, and discuss the degree of aqueous alteration.

Samples and Analytical Procedure:

Polished sections of nine CM2 chondrites (LEW85311, LAP03178, RA06172, MET01072, LEW87022, LAP02269, GRO95566, LAP031166 and MAC88100) are used in this study. Small pieces (200 microns in size) of matrix were picked up and analyzed by synchroton radiation X-ray diffraction (BL-39XU, Spring-8, Japan) to identify minerals in matrix. After that we observed the polished sections using SEM (HITACHI S-3400N, Tohoku university, Japan) and analyzed using EPMA (JEOL JXA-8200, NIPR, Japan) operated at 15kV and 10nA. A defocused beam of approximately 5μm diameter was employed in order to obtain bulk composition of matrix; one hundred spots were analyzed for each chondrite.

Result and Discussion:

The X-ray diffraction analysis and SEM observations indicate that serpentine is present in the matrix of all samples as a major phase, suggesting that all samples have undergone aqueous alteration and have not been heated to temperature enough to dehydrate serpentine. Two out of 9 samples (LEW85311 and LAP03178 hereafter GroupI) contain Fe-Ni metal grains in both chondrule and matrix and anhydrous silicates (olivine and pyroxene) in matrix (Fig. 1). Five of 9 samples (GRA06172, MET01072, LEW87022, LAP02269 and GRO95566 hereafter GroupII) contain fine-grained PCPs (mixture of tochilinite and cronstedtite) and anhydrous silicates in matrix but no metallic phases in matrix. In addition their chondrules are altered only in glassy parts and limited parts of anhydrous silicates are also altered (Fig. 1). The rest two of 9 samples (LAP031166 and MAC88100 hereafter GroupIII) do not contain Fe-Ni metal and PCPs and contain little anhydrous silicates in matrix. In addition chondrules are almost completely altered (Fig. 1). Since metallic phases are more susceptible to aqueous alteration than anhydrous silicates, the results suggest that the degree of aqueous alteration is in the order of Group I < Group II < GroupIII.

The EPMA analysis indicates that most data of matrix composition fall within the triangle area defined by McSween [5]: the area is enclosed by the composition of PCPs and two serpentines (the serpentin compositions are defined by those from Murry and Nogoya meteorites) in a Mg-Fe-Si ternary diagram (Fig. 2a-d). 9 samples have different compositional trends and PCP/(PCP+serpentine) ratios, suggesting that these 9 samples have suffered various extents of aqueous alteration. The matrix compositions reflect the conditions of aqueous alteration, because of its fine-grained nature. Therefore it is expected that, for instance, Group I samples show compositional trends similar within the Group, but different from other Groups. However, Group I sample (LAP03178) has the same trend as Group II sample (GRO95566), and Group II sample (MET01072) has the same trend as GroupIII sample (MAC88100) (Fig. 2). This suggests that aqueous alteration process is very complex: the starting matrix compositions are variable, and the resultant matrix compositions are also difference. This indicates that the result of EPMA analysis alone is not enough to define the degree of aqueous alteration.

References:

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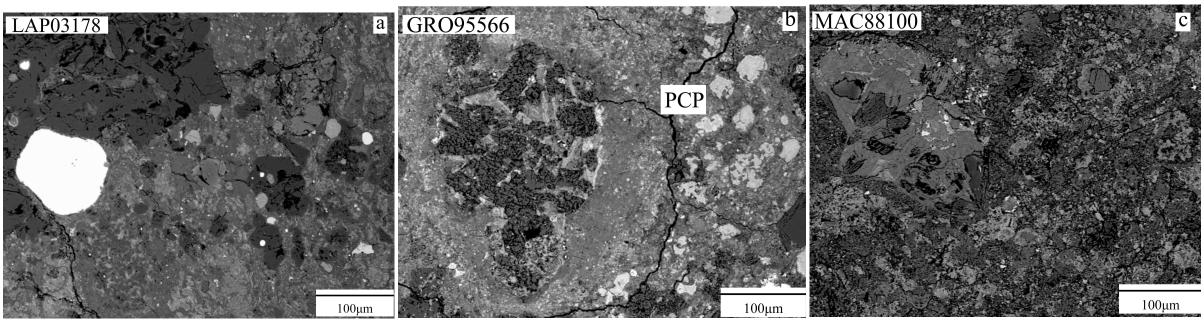

Fig.1. BSE images of 3 types in the CM chondrites. (a) LAP03178(GroupI) contain Fe-Ni metal grains(white part) in both chondrule and matrix. Chonrules are little altered. (b) GRO95566(GroupII) have no Fe-Ni metal phase in matrix, but contain fine-grained PCP. Chondrules are altered in glassy parts mainly. (c) MAC88100(GroupIII) showing no Fe-Ni metal and PCP graines in matrix.

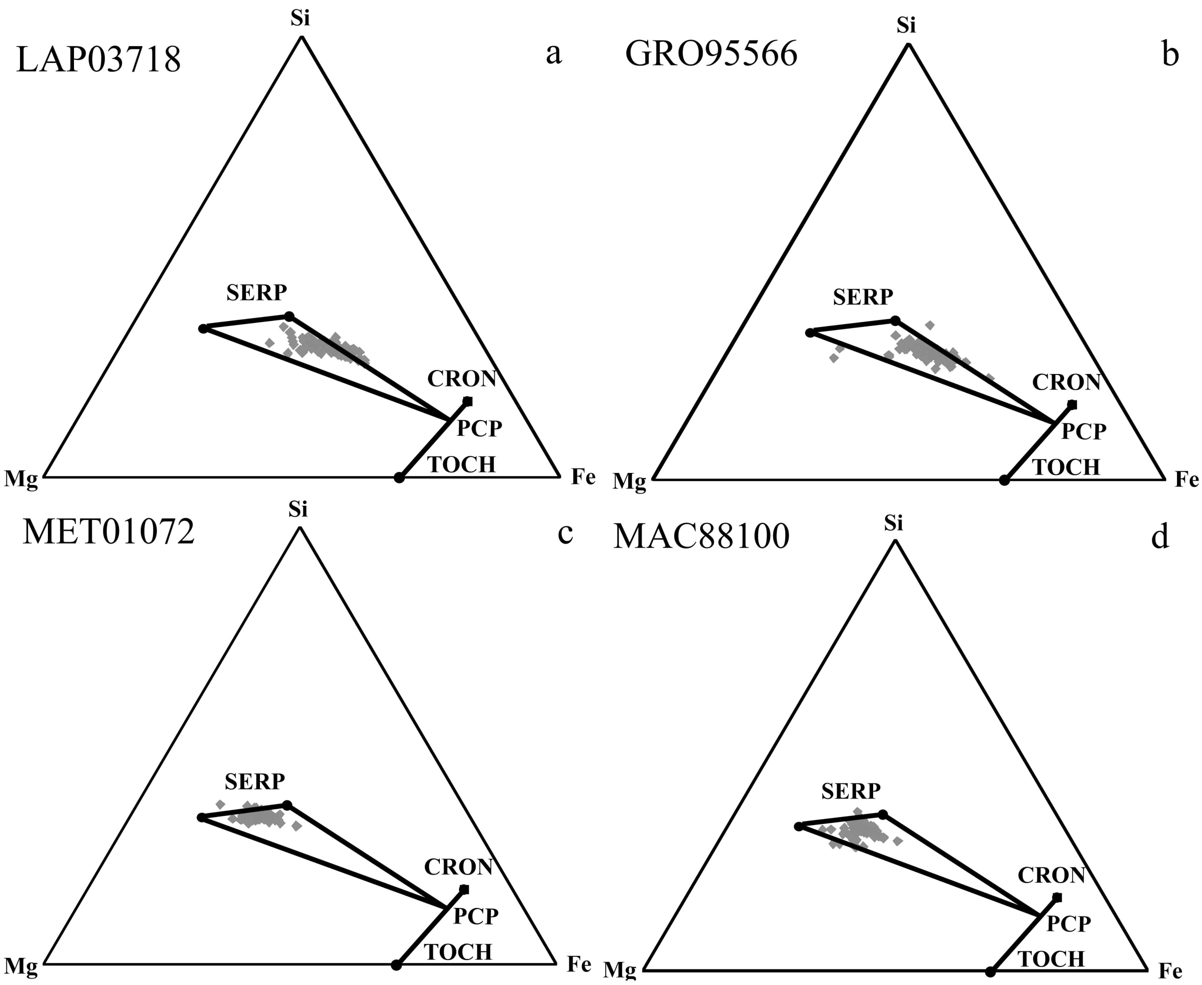

Fig.2. CM chondrite matrix defocused beam analyses mol%. The pattern of a(LAP03172: GroupI) has the same trend as b(GRO95566: GroupII), and c(MET01072: GroupII) has the same trend as d(MAC88100; GroupIII). Serpentine=SERP compositions are from Murray and Nogoya (data from [6]). PCP is a mixture of 25% tochilinite=TOCH and 75% cronstedtite=CRON.