MN-CR SYSTEMATICS OF SECONDARY FAYALITES IN THE CV3 CARBONACEOUS CHONDRITES A881317, MET00430 AND MET01074. K. Jogo[1], T. Nakamura[1], M. Ito[2,3] and S. Messenger[2], [1]Department of Earth and Planetary Sciences, Kyushu University, Fukuoka, Japan. E-mail: kaori@geo.kyushu-u.ac.jp. [2]ARES, NASA JSC, Houston TX, USA. [3]LPI-USRA.

Introduction: Fayalites are key components of the Bali-like oxidized subgroup of CV3 carbonaceous chondrites ($CV3_{OxB}$) [1,2]. They occur as grains or veins in chondrules and matrix, commonly coexisting with troilite and/or magnetite. Although both nebular or asteroidal origins for $CV3_{OxB}$ fayalites have been proposed [e.g., 2,3], mineralogy and oxygen isotopic studies suggest that fayalites formed in $CV3_{OxB}$ asteroid at low temperature (<300°C) during aqueous or hydrothermal alteration rather than nebula origin [4-6]. Recently, fayalites were also found in clasts in the Vigarano meteorite, classified in the reduced subgroup of CV3 carbonaceous chondrites ($CV3_{Red}$) [7-9].

Fayalites in $CV3_{Red}$ and in $CV3_{OxB}$ chondrites show similar petrographic characteristics (e.g., occurrence, coexisting minerals), implying that fayalites in $CV3_{OxB}$ and $CV3_{Red}$ formed via similar formation mechanisms in CV3 asteroid(s) [9]. Although petrological and mineralogical characteristics of CV3 fayalites are similar, there are variations in their Fa content (Fa#) and grain sizes [9]. For example, adjacent fayalite grains show different Fa#, if they belong to different clasts. Observed difference in Fa# may have resulted from different temperature condition during fayalite formation [10].

^{53}Mn-^{53}Cr isotopic systematics (^{53}Mn decays to ^{53}Cr with $t_{1/2}$ of 3.7 Ma) is a useful chronometer to determine the onset of fayalite formation on the CV3 asteroid [11], and the duration of metamorphism and aqueous alteration in CV3 asteroids in the early solar system. Systematic study of fayalites in several $CV3_{OxB}$ and $CV3_{Red}$ chondrites implies that their Mn-Cr formation ages were identical within errors [5,9,11], regardless of their Fa# or grain sizes.

In this study, we performed a detailed study of mineralogy and petrology of fayalites in $CV3_{Red}$ A881317 and $CV3_{OxB}$ MET00430 and MET01074 [12], and determined formation ages based on Mn-Cr systematics using the JSC NanoSIMS 50L ion microprobe.

Experimental Procedures: Chemical compositions, and mineralogical/petrological characterization of fayalites in A881317, MET00430 and MET01074, were obtained by SEM, FE-SEM and EPMA at Kyushu University.

Mn-Cr isotopic measurements were performed at Johnson Space Center/NASA using NanoSIMS 50L ion microprobe. A focused O^- primary ion beam was rastered over 3 x 3 or 5 x 5 μm depending on sample size. Secondary ions of $^{25}Mg^+$, $^{29}Si^+$, $^{52}Cr^+$, $^{53}Cr^+$, $^{55}Mn^+$ and $^{57}Fe^+$ were acquired simultaneously in multidetection with EMs at a high mass resolution of ~8000. We used elemental images of Mg, Si and Fe to find a small fayalites (5 to 30 μm) in chondrule and matrix (Fig. 1). San Carlos olivine was measured as a standard to determine the Mn/Cr sensitivity factor and instrumental mass fractionation .

Mineralogy and Petrology: A881317 is a breccia containing some clasts. A clast is composed of chondrules and surrounding olivine-rich fine-grained materials. Clasts are embedded in host matrix or have direct contact with adjacent clasts, which can be recognized by boundaries. In contrast, MET00430 and MET01074 are not considered breccias because no obvious boundaries were observed.

Fayalites in A881317. Among 22 clasts investigated, six clasts contain fayalites (Fa_{85-99}) with sizes up to 50 μm. Fayalites exist in interiors and peripheries of chondrules, in fine-grained materials in clasts, and in the host matrix. These fayalites occur as grains or constituents of veins, and commonly coexist with troilite and/or magnetite. They do not show Fe-Mg zoning, suggesting that fayalite had not been heated after its formation. However, fayalite in each clast and in the host matrix shows different Fa#.

Fayalites in MET00430 and MET01074. Fayalites in these meteorites exist in chondrule peripheries and in matrix. No fayalite was observed in chondrule interiors. Occurence of fayalites in these chondrites are similar to that in A881317. Fayalites in MET00430 show Fa_{79-94} and sizes up to 30 μm, and those in MET01074 show Fa_{97-99} and sizes up to 40 μm. In both meteorites, fayalites typically show Fe-Mg zoning pattern (Fa content decreases from the center toward the rim) suggesting that they formed as temperatures were increasing [10].

Mn-Cr systematics of fayalites: We performed Mn-Cr isotopic measurements on four fayalites in four different clasts from A881317, two fayalites from MET00430 and three fayalites from MET01074. These fayalites have high Mn/Cr ratios (MnO = 0.6-1.3 wt%; Cr_2O_3 <0.1 wt%). We also measured olivines and pyroxenes with low Mn/Cr ratios in chondrules or matrices near measured fayalites to determine the (^{53}Cr/^{52}Cr) intercept.

A881317. Although fayalites in each clast have different Fa# ($Fa_{93\sim98}$) and various grain sizes (10~30 μm in sizes) in A881317, Mn-Cr isotopic data points lie within analytical errors on a straight line with an inferred initial $^{53}Mn/^{55}Mn$ ratio $(1.9 \pm 0.5)\times10^{-6}$ (2σ) (Fig. 2).

MET00430 and MET01074. We analyzed two fayalites (5 and 15 µm, Fa_{79-82}) in MET00430 and three fayalites (10-30 µm, Fa_{97-99}) in MET01074. These fayalites in both meteorites show Fe-Mg zoning patterns. We have measured a central part (highest Fa#) in these fayalites because behaviors of Mn^{2+} and Fe^{2+} are highly correlated in olivines. Mn-Cr data of fayalites distribute along single isochrons (Figs. 3-4), and inferred initial $^{53}Mn/^{55}Mn$ ratios of MET00430 and of MET01074 fayalites are $(1.4 \pm 0.5)\times10^{-6}$ (2σ) and $(1.6 \pm 0.8)\times10^{-6}$ (2σ), respectively.

Regardless of their Fa# or grain sizes, inferred $^{53}Mn/^{55}Mn$ ratios of fayalites in A881317, MET00430 and MET01074 are identical within errors, suggesting that they formed at the same period: about 4563~4560 Ma ago based on angrite NWA 4801 [13,14]. Observed $^{53}Mn/^{55}Mn$ ratios from new $CV3_{Red}$ and $CV3_{OxB}$ chondrites are good agreement with previous studies of $CV3_{Red}$ (2.3×10^{-6}, 9) and $CV3_{OxB}$ ($(2.0\text{-}2.4)\times10^{-6}$, 5,6,11) chondrites within errors.

Our results constrain the formation timescale of CV3 asteroids containing fayalite formed in aqueous processes. [15] discussed alternative settings for aqueous alteration in carbonaceous chondrite parent bodies. Whereas alteration in small bodies (<50 km) occurred within (<1 Ma) of asteroidal formation, large bodies (~1000 km) required prolonged heating (>5 Ma). Fayalite formation conditions inferred from oxygen isotopic compositions [4-6] and thermodynamics [10] support alteration in small bodies. Since the duration of aqueous processing in small bodies is <1Ma, $CV3_{OxB}$ asteroids should have formed no earlier than 1Ma prior to fayalite formation. Because all CV3 fayalite formation ages are identical within errors, CV3 asteroidal formation might have simultaneously occurred about 4564~4561 Ma ago.

References: [1] Weisberg M.K. et al. (1997) *Met. Planet. Sci.*, 32, A138. [2] Krot A.N. et al. (1995) *Met. Planet. Sci.*, 30, 748 [3] Hua X. and Buseck P.R. (1995) *GCA*, 59, 563 [4] Choi B.-G. et al. (2000) *Met. Planet. Sci*., 35, 1239 [5] Hua X. et al. (2005) *GCA*, 69, 1333-1348. [6] Jogo K. et al. (2008) *LPS* 39, 1576. [7] Krot A.N. et al. (2000) *Met. Planet. Sci.*, 35, 817 [8] Tomeoka K. and Tanimura I. (2000) *GCA*, 64, 1971 [9] Jogo K. et al. (2009) *EPSL*, 287, 320 [10] Zolotov M.Y. et al. (2006) *Met. Planet. Sci*., 41, 1775 [11] Hutcheon I.D. et al. (1998) *Science*, 282, 1865 [12] Jogo K. (2009) Dr. thesis. [13] Shukolyukov A. et al. (2009) *LPS* 40, 1381. [14] Amelin Y. et al. (2007) *Workshop of Meteorites*, 4053. [15] Young E.D. (2001) *Phil. Trans. R. Soc. Lond.*, 359, 2095-2110.

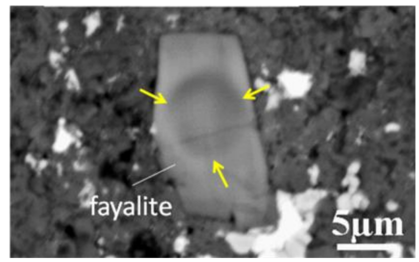
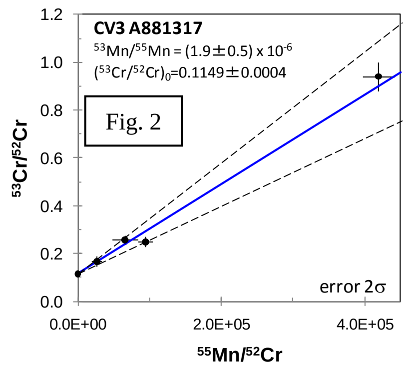
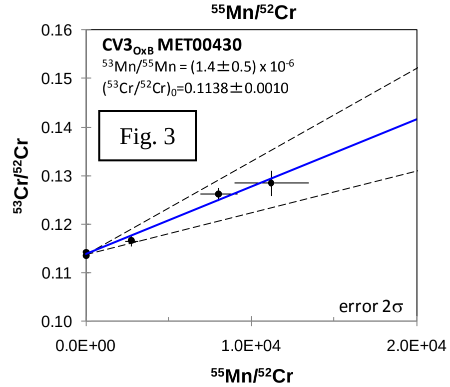


Fig. 1. A BSE image of fayalite in matrix. NanoSIMS beam spot is indicated by arrows.





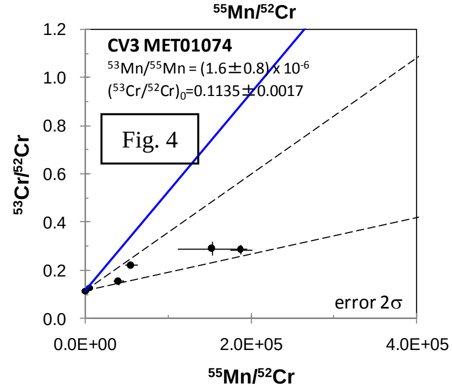


Fig. 2-4. ^{53}Mn-^{53}Cr isotopic ratios for fayalites in A881317, MET00430 and MET01074. The dotted lines show 2σ error of slope.