MN-CR AGES OF CARBONATES IN MURCHISON AND ALH 83100 CM CHONDRITES. W. Fujiiya¹, N. Sugiuara², K. Ichimura², N. Takahata³ and Y. Sano². ¹Department of Earth and Planetary Science, the University of Tokyo, 7-3-1 Hongo, Tokyo 113-0033, Japan (E-mail: fujiiya@eps.s.u-tokyo.ac.jp), ²Ocean Research Institute, the University of Tokyo, 1-15-1 Minami-dai, Tokyo 164-8639, Japan.

Introduction: Aqueously altered carbonaceous chondrites have secondary phases such as carbonates and phyllosilicates. Carbonates often contain relatively abundant Mn contents so that they are suitable for ⁵⁵Mn-⁵⁵Cr dating (half life: 3.7 Myr). Previous studies reported Mn-Cr systematics of carbonates in CI [e.g. 1] and CM chondrites [e.g. 2] obtained by Secondary Ion Mass Spectrometry (SIMS), indicating in-situ decay of ⁵⁵Mn. However, using the angrite LEW 86010 as a time anchor [3, 4], these data suggest that the onset of carbonate formation in CM chondrites predate that of CAIs [5, 6], which is inconsistent with a commonly accepted view of carbonate formation.

Here, we report Mn-Cr ages of carbonates in two CM chondrites; Murchison (CM2.5) and ALH 83100 (CM 2.1), using a newly determined Mn⁷/Cr⁶⁺ relative sensitivity factor for a synthetic calcite standard [7]. The two CM chondrites show different degree of aqueous alteration [8]. This makes it possible to determine minimum duration of alteration and see whether ages correlate with degree of aqueous alteration.

Experimental: Chemical compositions of carbonates in both Murchison and ALH 83100 were analyzed using SEM (BSE and CL) techniques. In Murchison, a dominant carbonate is calcite (CaCO₃) dispersed throughout the meteorite matrix. Mn is detectable in some but not all crystals and shows evidence of zoning based on CL characteristics and ion images obtained by a NanoSIMS (Fig. 1). The bright CL rims have elevated Mn contents (up to ~0.68 wt.%) and were analyzed for Mn-Cr dating by the NanoSIMS. The lower CL intensity cores generally show lower Mn contents and are not suitable for Mn-Cr dating. ALH 83100 contains calcite as well as dolomite (CaMg(CO₃)₂). Dolomites in ALH 83100 contain relatively abundant Mn contents (up to ~1.8 wt.%) and were analyzed for Mn-Cr dating. Carbonates in both Murchison and ALH 83100 have low Cr contents which are below the detection limit.

The Cr isotopic and ⁵⁵Mn⁷/Cr⁶⁺ ratio of the synthetic calcite standard and carbonate grains in two CM chondrites were obtained using a NanoSIMS 50 ion microprobe installed at Ocean Research Institute, the Univ. of Tokyo.

Results and Discussion: Cr isotopic and ⁵⁵Mn⁷/Cr⁶⁺ ratios for carbonates in Murchison and ALH 83100 are shown in isochron diagrams (Fig. 2). Errors are 2σ.
Data for Murchison and ALH 83100 consist of 5 and 6 grains, respectively (if possible, multiple analyses at different spots were performed in a single grain). $^{55}\text{Cr}/^{52}\text{Cr}$ ratios for both Murchison and ALH 83100 showed resolvable excesses with the highest value of $\sim 600$‰ and $\sim 800$‰, respectively. $^{55}\text{Mn}^{52}\text{Cr}$ ratios for ALH 83100 were higher (up to $\sim 30,000$) than those of the previous study for the same meteorite [9], due to the lower $\text{Mn}^{57}/\text{Cr}^{58}$ relative sensitivity factor than that of olivine (used in [9]) and the fine beam size of the NanoSIMS. Because abundances of Mn and Cr in Murchison were lower than those in ALH 83100, errors of the data for Murchison were larger than those for ALH 83100. $\delta^{53}\text{Cr}$ values were clearly correlated with $^{55}\text{Mn}^{52}\text{Cr}$ ratios, indicating in-situ decay of $^{55}\text{Mn}$. The initial $^{53}\text{Mn}^{55}\text{Mn}$, $\delta^{53}\text{Mn}^{55}\text{Mn}$, were estimated from the slopes of the isochrons using the York fit program and were found to be $(2.7 \pm 0.8) \times 10^8$ for Murchison and $(2.8 \pm 0.4) \times 10^8$ for ALH 83100.

Assuming homogeneous distribution of $^{53}\text{Mn}$ in the early solar system and using the age anchor of LEW 86010, these initial ratios correspond to absolute ages of $4562.6 \pm 1.4/-1.9$ Ma for Murchison and $4562.9 \pm 0.7/-0.9$ Ma for ALH 83100. This means the carbonate formation occurred $\sim 4.5$ Myr after the formation of CAIs.

The absolute age of the dolomite formation in ALH 83100 obtained in this study is slightly younger than that of the previous study [9]. This difference is likely caused by a systematic error of the $\text{Mn}^{57}/\text{Cr}^{58}$ relative sensitive factor. Similarly, ages reported earlier may have the same systematic errors. This younger age suggests that aqueous alteration took place in asteroids (rather than in the solar nebula or in small planetesimals prior to the formation of chondrite parent bodies).

These results also imply that age difference (up to $\sim 2$ Myr) between the two CM chondrites with different degree of aqueous alteration is smaller than proposed earlier (at least 4 Myr) [9]. If the ages correlate with degree of aqueous alteration, results in this study indicate duration of alteration is relatively short. However, the possibility that degree of aqueous alteration has no relationship to ages of the carbonate formation cannot be ruled out at this time.

A model calculation dealing with the flow of liquid water, conductive heat flow, oxygen isotope exchange between rock and liquid water, and progress of a model mineralogical reaction was performed earlier [10]. According to the model, a small icy planetesimal with a radius of 9 km which accretes 1.6 Myr after the formation of CAIs experiences aqueous alteration within the first several hundred thousand years of heating. Such a rapid evolution of a planetesimal is inconsistent with our age data of the carbonate formation. Therefore, if aqueous alteration in CM chondrites took place $\sim 4.5$ Myr after the formation of CAIs, we favor a relatively large body as the setting where aqueous alteration in CM chondrites occurred.