THE ^{26}AL-^{26}MG CHRONOLOGY OF A TYPE C CAI AND POIS IN NINGQIANG CARBONACEOUS CHONDRITE. N. T. Kita[1], Y. Lin[2], M. Kimura[3] and Y. Morishita[1]. [1]Geological Survey of Japan, AIST, AIST Central 7, 1-1-1 Higashi, Tsukuba 305-8567, Japan (noriko.kita@aist.go.jp), and [2] Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China, and [3]Ibaraki University, Mito 310-8512, Japan.

Introduction: As a part of systematic study of Ca, Al-rich inclusions (CAIs) in the Ningqiang carbonaceous chondrite (CC), we carried out the ^{26}Al-^{26}Mg isotopic measurements on a plagioclase-pyroxene rich (type C) inclusion and plagioclase-olivine-rich (POI) inclusions. Previous mineralogical studies on various CAIs in Ningqiang indicated that precursor of type C and POI might be anorthite-spinel-rich (ASI) inclusion and amoeboid olivine aggregates (AOA), respectively [1, 2]. Our main purpose is to give a time constraint of the melting events that formed type C and POIs.

Sample and analytical method: We analyzed one type C (W2#3), and one POI (W2#4), of which petrography and mineral chemistry were previously described [1, 2]. In addition, we analyzed an anorthite fragment (named as "An-frag") which contains nepheline lamellae and locates near another POI (C#1) with the known referred initial ^{26}Al/^{27}Al ratio of $(4.6\pm1.6)\times10^{-6}$ [3]. The same mineral chemistry, morphology and close spatial occurrence of the An-frag to that of the C#1 inclusion suggest that the fragment could be derived from the POI.

The isotopic analyses were carried out using a secondary ion mass spectrometer (SIMS) IMS-1270 at the Geological Survey of Japan (GSJ). The analytical procedures are similar to those in [4]. The Mg isotopes in plagioclase were analyzed with a beam spot of 3-5 µm by using a mono-collector in pulse-counting mode, while those in pyroxene were analyzed with a beam spot of 5-12 µm by using a multi-collector Faraday cups (FCs). The ^{26}Al ages are calculated relative to the time of CAI formation with canonical ^{26}Al/^{27}Al value of 5×10^{-5} [5].

Results: In all samples, we detected resolvable ^{26}Mg excess in the level less than a few ‰, though data of each inclusions showed disturbed ^{26}Al-^{26}Mg system on isochron plots (Fig.1).

Type C (W2#3): The results of multi-collector FCs measurements on Ca-pyroxene indicate a small, but resolvable, ^{26}Mg excess in the level of 0.6-1‰ with analytical precision of ~0.3‰. They plot very closed to the canonical isochron line, indicating either melting of type C or formation of their precursor was as old as the formation of other CAIs. In spite of the high Al/Mg ratios in plagioclase, ^{26}Mg excess could not be detected with analytical precision of 2‰, indicating their Mg isotopes were equilibrated with normal Mg at least 5Myr after the CAI formation time. The Mg distributed heterogeneously within plagioclase in µm-scale, as we saw tiny Mg bright areas that were difficult to avoid with 3-5µm SIMS beam. It implies that Mg in the plagioclase was mobile long after their crystallization. Although present data do not provide further arguments on the time of melting event, the existence of small ^{26}Mg excess in pyroxene is consistent with the proposed origin of type C as a remelting of ASI [2].

POI (W2#4): The POI W2#4 contains two textually different areas, dendritic and poikilitic textures. The plagioclase in the dendritic area is relatively low in Mg and show micro-scale heterogeneous Mg distributions, as in case of W2#3. The plagioclase in poikilitic area is homogeneously high in Mg. These plagioclase show clear ^{26}Mg excesses and the data plot along the isochron with initial ^{26}Al/^{27}Al ratio of $\sim5\times10^{-6}$. The heterogeneous plagioclase does not show detectable ^{26}Mg excess and plot significantly below the isochron made by homogeneous plagioclase.

An-frag: We analyzed positions both avoiding nepheline lamellae and on the lamellae. The data without the lamellae showed resolvable ^{26}Mg excess (~1‰), while the data on the lamellae do not indicate any ^{26}Mg excess. The analysis of plagioclase in POI C#1 is consistent with previous analyses [3]. The Al-Mg isotopic results obtained from nepheline-free area are very similar to those in C#1 indicates that this fragment was derived from the nearby POI C#1.

Discussion: The initial ^{26}Al/^{27}Al ratios in most of type C were found to be significantly lower than the canonical value [5,6]. One exception is type C TTA1-01 in which melilite and some plagioclase plot along the canonical isochron, though the most plagioclase in the same inclusion deviate below the canonical line [7]. Our Ca-pyroxene data in W2#3 plotting along the canonical isochron is further evidence for the old formation age of type C CAIs. Previous young ages in type C CAIs are mostly obtained from the analyses of plagioclase, from which the large ^{26}Mg excess might be more or less erased by the secondary alteration, such as formation of nepheline, which are common in many type C CAIs [6].

The poikilitic area in POI W2#4 gives the initial ^{26}Al/^{27}Al ratio very similar to other POIs; in the range of $(3\text{-}6)\times10^{-6}$ [3,8]. The relative ^{26}Al age is 2.4(-

0.2/+0.3) Myr after CAIs. It is interesting to note that the ^{26}Al ages of POIs are at the younger end of those of type I chondrules in CO3.0 (1.3-2.5 Myr [9]) and closed to Al-rich chondrules in CC chondrules (~3 Myr [9,10]).

All samples analyzed in this work showed disturbed ^{26}Al-^{26}Mg systems in the plagioclase with high Al/Mg ratios (>100). It should be noted that these plagioclase are accompanied with secondary nepheline lamellae (in An-Frag) or show heterogeneous Mg contents (W2#3 and dendritic area of W2#4) that indicate post-crystallization Mg redistribution. The plagioclase with the highest Al/Mg ratios in each samples give limits on the minimum metamorphic ages; 5.0, 3.7 and 4.2 Myr after CAIs for type C W2#3, POI W2#4, and An-frag, respectively. These ages are significantly younger than ^{26}Al ages of chondrules in the least equilibrated chondrites (1-3Myr [4,9,11]), but comparable to the age of plagioclase in H4 (5-6 Myr after CAIs [12]). Therefore, the isotopic systematics is likely disturbed by parent body metamorphism. By using the Mg self-diffusion rate in plagioclase [12] and plausible metamorphic temperature of Ningqiang (<300˚C if it is similar to Allende CV3 [14]), it would be difficult to erase ^{26}Mg excess in a few µm-sized plagioclase for even 1Gyr. However, as we see µm-scale heterogeneous distribution of Mg in plagioclase, parent body metamorphism should result in redistribution of Mg, even though the rate of isotopic exchange extrapolated from the high temperature diffusion experiment is slow [12]. This process may explain lack of ^{26}Mg excess among anorthitic plagioclase in some CAIs and Al-rich chondrules in mildly metamorphosed CCs (e,g,,Allende) and UOCs (e.g., Chainpur) [5,15,16].

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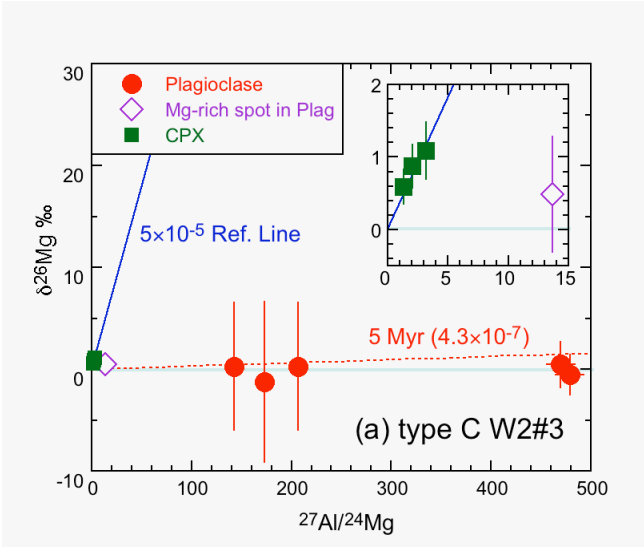

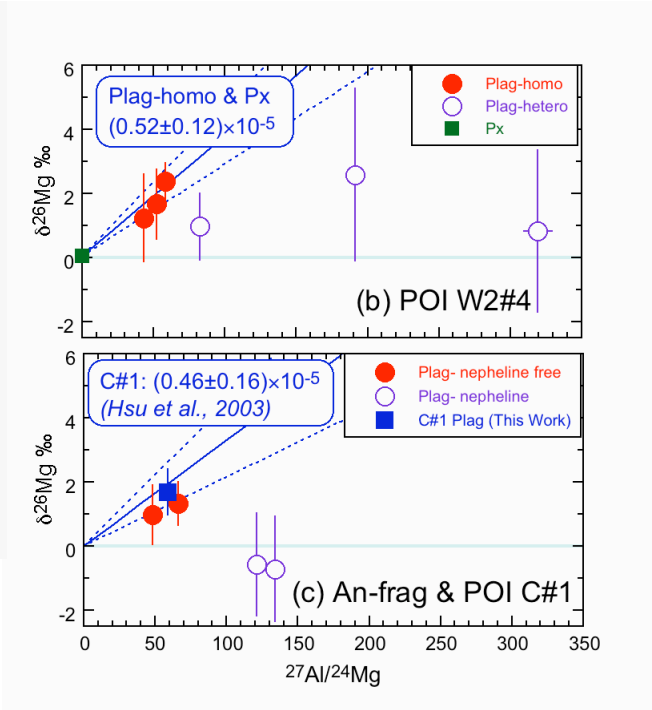

Fig. 1. The Al-Mg isochron diagram of type C and POIs in Ningqiang. (a) W2#2 type C. (b) W2#4 POI. (c) Anorthite fragment "An-frag" and nearby C#1 POI.