Cosmic-ray exposure age and heliocentric distance of the parent body of E chondrites ALH85119 and MAC88136. D. Nakashima[1], T. Nakamura[2], and R. Okazaki[2], [1]Department of Earth and Planetary Sciences, Graduate School of Sciences, Kyushu University, Hakozaki, Fukuoka 812-8581, Japan, [2]Department of Earth and Planetary Sciences, Faculty of Sciences, Kyushu University, Hakozaki, Fukuoka 812-8581, Japan. (naka@geo.kyushu-u.ac.jp)

Introduction: Enstatite (E-) chondrite parent bodies are considered to have formed at regions closer to the Sun than other chondrites on the basis of mineralogy and chemical properties of E chondrites [1-4]. However, there is no data indicating directly the heliocentric distances of the E chondrite parent bodies.

Anders [5] calculated the heliocentric distances of parent bodies of several kinds of meteorite classes based on noble gas data and two assumptions that (1) fluxes of solar wind (SW) and solar energetic particles (SEP) are in inverse relation to the square of heliocentric distance and (2) flux of galactic cosmic ray (GCR) is constant in the solar system. It was calculated that meteorite parent bodies could be distributed at the region of asteroid belt [5]. Wieler et al. [6] and Nakashima et al. [7] calculated the heliocentric distances of ordinary chondrite parent bodies and parent body exposure ages, and confirmed that the parent bodies were distributed at asteroid belt.

The purpose of this study is to determine the parent body exposure ages and the heliocentric distances of the two E chondrites ALH85119 and MAC88136. These chondrites are known to contain solar gases as well as cosmogenic ones [8].

From the concentrations of solar ^{20}Ne ($^{20}Ne_{So}$), ^{36}Ar ($^{36}Ar_{So}$), and cosmogenic ^{21}Ne ($^{21}Ne_{Cos}$), the parent body exposure ages, the heliocentric distances, and the space exposure ages of the two E chondrites were calculated.

Experimental and calculation procedures: The parent body exposure age T_P is the duration for which the raw materials of meteorites were exposed to solar cosmic ray (SCR) and GCR when they were on the parent body. The heliocentric distance r_P is the distance of the parent body of meteorites from the Sun. The space exposure age T_S is the duration for which the meteoroids were exposed to GCR. T_P and r_P were calculated by,

$$T_P = \frac{\left(^{21}Ne_{Cos}\right)_P}{P_{GCR} + P_{SCR}/r_P^2}, \quad (1)$$

$$r_P = \sqrt{\frac{\left(^{36}Ar_{So}\right)_L}{T_L} \bigg/ \frac{\left(^{36}Ar_{So}\right)_P}{T_P}}, \quad (2)$$

where suffixes P and L represent parent body and lunar, respectively, and P_{GCR} and P_{SCR} are the production rates of $^{21}Ne_{Cos}$ by GCR and SCR, respectively. In the equation (1), P_{SCR} is divided by r_P^2, because SCR flux is inversely proportional to r_P^2. Each shielding depth for P_{GCR} and P_{SCR} is assumed to be 0-10g/cm^2 and SEP can penetrate this depth. These production rates are calculated from data given by [9]. As found in the equation (2), the concentration of noble gas implanted on the parent body per unit time is inversely proportional to r_P^2, because fluxes of SW and SEP are in inverse relation to r_P^2. Since the distance from the Sun to the moon is 1AU, r_P can be calculated by comparing the concentration of solar gases implanted per unit time in lunar meteorites $(^{36}Ar_{So})_L/T_L$ with those of meteorites investigated in this study $(^{36}Ar_{So})_P/T_P$. Data for QUE93069 [10], ALH81005 [10], and EET87521 [11] are used for $(^{36}Ar_{So})_L$ and T_L. The $(^{21}Ne_{Cos})_P$ and $(^{36}Ar_{So})_P$ are obtained by noble gas analyses.

Sample weights range from about 0.5mg to 2.2mg. We analyzed 15 and 13 grains for ALH85119 and MAC88136, respectively. Each sample was heated at 1700°C to extract noble gases. The concentrations and isotopic ratios of He, Ne, and Ar were measured with a noble gas mass spectrometer at Kyushu University [12]. The concentrations of ^{84}Kr and ^{132}Xe were also measured.

Results: Correlations were found between the concentrations of $^{20}Ne_{So}$ and $^{21}Ne_{Cos}$ for both meteorites (Fig. 1). The ordinate intercept corresponds to the concentration of $^{21}Ne_{Cos}$ produced during the space exposure, while the excess from the ordinate intercept is the concentration of $^{21}Ne_{Cos}$ produced by GCR and SCR during the parent body exposure. This is because solar gases trapped on the meteoroid surface are lost during the atmospheric entry [13], and thus the contribution during the space exposure is only cosmogenic gases. From equations (1) and (2), we obtained T_P = 7.6±2.0Ma and r_P = 2.0±0.3AU for ALH85119, T_P = 17.1±4.6Ma and r_P = 2.9±0.4AU for MAC88136. Space exposure ages (T_S) are 2.1±0.4Ma and 2.9±0.8Ma for ALH85119 and MAC88136, respectively, with the production rate given by [14]. The errors are calculated from the 1σ confidence lines in Fig. 1.

Discussion: We compared the obtained r_P for ALH85119 and MAC88136 with the asteroid distribution in the present solar system. The parent bodies of E chondrites are thought to be E- and M-type asteroids [e.g., 15]. The E- and M-type asteroids distribute at inner part of asteroid belt (1.8-3.2AU) [16]. On the other hand, the obtained heliocentric distances of ALH85119 (2.0AU) and MAC88136 (2.9AU) indicate that the locations of the parent bodies in the past when some parts of the meteorites were exposed to the Sun. The heliocentric distances of ALH85119 and MAC88136 are in a good agreement with current E- and M-type asteroid distribution. It is therefore inferred that the heliocentric distances of the E chondrite parent bodies are relatively constant from a certain period in the past to present.

There is a possibility that the raw materials of meteorites were exposed to only GCR at depth that SCR could not reach on their parent body. In this case, we cannot distinguish the irradiation on parent body from the space exposure. Therefore, T_S is an upper limit for the space exposure age.

T_P is a lower limit for the parent body exposure age, because ALH85119 and MAC88136 may contain the portions bearing larger amounts of solar and cosmogenic noble gases than the samples in this study.

Conclusions: The heliocentric distances are 2.0AU and 2.9AU for ALH85119 and MAC88136, respectively. The parent body exposure ages are more than 7.6Ma and 17.1Ma for ALH85119 and MAC88136, respectively. The space exposure ages are less than 2.1Ma and 2.9Ma, respectively.

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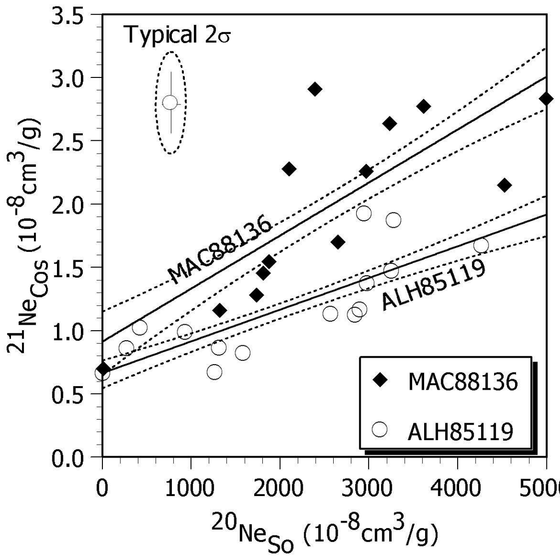

Fig. 1. A relationship between $^{21}Ne_{Cos}$ and $^{20}Ne_{So}$. The solid lines are the correlation lines for samples of ALH85119 and MAC88136. The dashed lines are 1σ confidence lines for the correlation lines.