NOBLE GAS ANALYSES OF UNIQUELY SHOCKED ANGRITE NORTHWEST AFRICA 7203.

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Introduction: Angrite is one of the oldest basaltic rock groups in the solar system. Previous studies reported that angrites show either quenched textures ("quenched" angrites) or relatively slowly-cooled textures ("plutonic" angrites) [e.g., 1]. Pb-Pb chronological analyses revealed that the quenched angrites formed earlier (*ca.* 4564 Ma) than the plutonic ones (*ca.* 4558 Ma) [e.g., 1]. Although angrites should be derived from the surface of large asteroid (>100 km in radius), they show almost no shock features [e.g., 1]. The exceptions are Northwest Africa (NWA) 1670 and NWA 7203 because these two quenched angrites contain shock-induced melt veins [2, 3]. Since angrites have formed in the early solar system, shock histories of angrites may constrain the early asteroidal formation/destruction processes. In order to reveal the angrites shock histories, we measured noble gases (He, Ne, Ar, Kr and Xe) in shocked angrite NWA 7203 and attempted to obtain its Ar-Ar and I-Xe chronological ages, which are sensitive to the shock events or low-temperature thermal metamorphic events. Moreover, cosmic-ray exposure (CRE) ages are also obtained on the basis of cosmogenic noble gas analysis.

Sample and Methods: In this study, noble gases in NWA 7203 quenched angrite were measured using a noble gas mass spectrometer (modified-VG3600) at the University of Tokyo [4]. We prepared two kinds of samples, one is an intact chip (7.4 mg) for whole-rock noble gas analysis and the other is a neutron-irradiated chip (26.0 mg) for Ar-Ar and I-Xe chronological analysis. The sample irradiation was conducted at the Kyoto University Research Reactor Institute. The Hb3gr hornblende Ar-Ar dating standard and synthesized CaF_2 and K_2SO_4 were simultaneously irradiated as monitors for neutron flux and neutron-produced Ar interference corrections [5]. The Shallowater meteorite (aubrite) was also irradiated for a I-Xe age anchor (4563.3±0.4 Ma) [6]. In order to yield Ar-Ar plateau and I-Xe isochron, noble gases in irradiated samples were measured by the stepwise heating method at temperatures ranging 500-1700 °C for 30 minutes in each step, while gas extraction from unirradiated sample was performed by total melting method at 1700 °C for 30 minutes. Before analyses, a sample chamber and gas-purification vacuum line were baked at 150-200 °C for about 30 hours to remove atmospheric contamination. Mass discrimination correction factors and sensitivities were determined by measuring atmospheric gas with known amounts. Blanks were determined at 500, 1000 and 1500 °C and the blank levels at 1500 °C were He: 1.6 x 10^{-10} cc, Ne: 5.1 x 10^{-12} cc, Ar: 2.7 x 10^{-9} cc, Kr: 2.6 x 10^{-13} cc and Xe: 4.8 x 10^{-14} cc at standard temperature and pressure (ccSTP).

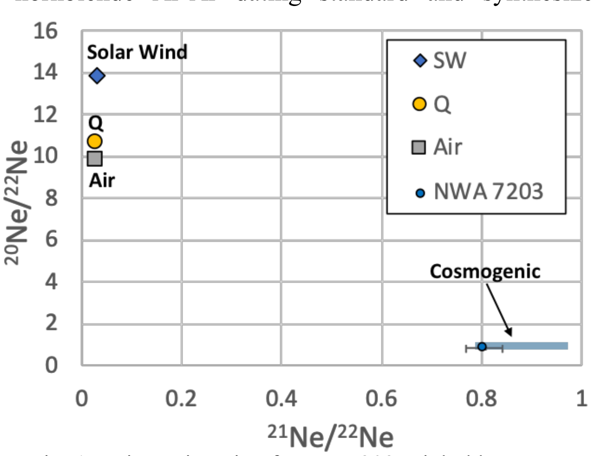

Fig. 1 Ne isotopic ratio of NWA 7203. Light blue area represents the cosmogenic Ne isotopic range.

Results: Whole-rock noble gas contents and Ne and Ar isotopic ratios were summarized in Table 1. Regarding Ne isotopic ratios of NWA 7203, cosmogenic Ne (Ne_{cosm}) is dominant in this sample (Fig. 1). The ratio of $(^{22}Ne/^{21}Ne)_{cosm}$, which is a reciprocal number of Ne ratio in Table 1, is a good indicator for shielding effects during cosmic ray exposure. If we assume Ne in NWA 7203 is purely cosmogenic, we can obtain $(^{22}Ne/^{21}Ne)_{cosm}$ = 1.24±0.06. This value is close to the other quenched angrites (Sahara 99555 and D'Orbigny) [7], and indicates that NWA 7203 may have been located near the surface of small body. However, we cannot determine the absolute preatomospheric size and located depth because this value (= 1.24) is significantly higher than the upper limit (= 1.19) of well-established indicator ranges in chondrites as pointed out by [7]. According to their study [7], production rates of $^{21}Ne_{cosm}$ for Sahara 99555 and D'Orbigny are 15.3-16.8 (10^{-10} ccSTP/g/Myr). Since NWA 7203 is a quenched angrite and may have a close bulk chemical composition to those of Sahara 99555 and D'Orbigny, we employ the value of 16.0±0.8 (10^{-10} ccSTP/g/Myr) for the ^{21}Ne production rate and obtained a CRE age of NWA 7203 as 20.3±2.2 Myr.

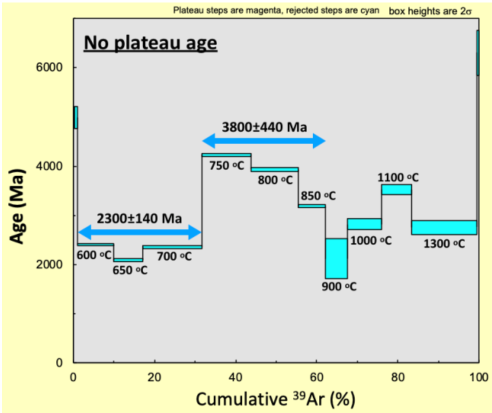

Fig. 2 Ar-Ar age from each fraction. No plateau age could be obtained.

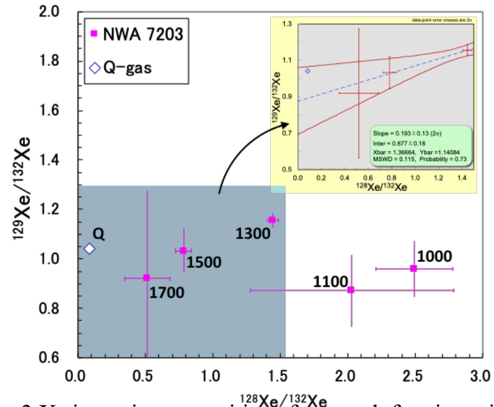

Fig. 3 Xe isotopic compositions from each fraction with error bars (2σ) Numbers at each point represent gas-extracted temperature. Data in a light blue box show ^{129}Xe*.

In Ar analysis, we decomposed our data assuming that trapped gas was derived from the phase "Q", which is enriched in heavy noble gases. On the other hand, the trapped components were small because the ^{36}Ar/^{38}Ar ratio is close to the cosmogenic one (~0.65) rather than that of Q-gas (~5.34). Regarding Ar analysis, obtained Ar-Ar ages are highly disturbed and we cannot define the plateau age (Fig. 2). Since this meteorite shows shock features, radiogenic ^{40}Ar (^{40}Ar*) may be partly degassed. The data from fractions with small errors (600-850 °C) indicate that there may be two Ar-Ar ages, 2300±140 and 3800±440 Ma (Fig. 2). Note that the temperature in Fig. 2 represents furnace temperature.

In I-Xe analysis, if a meteorite has contained the short-lived nuclide ^{129}I ($T_{1/2}$ = 15.7 Myr), we can obtain ^{129}Xe excess (^{129}Xe*) corresponding to the abundance of ^{128}Xe derived from neutron-irradiated ^{127}I. In NWA 7203, ^{129}Xe/^{132}Xe ratios obtained from low-temperature fractions (500-1100 °C) falls in 0.872-1.069 in spite of a vast range of ^{128}Xe/^{132}Xe (2.0-42.8), which indicates no ^{129}Xe*. However, Xe released at high-temperature (1300 °C) shows some ^{129}Xe* (Fig. 3). This result indicates that ^{129}Xe* was partly lost as well as ^{40}Ar* while minerals resistant against shock destruction (or high-temperature) could retain ^{129}Xe*. Therefore, NWA 7203 should have formed before extinction of ^{129}I and this is consistent with quenched angrites with crystallization age of ~4564 Ma [e.g., 1]. We will define I-Xe isochron of Shallowater meteorite and try to obtain a relative I-Xe age of NWA 7203 soon.

Discussion and Conclusion: Comparing the CRE ages in other quenched angrites, the CRE age of NWA 7203 is close to that of NWA 1670 (14.7-17.6 Myr) [8]. Since NWA 1670 is the other shocked angrite ever found, NWA 1670/7203 could have originated from the same "daughter" body.

The Ar-Ar ages from each fraction seem to have two plateaus and we have two interpretations for this result. One interpretation is that NWA 7203 has experienced two shock events. The first shock event at 3800±440 Ma was intense so that Ar-Ar age has been completely reset. Then, the second weak shock event partly reset the Ar-Ar age at 2300±140 Ma. This may reflect many intense shock events at 3800 Ma (so-called "late heavy bombardment" on the moon). However, such intense shock events would remove ^{129}Xe* completely, which is inconsistent with our result. On the other hand, the other interpretation could explain our result in one moderate shock event: Ar-Ar ages obtained from the fractions below 700 °C resulted from complete degassing and represent the shock age. Those from high-temperature (>750 °C) fractions resulted from partial degassing during the shock event and would be younger than the original Ar-Ar age (>3800 Ma). The ^{129}Xe* may be partly lost at this shock event. We prefer the latter scenario because no shock features reflecting intense or second shock events were reported in NWA 7203 while its shock features represent a moderate single shock [3].

References: [1] Keil K. (2012) *Chem. Erde*, *72*, 191-218. [2] Mikouchi T. et al. (2003) *Meteoritics & Planet. Sci.*, *38*, A115. [3] Hayashi H. et al. (2018) *LPS XLIX* Abst. #1932. [4] Ebisawa N. et al. (2004) *J. Mass Spectrom. Soc. Jpn.*, *52*, 219-229. [5] Roddick J. C. (1983) *GCA*, *47*, 887-898. [6] Gilmour J. D. et al. (2006) *Meteoritics & Planet. Sci.*, *41*, 19-31. [7] Busemann H. et al. (2006) *GCA*, *70*, 5403-5425. [8] Miura Y. N. et al. (2004) *Antarct. Met., XXVIII*, 50–51.

Table 1. Whole rock noble gas contents in unirradiated NWA 7203 and their isotopic ratios

	^{4}He	^{20}Ne	^{20}Ne/^{22}Ne	^{21}Ne/^{22}Ne	^{40}Ar	^{36}Ar/^{38}Ar	^{40}Ar/^{36}Ar	^{84}Kr	^{132}Xe
NWA7203	1912±57	3.3±0.1	0.82±0.04	0.80±0.04	722±24	1.03±0.05	147±5	1429±44	349±11

Units for He, Ne and Ar are 10^{-8} ccSTP/g, and those for Kr and Xe are 10^{-12} ccSTP/g.