ARGON-ARGON CHRONOLOGY OF TWO SHOCKED EUCRITES, NORTHWEST AFRICA 1000 AND YAMATO 980433. A. Takenouchi[1], H. Sumino[2], T. Mikouchi[3], H. Ono[4], and A. Yamaguchi[1], [1]National Institute of Polar Research (NIPR), Midori-cho, Tachikawa, Tokyo, Japan, takenouchi.atsushi@nipr.ac.jp, [2]Department of General Systems studies, Graduate School of Arts and Sciences, The University of Tokyo, Komaba, Meguro-ku, Tokyo, Japan, [3]The University Museum, The University of Tokyo, Hongo, Bunkyo-ku, Tokyo, Japan, [4]Planetary Exploration Research Center, Chiba Institute of Technology, Tsudanuma, Narashino, Chiba, Japan.

Introduction: The asteroidal impact histories provide a clue to reveal the formation history of our Solar System. Eucrites are one of the largest achondrite groups, and its parent body is thought to be the asteroid 4 Vesta [e.g., 1]. Revealing impact histories of eucrites can help understand the impact history of Vesta and, consequently, can constrain asteroidal movements through the Solar System history. Many previous studies have discussed the impact history of eucrites on the basis of K-Ar or Ar-Ar chronology [e.g., 2-5]. To further discuss the impact history of Vesta, we report new Ar-Ar analysis results of two shocked eucrites.

Samples and Methods: The Ar-Ar ages of two shocked eucrites, Northwest Africa (NWA) 1000 (a partly brecciated basaltic eucrite) and Yamato (Y) 980433 (a unbrecciated cumulate eucrite), are measured in this study. Warren (2002) [6] reported that half of plagioclase in NWA 1000 is maskelynitized, which is the characteristic of the shock degree "E" in a newly suggested shock classification [7]. Y 980433 has thin shock veins, and plagioclase around the veins is maskelynitized [8]. The shock degree of Y 980433 in the same scheme is the shock degree "D" [7].

We prepared a chip of NWA 1000 (18.0 mg), and that of Y 980433,58 (35.7 mg). Plagioclase in our chip of NWA 1000 is completely maskelynitized. The chip of Y 980433,58 apparently contains no shock veins. Each sample was irradiated with neutrons at the Institute for Integrated Radiation and Nuclear Science, Kyoto University. The Hb3gr hornblende Ar-Ar standard and synthesized CaF_2 and K_2SO_4 were also irradiated to monitor neutron flux and correct neutron-produced Ar interferences, respectively [9]. Samples were heated step-by-step to extract argon, and its isotopic compositions were measured with a modified VG-3600 mass spectrometer after gas purification [10]. NWA 1000 was heated by 13 steps with a heating time of 30 minutes/step from 500 °C to 1800 °C, while Y 980433 was heated by 27 steps with a heating time of 20 minutes/step from 500 °C to 1900 °C. The heating time of the last two steps (1700 and 1900 °C) was longer (30 minutes) to extract gases completely. Blank, mass discrimination, and radiogenic decay of ^{37}Ar and ^{39}Ar were corrected in this study. Due to small gas contents in our samples, blank levels are high in both samples, about 0-27 % for NWA 1000 and 3-42 % for Y980433, respectively. Data are plotted by Isoplot(R) [11-12].

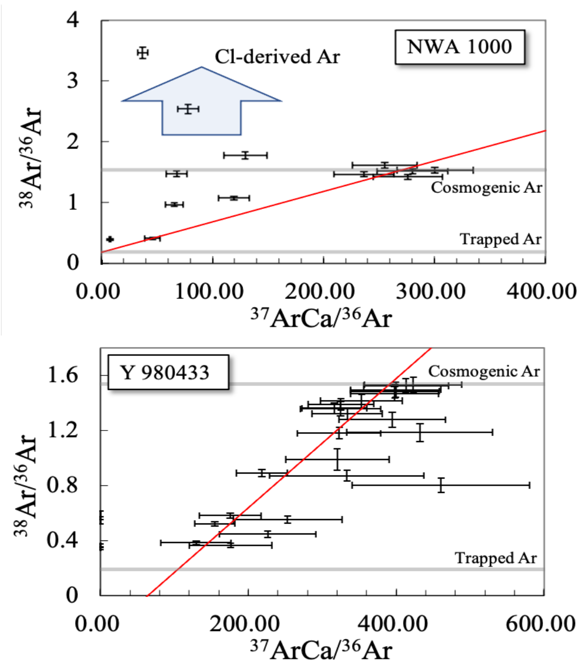

Fig. 1 Three isotope plots (cosmochron plots). Gray lines in each graph show isotopic compositions of trapped Ar (0.188: Q-gas or air) and cosmgonic Ar (1.54). Regression lines are exhibited by red lines (see the text in detail).

Results: Since the corrected data still contain Cl-derived Ar interferences, cosmogenic Ar_{cosm} and trapped Ar_{trap}, we need to evaluate each content and perform further reduction using plots of $^{37}Ar_{Ca}/^{36}Ar$ vs. $^{38}Ar/^{36}Ar$ (so-called a "cosmochron plot") (Fig. 1).

Since Y 980433 displays a relatively linear correlation between $^{37}ArCa/^{36}Ar$ and $^{38}Ar/^{36}Ar$, Cl-derived Ar interferences can be negligible in our measurement. On the other hand, NWA 1000 shows the scattered plots and some of them have higher $^{38}Ar/^{36}Ar$ ratios than that of cosmogenic Ar, implying the presence of Cl-derived Ar. We subtracted such interferences by assuming the $^{38}Ar/^{36}Ar$ ratio of the trap+cosmogenic Ar = 1.535. If we can define a regression line using data containing no Cl-derived Ar (red lines in Fig. 1), we can calculate cosmic-ray exposure (CRE) ages. When we adopt the Ca-spallation ^{38}Ar production rate as 2.1±0.3 (10^{-8} cm^3STP_{Ar}/g_{Ca}/Myr) [5], the CRE ages with 1σ errors are 23.5±4.6 Myr and 15.6±3.1 Myr for NWA 1000 and Y 980433, respectively.

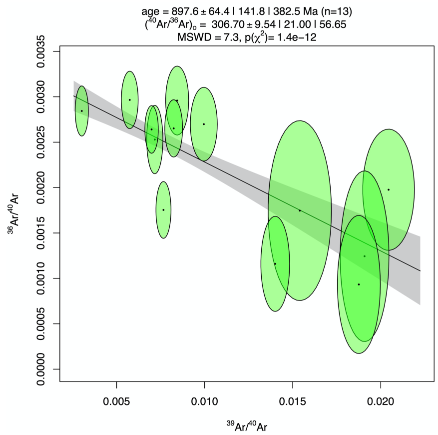

Fig. 2 The example of an inverse isochron plot defined using the data from 13 steps (800-1200 °C) in Y 980433. The intercept represents the possible trapped Ar isotopic composition.

Cosmogenic Ar_{cosm} is also subtracted from obtained data, and then we made inverse isochron plots using several successive steps to determine $^{40}Ar/^{36}Ar$ ratios of trapped components, as shown in Fig 2. After that, we can subtract trapped $^{40}Ar_{trap}$ and obtained the corrected Ar-Ar spectra of each sample (Fig. 3).

As is the case with shocked meteorites, we obtained no "plateau ages" in each sample. Instead, Ar-Ar ages become gradually older as the heating steps proceed, indicating partial ^{40}Ar loss during an impact-induced thermal event. For NWA 1000, the youngest and oldest ages with 2σ errors are 646±29 Ma and 3922±87 Ma, respectively. Y 980433 exhibits old ages with small ^{39}ArK amounts in the first several steps due to contaminated ^{40}Ar. Although the youngest age of Y 980433 is 381±357 Ma (2σ) at the eighth step, this significantly young and large-error age could be affected by terrestrial K contamination. Therefore, we adopt the isochron age (898±64 Ma) for the younger age of Y 980433. The oldest age of Y 980433 before the Ar_{trap} subtraction is 3404±102 Ma (2σ), while an isochron of high-temperature portions in Y 980433 (not shown) yields around 3.0 Ga and $(^{40}Ar/^{36}Ar)_{trap}$ = ~900.

Discussion and Conclusion: There are a few possible interpretations for the obtained Ar-Ar spectrum. One possibility is that the young and old ages represent the last "partial-degassing" thermal events and the last "complete-degassing" one, respectively. Many eucrites show the plateau ages around 3.4-3.8, 3.9-4.0, ~4.48 Ga [2-5]. The old age of the high-temperature portion in NWA 1000 may represent such a thermal event. Then, NWA 1000 was shocked and heated again at <646±29 Ma to partly vitrify plagioclase and to partially degas $^{40}Ar^*$. Note that Asuka-87272, another eucrite with shock degree "E" [7], exhibits a clear plateau age at

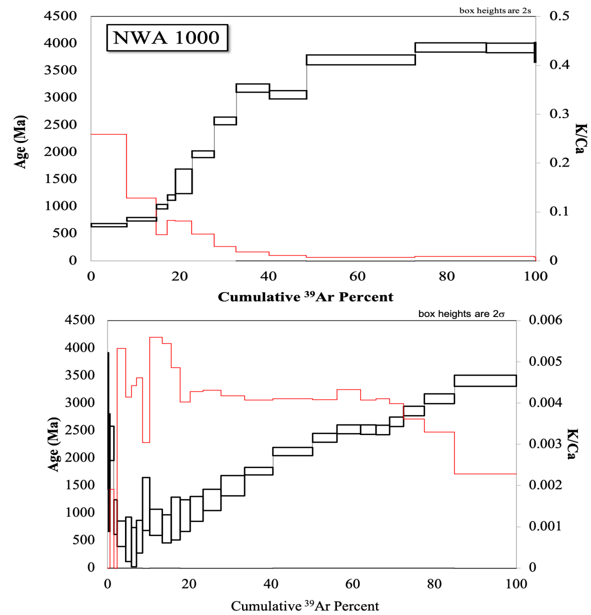

Fig. 3 Ar-Ar age spectra (black boxes, left axes) and K/Ca ratios (red lines, right axes) of each sample.

3659±11 Ma [5], experiencing a different shock history from that of NWA 1000.

The isochron of high-temperature portions in Y980433 may be false due to its high $(^{40}Ar/^{36}Ar)_{trap}$ ratio and its age of ~3.0 Ga never reported in other eucrites. Y 980433 possibly experienced the common thermal event at >3.4 Ga, and the later shock event at <898±64 Ma partly disturbed the isochron. In this case, the later event should be relatively long-term to degas Ar from high-temperature phases, while temperature should be low not to modify igneous textures. Quartz in the shock vein in Y 980433 [8] could form from SiO_2 glass or tridymite during such a long-term and low-temperature (at least <~870 °C) post-shock heating, although Y 980433 still contains a glassy region in the vein.

Our study revealed that above two eucrites record relatively young impact events at around <650-900 Ma in addition to the older common thermal events.

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