Noble gas chronology of Erg Chech 002 ungrouped achondrite

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Introduction: Differentiation and crust formation processes in the early solar system have been poorly understood. Elucidating detailed thermal histories of differentiated meteorites is essential to describe such asteroidal/planetary evolution. Recently discovered Erg Chech 002 (EC002), a unique andesitic achondrite crystallized at 4565.0 Ma (^{26}Al-^{26}Mg system), provides us clues to understand a formation process of a primitive igneous crust [1]. , A chemical zoning in pyroxene and the occurrence of silica polymorph combination in EC 002 indicates a cooling (1~5 °C/yr) at high-temperature (1200-800 °C) [1-3] and more rapid cooling at a lower temperature [1, 3]. Since an Ar-Ar age has a lower closure temperature than the Al-Mg age and can be measured by an incremental heating method, we can ensure such thermal history by conducting Ar-Ar dating. In this study, we report noble gas retention (Ar-Ar and I-Xe) ages to obtain thermochronological information of EC 002.

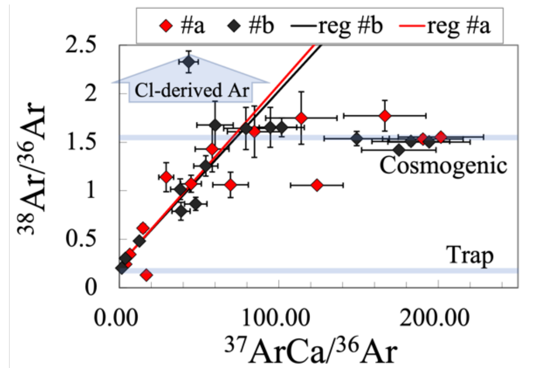

Fig. 2 Cosmochron plot of two specimens Regression lines are defined using low-temperature (<1000 °C) fractions.

Sample and Methods: We prepared two chips (labeled as #a and #b) of EC 002 sampled from different portions avoiding xenocrysts. Each chip was crushed into tiny grains and wrapped with Al-foil to make specimens weighing 23.4 mg (#a) and 26.7 mg (#b). Then, both specimens were irradiated with neutrons at the Institute for Integrated Radiation and Nuclear Science, Kyoto University. An Ar-Ar standard (Hb3gr hornblende) and neutron monitors (synthesized CaF_2 and K_2SO_4) were simultaneously irradiated to correct Ar interferences. Noble gases were extracted by step-by-step heating in 17 steps with 30 minutes from 500 to 1900 °C. Isotopic compositions were measured by the modified VG-3600 mass spectrometer after gas purification [5].

Results: Since EC 002 is enriched in K [1], EC 002 retains abundant radiogenic ^{40}Ar. As a result, blank and trapped Ar affects little on Ar-Ar dating. The ^{37}ArCa/^{36}Ar vs. ^{38}Ar/^{36}Ar plot (Fig. 1) supports small amounts of Cl-derived Ar interferences because part of the data exceeds cosmogenic ^{38}Ar/^{36}Ar ratios (~1.54). If we define regression lines using low-temperature (<1000 °C) fractions and assume the Ca-spallation ^{38}Ar production rate as 2.1±0.3 (10^{-8} cm^{3}STPAr/gCa/Myr) [6], cosmic-ray exposure ages are 65±19 Myr (#a) and 62±15 Myr (#b), which is older than previously reported one by ^{3}He and ^{21}Ne (25.6-26 Myr) [1]. We can define plateau ages in Ar-Ar spectra (Fig. 2), yielding 4.49±0.05 Ga (#a) and 4.52±0.05 Ga (#b). The average Ar-Ar plateau age is 4.51±0.04 Ga (2σ).

Regarding I-Xe ages, we need further careful data reduction because the ^{128}Xe/^{132}Xe vs. ^{129}Xe/^{132}Xe plot (not shown) is highly scattering and includes significant errors due to the correction of abundant fissiogenic Xe.

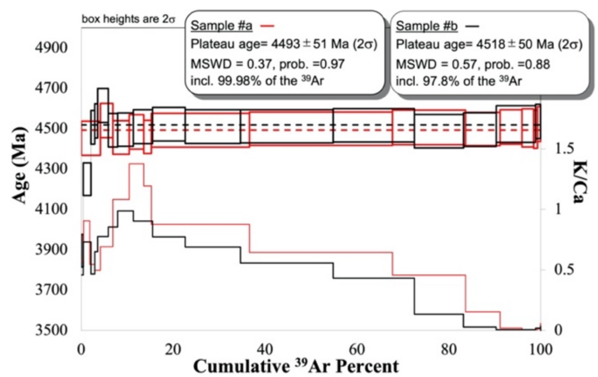

Fig. 1 Ar-Ar spectra (solid boxes) indicating plateau ages (dotted lines), and K/Ca ratios (solid lines).

Discussion and conclusion: The difference in cosmic ray exposure ages is attributable to the heterogeneity of EC 002 [1-3], resulting in heterogeneous production rates of cosmogenic nuclides, although we need further consideration. On the basis of the Ar-Ar spectrum, 99.98% (#a) and 97.8% (#b) of Ar yield identical ages. This result indicates that the cooling rate of EC 002 was so fast that no diffusion loss of ^{40}Ar* occurred during cooling. Such fast cooling is supported by the occurrence of silica minerals (cristobalite without quartz) [3, 7] and consistent with impact excavation [1, 3]. A slight difference between Ar-Ar and Al-Mg ages may represent a time-lag between Al-Mg and Ar-Ar systems' closure, possibly between crystallization and impact-excavation [1, 3], although the error of Ar-Ar ages are so large for precise discussion.

References: [1] Barrat J. A. et al. (2021) *PNAS* 118: e2026129118. [2] Mikouchi T. and Zolensky M. E. (2021) *LPS LII,* Abstract #2457. [3] Yamaguchi A. et al. (2021) *JpGU Annual meeting* Abstract PPS07-P09. [4] Roddick J. C. (1983) *GCA*, 47, 887-898. [5] Ebisawa N. et al. (2004) *J. of Mass Spectrom. Soc. of Japan,* 52, 219-229. [6] Kennedy T. et al. (2019) *GCA,* 260, 99-123. [7] Ono H. et al. (2021) *MAPS* (in press).