NOBLE GASES IN THE VERY PRIMITIVE CM CHONDRITES ASUKA 12085 AND 12236 – FILLING THE GAP.

H. Pacnik[1], L. M. Eckart[1], D. Krietsch[1], C. Maden[1], and H. Busemann[1], [1]ETH Zurich, Inst. of Geochem. & Petrology, 8092 Zurich, Switzerland (henner.busemann@erdw.ethz.ch).

Introduction: The pristine nebula material that our solar system, planets and minor bodies were initially made of can best be studied in pristine, often carbonaceous chondrites that originate from mostly unaltered asteroids. These formed 4.56 Ga ago and largely escaped severe parent body processing such as thermal metamorphism, partial melting, or planetary differentiation [e.g., 1]. However, evidence of milder forms of alteration, e. g. by aqueous alteration [2] or heating to comparably modest temperatures [3] can be observed even in type 1-3 carbonaceous chondrites considered most pristine. Parent body processing is recorded in meteorites and affected the compositions of the primordially trapped noble gas components that contribute to the meteorites' bulk volatile inventories [4]. Their - partially still unknown - carrier phases survived these processes to various degrees.

We initiated a systematic study to examine the consequences of parent body processing on the noble gases, group by group, but also to decipher e.g. consequences of terrestrial weathering [e.g., 5-8]. Understanding these modifications helps not only to sub-classify meteorites within a given group, identify most pristine and severely weathered members, or misclassifications, but will also provide data sets to allow modelling the volatile contents of those most primitive materials that could be potential building blocks of the terrestrial planets. Furthermore, it will help assessing the noble gases in the C-rich B- or C-type asteroids Ryugu and Bennu being sampled by current sample return missions [cf. 9 for first results].

In a recent study [6], we systematically outlined the effects of aqueous alteration, and to a lesser extent, thermal events, and the exposure to solar wind (SW), experienced by CM chondritic materials on their parent body(ies), or prior to their final accretion. We found that an important carrier phase is susceptible to mild aqueous alteration. This phase, possibly amorphous silicates [6, 10], although other perhaps additional carriers, such as e.g. C-, Fe, or S-rich phases cannot be ruled out, is easily identified as being particularly Ar-rich, but also carries the other noble gases He, Ne, Kr and Xe with diagnostic isotopic and elemental compositions, as found recently in a pristine CR chondrite [11]. Unfortunately, only a few CMs with petrologic types >2.5 (using the scale suggested in [12]) or >1.5 (as used by [13, 14]) were available for examination at the time of study by [6].

Here we present new noble gas data measured for two meteorites from the Asuka (A) dense collection area, A-12085 and A-12236. Both were reported to contain amorphous phases and to be among the most pristine CMs (types 2.8 and 2.9, respectively) found to date [15, 16]. The complete mass of only 2.3 g of another, even more pristine CM (A-12169, 3.0 [15]) was unfortunately too small to allow a similar examination. Nevertheless, the two CMs analyzed here perfectly complete and strengthen the trends suggested earlier [6], which we will discuss in the following.

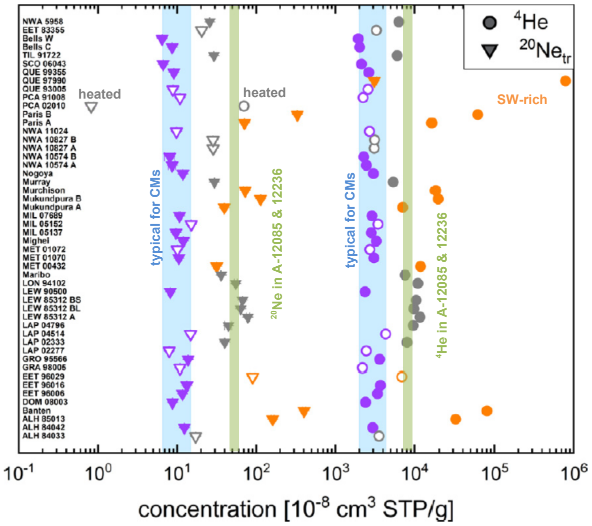

Fig. 1 Preliminary ^{4}He and ^{20}Ne concentrations in A-12085 and A-12236 compared to those of many recently measured CMs (Fig. taken from and modified after [6]).

Experimental: Both samples (2.2 mg of A-12236 and 15.5 mg of A-12085) were degassed in one temperature step at ~1700 °C in a crucible. Complete gas extraction was verified by essentially gas-free "re-extraction" steps at ~1750 °C. The noble gases were split into He-Ne, Ar and Kr-Xe-rich fractions and measured according to our standard protocols [6, 17] in a custom-built mass spectrometer. Blank corrections were essentially negligible, despite the small mass used for A-12236.

Results and Discussion: All new data support the trends observed earlier [6]. The Ne isotopic compositions place the two Asuka meteorites close to other CMs identified as most pristine, and indicate no clear major presence of SW, while a minor contribution cannot be excluded. The He and Ne concentrations (Fig.

1; in 10^{-8} cm^3/g of ~9000 for ^4He in both and ~65 and ~50 for ^{20}Ne in A-12236 and A-12085, respectively) are at the higher end of the range observed in primitive CMs (excluding those clearly containing SW, shown in Fig. 1 in orange) illustrating their pristine characters. The concentrations are similar e.g. to those in the very primitive CM LEW 85312 or moderately altered LAP 04796 (types 1.8 and 1.6, respectively, according to the scale by [13, 14]). Both Asuka CMs did not experience elevated temperatures [15], which is generally supported by the high noble gas concentrations. However, it needs to be noted that noble gases are severely depleted in CMs only once they experienced much higher temperatures of well >500 °C or “heating stage III or IV” [6,18].

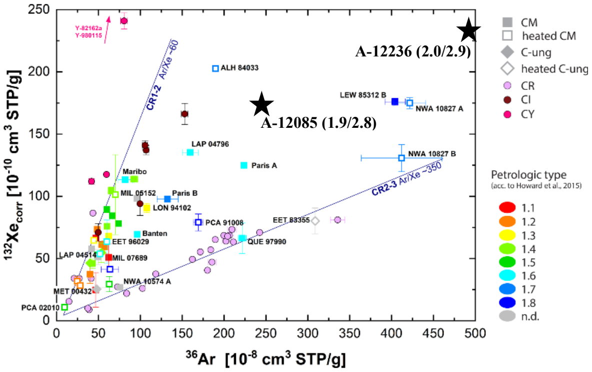

Fig. 2 Preliminary ^{36}Ar and ^{132}Xe concentrations in A-12085 (CM2.8) and A-12236 (2.9, both classified in [15] using the scale suggested in [12]). These are compared to many CMs, color-coded with petrologic types according to [14], CR and CI/CY chondrites [5-8]. Both new CMs would be of petrologic type 1.9 and 2.0 according to a formula given in [14]: Howard et al. scale = 0.96 × Rubin et al. scale −0.81). (Fig. taken from and modified after [6]).

In agreement with their classifications as type 2.9 and 2.8 CMs [15], A-12236 shows higher ^{36}Ar, ^{132}Xe concentrations, $^{36}Ar/^{132}Xe$ and $^{84}Kr/^{132}Xe$ ratios than A-12085 and both than most other CMs of types <2.6 [12] or < 1.6 [13, 14], respectively (Figures 2 and 3, [6]). A preliminary estimate of the exposure time to cosmic rays yields similarly for both CMs ~0.7-2 Ma, typically short for CMs, which may imply that the two rocks, found in the same icefield, might be paired.

In conclusion, the new noble gas data for A-12085 and A-12236 are consistent with their classification as some of the most primitive aqueously unaltered CM2s [15, 16]. They support the trends and conclusions found for the primordially trapped noble gases in CM chondrites by [6]. Furthermore, they add important new noble gas data to the carbonaceous chondrite database, necessary for comparison with the noble gas data obtained from asteroid Ryugu dust, recently returned by JAXA’s Hayabusa2 spacecraft [9].

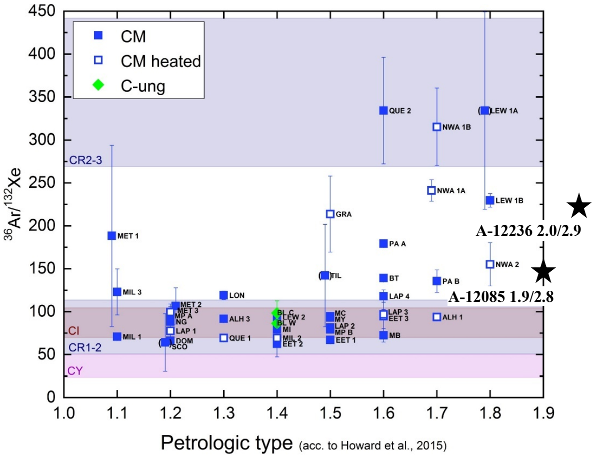

Fig. 3 Preliminary $^{36}Ar/^{132}Xe$ ratios found in A-12085 (CM2.8≡1.9) and A-12236 (CM2.9≡2.0), compared to those of many CMs [6] as a function of their petrologic types [14]. Ranges for CR and CI/CY chondrites [5, 8] are given for comparison. (see [6] for labels. Fig. taken and adopted from [6]).

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