NOBLE GAS, N AND C STEPWISE HEATING AND CRUSHING DATA FOR THE LUNAR METEORITE DHOFAR 1436

E.V. Korochantseva[1,2], A.I. Buikin[1], A.B. Verchovsky[3], J. Hopp[2], A.V. Korochantsev[1], M. Anand[3], M. Trieloff[2], [1]Vernadsky Institute of Geochemistry, Kosygin St. 19, 119991 Moscow, Russia, [2]Klaus-Tschira-Labor für Kosmochemie, Institut für Geowissenschaften, Universität Heidelberg, Im Neuenheimer Feld 234-236, 69120 Heidelberg, Germany (e-mail: Mario.Trieloff@geow.uni-heidelberg.de), [3]Planetary and Space Sciences, Department of Physical Sciences, The Open University, Milton Keynes, MK7 6AA, UK.

Introduction: ^{40}Ar-^{39}Ar data [1] on the lunar feldspathic impact melt breccia Dhofar 1436 showed that it is a gas-rich meteorite containing high concentrations of lunar trapped Ar, so-called "orphan" in rocks derived from the Moon [2]. In order to clarify the origin of orphan argon and to provide insight into its relation to the composition of trapped nitrogen, carbon and to other noble gas components, a combination of stepwise crushing and heating methods was performed for this breccia. Stepwise crushing is applied to a lunar meteorite for the first time.

Methods: The analyses were performed in two labs. Noble gases (He, Ne and Ar) from a whole rock (WR) sample of 117.5 mg were studied by stepwise crushing with cumulative number of strokes of 5000 in Heidelberg University (HU). At the Open University (OU) a WR sample of 19.78 mg was stepwise crushed with cumulative number of strokes of 12100. Part of the remaining powder of 4.96 mg and another WR sample of 3.12 mg were stepwise heated. At the OU nitrogen and noble gases (He, Ne and Ar) were measured during stepped crushing and combustion analyses while the carbon measurements were carried out only with combustion technique.

Results and discussion: The concentrations of ^{4}He, ^{20}Ne and ^{36}Ar equal to 569, 48 and 44 ($\times 10^{-6}$ cm^3 STP/g) released by crushing account for 93%, 86% and 76% of the total amounts extracted by crushing and subsequent heating of the remaining powder, respectively. Crushing analyses at HD extracted 34, 19 and 10 ($\times 10^{-6}$, cm^3 STP/g) of ^{4}He, ^{20}Ne and ^{36}Ar, respectively. In the first crushing steps ^{4}He/^{3}He ratios correspond to SW value and ^{20}Ne/^{22}Ne ratios are up to 12.57. The plot of ^{4}He/^{3}He vs.^{21}Ne/^{22}Ne and the neon 3-isotope diagram show a correlation that can be explained by mixing of solar-like and cosmogenic components, the latter is more pronounced in late crushing steps. Similar release patterns are observed for stepwise heating Ne data of Apollo samples reflecting a mixture of depth-dependent implantation-fractionated solar wind and GCR-component [3]. ^{40}Ar/^{36}Ar ratios of crushed samples range between 2-3, identical to $(^{40}\mathrm{Ar}/^{36}\mathrm{Ar})_{trapped}$ ratios reported in [1]. ^{36}Ar/^{38}Ar ratios of crushed samples are 5.31-5.40 and slightly decreasing in the final steps. The heated powder yielded lower ^{36}Ar/^{38}Ar ratios of 4.44-4.59, while the heated WR sample yielded intermediate values between 4.6 and 5.1. In all analyses the ^{4}He/^{20}Ne and ^{4}He/^{36}Ar ratios are strongly fractionated relative to SW but their behavior is distinct during stepwise heating and crushing: They decrease with progressive heating because of the higher He diffusion rate compared to Ar and Ne and increase with progressive crushing presumably due to additional contribution of radiogenic He from the mineral lattice [4].

The C abundance of heated WR sample is 555.3 ppm, with δ^{13}C of -28‰ to +11‰. N_2 contents released by crushing and by WR heating are 3.2 ppm and 20.8 ppm, respectively. In the beginning of crushing δ^{15}N decreases from -12‰ to -36‰ and further starts increasing up to +4‰. The ^{15}N-enriched signature is likely related to N_2 atmospheric contamination in the first steps and to a contribution of GCR component in final steps. The latter is supported by the aforementioned noble gas isotopic composition trends. The lightest nitrogen composition (δ^{15}N=-79‰) associated with the most ^{13}C-enriched signature (+11‰) and with minimum C/N ratio of 3.7 is measured during stepwise heating of WR sample at release peak of 1200°C, that is also the main degassing peak of Ne and trapped Ar [1].

Conclusions: The orphan Ar degassing at high temperatures during stepwise heating of Dhofar 1436 was trapped in gas inclusions. Its origin is related to the impact event caused by the last total reset of the Ar-Ar-system [1]. The isotopic compositions of trapped He and Ne are dominated by the SW component fractionated upon redistribution following the impact event. The composition of lunar trapped gases depends on the proportion and fractionation of mobilized and redistributed different noble gas components (radiogenic, re-implanted ^{40}Ar [e.g., 5], solar, cosmogenic) accumulated before the impact event in regolith material of the Moon. Hence, the calibration connecting the composition of orphan argon in lunar rocks and the antiquity [e.g., 2] is hardly possible. The crushing data of He and Ne also indicate a higher contribution of the cosmogenic component in advanced crushing steps. This is also observed for Ar and N_2. We assume that these cosmogenic gases were accumulated after the discussed impact event and are extracted from GCR tracks.

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