NOBLE GASES AND NITROGEN RELEASED BY CRUSHING FROM PESYANOE AUBRITE.
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Introduction: Aubrites are enstatite achondrites of magmatic origin [1] and probably formed in a common oxygen reservoir of E-chondrites, Earth and Moon [2]. The Pesyanoe aubrite (fell 1933, Russia) is a gas-rich polymict regolith breccia [3] consisting of several pyroxenitic lithologies, clastic and melt breccias, melt rocks, glass spherules and exotic chondrite inclusions [4]. Two of pyroxenite lithologies include pyroxene grains that are enriched in gas-filled inclusions. An occurrence of the inclusions indicates a high fluid content in some of parent magmas of Pesyanoe pyroxenites and a re-distribution of volatiles during a post-magmatic evolution of the rock. To obtain the isotopic characteristics of the gases trapped into minerals as fluid inclusions of the meteorite during differentiation of the parent body we studied noble gases and nitrogen isotope composition in two pyroxenite lithologies (dark Px-G and light Px-B) releasing gases by stepwise crushing [5]. The evolved gases have been analysed on high sensitivity Finesse mass-spectrometric complex [6]. For that reasons the samples of Px-B and Px-G weighing about 1 g were prepared by manual selection of enstatite grains from the sample of Pesyanoe, provided by the Collection of Meteorites of RAS, and were crushed under vacuum in steps with progressively increased number of strokes. The evolved gases have been analysed on Finesse for C, N, He, Ne and Ar. The residual powder weighing few mg has been recovered and analysed by step heating.

Results: *Mineralogy and petrography:* Pesyanoe is a coarse-grained breccia, mainly consisting of fragments of pyroxene crystals. The sources of pyroxene are coarse-grained igneous rocks – pyroxenites. The pyroxene is mainly orthoenstatite; its composition is $En_{99}Wo_1$. Enstatite usually contains glass inclusions, and occasionally, inclusions of diopside ($En_{55}Wo_{45}$), albite ($Ab_{95}Or_{3.2}$), silica, K-Na feldspar ($Ab_{74}Or_{25}$), roedderite, F-richterite, djerfisherite, other sulfides, metal Fe and osbornite. Glass inclusions are varying in composition (wt%): SiO_2 (68.4-89.4), Al_2O_3 (5.14-21.8), K_2O (0.1-6.65), Na_2O (0.24-10.4), and have notable abundances of volatile elements - S (0.12-1.63), F (0-0.32) and Cl (0-0.24). The rare fragments of diopside contain of exolution lamellae of enstatite; the compositions of coexisting pyroxenes indicate an equilibration temperature ~900°C [7]. The optical properties of pyroxene show that breccia components were expiring a maximum shock pressure ~25 GPa [8].

Macroscopically, the transparent, white and gray populations of pyroxenes are recognised in the breccia. Some of white (Px-B) and gray (Px-G) enstatites contain numerous fluid inclusions (FI). The FI were observed as in transparent as in polished sections; in a last case FI are visible under the surface of section as opened rounded holes on the polished surface. Px-B contains rounded inclusions, 1-5 µm in diameter, oriented according to the crystal growth directions. Px-G contains two populations of fluid inclusions; first one is similar to that of Px-G, other population represents elliptic and polygonal inclusions, 5-20 µm in size, and belongs to the systems of sub-parallel closed cracks, oriented along the one of main crystallographic dimensions of the host enstatite grains. The FI are gas-filled, rare glass inclusions with the gas bubbles were found.

Isotopic data: The gases released by crushing contain very low amount of CO_2 (just several ng of carbon), so that it was not possible to obtain reliable isotope signature. However it seems to be negative $\delta^{13}C$ values (between -10 and -20 ‰ PDB). For He, Ne, Ar and N_2 content our data correlate with previous step heating data for the Pesyanoe light and dark lithologies [9]. Px-G contains the higher amounts of all these gases in the inclusions then Px-B. The amount of He and Ar released during crushing is comparable with that released by heating. The amount of Ne released by crushing comprises around 10% of heating release; for nitrogen it is even less than 1%.

Neon isotope composition in the samples reflects the presence of cosmogenic component – probably also in fluid inclusions. As a whole, Ne released by crushing from Px-B contains 3 to 4 times higher proportions of cosmogenic component then neon of Px-G. It is also reflected in higher $^{38}Ar/^{36}Ar$ ratios in Px-B.
The argon isotope composition in these two rocks is quite different: for Px-G $^{40}Ar/^{36}Ar$ ratios vary between 36 and 42 (except the first extraction where atmospheric contamination is rather strong); in Px-B inclusions $^{40}Ar/^{36}Ar$ ratios vary from 220 to 110, pointing to a stronger influence of radiogenic argon. The nitrogen isotope composition released by crushing is similar in the samples with $\delta^{15}N$ values between -13 and -25 ‰, that is rather light in comparison with our step heating data, where it reaches positive values up to +16‰ (and

up to +44 ‰, data for the dark lithology by [9]). $\delta^{15}N$ values in crushing steps well correlate with nitrogen content: the less nitrogen in the step, the higher $\delta^{15}N$ it has (fig. 1).

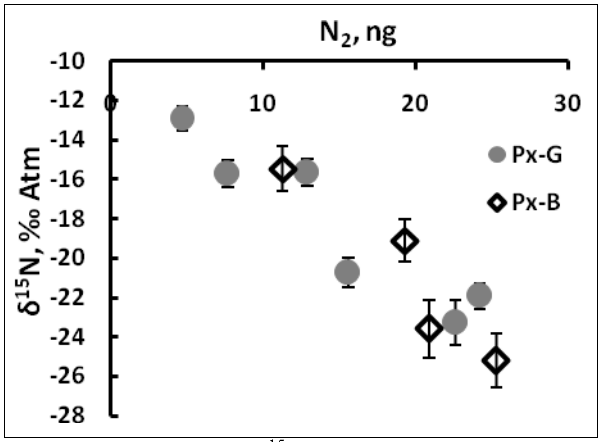

Fig. 1. Dependence of $\delta^{15}N$ values from nitrogen content in crushing steps in light (Px-B) and dark (Px-G) lithologies of Pesyanoe.

The same correlation can be observed at $\delta^{15}N$ vs N_2/Ar plot (fig. 2) the lower N_2/Ar ratios, the higher $\delta^{15}N$ values. Such variations could point to mixing between two different sources or to severe elemental and isotopic fractionation during formation of the inclusions.

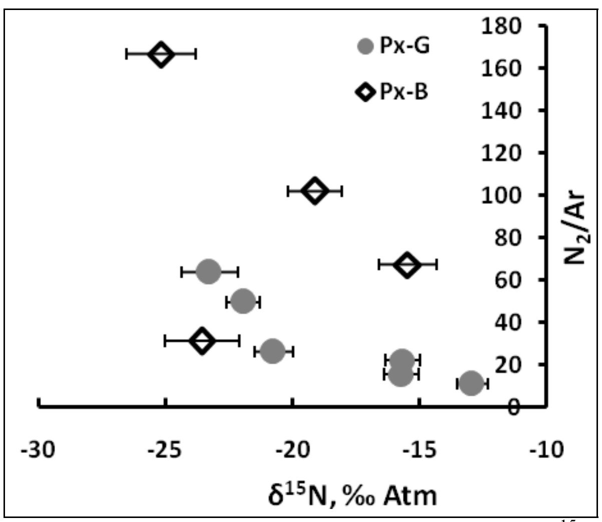

Fig. 2. Correlations between N_2/Ar ratios and $\delta^{15}N$ values in crushing steps of Pesyanoe light (Px-B) and dark (Px-G) lithologies.

As known, nitrogen and argon are characterized by similar solubility in silicate melts, and thus they should not fractionate during melt degassing and formation of the bubbles. The fractionation between nitrogen and argon could occur during distribution of the gases between melt and solid phase i.e. osbornite (TiN), which observed as inclusions in Px grains in Pesyanoe.

On the other hand, at the first crushing steps gases from the larger and less retentive fluid inclusions should be released. Such inclusions are described above in Px-G as secondary inclusions, which could be formed during redistribution of solar implanted gases at shock event led to the breccia formation. Indeed, the first crushing steps release nitrogen with higher proportion of light solar component (the same is for argon). With increasing number of strokes the smaller (primary?) inclusions and micro-defects formed by cosmogenic gases are being opened, and the proportion of cosmogenic Ne and Ar is increasing. At the same time, proportion of heavy nitrogen is also increasing with progressive crushing, indicating that this isotopically heavy nitrogen component could be a primary magmatic one.

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