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On the Separation Efficiency of Entrapped and in situ-Produced Noble Gas Components at Sample Crushing in Vacuum

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Abstract—The paper discusses specifics of gas separation techniques by means of sample crushing in vacuum, and, in particular, the stepwise crushing method for studying the sources and evolution of the fluid phase of rocks and minerals. The data on the Seblyavr massif, Kola Peninsula, are employed to demonstrate that, if the age of the minerals is old enough and they contain elevated concentrations of parental elements (U, Th, and K), in situ produced noble gas components can strongly distort the composition of the initially entrapped gases and thus result in misinterpretations of the analytical data. The application of stepwise crushing technique, as well as an individualized approach to data interpretation for each of the samples, makes it possible to solve the problem.

Keywords: He, Ne, and Ar isotopes, fluid inclusions, in-vacuum crushing, fluid sources

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INTRODUCTION

Recent years witness significant progress in studies of fluid phases in rocks and minerals with the application of various techniques that involve mechanical crushing of the samples in vacuum in order to extract gases entrapped as fluid inclusions (Hopp et al., 2007; Buikin et al., 2013, 2014a, b, 2017a, b; Akimova et al., 2017; Prasolov et al., 2018; and others). Data acquired in the course of such studies provide important information on the sources and evolution of the fluids and their involvement in the origin and alterations of the rocks and minerals. This is particularly important with regard for the fact that the fluid phase often serves as a transporting agent of strategic metals and many other ore components (Au, Ag, chalcophiles, REE, and other elements). The most valuable information on the genesis of fluids can be acquired by studying the isotopic composition of noble gases, because in contrast to major volatile components (H_2O and CO_2), these gases are chemically inert, and their composition is not modified by chemical interaction in the course of magmatic evolution. The contents of these gases in rocks and minerals are very low, and hence, these gases are highly susceptible to the addition of gas components generated by a diversity of nuclear reactions. Because of this, noble gases are widely used in, for example, cosmochemical studies. However, there is an "inconvenient" side in this property of rare gases. Namely, generated in situ (during the time elapsed since the formation of rocks and minerals) noble gas components can significantly modify the originally entrapped by rocks and minerals isotopic signatures of the gases. Until recently, most researchers (especially national, including the authors of the article) shared the opinion that these changes relate only to the lattice of the mineral and do not affect the gas–liquid inclusions. This was followed by the conclusion that the contribution of in situ radiogenic/nucleogenic gases can be neglected during the extraction of gases from fluid inclusions by means of mechanical crushing, because it is not able to destroy the crystal structures of the minerals. However, as has been demonstrated in (Scarsi, 2000), prolonged crushing of olivine and clinopyroxene can lead to the release of He contained in secondary inclusions and/or the lattices of the minerals. Yokichi with co-authors (Yokochi et al., 2005) have reported about releasing of considerable amount of cosmogenic He (up to 25%) from the olivine lattice during a prolonged crushing of this mineral. Below we use our data, including a detailed study of a pyroxenite sample from the Seblyavr ultramafic alkaline carbonatite complex, Kola Peninsula, to demonstrate that, when samples are mechanically crushed, the release of even minor amounts of in situ produced components