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Evaluation of radon specific exhalation in uranium-rich metamorphic rocks

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The processes of radon escape from a rock include emanation due to alfa-recoil of radon precursors, through which atoms are able to escape and to be trapped in pore spaces or in neighbouring grains, and exhalation, through gas-phase diffusion and advection, allowing radon to escape from pores and fractures reaching, eventually, the environment. The latter process can be expressed by the specific exhalation that depends on a number of chemical, physical and mechanical properties of the rock, such as uranium content and its distribution in the mineral grains, size and specific surface area of grains, degree of fracturing and fissuring, presence of water in cracks, and effective permeability.

Examples of studies on rock radon exhalation mainly concern volcanic and sedimentary lithotypes. In this paper, we investigate specific exhalation in two man-made cavities bored in metamorphic rocks, metarhyolites and porphyric schists, which underwent peculiar hydrothermal processes resulting in remarkable uranium enrichment. We combined spectrometric techniques and radon concentration measurements. Gamma-ray spectrometry was used to determine uranium activity concentrations, whereas solid-state nuclear track detectors provided radon concentrations. As the cavities were recently bored, firstly we evaluated the secular equilibrium condition by means of laboratory analyses performed on samples collected in one of the cavities. Results demonstrate also that the mineralization is not superficial but is related to mineral grains, homogeneously dispersed in the rock. Secondly, we performed calculations by tacking into account the variation of radon concentration with time, the radon from the rocks, the decaying radon atoms and the radon exchanged with the atmosphere. Due to the short monitoring period, a steady-state radon concentration is expected. No quantitative information on ventilation is available, but air temperature measurements allowed us to predict a unique ventilation regime with air flowing outside from the bottom of the cavities. Mass conservation calculations allowed determining the specific exhalation for the bulk rock. Results indicate that specific exhalation depends on the activity concentrations of uranium, but the relationship is not linear. In the cavity with the major specific exhalation, radon concentration is five times larger whereas activity concentration of uranium is less than three times.

In order to test this approach, we collected samples at points coinciding with those measured with gamma-ray spectrometry, and evaluated the specific exhalation with a laboratory technique. Samples were cut in tiles and enclosed in a dead-end volume. By taking into account the possible overestimation due to thoron contribution and back-diffusion, the exhalation rates were determined by means of radon concentration growth.

A comparison between the adopted approach and the laboratory measurements points out that the laboratory results could be regarded as lower bounds. Samples are small, massive and dry, thus the contributions of radon exhalated by fractures and water are ignored. Moreover, in the underground, uranium-bearing minerals are generally concentrated in heterogeneously spaced veins. Samples can reflect radioelement enrichment or depletion, whereas specific exhalation evaluated by means of the mass-conservation approach represents better average properties of a wider rock volume.