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Structural and Mechanical Factors on Radon Emanation During Heat Treatment Natural Mineral

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Abstract: Background radiation in space is largely determined by the radiological properties of materials and structures used in the construction of buildings. Mineral raw materials in the manufacture of building materials and structures are often subjected to heat treatment. Studied theoretically and experimentally increase radon emanation mineral raw materials as a result of the heat treatment. Analytical expressions for the activity concentration of radon and its rate of exhalation of mineral grains isometric form. On an example plagiogranites experimentally investigated the variation of the surface structure of samples and increase its radon emanation by increasing their porosity. The empirical dependence of the concentration of radon activity on temperature. The results of theoretical and experimental studies are qualitatively consistent with each other and indicate that the radon emanation of building constructions depends not only on the radiological properties of the original mineral but also on the heat treatment technology.

Key words: Building construction, mineral raw materials, radon emanation, temperature, structural alterations, porosity

INTRODUCTION

On radon and its decay daughter products account for about 75% of the dose to the population from natural radioactivity (ICRP, 1987; EPA, 2003). A significant portion of the dose (56-65%) due to radioactive materials and structures used in the construction of residential and industrial buildings (Goritskii *et al*., 1990; De Jong, 2010).

For the production of building materials and construction, raw materials with different natural radioactivity. Carrying out various processes (crushing, grinding, calcining, etc.) of natural raw materials mining leads to its physics-chemical and structural changes. Defect structure (micro-and macro-cracks), formed during the processing of mineral raw materials leads to a change in emission rates of radioactive gases into the environment (Keller *et al*., 2001).

To increase security, residential and industrial premises to study the effect of heat treatment on the ability of one emanation of the key components of building materials-granite.

THE MAIN PART

For natural minerals should be considered two stages radon migration (Nesmeyanov, 1972; McPherson, 1993):

- Radon emanation into the inner pore space
- Diffusion of radon atoms through pores with subsequent release into the ambient air

The release rate of radon into the internal pore space of the material is characterized by the emanation factor η, equal to the ratio of the number of radon atoms are highlighted in the pore space to the number of radon atoms formed in a solid matrix (skeleton) of the material. Typical value emanation factor for mining of mineral raw materials $\eta = 0.2$. Emanation of radon into the environment also depends on its diffusion coefficient in the air pore space D which has a value of 10^{-5}-1.2×10^{-5}(m^2/sec) (McPherson, 1993). Diffusion equation of radon atoms in the material is given by Keller *et al*. (2001):

$$\frac{\partial C_V}{\partial t} = \frac{D}{\varepsilon}\nabla^2 C_V - \lambda C_V + \lambda C_{max} \quad (1)$$

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Where:

$C_V(x, y, z)$ = Activity concentration of radon in the air pore space
λ = Radon decay constant (λ = 2.1×10^{-6} L sec^{-1})
ε = Porosity material
C_{max} = The highest possible activity concentration of radon in air pore space which is achieved in conditions of radioactive equilibrium and there is no leakage of radon from the material (Bq/m^3):

$$C_{max} = \rho C_{Ra}\eta/\varepsilon \quad (2)$$

Where:

ρ = Density material (kg/m^3)
C_{ra} = Activity concentration of radium in the material (Bq/kg)

Isolation of radon bulk minerals-quartz sand, crushed stone, gravel, granite, etc. the sum of the emanation of the individual grains (particles, pieces). Most of them have isometric form which is characterized by three main minor differences linear dimensions-length, width and thickness. When modeling the diffusion of radon from such particles will assume approximately spherical.

Write Eq. 1 in spherical coordinates and move to a new dimensionless variable $C = rC_V/(RC_{max})$ (Zeldovich and Mishkis, 1973):

$$\frac{\partial C}{\partial \tau} = \frac{\partial^2 C}{\partial x^2} - k^2C + k^2x \quad (3)$$

Where:

r = Radial coordinate (m)
R = Grain radius material (m)
$x = r/R$, $\tau = tD/R^2$,
$k = R/L, L = \sqrt{D/\lambda\varepsilon}$ = Radon diffusion length (m)

Under constant external conditions is a stationary regime of radon diffusion which is described by the Eq. 4:

$$\frac{\partial^2 C}{\partial x^2} - k^2C + k^2x = 0 \quad (4)$$

Equation 4 will be solved with the boundary conditions:

$$C\big|_{x=0} = 0,\ C\big|_{x=1} = 0 \quad (5)$$

Solution of Eq. 4 satisfying the boundary conditions Eq. 5 has the form:

$$C_V = C_{max}\left(1 - \frac{R}{r}\frac{sh(r/L)}{sh(R/L)}\right) \quad (6)$$

Speed exhalation E grain material is defined as:

$$E = -\varepsilon D \frac{dC_V}{dr}\bigg|_{r=R} = \frac{\varepsilon D C_{max}}{R}\left((R/L)cth(R/L) - 1\right) \quad (7)$$

As follows from Eq. 6 and 7 the main factors determining the rate of exhalation are the porosity of the material and the size of its grains.

The grain size of the mineral raw materials used for the production of building materials and structures (R = (0.001-0.03))m significantly less than the diffusion length of radon (L = (0.3-0.5) m) (Kovler *et al*., 2004) so $R/L \ll 1$ and $cth(R/L) \approx L/R + R/(3L)$. Then, Eq. 8 with regard to the expression Eq. 1 takes the form:

$$E = \varepsilon D C_{max} R/(3L)^2 = \varepsilon\rho\lambda C_{Ra} R/3 \quad (8)$$

Experimental studies of the effect of heat treatment on radon emanation made the example of granite. Granites investigated mineralogical composition corresponds plagiogranites (Pavlenko and Vetrova, 2006). The quantitative ratio of minerals plagioclase to total feldspar was 90-95%.

Differential thermal analysis plagiogranites, revealed the temperatures at which phase transformations accompanied by thermal effects: the 100, 450°C (endothermic) and 300°C (exothermic). Defectiveness granite structure was studied at these temperatures for a scanning probe microscope (class of atomic force microscopes) Stand Alone "Smena".

Scanning probe microscope Stand Alone "Smena" is a versatile atomic force microscope designed for a comprehensive study of surfaces of any objects.

Figure 1a shows the surface of the parent plagiogranites examined for scanning probe microscope (2D 50×50 μm) with a cross section 40 μm.

Figure 1b shows profilogram showing the flow probe on the surface plagiogranites. As seen from profilograms, granite surface has a structure close to the mirror.

Figure 2a and b presented granite surface after heat treatment at 100°C format 2D 50×50 μm, 3D 50×50×1 μm. When the temperature rises to 100°C, noticeable initial small spikes and dips stroke scanning probe microscope. It can be seen from the surface of the granite profilograms heat treated at 100°C (Fig. 2c) showing the progress of scanning probe microscope with a cross section 22 μm. This fact indicates the occurrence of microcracks on the surface of the granite.

Established (Nesmeyanov, 1972) that the 100°C intensified the process of radon emanation of plagiogranites (c 120 Bq/m^3 at 20°C to 135 Bq/m^3 at 100°C).

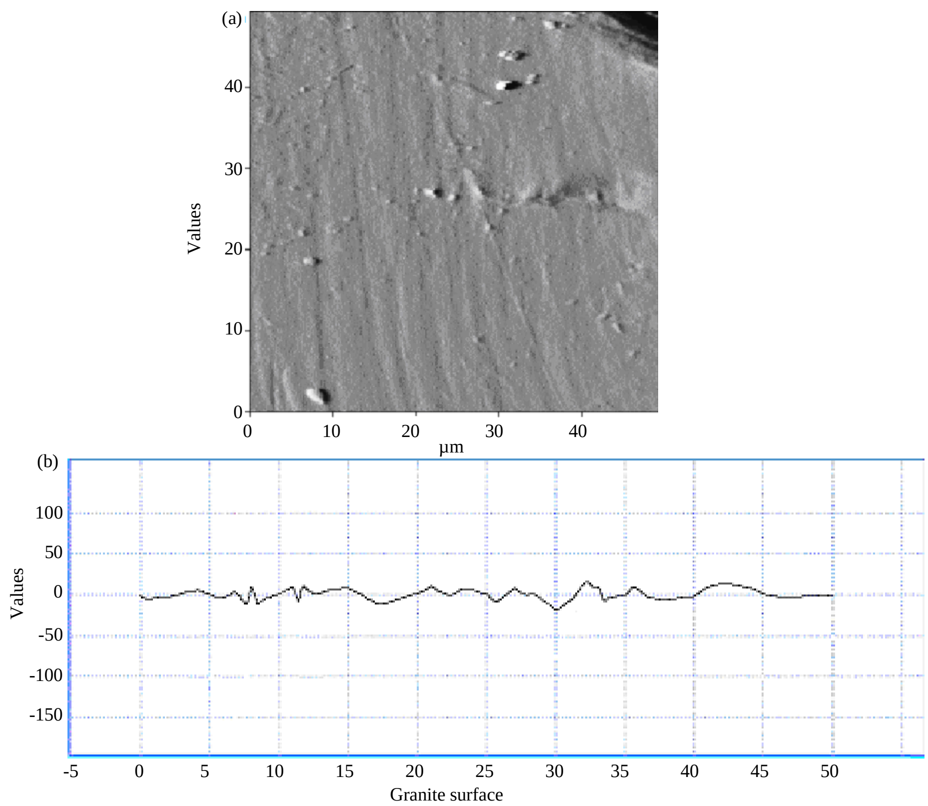

Fig. 1: a, b) Plagiogranites surface examined for scanning microscope

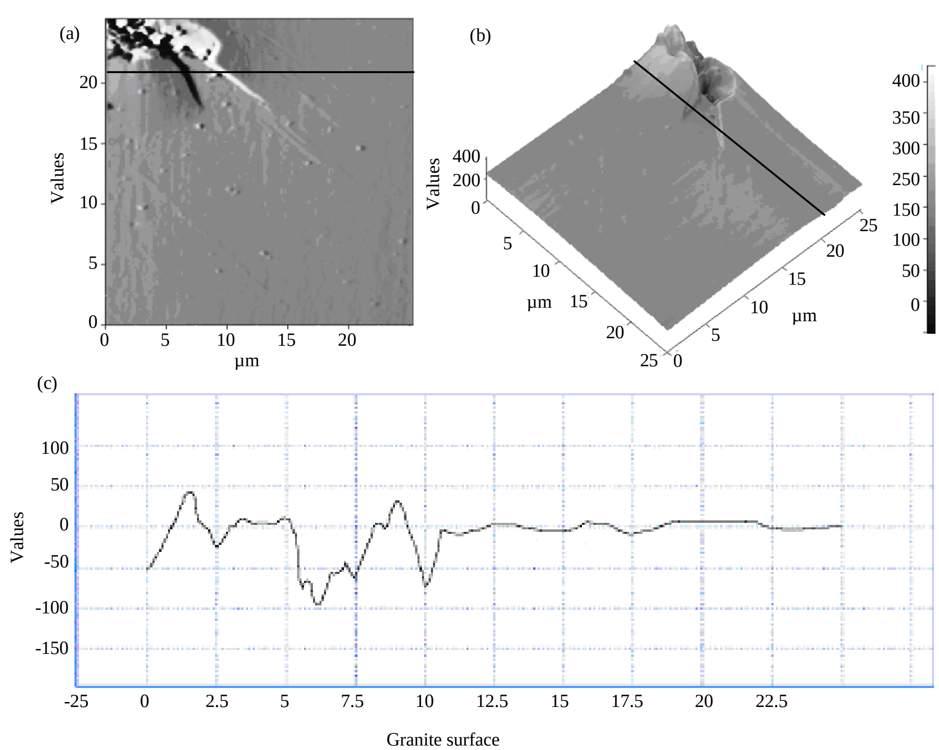

Fig. 2: a-c) Granite surface after heat treatment at 100°C, investigated by scanning electron microscope

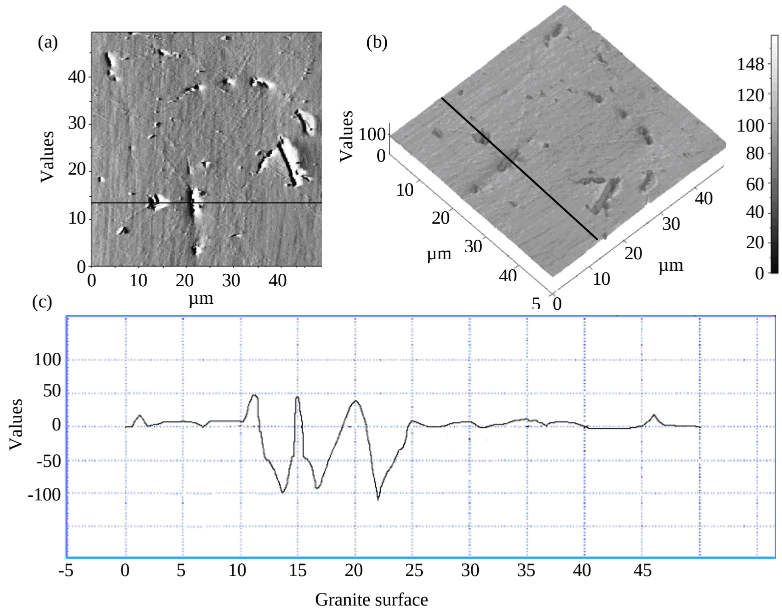

Fig. 3: a-c) Granite surface after heat treatment at 300°C, investigated by scanning electron microscope

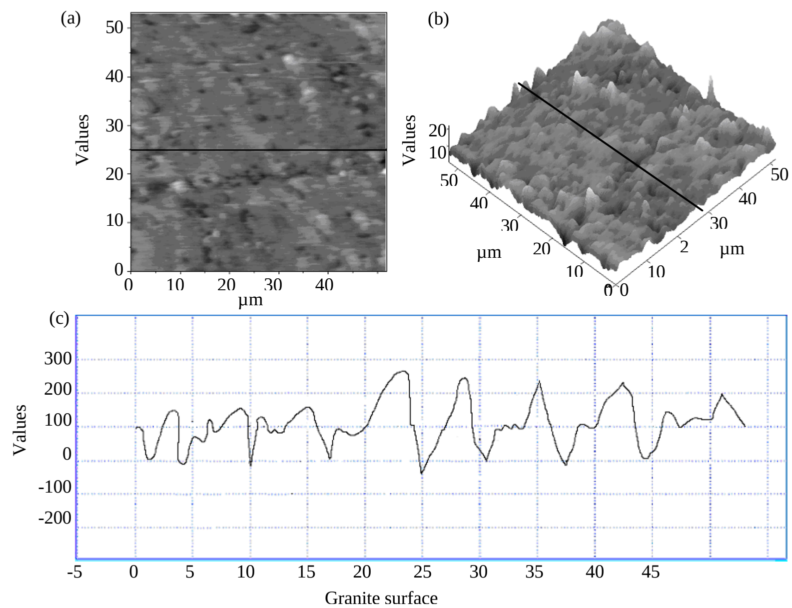

Fig. 4: a-c) Granite surface after heat treatment at 450°C, investigated by scanning electron microscope

Figure 3a and b presented granite surface after heat treatment at 300°C format 2D 50×50 µm и3D 50×50×1 µm, respectively.

Analysis profilograms (Fig. 3c) stroke scanning probe microscope in the field 14 µm on the surface of granite subjected to heat treatment at 300°C showed that the number of small bursts and dips probe markedly increased. This indicates the formation of microcracks on the surface due to the destruction of the mineral phases of granite. This process is accompanied by an increase in radon emanation from the surface of granite (to 140 Bq/m^3).

Figure 4a and b shows the surface after heat treatment at a granite 450°C format 2D 50×50 µm and 3D 50×50×1 µm, respectively.

After heat treatment at granite 450°C observed intense bursts and dips scanning probe microscope with a cross section 25 µm throughout the study area (Fig. 4c).

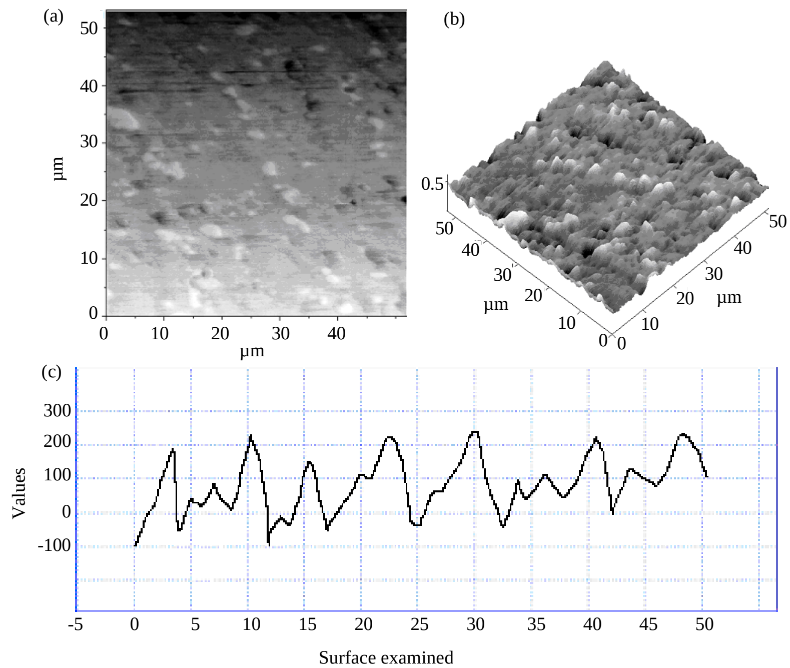

Fig. 5: Granite surface of, heat-treated at 450°C after cutting; a) 2D 50×50 μm; b) 3D 50×50×1 μm and c) profilogram stroke scanning probe microscope in the field 20 μm

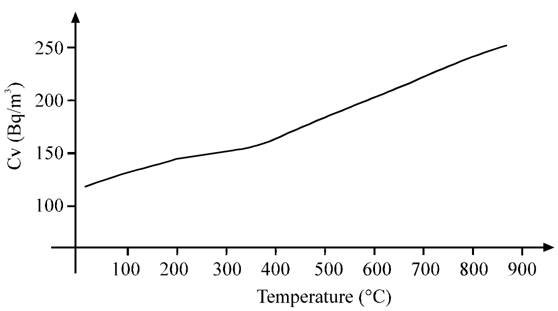

Fig. 6: Granite emanating ability on heating

This represents a significant destruction of granite surface with the formation of more micro and macro cracks. These structural changes on the surface and in the bulk granite accompanied by an increase in radon emanation to 160 Bq/m^3. This is also confirmed by the study of cut granite after heat treatment to 450 °C (Fig. 5).

Emanating capacity increase in the temperature range of granite 100-450°C, apparently due to mechanical factors structurally (separate mineral phase dissociation and the formation of micro-and macrocracks) which leads to an increase in the porosity of the material. Found as a result of processing of the experimental data of radon activity concentration dependence on temperature is shown in Fig. 6.

Figure 6 shows that the increase in granite emanating capacity with increasing temperature with sufficient accuracy can be approximated by a linear dependence. Because the speed of exhalation associated with activity concentrations linear balance equation, the increase in the rate exhalation when heated material is also subject linear law. This suggests that the above results of mathematical modeling and experimental data are in qualitative agreement with each other.

FINDINGS

- Speed exhalation natural minerals increases with its porosity and the size of its grain
- Thermal treatment of mineral raw materials leads to an increase in porosity and emanating capacity
- Technologies of building materials and structures should provide the minimum possible thermal processing of minerals

CONCLUSION

The main source of radon in the room is minerals which is part of building structures. The main factors determining the rate of radon emanation is the concentration of radioactive elements in the raw materials, the grain size of the raw material and its porosity. With the created mathematical model that an increase in porosity of grains of minerals and their size leads to an increase in the speed of exhalation. This conclusion is confirmed experimentally by the increase in the rate of emanation granite samples as a result of heat treatment which leads to irreversible damage of the structure of the material and increase its porosity. The results of theoretical and experimental studies are consistent with each other and show the need for low-temperature processing technology in the production of mineral building materials and structures.

REFERENCES

De Jong, P., 2010. Exposure to Natural Radioactivity in the Netherlands: The Impact of Building Materials. VDA, Arnhem, Netherlands, ISBN-13: 9789036743259, Pages: 186.

EPA., 2003. Assessment of risks from radon in homes. EPA 402-R-03-003, United States Environmental Protection Agency (EPA).

Goritskii, A.V., T.I. Likhtarev and I.P. Elk, 1990. Radioactivity of Building Materials. Builder Publishers, Kiev, Ukraine, pp: 38.

ICRP., 1987. Lung cancer risk from indoor exposures to radon daughters. Ann. ICRP, 17: 1-60.

Keller, G., B. Hoffmann and T. Feigenspan, 2001. Radon permeability and radon exhalation of building materials. Sci. Total Environ., 272: 85-89.

Kovler, K., A. Perevalov, V. Steiner and E. Rabkin, 2004. Determination of the radon diffusion length in building materials using electrets and activated carbon. Health Phys., 86: 505-516.

McPherson, M.J., 1993. Radiation and Radon Gas. In: Subsurface Ventilation and Environmental Engineering, McPherson, M.J. (Ed.). Chapman and Hall, London, UK., ISBN-13: 9780412353000, pp: 457-487.

Nesmeyanov, A.N., 1972. Radiochemistry. Khimiya Press, Moscow, pp: 591, (In Russian).

Pavlenko, V.I. and Y.V. Vetrova, 2006. Radioactivity and radon emanation of plagiogranites. Build. Mater., 11: 34-35.

Zeldovich, Y.B. and A.D. Mishkis, 1973. Elements of Mathematical Physics. Nauka Publishing, Moscow, pp: 351, (In Russian).