Sharapov V.N., Akimtsev V.A., Cherepanov A.N. On the kinetics and dynamics of heat-mass transfer in fractured porous rocks of the lithosphere above the area of basic melt boiling

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"Joining" of several tasks was used for the quantitative description of mass-heat transfer kinetics and dynamics for a spectrum of phase relationships of vapor-liquid-crystal (VLC) type associated with the processes of sublimation, local melting and precipitation from the gas phase: (1) degassing of crystallizing basic melt in the range of pressures from 0.5 to 10 kbar (KP KOMAGMAT was used to obtain a state diagram), (2) calculation of the equilibrium composition of the gas mixture for the temperature 900-1300^{o}C range (PK SELECTOR) estimated from the solution of the degassing task, (3) kinetics of basic and ultrabasic rock sublimation was described as the first approximation by a model of a volatile evaporation from the diffusion layer to the gas flow at the crystal surfaces of the rock in the even cracks, (4) rock melting "through" the liquid film of the gas condensate in the crack wall, (5) quasistationary crystal growth from the gas mixture of variable density according to VLC scheme on the crack wall.

The quantitative results are obtained on the first two tasks in the mentioned list. The results of instrumental studies of morphology and inner structure of crystals formed at sublimation of joining, cataclastic and budinaged gabbroids and ultrabasic rocks (xenoliths in basalts) were collected and systematized on the third and the fifth tasks. The model of sublimation kinetics is also developed. The qualitative results of the study on sublimation in the lithosphere rocks confirm that different intensity of the mentioned phase relationships is fixed for the different depth facies, which the authors preliminarily associate with density of the gas flow and also with local temperature gradients and change of the gas mixture composition during the magma boiling. Metasomatic processes near the contraction cracks, partial melting of the crack surfaces and deposition from the gas phase (most common) are typical for the volcanic and subvolcanic facies. The sublimation processes, rock melting near the crack walls up to formation of 10-15 vol.% bubbled basic melt migrating in cracks under the influence of the gas flow are predominant in the abyssal facies. Sublimation of mantle ultrabasic rocks is structurally displayed as net of cracks in olivine and pyroxenes and also pores at crystal boundaries. "Step" between the cracks can be about 0.15 mkm, width of cracks – from hundredth to tenth portions of micron. Their surface is "rigid" – presence of benches and cavities commensurable with a crack width. The chains of "bubbles" of 0.015-0.1 mkm in size with the 0.07-0.01 mkm gaps between them are observed along the cracks in crystals. The presence of dendrites, box-like and needle-like crystals of clinopyroxene, plagioclase, K-feldpspar and apatite on the crack walls and on the surfaces of olivine and orthopyroxene crystals is usual. Formation of chromite thin films on the etching surfaces of olivine and pyroxenes is typical. The sublimation of the flat crack walls in rock under the influence of filtrating magmatic fluid is described by the following quantitative model.

Let us consider that the cracks have the shape of flat channel and are evenly distributed in parallel to one another. Their width is much more than the diffusion layer thickness, changing of which during the evaporation of volatile compounds is negligible. The fluid moving along the cracks has constant average values of rate ν and temperature T_f for the channel section. Let us consider the coordinate system (x, z) with z-axis passing through the crack middle and x-axis perpendicular to the crack walls. According to the taken assumption on homogeneity of crack distribution and film surfaces let us consider the sublimation process for the channel semi-cell formed by a plane passing through z-axis and through the middle of the band of a host rock dividing the neighbor channels. Under the taken assumptions the system of equations and sublimation conditions are as follows:

$$c_s \rho_s \frac{\partial T}{\partial t} = \lambda_s \frac{\partial^2 T}{\partial x^2}; \quad X_s(t) \le x \le X_k; \qquad (1)$$

$$c_r \rho_r \frac{\partial T}{\partial t} = \lambda_r \frac{\partial^2 T}{\partial x^2}; \quad X_k(t) < x < X_0; \qquad (2)$$

$$-\lambda_s \left.\frac{\partial T}{\partial r}\right|_{X_s(t)} = \alpha(T_f - T_s) - \kappa_s \dot{M}; \qquad (3)$$

$$\lambda_s \left.\frac{\partial T}{\partial r}\right|_{X_{k-0}} = \lambda_r \left.\frac{\partial T}{\partial r}\right|_{X_{k+0}}; \quad T\Big|_{X_{k-0}} = T\Big|_{X_{k+0}}; \qquad (4)$$

$$\left.\frac{\partial T}{\partial r}\right|_{X_0} = 0, \qquad (5)$$

$$T\Big|_{t=0} = T_0, \qquad (6)$$

where c, ρ, λ - heat capacity, density and heat conductivity, respectively; the sublimating substance and rock parameters are marked by *s* and *r* indexes, respectively; α - coefficient of heat transfer from the fluid to the sublimating surface; κ_s – sublimation heat; $\left.\frac{\partial T}{\partial r}\right|_{X_s=0}$ – sublimation mass rate; T_f – fluid temperature. The concentration in the fluid volume, compared to that on the sublimation surface, being negligible the *M* value will be determined by the low of convective mass exchange

$M = \beta C_s$ (7),

where C_s – mole concentration of a volatile substance.

On the other hand, C_s value is connected with saturation pressure P_S and temperature T_S in the following equation

$C_S = P_S/RT_S$. (8)

Taking (7), (8) and Ps = P*e ($-\kappa_S$/RT) into account the equation (3) will be as follows:

$$-\lambda_s \left.\frac{\partial T}{\partial r}\right|_{X_s(t)} = \alpha(T_f - T_s) - \kappa_s \frac{\beta P^*}{RT} e^{-\kappa_s / RT_s}. \qquad (3a)$$

An approximate solution of such a task on sublimation dynamics by dimensionless equations was obtained. An algorithm for numerical experiments was developed. A quantitative estimate of sublimation dynamic parameters is supposed to be based on "joining" of the task of the basic melt retrograde boiling during cooling in the magmatic chamber and the suggested model of mass and heat transfer above the magmatic chamber.

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