Shmonov V.M. [1], Vitovtova V.M[1]., Zharikov A.V.[2] **Fluid permeability of the Earth crust (experimental data on a rock permeability at high temperatures and pressures)**

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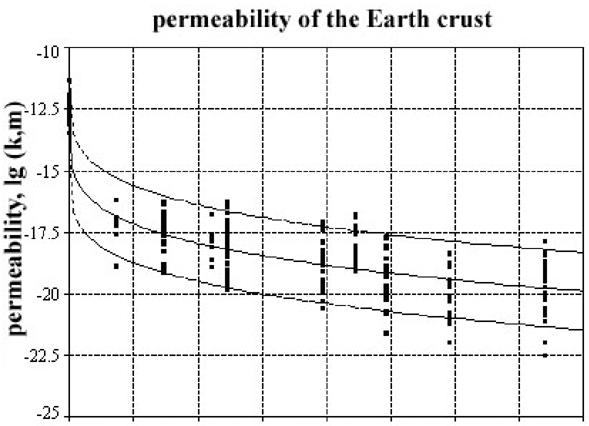
Permeability is a fundamental geochemical characteristics, which determines a mass transfer, migration, and accumulation of chemical elements in the Earth crust. According to recent estimations [1], a thickness of the continental crust is 40 km. There are regions of low thermal flux (thermal gradient 9^{O}C/km) of average and high thermal fluxes, 15 and 26^{O}C/km, respectively [2]. An average gradient of lithostatic pressure is 270 bar/km [1]. In accordance with the assumed thermal fluxes and the gradient of lithostatic pressure, which are measured geophysically, it would be expected, that temperature at the depth 40 km can be within 360-1040^{O}C at $P_{tot} = P_{fl} = 10.8$ kbar. An effective pressure in the Earth crust, which is responsible for the rock permeability, can not be measured by geophysical methods. In order to determine it, an "effective pressure law", i.e. $P_{eff} = P_{tot} - \alpha P_{fl}$, can be applied. A value of α are known only for ambient temperatures. According to [3], the most probable value of this coefficient is 0.85-0.95. Thus, if $P_{tot}=P_{fl}$, the effective pressure in the crust can vary from 54-162 bar at 4 km up to 540-1620 bar at 40 km.



This interval of the effective pressure (54-1620 bar) at temperatures 20-600^{O}C was included in our experimental study of the rock permeability [4, 5, 6]. The fluid permeability of amphibolites and gneisses of the Kola borehole, the Novoukrainian and Varzobskii granites, granodiorite, and diorite of Sayak deposit (11 samples, 132 experimental points) was measured by the method of the stationary gas filtration. In order to determine the values of permeability from the surface to 5-7 km, we used our data [7] on the permeability of sand, sandy loam, loam, and humus soils, obtained in the Orlovka region (Eastern Transbaikalia). An interval of the permeability on different depths of different rocks is within 4 orders of magnitude. Within this interval, most samples show a regular decrease of the permeability with depth. This allowed determination of the general regularity: the decrease of the rock permeability with depth. The figure show a general trend of the permeability of crustal rocks, deduced from our experiments. The permeability, k (m^2), decreases with depth, H (km), according to the power law log $k=a+bH^C$, where a = -12.56, b = -3.225, and c = 0.2230 (the central curve). The predicted interval at 90 % of probability is confined by two boundary lines.

According to [8], the permeability values are from 6.3×10^{-18} to 7.9×10^{-16} m^2 during metasomatism in the shear zones, 1×10^{-19} to 4×10^{-17} during the contact metamorphism, and 1.8×10^{-21} to 3.55×10^{-18} during the regional metamorphism.

According to the regional analysis of ground water fluxes and thermal transfer [9] in the upper crust, the permeability is within 10^{-17}-10^{-14} m^2. In the active metamorphic systems, the paleo-permeability predicted from the necessary fluid fluxes decreases from 10^{-16} down to 10^{-18} m^2 at the depths from 5 to 12 km. Below 12 km, where the rock state is brittle-plastic, the average paleo-permeability is $10^{-18\pm1}$ m^2 and practically does not depend on depth [9].

We have estimated [10] the paleo-permeability of the sand-schist sequence by the value of oxygen ratio during metasomatism. The obtained value is by three orders of magnitude higher than the experimental one. Such deviation is not unexpected. The paleo-permeability is an integral value in time (for 100 thousands years – 1 million years). During the separate moments of time, it could increase ot decrease under influence of varying temperature and pressure, and physico-chemical processes, etc.

Thus, the paleo-permeability measured from the isotopic exchange [10] and metamorphic systems [8, 9] presents the permeability during the long period, and, as a rule, is higher than the experimental values [4, 5, 6]. The latter characterize the crust state in mechanical and physico-chemical equilibrium.

Conclusions.

1. The experimentally measured permeability of the Earth crust (k, m^2) decreases with depth (H, km) according to the power law log $k=a+bH^C$, where a = -12.56, b = -3.225, and c = 0.2230.

2. The permeability varies from $2.75\times10^{-13\pm1.9}$ m^2 at the surface up to $1.67\times10^{-20\pm1.5}$ m^2 at the crust bottom, and changes with the rock type.

3. The experimental permeability reflects the crust state in the isotropic strained state ($\sigma_x=\sigma_y=\sigma_z$) in the case of absence of physico-mechanical ($d\varepsilon_x= d\varepsilon_y= d\varepsilon_z$) and physico-chemical ($\Delta G = min$) processes.

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