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Probably reasons of Apparent Permeability Loss over Time in Long-term Measurements

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Background

- In the last few years, a study of filtration properties of ultralow-permeable rocks has acquired particular significance. Such rocks can be subjected to considerable compaction during oil field development, which manifests itself in the permeability loss in time under constant net confining stress
- In the laboratory, the compaction (or creep) of porous rock samples under constant stress was observed by many researchers for experiment durations ranging from several hours to several weeks. Conducting such lengthy filtration experiments is accompanied by a number of challenges
- It is necessary to exclude the factors which are not related to the deformation of the sample. In this study, we analyzed possible causes of the time trends observed in the long-term filtration tests of low-permeable core samples
- We suggest that observed significant decrease in the permeability over time can be caused by clogging of the tested sample pore space by gas dissolved in the fluid

Procedure

- Experimental study of flow in a limestone core sample taken from the aquifer well was conducted
- Before the start of the series of tests, the sample was evacuated and saturated
- The filtration properties of the sample are studied with the steady-state method in a flow of water or gas (nitrogen)

- Apparent permeability of the sample is calculated according to the Darcy law under stationary flow conditions
- Over the series of tests lasting 40 days, the fluid pumping was carried out in several stages with different constant values of the confining pressure (0.7 - 15 MPa) and the pore pressure (0.05-0.15 MPa)

Experimental setup

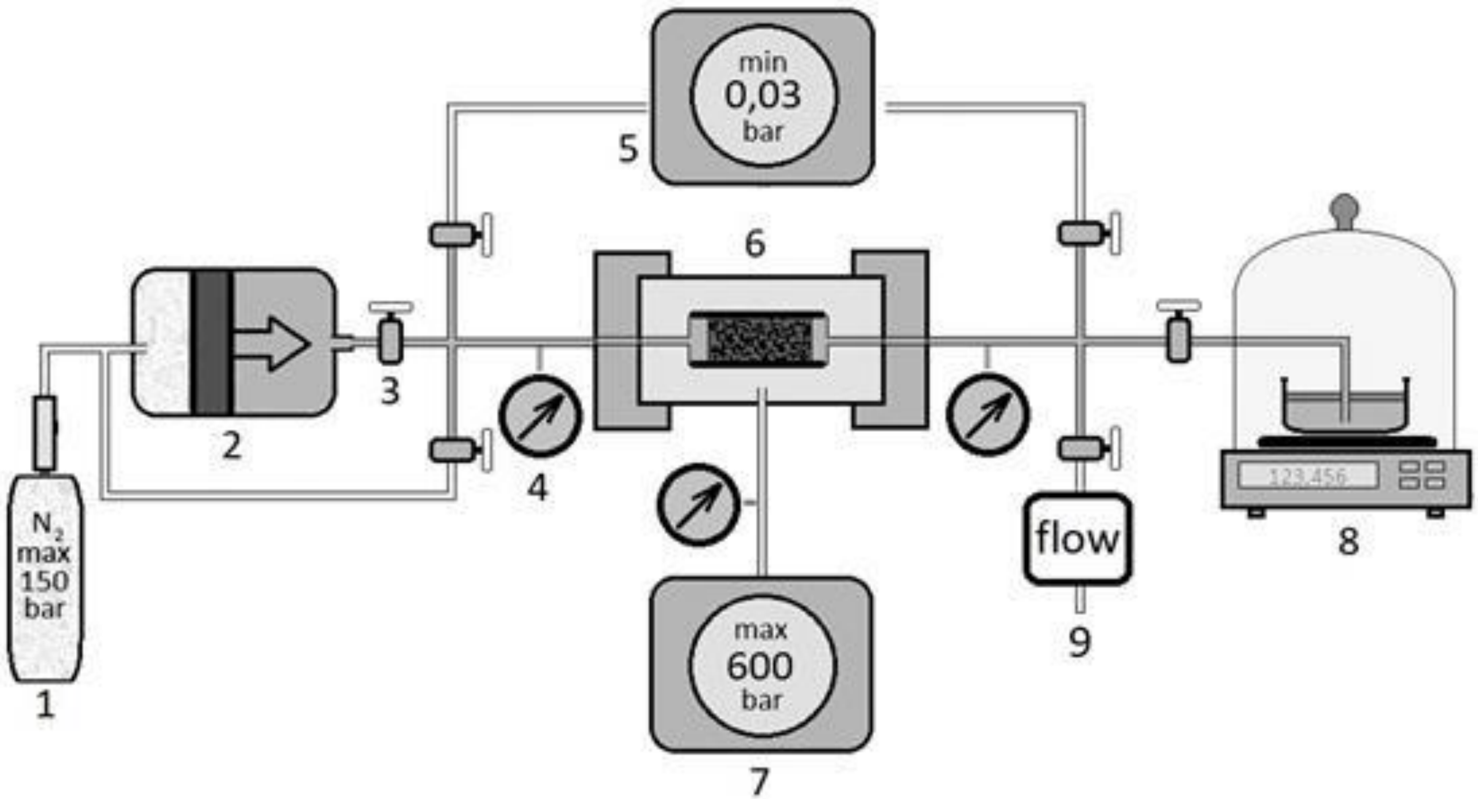
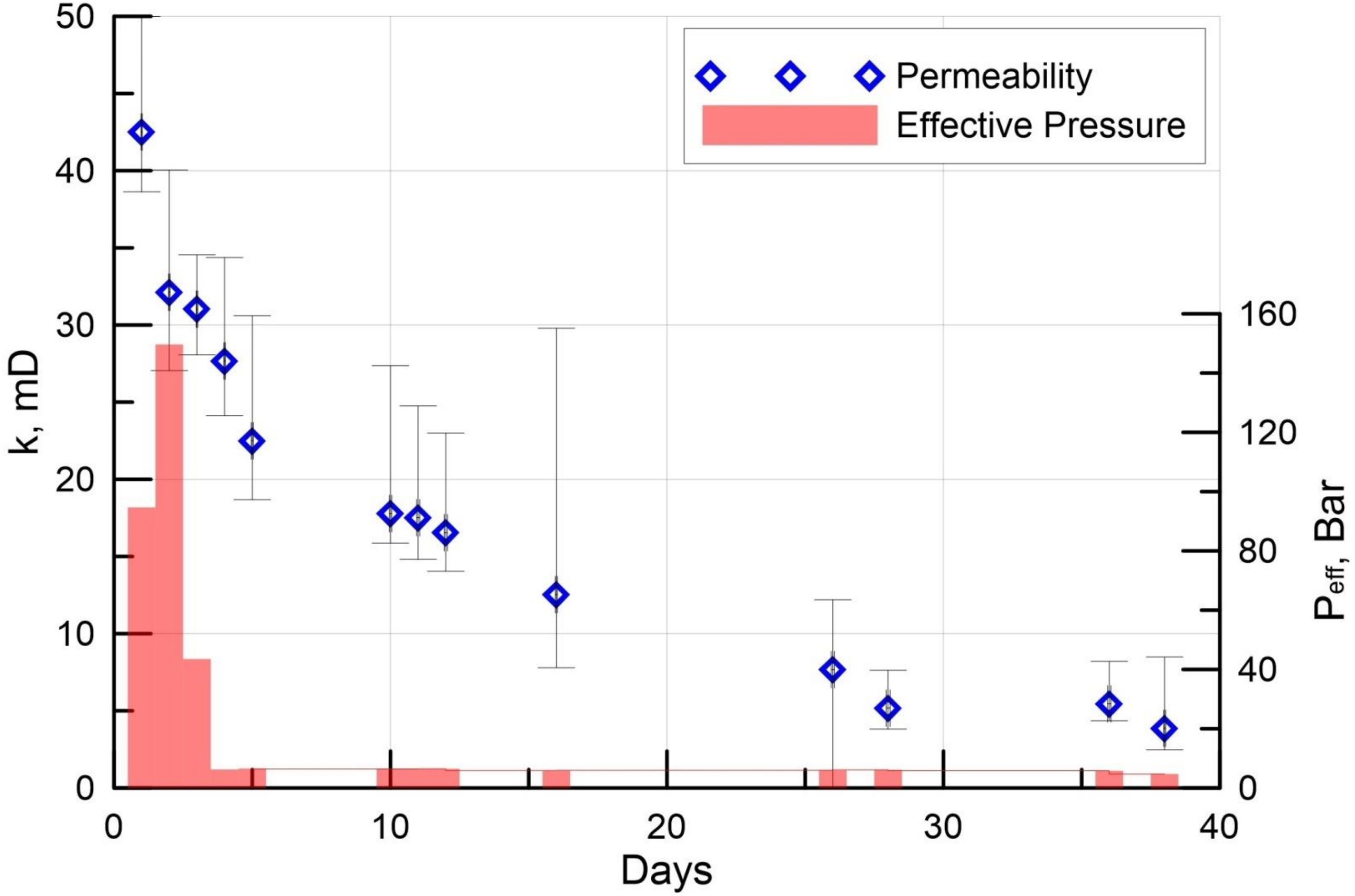


Fig. 1. Experimental setup. 1 – buffer tank; 2 – hydroaccumulator; 3 – valves; 4 – pressure sensors; 5 – vacuum pump; 6 – core holder; 7 – high pressure pump; 8 – balance with tank for accumulated fluid; 9 – thermal mass flow meter

Effective pressure and permeability of the sample over the series of tests with time.



Each point corresponds to the average permeability measured during each test.

We suggest that a significant decrease in permeability over time could be caused by clogging of the pore space of the sample.

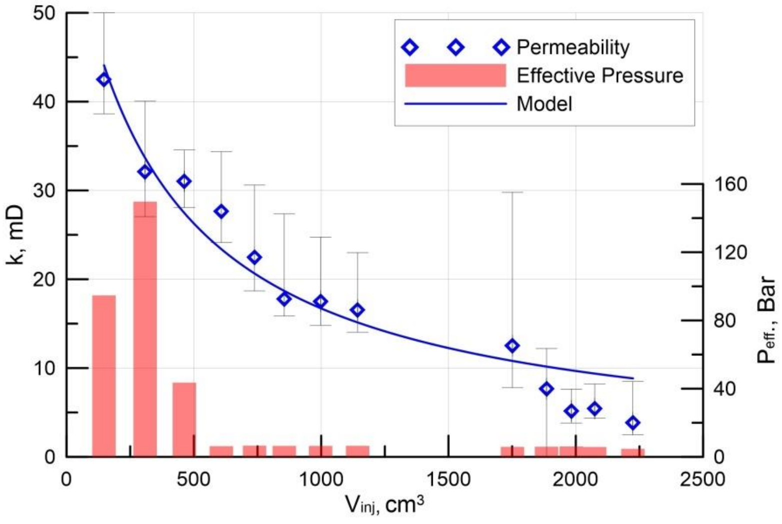
The change in permeability *k* of a porous medium filtering thin suspension with a constant concentration of particles can be described by the equation [1]

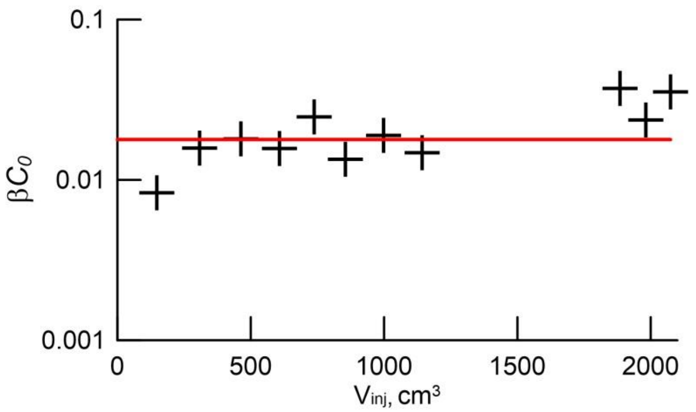
$$k = k_0 \frac{1}{1+\beta C_0 V_{inj}(t)/V_{pore}} \approx 1-\beta C_0 V_{inj}(t)/V_{pore}$$

$V_{inj}(t)$ - volume of fluid pumped through the sample

V_{pore} - total pore space volume

C_0 - initial volume fraction of particles

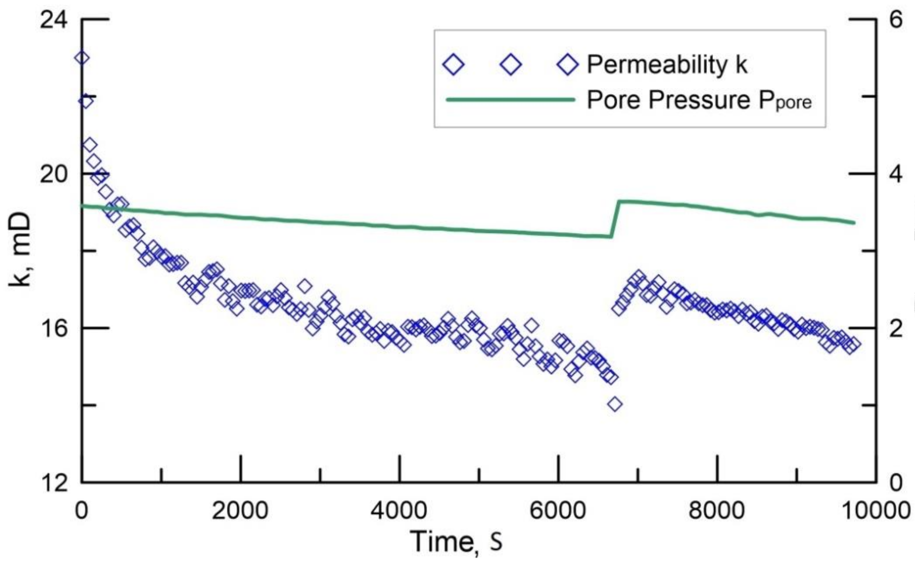


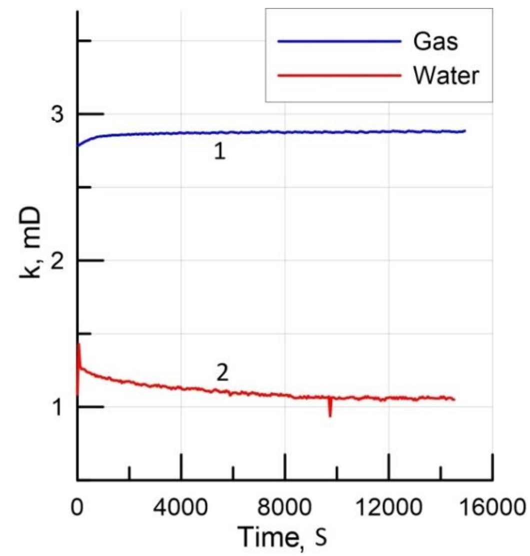


βC_0 value for each stage of the experiment with the total volume of liquid pumped. The line shows the value of the coefficient for the entire experiment.

1. Mikhailov, D. N., Ryzhikov, N. I., & Shako, V. V.: Experimental investigation of transport and accumulation of solid particle and clay suspensions in rock samples. Fluid Dynamics, 50(5), 691–704 (2015), doi:10.1134/s0015462815050117

We propose that gas contained in the flow of liquid can act as a dispersed phase that clogs pores.





- This is indicated by significant effect of a slight increase in the pore pressure on permeability of the sample (left figure).

- In additional tests with sequential single-phase nitrogen and water flows (left figure) permeability is almost constant in the gas flow but decreases in the water flow.

Conclusion. The possibility of clogging of core sample pore space must be considered when conducting long-term experiments on study of the permeability by the steady-state method.