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Imbibition rate of water in sandstone and its rate-determining process

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When a rock contacts water, spontaneous imbibition of water proceeds by capillary force. Lucas-Washburn (L-W) equation is often used as the equation which can express the relationship between the distance of water penetration (x), time (t) and pore radius (r): $x^2=r\gamma t\cos\theta/2\mu$, where μ is the liquid viscosity, γ is the liquid surface tension, and θ is the contact angle. It is generally known that a pore size significantly smaller than the main pore size is obtained by inserting measured values of x and t in the L-W equation. We evaluated whether the reason is related to a factor not considered in the L-W equation or the imbibition rate is indeed controlled by the imbibition in small pore. Berea sandstone from Ohio, USA, was used in the experiment. The main pore radii of the sandstone are 1-100 μm and more than 95% of the pores have radii greater than 3 μm. First, the bottom of a dried rock core (diameter 2.6 cm; height 5.4 cm) was dipped in water and the imbibition height x and time t were measured (dried condition). In this condition, all the pores can absorb water. Next, the pores smaller than 3 μm radii were filled with water by expelling pore water of the other sizes using a gas injection technique (water-expulsion method) and x and t were measured (wet condition). Under the wet condition, absorption of water proceeds only in the pores greater than 3 μm radii. The imbibition rate in the dry condition was found to be approximately one-half of that under the wet condition. The result suggests that the rate of overall imbibition process is controlled by slow imbibition in small pores.

Keywords: capillary force, imbibition rate, pore